

# Kerala Agricultural University

## RESEARCH REPORT 2018

Compiled and Edited by  
**Dr. P. Indira Devi**  
Director of Research



**Kerala Agricultural University**

Vellanikkara, Thrissur, Kerala.

**December 2018**

**Kerala Agricultural University RESEARCH REPORT 2018**  
**Dr. P. Indira Devi**

December 2018

Copies: 500

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Published by  
**Kerala Agricultural University**  
Vellanikkara, Thrissur, Kerala.

Printed at Lumiere Ptinting Works  
Thrissur 680 020

## **FOREWORD**

Kerala has been a fore runner in many of the development indicators, developing models which others can emulate. Despite being a service sector oriented economy, agricultural sector of the state was showing a positive growth rate during the recent past. The role of science based policy intervention in attaining the growth is evident, as the cropped area has not been increasing. The research focus by Kerala Agricultural University in developing technologies that aim at productivity, sustainability and social acceptance has played a significant role in maintaining and promoting the agriculture sector in the state. Continuing the efforts, Kerala Agricultural University is proud to present the major research findings during the year 2017-18, from various projects implemented by us. We reaffirm our commitment towards the agricultural development of the state especially in rebuilding a new Kerala. The devotion and commitment of Kerala Agricultural University fraternity towards the achievements are to be remembered and acknowledged in this juncture. I may take this opportunity to congratulate all those who have contributed to this endeavor.

**Dr. R. Chandra Babu**  
Vice-Chancellor

## PREFACE

Agriculture in Kerala is distinctly different from the rest of India, in many ways. Predominance of non-food-plantation sector, multi cropping systems, homestead farming and abundance of biodiversity are a few among these specific features. The proportion of farming households in the state is reported to be the lowest among the states in India. The socio economic and demographic setup have resulted in further diversity in farming objectives and practices. The farming practices range from micro level terrace and backyard systems to large scale commercial plantations. The objectives in this sector have undergone drastic changes with focus on quality rather than volume of production. So also, a shift from domestic to export and direct consumption to processing and value addition is also being witnessed. Simultaneously the demand for green technologies arise from the public, owing to higher literacy and awareness. The research system in Kerala Agricultural University is tuned to address these challenges. There are research results that offer solutions to many of the problems at field level.

The research projects in Kerala Agricultural University is mainly funded by the public sector which include Indian Council of Agricultural Research, Indian Council for Forestry Research and Education, Directorate of Biotechnology, Department of Science and Technology, Kerala State Council for Science Technology and Environment. Prominent among them are the All India Co-ordinated Research Projects (AICRP's), which are mainly funded by Indian Council of Agricultural Research (ICAR). These together enjoyed funding support to the tune of Rs. 25.23 crores. Support from State government constituted 35.31 per cent of research grants. The total amount obtained for implementing research projects was to the tune of Rs. 39 crores in 2017-18.

The projects are implemented by the scientists working in the seven colleges and 26 research stations of the university. These scientists are also discharging extension and teaching duties. Apart from this, the results from post graduate and Ph.D academic programmes are also there.

The research management in the university is done by the Directorate of Research, where the Director of Research is supported by Associate Directors of Research, one each for the five zones and four in the Head Quarters. There are three faculties, Agriculture, Forestry and Agricultural Engineering, where the research implementation is vested with the Research Coordinator, who is a senior Professor. There are twenty four subject specific Project Co-ordination Groups, 19 in agriculture, 2 in Forestry and 3 in Agricultural Engineering. The Project Co-ordinators monitor the research project implementation.

It is worth mentioning that our scientists have published quality research articles in reputed journals.

With great pride, I may also mention that Kerala Agricultural University has released 23 varieties in different crops during this period (17-18). We could also make 65 technologies ready for transfer to potential entrepreneurs.

In this background, it is worth pointing out the fact that the achievements of the university are on account of the united work of all sections of farm workers, supportive ministerial and the scientific community. The role of the Research Associates and other temporary employees are also equally acknowledged. We also thank all the funding agencies and other organizations, who supported us for effectively discharging the responsibilities.

The post flood scenario of the State demands a paradigm shift in the research policy of university for rebuilding the agricultural sector of the state. KAU has initiated efforts to strengthen the research programmes for addressing the same, which is the need of the hour. The support of one and all in this regard, is solicited.

**Dr. P. Indira Devi**  
Director of Research

**The Newly Released Crop Varieties from  
Kerala Agricultural University**

## The Newly Released Crop Varieties, KAU (vide 27<sup>th</sup> State Seed Sub Committee held on 12/12/2017)

Kerala Agricultural University has released 23 improved varieties in rice, vegetables, tuber crops, spices and medicinal plants, at the 27<sup>th</sup> State Seed Sub Committee held at Thiruvananthapuram on 12/12/2017. The formal release of these varieties was done by Sri. Pinarayi Vijayan, Hon'ble Chief Minister, Kerala on 26/05/2018 at KAU, Head Quarters, Vellanikkara.

### Rice (*Oryza sativa*)



KAU Pournami



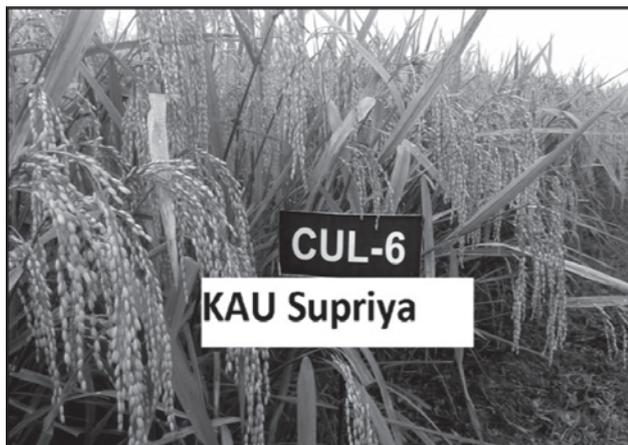
KAU Manuratna



KAU Lavanya



KAU Jyotsna



KAU Supriya



KAU Akshaya

**Yard long bean (*Vigna unguiculata* var. *sesquipedalis*)**



KAU Manjari



KAU Mithra

**Culinary melon (*Sambar Vellari*)  
(*Cucumis melo* var. *acidulous* L.Naudin)**



KAU Vishal

**Cucumber  
(*Cucumis sativus* L)**



KPCH 1

**Tapioca (*Manihot esculenta* Crantz)**



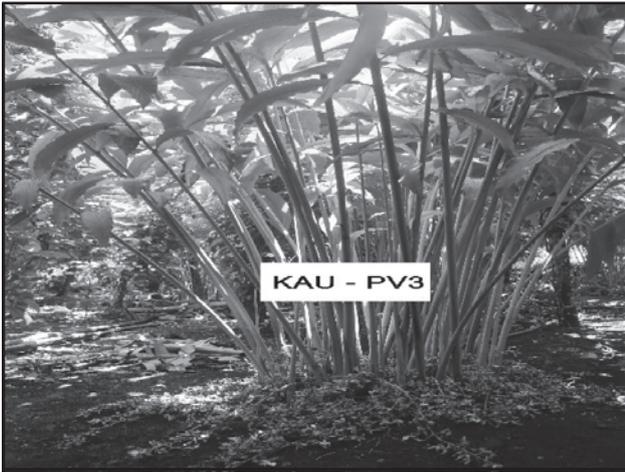
KAU Uthama

**Black Pepper (*Piper nigrum* L)**



Panniyur 9

**Cardamom (*Elettariacardamomum* M)**



KAU PV 3



KAU PV 5

**Camboge/ Malabar Tamarind (*Garcinia gummi-gutta*)**



KAU Nithya

**Nutmeg (*Myristicafragrans* H)**



KAU Punnathanam

**Nutmeg (*Myristicafragrans* H)**



KAU Pullan



KAU Kochukudy

**Nutmeg (*Myristicafragrans H*)**



KAU Mundathanam



KAU Poothara

**Ginger (*Zingiberofficinale*Rosc)**

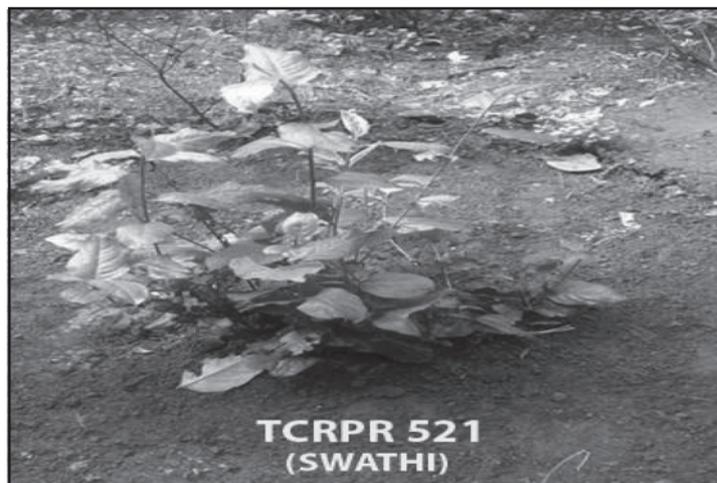


KAU Chandra

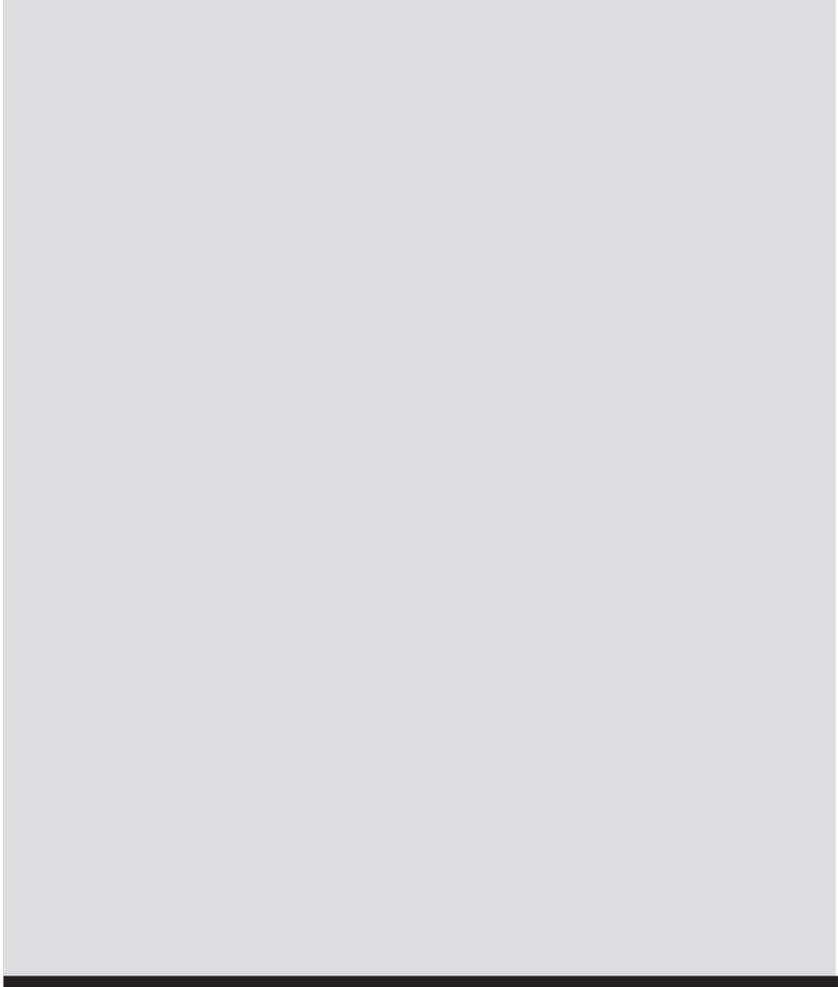


KAU Chithra

**Chethikoduveli (*Plumbago rosea*)**



KAU Swathi



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# **Faculty - Agriculture**

**Dr. Vijayaraghava Kumar**  
**Professor (RC)**

**Name of Project Coordination Group : (01)**  
**Rice**

**Compiled by:**  
**Dr. Reena Mathew, Protect Coordinator**

**Plan & External Aided Projects**

**Ongoing Projects: 73 Nos.**

**Post Graduate Projects**

**Concluded Projects: 5 Nos.**

**Ongoing Projects: 2 Nos.**



## ONGOING EXPERIMENTS 2017-2018

### 1. Genetic conservation of rice germplasm, collection, maintenance, cataloguing and evaluation

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

New entries were included in germplasm collection which comprised of farmer varieties, varieties released from other institutes and recent breeding lines. Characterization of 443 accessions including 93 short duration, 226 medium and long duration, 124 traditional rice varieties under the germplasm collection in Pattambi were completed under this project. The pure seeds multiplied were stored under Medium Term Storage facility developed at RARS, Pattambi under this project.

Molecular characterization of germplasm is progressing using SSR markers. Molecular characterization of 58 varieties and released from Pattambi was completed using markers RM 19, RM 25, RM 44, RM 55, RM 72, RM 152, RM 201, RM 202, RM 205, RM 212, RM 219, RM 225, RM 228, RM 259, RM 263, RM 334, RM 336, RM 431, RM 433, RM 518 AND RM 3586.

Forty six traditional rice varieties were characterized using 14 SSR markers. Chennellu, Kalluruli, Karanellu, Kalladiaryan, Thondi Navara, Anjali, N-22 were characterized using ten drought specific molecular markers. Traditional varieties- Ponkuruka, Chenkayama, Pallippuram pokkali, Cheriya oorpandi, Karuthakuruka, Chettivirippu, Gandhakasala, Pandichampan, Kuttithekkan, Veluthavattan, Mundakan, Vellari, Velutharikayama, Thekkan chitteni and high yielding varieties were also characterized for ten molecular markers specific for salinity. Molecular characterization of the germplasm collection is progressing. The result generated from molecular study will be highly useful in breeding for varieties with biotic and abiotic stress tolerance. Selections from land races Veluthitryan and Kalluruli were tested for yield performance along with check varieties during 2017-18.

### 2. Breeding high yielding, tall, photo sensitive varieties with good straw yield specifically suited for the mundakan season of Kerala.

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, Cul 5(0614-1-6-21 IET 26080) was tested under Advance variety trial -1-late in AICRIP. Quality characters of Cul 5 were found to be excellent on assessment at IIRR, Hyderabad. Cul 6(0614-7-8-24 KAU Supriya), Cul 14(0615-01-25-17 KAU Akshaya) and Cul 19(0615-01-28-34-1) were tested under Initial varietal trial as IET 27244, 26951 and 26941 respectively.

### 3. Collection, maintenance and evaluation of rice germplasm.

Dr.Leenakumari, S.  
Professor  
[leenakumarys@kau.in](mailto:leenakumarys@kau.in)

The Objective was to collect, maintain and evaluate the available germplasm of rice, both rationing and exotic for utilization in the breeding programme. During 2017-18 14 entries selected from the AICRIP (International Network for Genetic Evaluation of Rice) were added to the 710 entries already maintained during the period, total of 724 entries.

### 4. Evolution of semi tall or dwarf types of tall Indica rice varieties.

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

Thirteen mutant lines of PTB 18 and 21 were subjected to selection in M6 generation during. Preliminary Yield trials were conducted with three uniform mutant lines (170 Gy Gamma ray mutant of PTB 18) selected from previous generation along with PTB 18 and PTB 21. All three lines were found to be promising and exhibited 100 to 114% improvement in yield over the parents. These entries will be forwarded to advanced trials. During 2017-18, sixteen mutant lines of PTB 18 and 21 were subjected to selection in M7 generation. Preliminary Yield trials of six uniform mutant lines identified during 2016-17 (170 Gy Gamma ray mutant of PTB 18, 21 and 220 Gy mutant of PTB 18) and Comparative yield trials of 3 mutant

lines (170 Gy mutants of PTB 18) were conducted with PTB 18, PTB 21, Jyothi, Uma, Swetha, Aathira and Karuna. Promising entries will be forwarded to advanced trials. Uniform lines with promising characters identified will be tested in yield trials during 2018-19. The varieties evaluated for drought tolerance and biotic stress tolerance screening. Culture M5 (2011mutant46-1-1-1), 170 Gy mutant of PTB 18, was tested at Initial Varietal trial-irrigated medium at AICRIP National Multilocation Testing during Kharif 2017 as IET 26856 and was found to have moderate resistance to neck blast.

## 5. Breeding lodging resistant rice varieties for dry sowing conditions during virippu season

Dr. Abida.P.S  
Professor  
[abida.ps@kau.in](mailto:abida.ps@kau.in)

F<sub>5</sub> plants were raised in ear to row method and Observations were made on characters such as Days to flowering, Plant height (cm), No. of tillers, No. of panicles and Panicle length (cm). According to the above characteristics the homozygous superior plants were selected and seed were harvested to further forward to the F<sub>6</sub> generation.

## 6. Initial Variety Trials

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

This experiment is conducted at RRS, Moncompu as part of the All India Co-Ordinated Rice Improvement Project where in the comparative performance of superior rice cultures of different duration developed at different rice research centres throughout the country are evaluated for their yield and suitability for our situation. Initial Variety Trial is the first stage of evaluation of the cultures. Three sets of cultures belonging to VeryEarly, Early and Mid Early groups are evaluated for their performance every year. The seed material for the trial is received from DRR, Hyderabad. The results of experiments conducted during 2014-15 from the three trials are furnished below.

### 6.1. Initial Variety Trial - Early (IVT-E-TP) Transplanted

Dr. Leenakumari, S.  
Professor  
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The trial was laid out in RBD with 63 entries and 2 replications. Observations were recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack *etc.* The highest grain yield was recorded by IET No.26762(CU1748) (7097.22 Kg/ha) followed by entry no IET No.26777 (CR3993-4-9-6-3-1) (6597.22 kg/ha) and local check Prathyasa yield 5125kg/ha.

### 6.2 Initial Variety Trial-Biofortification (IVT-Biofort)

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

Observations were recorded on various characters like days to 50% flowering, plant height, plot yield, disease/pest attack *etc.* Among the entries, IET No. 27167 (NVSr-335) recorded the highest grain yield of 10800 kg/ha followed by IET No: 27163 (CR 2830-PLS-118) (10775 kg/ha) and the local check Uma yield 9175 kg/ha. During the season the pest / disease incidence was low.

### 6.3 Initial Variety Trial –Early

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Professor  
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During Kharif 2017, the trial was laid out in RBD with 64 entries and 2 replications. Observations were recorded on various characters like plant height, days to 50% flowering, grain yield, disease/pest attack *etc.* The highest grain yield was recorded by Entry No.3608 (7097 kg/ha) followed by Entry No.3629 (6597 kg/ha) which was superior to the grain yield of the local check Prathyasa (5125 kg/ha).

#### 6.4. Initial Variety Trial – IME

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The trial was laid out in RBD with 64 entries under report and 2 replications. Observations recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc. Observations were recorded on various characters like days to 50% flowering, plant height, plot yield, disease/pest attack etc. Among the entries, IET No. 26877 (IR73930-31-3-1-2 CR 3728-2-2) recorded the highest grain yield of 11111.11 kg/ha followed by IET No: 26879 (CB-14502) with a per hectare yield of 10543.06 kg/ha. During the season the pest / disease incidence was low.

#### 7. Advanced Variety Trials

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

The entries in Initial Variety Trials which give more than 5% yield increase than the check varieties will be tested in Advanced Variety Trials 1 and 2. At Rice Research Station, Moncompu, different duration groups viz., Early and Mid-Early are tested for their regional suitability.

##### 7.1. Advanced Variety Trial -1

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

The trial was laid out in RBD with 11 entries under report and 3 replications. Observations recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc. Observations were recorded on various characters like days to 50% flowering, plant height, plot yield, disease/pest attack etc. Among the entries, IET No. 25746 (KPH-471) recorded the highest grain yield of 9972.22 kg/ha followed by IET No: 24934 (NK-5251 Plus Hybrid) with a per hectare yield of 8996.30 kg/ha. During the season the pest / disease incidence was low.

##### 7.2. Advanced Variety Trial- 2- Irrigated Mid Early

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

Observations were recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc. Mean data of the best entries is furnished below. The highest grain yield was recorded by US 312 (HC) with an yield of 9638.89 Kg/ha followed by IET No. 24951-(VNR-218)(Hybrid) with a per hectare yield of 8861.11 Kg. The local check Uma recorded an yield of 6750 Kg/ha.

##### 7.3. Advanced Variety Trial-1 Biofortification (AVT -1 Biofort)

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

The trial laid out with 17 entries including local check with 3 replication. Observations were recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc. The highest grain yield was recorded by IET NO: Kalanamak (Micro nutrient check) with a yield of 10176.67 Kg/ha.

##### 7.4. Advanced Variety Trial-2 Biofortification (AVT -2 Biofort)

Dr. Leenakumari, S.  
Professor  
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The trial was laid out in RBD with 16 entries under report and 3 replications. Observations recorded on various characters like plant height, days to 50% flowering, plot yield, disease/pest attack etc. The highest grain yield was recorded by IET NO: 25461 (R-RHZ-MI-30) with a yield of 10986.67 Kg/ha.

## **8. Initial Variety Trials**

### **8.1. Initial Variety Trial (IVT - E - TP)**

Dr. Faseela K.V.  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 62 entries were tested, of which the entry IET 26755 with 8279.1kg/ha was found to be superior with respect to yield.

### **8.2. Initial Variety Trial – Biofort (IVT- Biofort) PTB**

Dr. Faseela K.V.  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 34 entries were tested, of which the entry IET 27159 with 5070.2 kg/ha was found to be superior with respect to yield.

### **8.3. Initial Variety Trial Irrigated Mid Early**

Dr. Faseela K.V.  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 59 entries were tested, of which the entry IET 26884 with 7707.2 kg/ha was found to be superior with respect to yield.

### **8.4. Initial Variety Trial Irrigated Medium**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 63 entries were tested, of which the entry IET 26836 with 9198.49 kg/ha was found to be superior with respect to yield.

### **8.5. Initial Variety Trial Aromatic Short Grain**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 22 entries were tested, of which the entry Ketekijoha (QC) with 8086.83 kg/ha was found to be superior with respect to yield.

### **8.6. Initial Variety Trial New plant Type**

Dr. Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 36 entries were tested, of which the entry IET 27260 with 6551.48 kg/ha was found to be superior with respect to yield.

## **9. Advanced Variety Trials**

### **9.1. Advanced Variety Trial-1 Biofortification (AVT -1 Biofort) PTB**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 15 entries were tested, of which the entry IET 26378 with 4404.27 kg/ha was found to be superior with respect to yield.

**9.4. Advanced Variety Trial-2 Biofortification (AVT -2 Biofort) PTB**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 15 entries were tested, of which the entry IET 25461 with 3195.25 kg/ha was found to be superior with respect to yield.

**9.5. Advanced Varietal Trial-1 Irrigated Mid Early**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

Out of the 11 entries tested during 2017-18, MTU 1010 (ZC) with 6155.1 kg/ha was found superior to all other entries with respect to yield.

**9.6. Advanced Varietal Trial-1 Irrigated Medium**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

Out of the 20 entries tested during 2017-18, IET 25229 with 9293.4 kg/ha was found superior to all other entries with respect to yield

**9.7. Advanced Varietal Trial-1 New Plant Type**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 14 entries were tested, of which the entry Jaya (NC) with 5941.8 kg/ha was found to be superior with respect to yield.

**9.8. Advanced Varietal Trial-1 Aromatic Short Grain**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

Out of the 9 entries tested during 2017-18, IET 26205 with 6236.4 kg/ha was found superior to all other entries with respect to yield

**9.9. Advanced Varietal Trial-1 Near Isogenic Lines – Blast & BLB**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 35 entries were tested, of which the entry Akshayadhan (RP) with 7221.4 kg/ha was found to be superior with respect to yield.

**9.10. Advanced Varietal Trial-2 Irrigated Mid Early**

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

Out of the 12 entries tested during 2016-17, IET 25341 with 6185.52 kg/ha was found superior to all other entries with respect to yield.

### 9.11. Advanced Varietal Trial-2 Irrigated Medium

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 12 entries were tested, of which the entry Swetha (LC) with 4530.3 kg/ha was found to be superior with respect to yield.

### 9.12. Advanced Varietal Trial-2 Near Isogenic Lines – Blast

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

Out of the 12 entries tested during 2016-17, Samba Mahsuri (RP) with 4570 kg/ha was found superior to all other entries with respect to yield.

### 9.13. Advanced Varietal Trial-2 Special Samba Mahsuri Trial

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, 3 entries were tested, of which the entry IET 26241 with 3175.11 kg/ha was found to be superior with respect to yield.

### 10. Evolving multiple disease and pest resistant rice var. for second crop of Kuttanad

Dr.Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

During 2017-18 cultures KAUM 236-1-2-1-1 and KAUM238-1-1-1-1 were the best performers with respect to grain yield. These cultures have given grain yield comparable with the check variety Uma. All the cultures showed resistant reaction to sheath blight while the check variety was moderately resistant to sheath blight.

### 11. Evolving high yielding multiple resistant rice varieties through gene pyramiding

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-18, promising entries from the crosses Swetha x Kuruka, Pranava x Chettadi, Pranava x Vellari, NPT cultures derived from Interspecific crosses of IIRR, Selection from Jaya variety and mutant lines of PTB 18 and 21 were screened for pests like stem borer and leaf folder. Among the tested 10 cultures exhibited resistance to stem borer and 16 cultures exhibited resistance to leaf folder. Six cultures (Cul 1, 2, 3, 16, 18, JS-3) exhibited resistance to Stem borer and Leaf folder on field screening. The entries were tested in yield trials during Rabi 2017-18.

Under National MLT it was found that Cul 5 has moderate resistance to neck blast and glume discoloration, Cul 14 possess Resistance to Neck blast and Cul 19 has moderate resistance to leaf blast, neck blast and sheath rot.

### 12. Breeding for drought tolerant rice varieties suitable for upland ecosystem

Dr.Faseela.K.V  
Asst.Professor  
[faseela.kv@kau.in](mailto:faseela.kv@kau.in)

During 2017-2018, forty three elite entries were evaluated under rain-fed upland condition, among the entries. IET 26612 IET 26614, IET IET 26616, IET 26626 IET, 26628, IET 26633, IET 26634 IET 26637 IET 26641 recorded the highest yield and performed better and compared to the local check, Vaishak, these promising entries are suitable for rainfed condition

### 13. Physiological and biochemical basis of heat tolerance in rice.

Ninety two rice genotypes from ricegermplasm, AICRIP and NICRA entries were selected based on high temperature stress tolerance. The identified tolerant genotypes is being evaluated biochemically and further evaluation under field condition in summer 2018-2019. The promising entries will be selected as donors for breeding programmes.

### 14. Evaluation of fungicides against brown spot

Dr. Raji. P  
Assoc. Professor  
[raji.p@kau.in](mailto:raji.p@kau.in)

Eight combination fungicides were evaluated during the year 2017-18, against brown spot. Azoxystrobin 11% + tebuconazole 18.3% SC (1.5 ml/l) and Azoxystrobin 18.2 % + difenoconazole 11.4 % SC (1 ml/l) were effective for the management of brown spot.

### 15 Breeding for high yielding rice varieties with resistance / tolerance to adverse soil conditions

Dr. Leenakumari. S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

During 2017-18 KAUM 164-1, KAUM 174-3 and KAUM 168-1 were found to be promising with respect to grain yield. These cultures were on par with the check variety Uma in grain yield. Hybridisation programme – 4 cultures are in comparative yield trial stage.

### 16. Conservation and Utilisation of Rice Biodiversity in Kuttanad

Dr. Leenakumari, S.  
Professor  
[leenakumary.s@kau.in](mailto:leenakumary.s@kau.in)

Morphological characterisation based on Rice Descriptor of one hundred and fifty accessions has been completed and these accessions were evaluated under various stresses to identify varieties showing resistance/ tolerance reaction. Molecular characterisation of 40 varieties has been completed at RRS, Vytilla.

#### Morphological characterization

Artificial screening for diseases was done in the plant pathology division. Out of the 50 varieties, 1 variety ie, Thondi showed resistance to BLB (score- 0), 28 vars. resistant to sheath blight (score-3), and most of the varieties were resistant with 0 score for sheath rot, brown spot and glume discoloration. Many rice varieties supposed to be extinct have been collected and are being described which will enable their use in further breeding programmes

### 17. Network project on Seeds and Planting materials production

Dr. Reena Mathew  
Professor  
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Breeder and foundation seeds of the MO varieties were produced during 2017-18. A total quantity of 1275.3 kg Breeder seeds, 253 kg Foundation seeds and 4483 kg truthfully labelled seeds were produced and distributed to various agencies, Deptl. Farms, farmers *etc.*

### 18. Breeding of short duration rice varieties for virippu season and photosensitive, semi tall high yielding varieties for mundakan season in Onattukara

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Quality analysis of culture-23, culture -28 and culture -35 is progressing. The result obtained from grain quality analysis of certain physical parameters is given below:

Sl.No	Charecters	Culture 23	Culture 28	Culture 35
1	Hulling %	70.2	73.92	76.54
2	Milling %	68.5	70.12	72.32
3	Head rice %	60.8	63.2	65.6
4	Kernal colour	Red	Red	Red
5	Abdominal white	Present	Present	Present
6	Length of milled grain	4.08	5.02	5.02
7	Width of milled grain	2.76	3.02	3.0
8	L/B ratio	1.48	1.66	1.67
9	Length of cooked grain	5.04	6.02	6.0
10	Width of cooked grain	3.74	4.8	4.8
11	L/B ratio	1.35	1.25	1.25
12	Water uptake ratio	1.20	1.27	1.25
13	Cooking time	20 min	22 min	25 min
14	Gelatinisation temperature	High	High	High
15	Gel consistency	Soft	Medium hard	Soft
16	Amylose content	19.5%	21.5%	22%

b. Mundakan: Pooled mean analysis of comparative yield trial revealed 2 cultures as high yielding viz. Culture- 4 and culture - 30. These cultures were recommended for farm trial, which will be carried out during mundakan of 2018.

#### 19. Breeding for high yielding rice with resistance to major pests of rice in Kuttanad

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The objective is to develop high yielding rice varieties with resistance to pest like thrips, caseworm, leaf folder, stem borer etc. which are attaining the status of major pests. During Kharif 2017, CYT was repeated with four cultures viz., KAUM 230-2-1-1, KAUM 230-1-2-1, KAUM 231-5-2-1 and KAUM 230-1-1-1 along with 4 checks. During puncha crop 2017-18 cultures KAUM 231-5-2-1 and KAUM 230-1-2-1 were the best performers with respect to grain yield. These cultures out yielded the check variety Uma in grain yield (2973.46 kg/ha.). During Puncha 2017 also cul. KAUM 231-5-2-1 ranked first in yield.

#### 20. Breeding for high yielding rice varieties with submergence tolerance

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During puncha crop 2017-18, CYT was repeated with 2 selected cultures. KAUM 179-1 and KAUM 180-2 were found to be on par with each other and the check variety Uma and high incidence of stem borer attack occurred. KAUM 179-1 and KAUM 180-2 have showed low score value compared to the check varieties.

#### 21. Testing the adaptability and stability of high yielding varieties of rice in Onattukara

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MDU-5, Athira and Aiswarya will be recommended for inclusion in the POP. High yielding varieties identified for mundakan season are Aruna and ADT 16.

#### 22. Genetic improvement of the medicinal rice (*Oryza sativa*. L) varieties of Kerala

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During puncha 2017 Njavara 13-3-1 and Njavara 7-1-2-1 were found to be the highest yielders with a per ha. yield of 5032.19 kg and 2744.318 kg. respectively. 12 mutant cultures which attained uniformity were advanced to Initial Evaluation Trial.

### 23. Genetic Improvement of rice to meet the location specific varietal needs of Kuttanad

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The combination fungicide Tricyclazole 18 % + Mancozeb 62 % WP (Merger) was found superior for sheath blight disease and grain discolouration control and other fungicides were on par.

### 24. Monitoring soil quality and crop productivity under emerging rice production systems (Kharif and Rabi) RIC/08-00-01-2004/MON(3)/AICRIP(2)

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The trial was started in 2015 and targeted to continue for five years. In Kharif 2016, there was no significant difference in yield. But in Puncha, 2016 transplanted rice recorded significantly superior yield. Straw yield also recorded the same trend. In case of nutrient management practices, maximum yields were obtained with 75% RDF +25% organics and 100 % RDF+ 50 % through organics in the first and second season respectively. The lowest yielding treatment was 100 % organics. Conjunctive use of organics and inorganics was found to increase yield without deteriorating soil quality. The results of the study indicated that the use of organic matter addition was necessary to sustain soil quality in soil test based nutrient management also.

### 25. Gall Midge Biotype monitoring trial (GMBT)

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Gall midge biotype monitoring trial was constituted with a set of gene differentials categorized into groups with known genes (Gm1 to Gm11, No genes). The results of evaluation indicated that, *Gm1* and *Gm8* genes hold promise against Biotype 5 populations. The differentials KAVYA and W1263 with Gm 1 genes as well as the differentials AGANNI, INRC 15888 and INRC 3021 with Gm 8 genes exhibited no damage against gall midge Biotype 5.

Evaluation of the gene differentials in field tests against biotype 5 of gall midge identified Aganni (Gm8), INRC 15888 (Gm8), INRC 3021 (Gm8), KAVYA (Gm1), W1263 (Gm1) as promising in the tests. The results suggest that Gm8 and Gm1 hold promise against gall midge Biotype 5.

### 26. Gall midge screening (GMS)

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The objective of this trial is to evaluate the breeding lines specifically bred for gall midge resistance. Gall midge trial was constituted with 60 entries (54 breeding lines and six checks). Evaluation of the entries revealed that, the test line WGL1196 was found promising (<10% DP).

### 27. Insecticides Evaluation Trial

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Combination insecticide, Spinoterum + Methofenoxifenozide @ 400 ml/ha and chlorantraniliprole @150ml/ha were found effective to stem borer. Spinoterum + methofenoxifenozide @ 400 ml/ha, chlorantraniliprole @150 ml/ha and acephate 95%SG@526g/ha were found effective to leaf folder.

## 28. National Screening Nursery

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Among 137 hybrids screened, IET 26488 showed nil damage and W 1263 showed low incidence of silver shoots caused by gallmidge. IET26520, 26530, 26546, 2654, Swamadhan showed low damage of whorlmaggot while hybrids IET 26545, 26553, WGL 14, Abhaya, PTB 33 and W1263 showed low damage of leaf folder.

During the period 292 hybrids were screened, between them W1263 and Kavya showing consistent resistance to gallmidge besides that hybrids IET 25708, 25759, 25773 and 26488 found resistance to gallmidge. Entries Pantchan-19/NDR-8002, IET26520, 26530, 26546, 2654, Swamadhan found resistance to whorlmaggot. Hybrids IET 25731, 25752, 25766, 26545, 26553, WGL 14, Abhaya, PTB 33 and W1263 were found resistance to leaf folder.

## 29. National Screening Nursery

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1314 cultures (354 NSN-1, 743 NSN-2, 127 NHSN, 90 DSN cultures) were screened against Sheath blight and Bacterial leaf blight incidence. 204 cultures showed their multiple resistance during Kharif 2017 and 160 cultures during Rabi 2017-18.

## 30. Gall Midge Special Screening Trial

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This trial constituted with 85 donors (including gene pyramided lines along with check varieties) was carried out to identify new sources of resistance to gall midge biotype 5. Evaluation of the entries for GMB5 revealed that, 16 entries recorded nil damage.

## 31. Gall midge biotype screening trial

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Among 85 tested entries tested, all entries showed higher incidence of silver shoots except W1263 which recorded lowest silver shoot damage of 16.13%. 135 entries were screened during the period. Two entries JGL 13595 and JGL 3828 and W1263 showed resistance to gallmidge biotype 5. The studies on resistance genes in rice entries a change in virulence pattern of gall midge biotype 5. So, studies will be undertaken to confirm the existence of biotype 5.

## 32. Pesticides compatibility trial

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During the period, two insecticides and two fungicides were tested alone as well as in combination for control of major insect pests as well as sheathblight disease. The results showed that gallmidge incidence was low in DPX-RAB 55 (0.48ml/lit.) treated plots while stem borer incidence was low in combination treatments viz., DPX-RAB 55 + hexaconazole and DPX-RAB 55 + tricylazole treated plots. Leaf folder incidence was low in Spinoterum + methoxyfenozide (0.75ml/lit) as well as in combination with hexaconazole and tricylazole treated plots. Sheath blight incidence was low in fungicides treated plots as well as in combination with Spinoterum + methoxyfenozide and DPX-RAB 55 treated plots. During the period, systemic insecticide treated alone had complete reduction of gallmidge while stem borer was low in DPX-RAB 55 + hexaconazole and DPX-RAB 55 + tricylazole treated plots. Leaf folder incidence was low in Spinoterum + methoxyfenozide (0.75ml/lit) as well as in combination with hexaconazole and tricylazole treated plots. Sheath blight incidence was low in fungicides treated plots as well as in combination with Spinoterum + methoxyfenozide and DPX-RAB 55 treated plots.

**33. Population dynamics of insect pests assessed through Light Trap**

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Assessment of insect populations throughout the year using light traps was done. The data revealed that stem borers and plant hoppers are the most widespread pest in terms of numbers. Maximum number of insect species (including pests and natural enemies) were recorded. SBs, GM, LF, GLH, BPH, WBPH, ZZLH, black bug, coccinellids, mirid bug, and rove beetle were recorded. GLH was found more active up to 18 SW with highest count of 341 during the first SW. BPH also showed similar trend and was most abundant (912) in 12 SW. Black bug catches were highest (332) in 51 SW. Among the natural enemies, rove beetles were found in considerable numbers and maximum catches (591) were recorded in 50 SW, at the end of season.

**34. Monitoring of Pests and their Natural Enemies (MPNE)**

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Stem borer species composition: Three stem borer species were observed viz., YSB, PSB and WSB. YSB was the dominant species, PSB was observed as a second species and WSB was observed to the extent of 4.39%. Egg parasitoids of stem borer: Three egg parasitoids of stem borer were observed with *Trichogramma japonicum* being dominant while *Tetrastichus schoenobii* and *Telenomus* species were also observed. The egg parasitisation observed was 12.23%. Gall midge: Data on gall midge during *rabi* revealed that, 130 galls were observed from hundred hills of which 72.70 % were parasitized. The only parasitoid observed was *Platygaster oryzae*.

**35. Ecological Engineering of Plant hopper management (EPPM)**

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This trial has the objective of habitat management through cultural and non-pesticidal methods along with floral diversity to increase natural biological control and augment egg predators of hoppers for managing planthoppers by enhancing natural enemy fitness. Data were recorded on hoppers and their natural enemies and analyses were done using the independent 't' test.

During *kharif* 2017, the combination of interventions such as organic manuring and growing of flowering plants on bunds increased the natural enemy populations like mirids and spiders. The bund planting of marigold was taken up in EE plots. The pooled analysis revealed that number of hoppers was very low and did not differ significantly in EE and FP plots. However, green mirids (3.95/10 hills) and spiders (3.95/10 hills) were significantly higher in ecological engineering plots. Drynid parasitisation of hoppers did not differ significantly between the two treatments.

**36. Screening for sheath blight resistance**

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In 2017-18, in National Screening Nursery 1 (NSN1), 354 entries were screened. Out of which 4 entries were moderately resistant to sheath blight with score 3. The National Screening Nursery 2 (NSN-II) consisted of 743 entries of which 3 entries showed moderate resistance reaction (score 3). In NHSN and DSN no entries were resistant.

**37. Screening for leaf blast resistance**

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In the year 2017-18, 354 entries in National Screening Nursery 1 (NSN1), 743 entries in National Screening Nursery 2 (NSN-2), 127 entries in National Hybrid Screening Nursery (NHSN) and 90 entries in Donor Screening Nursery (DSN) were

evaluated. Out of these, 10 entries in NSN 1, 28 entries in NSN2 and 14 entries in DSN were resistant to leaf blast with score 1.

### 38. Disease Observation Nursery

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The fortnight trial was conducted with the cultivars Shreyas (MO 22, Prathyasa (MO 21) and Uma (MO 16) at three different dates at twenty days interval to identify the time and intensity of the disease occurrence. Sheath blight disease was moderately high in the normal sown crop (2<sup>nd</sup> week of June) of Prathyasa variety (42.22 %) and low in late sown crop of Uma variety (9.63%) during Kharif 2017. The BLB incidence was moderately high in early sown crop (May 4<sup>th</sup> week) of Prathyasa variety (24.08 %) and low in late sown crop (June 4<sup>th</sup> week) of Uma variety (5.74 %). During Rabi 2017-18, high incidence of sheath blight was observed in the late sown crop (3<sup>rd</sup> week of December) of Prathyasa variety (56.05 %) and low in normal sown crop of Uma variety (26.67%).

### 39. Production Oriented Survey

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Production oriented survey was conducted at Alappuzha (3500 acre) and Kottayam (1750 acre) districts during Kharif 2017 from booting stage to maturity stage of the rice crop. The survey covered four taluks in Alappuzha District, viz., Ambalapuzha, Kuttanad, and Haripad, while in Kottayam district two taluks namely Kottayam and Vaikom could be surveyed.

The predominant cropping sequences were rice-fallow, rice-rice and fallow-rice. The predominant varieties in those districts were Uma and Jyothi. The weed population was moderate. Weeds like *Cyperus difformis*, *Cyperus iria*, *Echinochloa crusgalli*, *Sacolepis interrupta* were the major weeds observed during the visit. *Echinochloa spp* was the major weed found in both Alappuzha and Kottayam districts along with wild rice infestation. Moderate incidence of the biotic constraints like sheath blight, bacterial leaf blight, leaf folder, case worm, rice bug and rats were observed. Lack of sufficient labourers and high labour cost were the main problems faced by the farmers.

### 40. Screening for bacterial leaf blight resistance. ( PATTAMBI)

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During the year 2017-18, none of the entries in National Screening Nursery 1 (NSN1), National Screening Nursery 2 (NSN-2), National Hybrid Screening Nursery (NHSN) and Donor Screening Nursery (DSN) showed resistance reaction to bacterial leaf blight.

### 41. Field monitoring of virulences in *Xanthomonas oryzae* pv. *Oryzae*( PATTAMBI)

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Kharif 2017: Virulence analysis of bacterial blight pathogen of rice *Xanthomonas oryzae* pv. *oryzae* was carried out during Kharif 2017 with 31 isogenic lines (IRBB background) possessing different bacterial blight resistance genes either singly or on various combinations of four genes viz. Xa 4, Xa 5, Xa13 and Xa21 in the background of rice cultivar IR 24. 30 showed their resistance against BLB pathogen. Most of the genes and gene combinations listed offered satisfactory resistance reaction to the native isolates of Bacterial Blight pathogen during Kharif season. During Rabi 2017-18, 14 entries showed resistant reaction to BLB pathogen.

**42. Field monitoring of virulence in *Pyricularia grisea* (PATTAMBI)**

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In the year 2017-18, Tetep (Sore1), RIL-10 (score 2.0), Raminad-STR-3 (score 2.3) and C101 LAC (score 2.5) were resistant to local isolate of blast pathogen.

**43. Field Monitoring virulence in *Xanthomonas oryzae.pv.oryzae* (MON)**

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Virulence analysis of bacterial blight pathogen of rice *Xanthomonas oryzae.pv.oryzae* was carried out during Kharif 2016. Virulence analysis of bacterial blight pathogen of rice *Xanthomonas oryzae.pv.oryzae* was carried out during 2017-18. 31 isogenic lines (IRBB background) possessing different bacterial blight resistance genes either singly or on various combinations of four genes viz. Xa 4, Xa 5, Xa13 and Xa21 in the background of rice cultivar IR 24. 14 entries showed resistant reaction to BLB. All resistant gene combination isogenic lines showed their resistant nature to the native bacterial blight pathogen.

**44. Integrated management of emerging disease in rice**

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During Kharif 2017, Sheath blight and BLB disease was low in Uma variety (18.19% and 15.78%) with FYM + PGPR1 + *Pseudomonas* (seed+ soil+ foliar+ Neemcake+ Neem based chemical (V<sub>3</sub>M<sub>1</sub>)) and high in Jyothi variety 23.69% with no management practices (V<sub>1</sub>M<sub>6</sub>).

During Rabi 2017-18, Sheath blight disease was low in Uma variety (21.53%) in the FYM + PGPR1 + *Pseudomonas* (seed+soil+foliar) + Neemcake + Neem based chemical treated plot (V<sub>3</sub>M<sub>1</sub>) when compared to Jyothi and Prathyasa. BLB was moderate and which was low in Uma variety (9.02%) with NPK as per POP + Bleaching powder/Kocide/streptocycline (V<sub>3</sub>M<sub>5</sub>) and high in Jyothi variety with no management practices (V<sub>1</sub>M<sub>6</sub>).

**45. Development of formulation of endophytic Bacteria for the management of soil borne diseases of rice with special emphasis on Sheath blight and Bacterial blight.**

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In Kharif 2017 the field trial was conducted at the station for evaluating the efficient endophytic *Bacillus sp* viz., B15, B17, B33 with standard *Pseudomonas* (P1) and check fungicides (Hexaconazole for sheath blight and Streptocycline for BLB). In Rabi 2017-18 three *Bacillus spp.* isolated from Kozhichal (B 15), Vellirackal (B17), Padachal (B 33) were found effective against sheath blight pathogen and BLB pathogen under *in vitro* condition. These bacterial cultures were sent to National Bureau of Agricultural Important Microorganisms, ICAR, Uttar Pradesh for accession number.

Test for volatile compound production of *Bacillus* cultures namely B 15, B 17 and B 33 were carried out under invitro condition. B 15 produce high quantity of volatile compounds against sheath blight pathogen followed by B 17 and B 33. Pot culture techniques were laid out for testing the biometric characteristic of the effective strains of B 15, B17, B 33 and the shelf life studies of the above strains are under progress. Seed and soil application of the formulations were carried out in the station field. Pot culture experiments were laid out in net house with the promising five isolates viz., Pf 7, Pf 82, Pf 87, B10, and B 42 along with standard culture (P1) for evaluating PGPR studies. Observations on plant characters are being recorded.

#### 46. Evaluation of rice genotypes for terminal heat tolerance

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During 2017-2018, thirty four entries were evaluated for high temperature stress from seedling stage to maturity. The crop was exposed to elevated temperature 5 to 6 °c above ambient condition in polyhouse. Under elevated temperature the yield was reduced more than 60% in most of the genotypes. IET 26768, IET 26778, 175-2K, IET 26763, IET 26776, S-458, IET 26772 produced relatively higher yield under heat stress condition. Spikelet fertility under ambient condition ranged from 70% to 92% but under high temperature it ranged from 13 to 90%. The variability in tolerance to high temperature of few genotypes is due to cellular level tolerance imparted by the production of heat shock proteins acting as molecular chaperons.

#### 47. Physiological characterization of rice genotypes for multiple abiotic stress resistance (PTB)

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Nineteen entries were subjected to multiple abiotic stresses (drought-1 and 2% mannitol; salinity-100ppm NaCl; and anaerobic germination), under hydroponics. The imposition of different abiotic stresses shows detrimental effect on germination and seedling growth. The genotypes 175-2K, IET 24053, IET 24934 were superior under 1% mannitol water stress and IET 26132, IET 26110, IET 26089, IET 26089, IET 26074 were superior under 2% manitol water stress. Similarly under salt stress and anaerobic stress 175-2K showed higher seedling vigour. Across all the stresses IET 24934, IET 24053, 175-2K showed superior performance among all the varieties tested.

#### 48. Advanced rice breeding cum seed production centre 2014-15 (Pilicode)

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Under a GoK plan project of rice named 'Advanced rice breeding centre' which was completed in 2016 -17, 5 traditional rice genotypes were collected from North Kerala districts. This programme of collection and conservation is continuing. This year six more genotypes were collected. Field conservation of the entire collection was done e both at institute and farmers' field.

#### 49. Evolution of high yielding rice varieties suitable for Pokkali tract of Northern Kerala through farmer's participatory breeding approach (KAU plan project) (Pilicode)

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During the year of 2017-18, five released varieties 'Ezhome -1', 'Ezhome -2', 'Ezhome -3', 'Ezhome -4', and 'Jaiava' and five pre-release cultures namely JO 583, JK 59, JK 14, JK 71 and MK 115 from North Kerala through breeder seed production programme were maintained, 2805 kg of seed of five released varieties namely 'Ezhome -1', 'Ezhome -2', 'Ezhome -3', 'Ezhome -4', and 'Jaiava' were produced and Multi location / farm trial of saline tolerant culture JO 583 in Pokkali tract of Ernakulam district and MLT in Pokkali soil was conducted both in research station of KAU and also in farmers' field were done. F<sub>4</sub> generations of Salinity pyramiding cross combinations namely Ezhome -1 x FL 478, Pokkali x Orkayama, Kuthiru x Orkayama were raised in non-saline wetland during 2017 Kharif to advance filial generation to F<sub>5</sub>. The F<sub>6</sub> generation of selected breeding lines for saline Kaipad as well as for non-saline wetland were raised under organic management during Rabi 2017-18 to advance generation to F<sub>6</sub> as well as for selection of breeding lines for rabi crop.

#### 50. Development of weather based forewarning system for Blast disease and Leaf folder pest of rice and formulation of Crop-Weather advisories to the rice farmers of Kuttanad region.

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ha in both alternatively and flooded condition. Study on host pathogen and environmental interaction are in progress.

**51. Long term evaluation of weed management**

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The treatment of pre emergence chemical application followed by post emergence herbicide application showed the better yield equal to that of mechanical methods of weed control. No much yield responses noticed in different weed control treatments tested in POP and modified SRI methods of rice cultivation.

**52. Yield maximization of rice through different sources of nutrient (Spl. Collaborative trial Geolife)**

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Professor  
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Responses to 100 per cent RDF + Tabsil (effervescent tablet with silicate) @ 2.5 kg / ha applied at 25 DAT was recorded the highest grain yield of 4.49 t/ha.

**53. Analysis of long term meteorological data (temp and rainfall) for identifying the reasons for yield reduction**

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Agronomy Division of RARS, Pattambi, taken the initiative steps to start this program and taken as lead center to collect the data from ten other rice centers in India. Datum was grouped and analyzed critically and observed the changes in temperature and rainfall and its influence on the rice yield. Results inferred that the climate parameters changed a lot in each rice zone particularly in minimum temperature raise was very visible. This program is continuing again with more centers and able to address the whole issue of climate change and its impacts on rice productivity in totality so as to cope with it through adaptation and mitigation.

**54. Frontline Demonstrations (FLD) on Rice Farm Mechanization**

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Total of 50 acres of rice plots were selected at Pudunagaram, Nallepilly, Kodumbu, Mannarkkad, Mannurr and Kottayi panchayat's for conducting this program. Yield advantages are observed in all the panchayats when compared to the normal practice manual planting. Farm mechanization in rice farming recorded the yield advantage of 625 to 1550 kg extra yield over manual planting. Besides farm mechanization in rice is also imparting cost reduction, timely planting and attracting the farmer's to continue rice farming.

**55. Evolution of high yielding rice hybrids suitable or Kerala.**

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The evaluation of KRH4 was continued in Rabi 2017-18 with popular high yielding check varieties. Hybrids with high yield and acceptable cooking quality identified from the study will be recommended for the state. Hybrid seed production package for Kerala is to be finalized utilizing the parental lines of superior hybrids identified from the study. CMS A lines, IR 58025A, IR 68897 A and IR 79156 A, were collected from IIRR and crossing programme has been initiated with varieties Thavalakkannan, Thekkancheera, Kattamodan, Thekkan chitteni, kayama, Annapoorna, Jyothi, Swarnaprabha, Mattatriveni, Aathira, Harsha, Samyuktha, Vaishak and Jaya during 2017-18. Progeny evaluation will be continued.

## 56. State Seed Testing Laboratory

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Quality of 203 seed samples were analysed in the State Seed Testing Laboratory Pattambi during 2017-18, in various crops like Rice (168), Vegetables (18) and pulses (17).

## 57. Development and evaluation of non conventional nutrient management technologies in rice (COE)

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Seedling root dip was tested using combinations of 19-19-19 and Sampoorna KAU multi mix. Based on the shoot length, root length and dry weight of the seedlings, the treatments such as seedling root dip for 10 minutes in 0.5% 19-19-19 and 1% Sampoorna KAU multimix, 3% 19-19-19 and 0.1% Sampoorna KAU multimix and for 20 minutes in 1% 19-19-19 and 0.5% SampoornaKAU multimix were selected for experiments in field.

## 58. Planting geometry modification in rice to exploit border effect-COE in rice

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Farm trials were conducted with paired row planting with 35-15X10 cm and 20X15 cm spacing in five locations and on an average 17 per cent yieldincrease were obtained in farmers field. It is recommended for multi location trial.

## 59. Evaluation of Radiation and Nitrogen use efficient promising rice genotype

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During 2017-2018, trial was conducted with three nitrogen treatments (0, 100 and 50%RDNN) and recommended P & K fertilizer as basal dose. Among the tested varieties Varadhan X MTU1010/2 showed minimum reduction in grain yield/m<sup>2</sup> with low nitrogen among the tested varieties, highest grain yield (g/m<sup>2</sup>) was observed in BPT 5204, VaradanX BPT5204/6 (0% RDN) and Varadan X BPT 5204/6, Varadan X MTU 1010/2 (50% RDN)and Sampada , Varadan x BPT 5204/6(100% RDN) among the high yielding varieties under three N levels, Varadan x BPT 5204/6 performed well under all the three N levels .

## 60. Development CMS lines for hybrid rice through marker assisted back crossing from identified maintainers and evaluation of promising hybrids

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The main objectives were Development of CMS lines from the identified maintainers through Marker Assisted Back Crossing andEvaluation of the identified Superior hybrids

In this study maintainers were grown during May and June 2017 and the crossing programme was undertaken during August and September, 2017. Four Maintainersviz., Jyothi, Kanchana, Aruna and Bharathi, were used as paternal recipient parent, and CMS line CRMS31A was used as maternal CMS-donor parent in first cross. In 2017, with the first cross between these lines, CMS of CRMS31A parent was transferred to F<sub>1</sub> generation. To conduct this crossing between CMS line and maintainers staggered sowing was done. Maintainers were sown in three replications, 10 days before the sowing date of CMS line, at the sowing date of CMS line and 10 days after the sowing date of CMS line.

Maintainers used in this experiment were obtained from RRS Moncompuand RARS pattambi and CMS line i.e.CRMS31A was obtained from CRRI, Cuttack. At the end of the crossing season four hybrid seeds (F<sub>1</sub>'<sub>s</sub>) were produced. Seeds from individual plants were harvested separately.Evaluation of F<sub>1</sub>'<sub>s</sub> for pollen sterility was done during February 2018 and spikelet sterility during March 2018. Some F<sub>1</sub> seeds were kept reserved for growing F<sub>1</sub> generation in next season to conduct backcross (BC<sub>1</sub>F<sub>1</sub>). The plants of F<sub>1</sub>'s showing highest sterility percentage were sown during April, 2018 to conduct backcross.

Seeds of all the varieties used in this study were grown on a raised bed. Then twenty-one days old seedlings were transplanted in the main field with the spacing between and within rows maintained at 15 X 10 cm with single seedling per hill. The fertilizer recommendations of 70 kg N, 35 kg P<sub>2</sub>O<sub>5</sub> and 35 kg K<sub>2</sub>O ha<sup>-1</sup> was followed for short duration varieties, 90 kg N, 45 kg P<sub>2</sub>O<sub>5</sub> and 45 kg K<sub>2</sub>O ha<sup>-1</sup> for medium duration varieties according to POP published by KAU. The standard agronomic cultivation practices were adopted. Plant protection measures were applied as and when required to crop to maintain the plant population and health of crop.

Among four hybrids (CRMS31A x Jyothi, CRMS31A x Kanchana, CRMS31A x Aruna and CRMS31A x Bharathi) CRMS31A x Jyothi F<sub>1</sub> shown highest percentage of pollen sterility and spikelet sterility as compared to other crosses.

Pollen fertility test of F<sub>1</sub> generation was performed via color staining by Acetocarmine. Using a light microscope, staining of pollen grains was evaluated. Ten microscopic fields were counted for each treatment and pollen sterility is expressed in percentage. Round well filled and deeply stained pollen gains were considered as fertile and unstained or poorly stained and shriveled pollen grains were counted as sterile.

Three panicles each from all plants were bagged at the time of anthesis with butter paper bag for selfing. At maturity, seed set was assessed by taking the actual count of seeds obtained to the total number of spikelets percent and expressed in percentage. Obtained to the total number of spikelets percent and expressed in percentage.

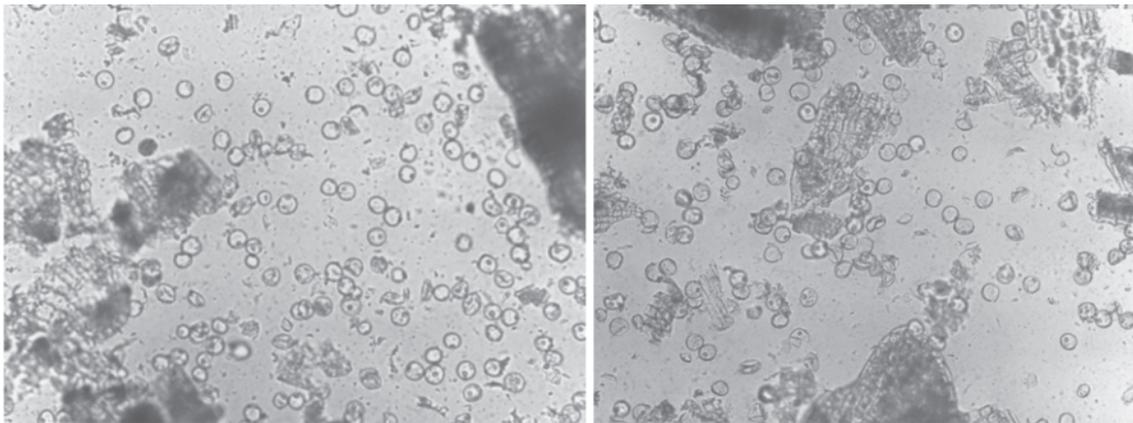


Fig. 1: CRMS 31A x Jyothi hybrid pollen grains stained with acetocarmine

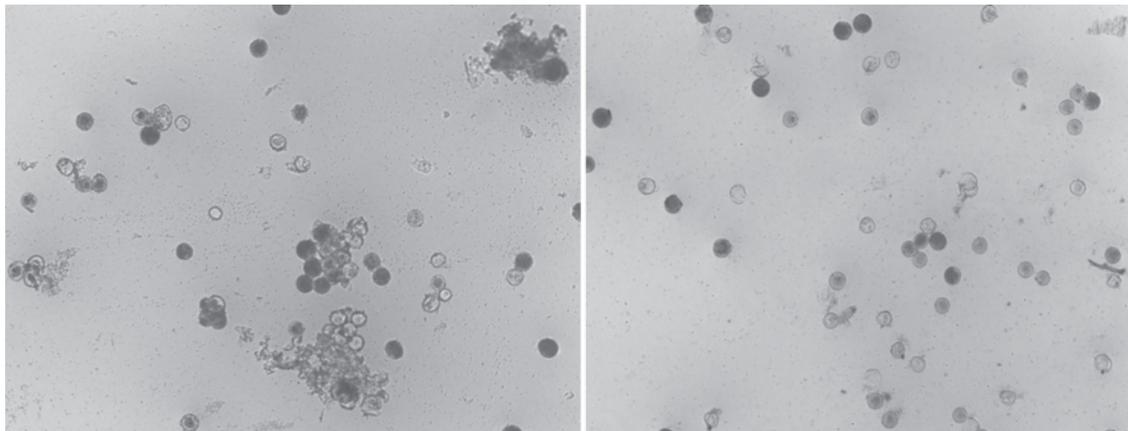


Fig. 2: CRMS 31A x Aruna hybrid pollen grains stained with acetocarmine

Out of 30 CRMS31A x jyothis hybrid plants, only 2 plants showed 99% male sterility. Out of 27 CRMS31A x Kanchana hybrid plants, 4 plants showed 80% male sterility. But in case of CRMS31A x Bharathi and CRMS31A x Aruna hybrid plants percent of male sterility transformed was very less (77% and 50% respectively). F<sub>1</sub> seeds (of the potential maintainer) giving 99% spikelet sterility is sown to obtain BC<sub>1</sub>F<sub>1</sub> seeds. A week before sowing F<sub>1</sub> seeds and Jyothi seeds, Jyothi paternal seeds was sown to overlap maximum anthesis. These F<sub>1</sub> seedlings are in field condition which will start flowering by 1<sup>st</sup> week of June 2018. By backcrossing these sterile F<sub>1</sub> plants with the maintainer, BC<sub>1</sub>F<sub>1</sub> seeds will be obtained by the mid of July month.

### **Molecular work:**

Due to successful application of molecular markers in selection programs for specific traits, in this study we used single locus SSR markers with codominant inheritance that is best suitable for recovery of RPG content in early generations. Leaf sampling for DNA extraction was performed at tiller stage. Genomic DNA from the young plant leaves of each parent was extracted using cetyltrimethyl ammonium bromide (CTAB) method to select 24 polymorphic SSR primers specific to maintainer. Out of these 38 SSR markers, 4 polymorphic SSR markers were selected for background selection. Controlling the quality and quantity of DNA was done by electrophoresis in 1% agarose gel.

Table 1: Purity of genomic DNA of Parental material

Parent	DNA purity
Jyothi	1.6
Aruna	1.5
Kanchana	1.38
Bharathi	1.7
CRMS31A	1.58

- RM 595, RM592, RM1 and RM228 were found polymorphic.
- Remaining 20 polymorphic SSR primers will be selected

Table 2: list of SSR primers screened to select polymorphic SSR markers for background selection:

Sr. no.	Primer name	Annealing Temp.
1	RM206	55
2	RM224	57
3	RM551	56
4	RM545	55
5	RM567	56
6	RM444	55
7	RM547	57
8	RM333	59
9	RM335	59
10	RM228	60
11	RM171	59.3
12	RM6100	56
13	RM6344	56
14	RM258	57.8
15	RM595	57
16	RM592	57
17	RM210	57
18	RM3233	61
19	RM204	62
20	RM3873	62
21	RM244	59
22	RM443	58.2
23	RM7003	59.3
24	RM1	60
25	RM187	59
26	RM311	51.3
27	RM527	54
28	RM585	61.3
29	RM315	61.5
30	RM591	61.3
31	RM440	58.4
32	RM216	58.4
33	RM151	60
34	RM260	56
35	RM287	57
36	RM229	55
37	RM21	57
38	RM204	58

**EXPERIMENT II****EVALUATION OF CMS BASED RICE HYBRIDS DEVELOPED FROM KERALA RICE VARIETIES IDENTIFIED AS RESTORERS**

The experiment was conducted at two sites, College of Agriculture, Vellayani, Thiruvananthapuram and IFSRS (Integrated Farming System Research Station), Karamana, Thiruvananthapuram.

**Hybrid seed production**

The identified parents (CMS lines and Restorers) were grown during May and June 2017 and the crossing programme was undertaken during August and September, 2017 (*Virippu*, 2017) and evaluation of  $F_1$ s along with parents and two standard checks was done during *Mundakan* 2017-18.

Two CMS lines (CRMS31A and CRMS32A) and the restorers (Remya, Jayathy, Swarnaprabha, Kanakom and Neeraja) were sown in May-June 2017. The restorers were sown in three staggered dates, 10 days before the sowing date of CMS lines, at the sowing date of CMS lines and 10 days after the sowing date of CMS lines. Synchronized flowering dates of the CMS and restorer line were recorded. CRMS31A was crossed with Remya, Jayathy, Swarnaprabha, Kanakom and Neeraja. CRMS32A was crossed with Annapoorna, Aiswarya, Mattatriveni and Kanakom. A total of nine hybrid seeds were produced. The six specific crosses that had given sufficient amount of viable seeds for evaluation in the next season was taken for hybrid evaluation.

**Evaluation of six hybrids**

The experiment was laid out in a Randomized Block Design with three replications during *mundakan*, 2017 at Integrated Farming System Research Centre, Karamana. The experimental material consisting of thirteen treatments ie, six  $F_1$ s viz., CRMS31A x Jayathy, CRMS31A x Kanakom, CRMS31A x Remya, CRMS32A x Annapoorna, CRMS32A x Kanakom, CRMS32A x Mattatriveni, five restorers viz., Annaopporna, Jayathy, Kanakom, Mattatriveni, Remya and two standard checks (Uma and Kanchana) were sown on 5<sup>th</sup> October 2017. Then twenty-five days old seedlings were transplanted in the main field at 20 x 15 cm spacing with single seedling per hill having plot size 2 x 2 m in three replications.

Farm yard manure @ 5 t ha<sup>-1</sup> was added to all the plots uniformly. The fertilizer recommendation of 70 kg N, 35 kg P<sub>2</sub>O<sub>5</sub> and 35 kg K<sub>2</sub>O ha<sup>-1</sup> was followed for short duration varieties, 90 kg N, 45 kg P<sub>2</sub>O<sub>5</sub> and 45 kg K<sub>2</sub>O ha<sup>-1</sup> for medium duration varieties according to POP KAU and 150 kg N, 75 kg P<sub>2</sub>O<sub>5</sub> and 75 kg K<sub>2</sub>O ha<sup>-1</sup> were followed for all the hybrids (Mohan, S., 2010). All standard agronomic recommended practices, irrigation and plant protection measures were adopted for raising healthy crop.

Five sample plants were randomly selected from each plot excluding the border plants and the following data were recorded: Plant height, number of productive tillers, days to flowering, panicle length, pollen fertility, number of spikelets panicle<sup>-1</sup>, days to maturity, number of filled grains panicle<sup>-1</sup>, length - breadth ratio of grain, 1000 grain weight, grain yield (g) plant<sup>-1</sup> yield plot<sup>-1</sup>, cooking quality (optimum cooking time, volume expansion) grain quality (kernel length, kernel breadth, Kernel length by breadth ratio, kernel colour), head rice recovery in milling, chemical characterization (amylose content, gelatinization temperature). The estimation of Standard heterosis and heterobeltiosis were done.

Five among the six hybrids were brown rice. All the hybrids were medium in size. Among that three hybrids (CRMS31A x Jayathy, CRMS31A x Kanakom, CRMS32A x Kanakom) were found to be showing heterobeltiosis (Superiority over the better parent) and three hybrids (CRMS31A x Jayathy, CRMS31A x Remya, CRMS32A x Kanakom) were found to be showing standard heterosis over the standard check variety Uma for yield. Two viz., CRMS32A x Annapoorna and CRMS32A x Mattatriveni were found to be showing standard heterosis for early flowering over the check variety for earliness Kanchana.

Hybrid H5 (CRMS 32A x Kanakam) is found to be promising with 23% yield advantage over the commercially accepted variety Uma. This hybrid should be evaluated over locations and seasons to confirm its superiority. The grain quality of this hybrid is also satisfactory with red medium bold grains.

**61. Breeding high yielding rice varieties suitable for pokkali area by hybridization between Pokkali varieties and other high yielding varieties.**

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Selected superior F5 plants were raised and evaluated in the F6 generation. F1 of the new cross of VTL 4 and Pusa 44 was

raised in pots to evaluate the performance and F2 seeds were collected. Crossing block for new crosses with VTL 1 and VTL 2 with Pusa 44 were started.

#### **62. Induced mutagenesis of pokkali rice land races**

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The mutant cultures differed significantly in CYT and the culture M 27.1 recorded the maximum yield of 6250 kg/ha followed by cultures M 51.5 (6067 kg/ha), M 48.4 (5233 kg/ha) and M 27.2 (5142 kg/ha). Culture 27.1 and cul 51.5 showed significantly high yield than the check and they were evaluated in farm trial.

#### **63. Collection, maintenance and utilization of saline resistant rice varieties**

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69 accessions were raised in the field during Kharif 2017. Data on morphological characters, yield and yield attributes were recorded. True to type panicles were collected.

#### **64. Response of pre-release Moncompu cultures to varying nutrient ratios**

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The fertilizer recommendation of the variety Shreyas (MO-22) can be fixed at 90:45:45 NPK kg/ha applied as  $\frac{1}{2}$ ,  $\frac{1}{4}$ ,  $\frac{1}{4}$  requirement of NPK at seedling, active tillering and panicle initiation stage of the crop. The yield of the variety was statistically on par at 90:45:45 and 100:45:45 NPK kg/ha. The variety exhibits lodging tendency at higher levels of nitrogen applied at panicle initiation stage of the crop.

#### **65. Crop management approaches for sustainable rice farming in Kari soils**

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Twenty five soil samples were collected from different locations of Kari lands in Kuttanad and analysed for 13 soil fertility parameters. Extensive soil acidification, excess levels of phosphorus and wide spread deficiencies of calcium, magnesium and boron were the major limitations to crop production in these soils. Amelioration of soil acidity and external inputs of secondary and micronutrients along with the major nutrients are essential for enhancing crop productivity in these soils.

#### **66. Evaluation of the efficacy of the herbicide molecule Penoxsulam 1.02 % (w/w)+ Cyhalofop butyl 5.1% (w/w) OD for weed control in direct seeded rice**

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Asst. Professor  
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The herbicide molecule Penoxsulam 1.02 % (w/w)+ Cyhalofop butyl 5.1% (w/w) OD was tested for broad spectrum management of weeds in DSR with special emphasis to the rice fields of Kuttanad. The new test molecule was found to be effective for broad spectrum control of weeds in direct sown rice @ 120 g ai/ha applied at 3-4 leaf stage of the weeds. The chemical was found to be less effective for the control of *Ludwigia sp.*

#### **67. Testing of insecticide "Avana" – (EID Parry Ltd.)**

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The insecticide 'Avana' of EID Parry (India) Ltd was tested for its bioefficacy in controlling the Stem borer and leaf folder

pests of paddy for one season. In the experiment, Avana 15 kg/ha was found to be the best treatment against Stem borer and Carthap hydrochloride 4%G@750gm/ha gave the best control of Leaf folder.

**68. Alkaline Tolerant Variety Trial (SATVT) and International Rice Saline Alkaline Tolerance Observational Nursery (National Saline Alkaline Screening Nursery (NSASN) Saline IRSATON)( RIC-03-03-20-94/VTL (9) KAU**

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Professor  
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During Kharif 2017, 43 new entries were received for evaluation under INGER IRSSTN for coastal salinity. These entries were evaluated in an RBD with two replications. The material consists of 29 test entries developed by IRRRI and 10 check varieties from IRRRI, India, and Sri Lanka. The check varieties were compared with the test entries for their adaptability to our condition. These test entries were also compared with our local check variety VTL 6. The check entries along with promising ones were included in our germplasm collection for further utilization in the breeding programme.

**CSTVT Kharif 2017**

Fifteen entries of the AVT (CSTVT, 2017) were evaluated and only one entry, 5102 outyielded the check VTL 6 and that too was on par with the local check. None of the varieties showed significant yield advantage over local check. In IVT (CSTVT, 2017), among 38 entries tested, the four entries (Nos. 5201, 5204, 5208 and 5220) were outyielded the check VTL 6. The two entries which show significant yield advantage were selected for further evaluation.

**69. Hybridization programme-improvement of pokkali rice**

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The selected F5 progeny lines were raised in the field during kharif 2017. Homozygosity were observed. Homozygous lines were harvested together for yield evaluation.

**70. Climate resilient rice production technology for Kuttanadu- Sub project –Screening of rice grmplasm for biotic and biotic stress**

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The objective of the experiment is developing new rice varieties combining high yield and resistance to biotic and abiotic stresses in the changed climate scenario. Five promising cultures selected from the lines developed under the Kuttanad package project are further evaluated during the period along with 4 check varieties.

During Kharif 2017, CYT was conducted with five cultures viz., KAUM 242-4-2-1-1-1, KAUM 261-1-3-1-1-1, KAUM 255 1-2-1-1-1, KAUM 250-1-1-1-1-1 and KAUM 259-5-3-1-1-1. Among the 5 cultures the highest grain yield was recorded by KAUM 242-2-1-1-1-1 (7007 kg/ha).

During Rabi 2017-18, among the 5 cultures the highest grain yield was recorded by KAUM 250-1-1-1-1-1 (3103.49 kg/ha).

**71. Breeding for high yielding rice varieties having short duration, seed dormancy and resistance to biotic and abiotic stress suitable for Kuttanad**

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During Kharif 2017, CYT was conducted with seven cultures viz., KAUM 184-1-2-1-1-1, KAUM 184-1-4-2-2-1, KAUM 185-2-1-1-1-1, KAUM 188-1-2-1-3-1, KAUM 192-1-1-1-2-1, KAUM 194-31-1-1-1 and KAUM 200-2-2-3-2-1 along with 4 checks. Among the 7 cultures the highest grain yield was recorded by KAUM 185-2-1-1-1-1 (9179kg/ha).

During puncha crop 2017-18, 7 cultures selected for comparative yield trial. The cultures KAUM 185-2-1-1-1-1 and KAUM 200-2-2-3-2-1 were the best performers with respect to grain yield. These cultures out yielded the check variety Uma in grain yield (3212 kg/ha). During Puncha 2017 also cul. KAUM 185-2-1-1-1-1 ranked first in yield.

## 72. Development of technology for enhancing the productivity of organic rice

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Organic rice production trials of Soil Science and Agronomy divisions of IIRR were tried in both *Kharif* and *Rabi* seasons. Results were shown that the comparable yields of 3.75 t/ha in organic inputs applied plots. Cost of organic inputs particularly FYM and its availability was realised in this trial. Moreover the yield reduction of 9.5 per cent with respect to 100 per cent inorganic N on organic inputs applied plots.

## 73. Virulence analysis of *Xanthomonas oryzae pv oryzae*

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During the year 2016-17, virulence analysis of bacterial blight pathogen of rice *Xanthomonas oryzae pv. oryzae* has been carried out with 31 near isogenic lines (IRBB background) with different bacterial blight resistance genes and their combinations. None of the gene combinations tested offered satisfactory resistance reaction to the native isolate of bacterial blight pathogen. However three NILs, IRBB-59, IRBB-60 and IRBB 66 showed moderate resistance to bacterial blight with Score3.

In 2017-18 also NILs, IRBB-60, IRBB-63 and IRBB-66 showed moderate resistance to bacterial blight with score3.

## PG Projects

### Concluded Projects

#### 1. Bioefficacy and soil health impact of flucetosulfuron in wet seeded rice (*Oryza sativa* L.)

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The PG project entitled 'Bioefficacy and soil health impact of flucetosulfuron in wet seeded rice (*Oryza sativa* L.)' was carried out at College of Agriculture, Vellayani, and Thiruvananthapuram during the first and second crop seasons of 2016-17. The study was aimed at assessing the bioefficacy of flucetosulfuron in wet seeded rice; identification of indicator plant for flucetosulfuron and the herbicide residue assessment in post-harvest soil through bioassay using the selected indicator plant. The study also envisaged to analyse the impact of flucetosulfuron on soil health by determining the microbial count, earthworm population and enzyme status. Experiment was also conducted to assess the effect of flucetosulfuron on weed seed bank as well as to study the *in vitro* sensitivity of biofertilizer organisms and biocontrol agents to flucetosulfuron. The investigation was conducted as six parts *viz.*, screening of suitable indicator plant for the residue studies of flucetosulfuron, field experiment for evaluating the bioefficacy of flucetosulfuron in wet seeded rice, assessment of herbicide residue in post-harvest soil through bioassay using the selected indicator plant, assay of weed seed bank, assessment of soil health impact of flucetosulfuron and determination of *in vitro* sensitivity of biofertilizer organisms and bio control agents to flucetosulfuron.

#### PART I: SCREENING OF INDICATOR PLANTS FOR FLUCETOSULFURON

As first part of the experiment, identification of the most suitable indicator plant for the determination of flucetosulfuron residue in soil, was carried out as a laboratory experiment, with eight different concentrations (0.01, 0.05, 0.1, 0.5, 1, 10, 50 and 100 mg L<sup>-1</sup>) of flucetosulfuron and a control. Among the indicator plants tested *viz.*, barnyard millet, cucumber, sunflower and maize, sunflower was identified as the most suitable indicator plant. Among the different parameters tested, shoot length of sunflower was selected as the most sensitive parameter to identify flucetosulfuron residue in soil, since it recorded the highest multiple correlation coefficient ( $R^2 = 0.9462$ ). The logarithmic linear regression equation,  $Y = 4.309788 - 0.64968 \ln(X)$ ,  $R^2 = 0.946$  was developed for shoot length of sunflower.

#### PART II: FIELD EXPERIMENT- BIOEFFICACY OF FLUCETOSULFURON IN WET SEEDED RICE

In the present study, the major weed flora identified in the experiment field included grasses, *viz.*, *Isachnemiliacea*, *Echinochloa colona*, *Echinochloa crusgalli*, *Echinochloa stagnina*, broadleaved weeds *viz.*, *Limnocharis flava*, *Commelinadiffusa*, *Monochoria vaginalis*, *Ludwigia perennis*, *Marseliaquadrifolia*, *Linderniarotundifolia* and sedges *viz.*, *Schoenoplectus juncooides*, *Cyperusiria*, and *Cyperushaspan*. The field was more diverse with broadleaved weeds compared to sedges and grasses

whereas it was more quantified, by means of dry weight, with sedges than grasses and broadleaved weeds. The problematic weed found in the experimental area in the present study was *Schoenoplectus juncooides*, a sedge species.

Quantitative assessment of weed vegetation analysis parameters revealed that the time of application of flucetosulfuron is critical in reducing the weed infestation. Application of flucetosulfuron at 10-12 and 18-20 DAS as well as hand weeding treatments were found to be significantly superior in reducing the absolute density of grasses, broadleaved weeds and sedges, at the time of observations viz., 30, 45 and 60 DAS, compared to its application at 2-3 DAS, irrespective of the various doses tested. Similar trend was observed in the case of total weed density also, indicating that flucetosulfuron applied at 2-3 DAS was less effective, may be because it could not reduce the later emerged weed flushes. The highest total weed density was recorded by weedy check during both the crop seasons .

Analysis of weed dry weight, another imperative parameter to assess the weed infestation, revealed that, at the critical stages of crop weed competition viz., 30, 45 and 60 DAS, application of flucetosulfuron at 10-12 and 18-20 DAS and hand weeding twice registered significantly lower dry weight of grasses, broadleaved weeds and sedges compared to its application at 2-3 DAS, during the I and II crop seasons, indicating the importance of time of application of flucetosulfuron in controlling weeds. The results revealed that application of flucetosulfuron @ 2-3 DAS could control weeds only for around 15 DAS, whereas the effect of other times of application viz., 10-12 and 18-20 DAS lasts for more than 40 days. Hand weeding twice (at 20 and 40 DAS) also recorded high efficacy in reducing total weed dry weight at 30, 45 and 60 DAS. The weedy check reported the highest total weed dry weight at 15, 30, 45 and 60 DAS during I (5.34, 42.36, 415.65 and 569.34 g m<sup>-2</sup> respectively) and II crop (5.97, 32.85 301.37, 584.28 g m<sup>-2</sup> respectively) seasons, compared to other weed management treatments.

The absolute frequency of weeds viz., grasses, broadleaved weeds and sedges was lower when flucetosulfuron was applied at 10-12 and 18-20 DAS irrespective of the various doses tested (20, 25 and 30 g ha<sup>-1</sup>), compared to its application at 2-3 DAS, implying the importance of time of application of flucetosulfuron in reducing the weed occurrence. Total absolute frequency of weeds varied significantly at all the stages of observation during both the seasons. At 30, 45 and 60 DAS, during both the seasons, the highest absolute frequency of weeds was registered by weedy check. However, application of bispyribac sodium @ 25 g ha<sup>-1</sup> at 15 DAS was found to be on par with it, many a time, implying that these treatments were least effective in controlling the emergence of weeds.

Critical analysis of the relative frequency of grasses, broadleaved weeds and sedges, revealed that, sedges are having higher relative frequency than grasses and broadleaved weeds during both the seasons, indicating that the infestation intensity of sedge species is more in the experimental field, compared to grasses and broadleaved weeds.

Bispyribac sodium was less effective in managing the sedges especially *Schoenoplectus juncooides*, which was the dominant and problematic weed in the experimental area, resulting in comparatively higher weed density and dry weight in these plots. Weedy check recorded significantly higher weed density and weed dry weight, compared to all other weed control treatments indicating the need for timely weed management.

During the critical periods of crop-weed competition viz., 30, 45 and 60 DAS, higher weed control efficiency was registered in the plots where flucetosulfuron was applied at 10-12 and 18-20 DAS, irrespective of the doses tested. Hand weeding twice also recorded significantly higher weed control efficiency at critical stages. Application of flucetosulfuron at 2-3 DAS as well as application of bispyribac sodium at 15 DAS resulted in significantly lower weed control efficiency.

Weed management practices significantly influenced the crop growth especially, crop dry matter production. During both the seasons, application of flucetosulfuron at 10-12 DAS and 18-20 DAS as well as hand weeding twice recorded relatively higher dry matter production at all the crop growth stages. Lower dry matter production was recorded when flucetosulfuron was applied at 2-3 DAS irrespective of various doses tested. The lowest crop dry matter production was recorded in weedy check.

The yield attributes viz., productive tillers m<sup>-2</sup>, spikelets panicle<sup>-1</sup> and sterility per cent varied significantly due to the weed management practices adopted. Time of application of flucetosulfuron was the determining factor than various doses tested. Application of flucetosulfuron at 10-12 and 18-20 DAS and hand weeding twice resulted in significantly higher yield attributes in comparison with its application at 2-3 DAS. Weedy check registered the lowest values for all the yield attributing characters.

Significantly higher grain yield was obtained with flucetosulfuron applied at 10-12 and 18-20 DAS as well as with hand weeding twice during both the crop seasons. For the best weed management treatment (flucetosulfuron @ 25 g ha<sup>-1</sup>

applied at 10-12 DAS) during the I crop season, percentage yield increase over weedy check was 52.33, whereas that for the best treatment (flucetosulfuron @ 20 g ha<sup>-1</sup> at 10-12 DAS) during the II crop season was 55.61. Pooled analysis of the data indicated that the highest grain yield of 8.33 t ha<sup>-1</sup> was recorded by flucetosulfuron @ 25 g ha<sup>-1</sup> at 10-12 DAS and was found to be on par with hand weeding twice, and flucetosulfuron @ 20 g and 30 g ha<sup>-1</sup> at 10-12 DAS. Application bispyribac sodium @ 25 g ha<sup>-1</sup> at 15 DAS recorded significantly lower grain yield because of its poor efficacy in controlling the sedges present in the experimental area. Weedy check recorded significantly lower grain yield during both the season compared to all other treatments. The results of the field experiment conform the suitability of using of flucetosulfuron as an early post emergence or post emergence herbicide in wet direct seeded rice for realising higher grain yield.

Higher harvest indices were recorded by the application of flucetosulfuron at 10-12 DAS and 18-20 DAS during both the crop seasons, compared to its application at 2-3 DAS. Application of flucetosulfuron @ 25 g ha<sup>-1</sup> at 10-12 DAS recorded the highest harvest index (0.50) during the I crop season whereas during the II crop season, application of flucetosulfuron @ 20 g ha<sup>-1</sup> at 10-12 DAS recorded the highest harvest index (0.51). Lower weed index *i.e.*, percentage yield reduction due to weeds, was recorded by the application of flucetosulfuron at 10-12 DAS and 18-20 DAS as well as hand weeding twice during both the crop seasons. The yield loss due to weeds was maximum in weedy check as evident from the highest weed index (52.33 and 55.61 during the I and II crop seasons respectively) recorded in this treatment compared to the lower weed indices ranging from 8.21 to 9.52 and 4.22 to 4.29 per cent during the I and II crop seasons respectively in the most effective treatments *viz.*, flucetosulfuron @ 20, 25 and 30 g ha<sup>-1</sup> applied at 10-12 DAS.

Economic analysis was also carried out and pooled analysis of the data indicated that flucetosulfuron @ 25 g ha<sup>-1</sup> at 10-12 DAS recorded the highest net returns (1,79,820 0 ha<sup>-1</sup>) which was on par with flucetosulfuron @ 20 and 30 g ha<sup>-1</sup> at 10-12 DAS and flucetosulfuron @ 20 g ha<sup>-1</sup> applied at 18-20 DAS. Similar results were obtained for B:C ratio also. Highest B:C ratio of 2.53 was reported by flucetosulfuron @ 25 g ha<sup>-1</sup> at 10-12 DAS. Even though weed control efficiency as well as grain yield of hand weeding twice treatments was comparable to flucetosulfuron @ 20, 25 and 30 g ha<sup>-1</sup> at 10-12 DAS, net income and B:C ratio were comparatively low for this treatment due to the huge expenditure incurred for manual weeding. The weedy check registered the lowest net income and B:C ratio implying the essentiality of herbicidal weed management in direct seeded rice for realising economic returns. Based on the yield and economics, application of flucetosulfuron @ 20, 25 and 30 g ha<sup>-1</sup> at 10-12 DAS is the best treatment among the various weed management practices tested.

#### PART III: ASSESSMENT OF HERBICIDE RESIDUE IN SOIL THROUGH BIOASSAY USING SELECTED INDICATOR PLANT:

As the third part of the study, after each field experiment, bioassay was conducted, using the selected indicator plant, sunflower, to find out whether there is any residual effect of flucetosulfuron in the paddy soil. The results revealed that there was no significant difference among the weed management practices on the different growth parameters *viz.*, shoot and root length and shoot fresh and dry weight of sunflower, during both the crop seasons, indicating that, the herbicide flucetosulfuron @ 20, 25 and 30 g ha<sup>-1</sup> at 2-3, 10-12 and 18-20 DAS, applied to wet seeded paddy soil do not result in perceivable residue build up in soil. Hence, application of flucetosulfuron even at its tested higher dose will not cause any harmful effects on the succeeding crop and is environmentally safe.

#### PART IV: WEED SEED BANK ASSAY

Weed seed bank assay was carried out as the fourth part of the study and the seed bank assay conducted before and after each field experiment revealed that weed management practices significantly influenced the soil weed seed bank. Before the experiment, emergence of weeds from the soil seed bank was non-significant during both the crop seasons. However, after each field experiment, number of weeds emerging from the field varied significantly due to the weed management practices adopted. The lowest count of grasses, broadleaved weeds, sedges and total weeds was recorded from plots where flucetosulfuron was applied at 10-12 and 18-20 DAS irrespective of the doses of application. The data on weed emergence after both the crop season revealed that weedy check recorded the highest emergence of all the categories of weeds (grasses, sedges and broadleaved weeds) and total weed emergence, indicating the necessity for timely weed control through herbicides for depleting the weed seed bank in the soil.

#### PART V: ASSESSMENT OF SOIL HEALTH IMPACT OF FLUCETOSULFURON

The fifth part of the study was assessment of soil health impact of flucetosulfuron in terms of earthworm count, spider count, microbial population, enzyme (dehydrogenase, urease and acid phosphatase) dynamics and organic carbon status of soil. Herbicide application did not cause any significant alterations in the earthworm count before and after the crop. Even though a slight reduction in the average count of earthworm could be seen compared to the same before starting the crop in the field, no alarming reduction due to herbicide application could be found in the study. The effect of weed

management treatments on spider count was also found to be non significant.

Six days after herbicide application, the microbial population (bacteria, fungi and actinomycetes) in the herbicidal plots was found to be increasing compared to the corresponding pre-treatment values and population in the non-herbicidal plots, indicating the safety of the tested doses of flucetosulfuron for soil microbial population.

An increasing trend in the enzyme activity could be seen from just before herbicide application (JBHA) to 30 days after herbicide application (DAHA) in both the crop seasons. Just before herbicide application, there was no significant variation among the treatments, during both the crop seasons. At both the time of sampling viz., 15 as well as at 30 DAHA, dehydrogenase enzyme activity was found to be significantly higher compared to the pre-treatment values. Application of flucetosulfuron at 10-12 and 18-20 DAS recorded relatively higher dehydrogenase enzyme activity compared to its application at 2-3 DAS, just because of the difference in crop growth stages during the time of sampling. Hand weeding also recorded significantly higher dehydrogenase enzyme activity and weedy check recorded the lowest enzyme activity.

Acid phosphatase enzyme activity, at 15 and 30 DAHA, was found to be non-significant. In general, the soil exhibited lesser acid phosphatase enzyme activity irrespective of the treatments. This might be due to the less phosphorus stress experienced in the high P soil.

Herbicide application could increase the urease enzyme activity irrespective of dose and time of applications tested. Just before herbicide application, the enzyme activity was found to be non significant during both the crop seasons. At 15 and 30 DAHA significantly higher urease enzyme activity was recorded in the herbicide applied plots compared to the non herbicidal plots. Compared to pre-treatment values, urease enzyme activity increased at 15 and 30 DAHA. The soil organic carbon (OC) content was found to be increasing from JBHA to 15 and 30 DAHA during both the crop seasons, that too in the herbicidal plots compared to the non herbicidal plots. Correlation analysis of soil OC and dehydrogenase enzyme revealed significant positive correlations between the variables assayed.

A critical analysis of the impact of the herbicide, flucetosulfuron at all the tested doses (20, 25 and 30 g ha<sup>-1</sup>) and times of application (10-12 and 18-20 DAS) on soil health indicators viz., soil microbial count, enzyme status, earthworm and spider count and organic matter content of soil confirmed the environmental safety of flucetosulfuron.

#### IN VITRO SENSITIVITY OF BENEFICIAL ORGANISMS TO FLUCETOSULFURON

*In vitro* sensitivity of the biofertilizer organisms viz., *Azospirillum lipoferum*, *Azotobacterchroococcum*, *Bacillus megaterium* and *Frateuria aurantia* revealed that none of the organisms produced any inhibition zone due to the presence of filter paper disc impregnated with different doses of flucetosulfuron (30-90 µL L<sup>-1</sup>) implying the safety of the herbicide even at double the recommended dose and confirming the possibility of combined application of flucetosulfuron and these biofertilizers.

Results of the *in vitro* study of *Trichoderma viridae* revealed that the tested concentrations (30-90 µL L<sup>-1</sup>) of flucetosulfuron did not significantly affect the radial growth of *Trichoderma viridae*. At all the concentrations of flucetosulfuron, *Trichoderma viridae* showed a colony diameter of 9mm uniformly with zero per cent inhibition (Plate 5). Similarly, *in vitro* sensitivity of *Pseudomonas fluorescens* revealed that there was no zone of inhibition at different concentrations (30-90 µL L<sup>-1</sup>) of flucetosulfuron tested and the growth of *Pseudomonas fluorescens* was found to be positive also. The results revealed that flucetosulfuron is compatible with the bio control agents, indicating the possibility of using these bio control agents along with flucetosulfuron in integrated pest and disease management programmes.

From the study, it can be concluded that, application of flucetosulfuron @ 20, 25 and 30 g ha<sup>-1</sup> at 10-12 DAS was very effective for controlling weeds and recorded higher yield and monetary benefits in wet direct seeded rice. Flucetosulfuron applied at 10-12 and 18-20 DAS was very effective in depleting the soil seed bank and the bioassay studies revealed that flucetosulfuron did not leave any toxic residues in the soil. The study results also indicated that, application of flucetosulfuron @ 20, 25 and 30 g ha<sup>-1</sup> applied at 2-3, 10-12 and 18-20 DAS has no adverse effect on soil health, as evidenced by the count of earthworm, spider and microorganisms as well as soil enzyme activity and was found compatible with the biofertilizer organisms (*Azospirillum lipoferum*, *Azotobacterchroococcum*, *Bacillus megaterium* and *Frateuria aurantia*) and bio control agents (*Trichoderma viridae* and *Pseudomonas fluorescens*).

## 2. Effect of soil amelioration and supplementary foliar nutrition on rice yield in kuttanad

A study on "Effect of soil amelioration and supplementary foliar nutrition on rice yield in Kuttanad" was carried out at College of Agriculture, Vellayani to evaluate the effect of soil amelioration with rice husk ash in abating iron toxicity and

supplementary foliar application of a customized nutrient formulation in increasing rice yield in the low lands of Kuttanad. The overall fertility status of this region indicated that the soil was acidic with high level of P, medium level of available N and K and wide spread deficiencies of Ca, Mg, Cu, Zn and B.

A customized nutrient formulation with a composition of K (8.9%), Mg (3.2%), Ca (3.7%), Zn (2.1%), Mn (0.23%), B (3.5%) and Cu (0.96%) was developed based on the available nutrient status of the region and crop requirement. This formulation was used for supplementary foliar nutrition @ 5 kg ha<sup>-1</sup> as foliar application of 0.5% solution in two splits at maximum tillering and panicle initiation stage. The field experiment was conducted at Rice Research Station, Moncompu (July to November 2017) with nine treatments and the treatments were T<sub>1</sub> (Recommended dose of fertilizer and lime (RDF)), T<sub>2</sub> (Soil test based RDF and lime (based on pH)), T<sub>3</sub> (Soil test based RDF + Rice husk ash (RHA) @ lime in T<sub>2</sub>), T<sub>4</sub> (Soil test based RDF + RHA @ ½ lime in T<sub>2</sub>), T<sub>5</sub> (T<sub>1</sub> + foliar spray of 0.5% solution of customized formulation at tillering and panicle initiation stage (FS)), T<sub>6</sub> (T<sub>2</sub> + FS), T<sub>7</sub> (T<sub>3</sub> + FS), T<sub>8</sub> (T<sub>4</sub> + FS). And T<sub>9</sub> (50% Soil test based RDF + RHA @ lime in T<sub>2</sub> + FS) replicated thrice in RBD using rice variety Uma.

Growth and yield of rice increased significantly due to soil amelioration and supplementary foliar nutrition. During the maximum tillering stage, the highest plant height (55.32 cm) was recorded in the treatment T<sub>5</sub> and was on par with all other treatments except treatment T<sub>9</sub>. The treatments did not show a significant influence on number of tillers at maximum tillering and panicle initiation stages. Treatment T<sub>7</sub> recorded the highest number of productive tillers (12.36), which was on par with treatments T<sub>6</sub>, T<sub>5</sub>, and T<sub>3</sub>.

The treatment T<sub>7</sub> recorded the highest value for all the yield attributes and yield such as panicles per m<sup>2</sup> (549.62), thousand grain weight (26.6 g), number of filled grains per panicle (136.5), grain yield (6.60 t ha<sup>-1</sup>) and straw yield (8.34 t ha<sup>-1</sup>). The highest number of panicles per m<sup>2</sup> recorded for the treatment T<sub>7</sub> was found to be on par with treatments T<sub>5</sub> and T<sub>6</sub> while for the thousand grain weight treatment T<sub>7</sub> was on par with treatment T<sub>6</sub>, T<sub>8</sub> and T<sub>4</sub>. For grain yield treatment T<sub>7</sub> was found to be on par with all other treatments except treatment T<sub>4</sub> and T<sub>9</sub>.

The results of scoring of iron toxicity using standard evaluation system for rice (IRRI, 1996) at maximum tillering stage and panicle initiation stage revealed that during maximum tillering stage, there was no visual symptom on the plants, but during panicle initiation stage, the symptoms were expressed in treatments T<sub>1</sub> and T<sub>9</sub>, and T<sub>9</sub> recorded the highest score (3).

Soil analysis done at the time of harvest showed that the pH increased from the initial value of 4.35 to the highest value of 5.5 which was recorded for the treatment T<sub>7</sub> and was on par with treatments T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>8</sub> and T<sub>9</sub>, while the treatments did not have a significant influence on the EC. The treatment T<sub>7</sub> recorded the highest organic carbon content (3.06 %). In the case of primary nutrients, for both available N and P treatment T<sub>8</sub> recorded the highest value (385.76 kg ha<sup>-1</sup> and 25.22 kg ha<sup>-1</sup>) and for available K (218.4 kg ha<sup>-1</sup>) it was recorded by treatment T<sub>7</sub>. For exchangeable Ca and Mg the highest value was recorded for treatment T<sub>6</sub> (157.33 mg kg<sup>-1</sup>) and T<sub>7</sub> (29.86 mg kg<sup>-1</sup>) respectively which was superior to all other treatments. In the case of available S, the treatment T<sub>5</sub> recorded the highest value (21.17 mg kg<sup>-1</sup>). The results showed that the treatment T<sub>7</sub> recorded the lowest available Fe (322.53 mg kg<sup>-1</sup>) and Mn (3.27 mg kg<sup>-1</sup>) content during the harvest stage. For available Zn, Cu, B and Si, the treatment T<sub>7</sub> recorded the highest value (3.01, 2.73, 0.504 and 36.83 mg kg<sup>-1</sup> respectively) and was superior to all the treatments except for Zn where the treatments did not have a significant influence.

The results of the plant analysis revealed that the treatment T<sub>7</sub> recorded the lowest leaf iron content during the maximum tillering and panicle initiation stage (125 and 141 mg kg<sup>-1</sup>). In the case of primary nutrients, for N and K content in grain (1.30 and 0.666 mg kg<sup>-1</sup>) and straw (0.77 and 2.32 mg kg<sup>-1</sup>) the treatment T<sub>7</sub> recorded the highest value and the treatment T<sub>8</sub> recorded the highest P content in grain (0.196 mg kg<sup>-1</sup>) and straw (0.146 mg kg<sup>-1</sup>). In the case of secondary nutrients, the treatment T<sub>7</sub> recorded the highest grain and straw content for Ca (0.28 and 0.54 mg kg<sup>-1</sup>), Mg (0.087 and 0.146 mg kg<sup>-1</sup>), S (0.151 and 0.173 mg kg<sup>-1</sup>) and also for the beneficial element Si (0.81 and 3.98 mg kg<sup>-1</sup>). Treatment T<sub>7</sub> recorded the highest micronutrient content in grain and straw for Mn (42.9 and 157.7 mg kg<sup>-1</sup>), Cu (6.0 and 14.2 mg kg<sup>-1</sup>), Zn (29.3 and 58.4 mg kg<sup>-1</sup>) and B (12.1 and 16.4 mg kg<sup>-1</sup>) but recorded the lowest value for Fe content in grain and straw (55 and 154.3 mg kg<sup>-1</sup>) which indicated the influence of rice husk ash in reducing the iron uptake in plant. The treatment T<sub>7</sub> recorded the highest value for uptake of all the nutrients except for Fe uptake in the plant.

The study revealed that the treatment T<sub>7</sub> recorded the lowest percentage of incidence of leaf roller (4.37) and there was no incidence of major diseases during the crop period. Treatment T<sub>7</sub> recorded the highest net income (Rs. 87679/-) and BC ratio (1.82).

From the investigation it can be concluded that treatment T<sub>7</sub> (Soil test based RDF + Rice husk ash @ lime (based on pH) + foliar spray of 0.5% solution of customized formulation at tillering and panicle initiation stage) was the best treatment in which the yield increased by 21 % compared to RDF and B:C ratio increased from 1.44 to 1.82. Effect of rice husk ash in ameliorating soil acidity was found to be on par with application of lime based on pH. Use of rice husk ash as soil ameliorant along with soil test based RDF and supplementary foliar nutrition improved rice yield in Kuttanad and reduced the nutritional constraints due to iron toxicity

### 3. Pyramiding Bacterial Leaf Blight Resistance Genes Into Popular Rice Varieties Of Kerala Through Marker Assisted Selection

Bacterial blight (BB) caused by *Xanthomonas oryzae* pv. *oryzae* (Xoo) is a devastating disease of rice in Asia and Africa. Major rice growing areas of Kerala are highly prone to this disease which results in damage upto 35 per cent. Exploitation of host plant resistance is the only practical strategy for managing the disease in an ecofriendly manner. Till date, more than 40 resistance genes for BLB have been identified from diverse sources and pyramiding of these resistance genes will impart durable resistance. So, the present study entitled "Pyramiding Bacterial Leaf Blight resistance genes into popular rice varieties of Kerala through marker assisted selection" was undertaken at the College of Agriculture Vellayani Thiruvananthapuram, to pyramid the genes for resistance to bacterial blight (*xa13*, *Xa21*, *Xa33*, *Xa38*) into the popular rice varieties, Prathyasa and Aiswarya through foreground selection for the genes using molecular markers, to obtain lines with the two/three resistance genes combination in the background of above cultivars.

DNA markers closely linked to the BB resistance genes, such as pTA248 (*Xa21* gene), *xa13* pro (*xa13* gene), RMWR7.1 (*Xa33* gene) and Os04g53050-1 (*Xa38* gene) were used for validation of the marker polymorphism in the donors of the genes for resistance to BB viz. Improved Samba Mahsuri with *xa13* and *Xa21*, Improved Samba Mahsuri with *Xa33*, and PR-114 with *Xa38* and susceptible recipient parents Aiswarya and Prathyasa. This validation confirmed the absence of the genes in the recurrent parents chosen for the study. These polymorphic markers were also used for foreground selection in F<sub>1</sub> plants and backcross generations.

Initial hybridization was performed between two recipient parents and three donor parents to transfer the genes for resistance. Foreground selection was carried out in 193 F<sub>1</sub> plants from these six crosses using molecular markers specific to the genes. F<sub>1</sub> plants (163) with heterozygous loci for trait specific marker were backcrossed with respective recurrent parent and obtained 776 BC<sub>1</sub>F<sub>1</sub> plants in six cross combinations. These plants were screened with four trait specific foreground markers and 279 plants were identified with genes of interest. From among these forty two plants in the 2 crosses Aiswarya x ISM (*xa13* and *Xa21*) and Prathyasa x ISM (*xa13* and *Xa21*) had both genes (*xa13* and *Xa21*) in heterozygous condition.  $\chi^2$  test was done with the genotypic data of BC<sub>1</sub>F<sub>1</sub> plants with single gene viz. *Xa33* and *Xa38*. Segregation ratios in BC<sub>1</sub>F<sub>1</sub> population from the crosses viz. Prathyasa x ISM (*Xa33*), Aiswarya x PR-114 (*Xa38*) and Prathyasa x PR-114 (*Xa38*) did not show significant deviation from the expected 1:1 ratio. But BC<sub>1</sub>F<sub>1</sub> plants with *Xa33* gene of the cross Aiswarya x ISM showed significant deviation from 1:1 segregation ratio. This suggests the presence of segregation distortion in these segregants.

For the background selection four varieties were genotyped with 270 microsatellite loci and 180 discrete, unambiguous amplicons specific for the four varieties were identified. The background selection was carried out on altogether 279 plants from six BC<sub>1</sub>F<sub>1</sub> populations using 143 loci polymorphic in the parents. The BC<sub>1</sub>F<sub>1</sub> plants with highest percentage of recurrent parent genome recovery in the six populations were selected based on the background markers. These plants were used for intermating programme to pyramid the genes.

The disease screening of donors, Improved Samba Mahsuri (*xa13* and *Xa21*), Improved Samba Mahsuri (*Xa33*), and PR-114 (*Xa38*) against local isolate of *Xanthomonas oryzae* pv. *oryzae* conducted at RRS, Moncompu showed resistant disease reaction in the donors ISM (*xa13* and *Xa21*) and ISM (*Xa33*). PR-114 (*Xa38*) exhibited moderate susceptible disease reaction and so this donor was excluded from further breeding programme.

BC<sub>1</sub>F<sub>1</sub> plants having *xa13* and *Xa21* genes were used as female parent and BC<sub>1</sub>F<sub>1</sub> plants with *Xa33* used as male parent in intermating programme for pyramiding. Foreground selection was performed in the intermated plants using trait specific markers. Among Aiswarya derived BC<sub>1</sub>F<sub>1</sub> intermated plants, seven plants showed three resistance gene combination (*Xa21* + *xa13* + *Xa33*) and forty four plants showed two resistance gene combinations. Among the forty four plants with two resistance gene combination, seventeen had *xa13* + *Xa33*, 18 had *Xa21* + *xa13* and 9 had *Xa21* + *Xa33*. In Prathyasa derived BC<sub>1</sub>F<sub>1</sub> intermated plants 12 plants had *Xa21* + *xa13* gene combinations and nine had *xa13* + *Xa33* resistance gene combination. Based on the four quantitative traits (plant height, number of productive tillers, grain L/B ratio and days to maturity) Euclidean coefficient of dissimilarity was assessed in comparison with the respective recurrent parents, in plants pyramided with resistance genes. In Aiswarya derived pyramided plants coefficient of dissimilarity with Aiswarya for the four

quantitative traits varied from 2.24 to 27.25. Coefficient of dissimilarity with Prathyasa in the Prathyasa derived pyramided lines based on the four quantitative traits ranged from 3.00 to 17.47. The morphological traits of the two / three gene pyramided BC<sub>1</sub>F<sub>1</sub> genotypes were found to be either superior or on par with the recurrent parents Aiswarya and Prathyasa. Majority of pyramided lines showed red kernel colour of the recurrent parents.

This research led to development of plants pyramided with two / three genes for resistance to BB in the background of Aiswarya and plants with two resistance genes in the background of Prathyasa. These pyramided lines can be used for further breeding programme to develop Essentially Derived Varieties (EDVs) to tackle the Bacterial Leaf Blight (BB) disease.

#### **4. Genotyping of *Rf* (Restoring fertility) loci of rice varieties of Kerala using molecular markers”**

Hybrid rice technology aims to increase the yield potential of rice beyond the level of high yielding varieties by exploiting the phenomenon of hybrid vigour or heterosis. It is the only technology available now to break the yield plateau attained in rice. Commercial production of hybrid rice can be achieved through three line system of hybrid rice development. Identification of restorers and maintainers for the system is the initial step in hybrid rice breeding. So the present study entitled “Genotyping of *Rf* (Restoring fertility) loci of rice varieties of Kerala using molecular markers” was undertaken as an initial step for the development of hybrid rice for Kerala with the objectives to locate restorers and maintainers from Kerala rice varieties using molecular markers, validation of the restoration of fertility in cross with WA Cytoplasmic Male Sterile (CMS) lines, study of inheritance pattern of restorer gene and to locate heterotic combiners from the possible restorers and maintainers.

In the present study twenty one rice varieties were screened with 13 SSR markers linked to different *Rf* genes i.e *Rf3*, *Rf4*, *Rf5*, *Rf6* and *Rf7*. Three varieties had only one *Rf* gene, seven varieties had two *Rf* gene, four varieties had three *Rf* gene. Rice varieties Remya, Manupriya and Swarnaprabha had four *Rf* genes and PTB-9 had all the *Rf* genes. For identification of maintainers and restorers from among the 21 rice varieties under study, these lines were crossed with 4 CMS lines (IR58025A, UPRI95-17A, CRMS31A and CRMS32A). Pollen and spikelet fertility of the hybrids recorded that Remya, Swarnaprabha, Manupriya, Varsha and Aiswarya were restorers for CMS line IR58025A, Remya, Jayathi, Annapoorna, Neeraja, Aiswarya and Pavizham were restorers for UPRI95-17A. Remya, Jayathi, Swarnaprabha, Kanakom and Neeraja were restorers for CRMS31A and Remya, Jayathi, Swarnaprabha, Annapoorna, Kanakom, Mattatriveni and Pavizham were restorers for CRMS32A. Rice variety Remya alone was found to be the restorer for all four CMS lines. Rice varieties Jyothi, Kanchana and Aruna were identified as maintainers for IR58025A. Only one variety Kanchana identified as maintainer for UPRI95-17A. Bharathy, Jyothi, Kanchana and Aruna were identified as maintainers for CMS line CRMS31A, while Kanchana and Bharathy were identified as maintainers for CRMS32A. Kanchana alone was found to be the maintainer for all four CMS lines. In field validation Remya which had 4 *Rf* genes (*Rf3*, *Rf4*, *Rf5* and *Rf6*) was found to be a restorer for all the lines with WA Cytoplasm studied. All the restorers identified through field validation had either *Rf3* or *Rf4* gene which were reported as the major genes for fertility restoration.

Study of inheritance pattern of restorer gene was analysed in F<sub>2</sub> generation of the crosses between CMS lines and the restorers. It was found that in UPRI95-17A x Remya, UPRI95-17A x Jayathi, UPRI95-17A x Annapoorna, UPRI95-17A x Aiswarya and UPRI95-17A x Pavizham the restoration of fertility is governed by 2 dominant gene. Co-segregation of the molecular marker linked to *Rf* loci and the trait of restoration of fertility in the segregating population was analysed through Bulk Segregant Analysis (BSA) and found co-segregation of marker RM1 with *Rf3* gene and marker RM171 with *Rf4* gene. This shows that the marker loci and fertility restoration genes *Rf3* and *Rf4* are tightly linked.

The selected twenty one rice varieties were grown in completely randomized block design with 2 replications in pots for assessing the genetic parameters and observations were taken on 12 metric traits. The study revealed high heritability coupled with high genetic advance as per cent of mean for Pollen fertility, number of spikelets/panicle, number of filled grains/panicle, LB ratio, number of grains/panicle and grain yield/plant. Hence these traits are predominantly under the control of additive gene action and hence these characters can be improved by selection. Grain yield per plant recorded a significant positive correlation with total no of tillers, number of productive tillers per plant, panicle length, number spikelets/panicle, number of filled grains/panicle, number of filled grains per panicle. Divergence analysis grouped the rice varieties into eight clusters. Cluster II consisting of Mattatriveni and cluster VI consisting of Jayathi, Swarnaprabha, Kanakom and Aiswarya was the farthest.

The hybrid developed from 23 crosses between identified restorers and 4 CMS lines were evaluated for heterosis and identified promising hybrids were UPRI95-17A x Aiswarya, UPRI95-17A x Neeraja, UPRI95-17A x Remya and CRMS31A x Kanakom based on high mean grain yield per plant and high standard heterosis over standard check Uma.

In order to assess heterosis in different combination of the identified maintainers and restorers an L x T analysis was done with maintainers as the lines and restorers as the testers. Perusal of findings indicated that line Jyothi is a good general combiner as it recorded a high over all GCA status. The hybrid Aruna x Varsha was the best specific combiner followed by, Jyothi x Pavizham and Kanchana x Mattatriveni. Three crosses viz; Aruna x Varsha, Jyothi x Pavizham and Bharathy x Annapoorna registered high significant heterosis for grain yield per plant over mid parent, better parent and standard check Uma.

The present study could identify restorers and maintainers for 4 CMS lines from the Kerala rice varieties and also heterotic combination of restorers and maintainers. By reconstituting the identified maintainer with sterile cytoplasm of the CMS lines heterotic hybrids with grain qualities specific to Kerala can be developed. The superior hybrids obtained from identified restorers and CMS lines can be directly used for commercial release after yield trial.

### 5. Development of Near Isogenic Lines of rice variety 'Uma' for blast resistance genes through molecular marker assisted backcross breeding" CoA Vellayani,

Blast disease, caused by *Magnaportheoryzae* is one of the most devastating disease in rice and a great threat to food security worldwide. During *kharif* season, the disease is prevalent throughout the rice growing areas in India including the southern states of Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Approximately 100 major blast resistance genes have been reported in rice and hence exploitation of host plant resistance through gene pyramiding can be employed effectively for the management of blast. Developing Near Isogenic Lines (NILs) i.e., lines carrying each of the major resistance genes in the background of susceptible recurrent parent is a major step in the pyramiding work to be carried out for developing multi race resistant varieties. So, present study entitled "Development of Near Isogenic Lines of rice variety 'Uma' for blast resistance genes through molecular marker assisted backcross breeding" was undertaken at the College of Agriculture, Vellayani Thiruvananthapuram, to develop Near Isogenic lines (NILs) of rice variety Uma for blast resistance genes (*Pi1*, *Pi-2* and *Pi-kh*) using identified donors through marker assisted back cross breeding.

DNA markers closely linked to the blast resistance genes viz., RM527 (*Pi2* gene), RM 224 (*Pi 1* gene) and RM 206 (*Pikh* gene) were used for validating marker polymorphism in the identified traditional donors of blast resistance genes viz. PTB 21 (Thekkan) with *Pi2*, PTB 7 (Parambuvattan) with *Pi1* and *Pikh* and susceptible recipient parent Uma (MO16). This validation confirmed the absence of genes in recurrent parent, Uma chosen for the study. These polymorphic gene specific markers were also used for foreground selection in  $F_1$  plants and backcross generations.

Hybridisation was carried out between recipient parent Uma and the two donor parents viz., PTB 21 and PTB 7 to transfer genes for resistance.  $F_1$  plants with heterozygous loci for blast resistance genes specific markers were identified through foreground selection and backcrossed with recurrent parent Uma to obtain the  $BC_1F_1$  generation. The  $BC_1F_1$  plants were screened with foreground markers and those plants containing the respective resistance genes were identified. Among the plants screened for a particular cross, 12 were found to contain *Pi2* gene, 17 had *Pi1* gene and 21 plants contained *Pikh* gene.  $\chi^2$  test was done with the genotypic data of  $BC_1F_1$  plants with single genes viz. *Pi1*, *Pi2* and *Pikh*. Segregation ratio in  $BC_1F_1$  population from the cross Uma x PTB7 (*Pi1*) showed significant deviation from the expected 1:1 ratio. This suggests the presence of segregation distortion in these segregants.

For the background selection, three parental lines were genotyped with 30 microsatellite loci and the ones polymorphic for Uma and the donors were identified. 12 markers were found to produce discrete amplicons for Uma and PTB 21 while 17 were polymorphic for Uma and PTB7. Five of the polymorphic markers were used for background selection in  $BC_1F_1$  plants with resistance genes of the three crosses. The  $BC_1F_1$  plants with highest percentage of recurrent parent genome recovery in the three populations were identified. Highest recovery percentage of 70 could be obtained in backcross population of all the three crosses.

Morphological data for 7 seven quantitative and one qualitative character (kernel colour) was recorded for the  $BC_1F_1$  plants with the resistant genes. Euclidean coefficient of dissimilarity was assessed in comparison with the recurrent parent Uma. All the  $BC_1F_1$  plants with resistance genes were used to raise the  $BC_2F_1$  generation.

The  $BC_2F_1$  populations of the three crosses was subjected to foreground selection and plants with resistance genes were identified.  $\chi^2$  analysis of genotypic data revealed significant deviation from the expected 1:1 ratio in the  $BC_2F_1$  population of crosses Uma x PTB21 (*Pi2*) and Uma x PTB7 (*Pi1*) suggesting segregation distortion. Background selection was carried out in  $BC_2F_1$  plants with resistance genes using 12 polymorphic markers in cross Uma x PTB 21 (*Pi2*) and 17 markers in plants identified in the  $BC_2F_1$  of Uma x PTB7 (*Pi1* and *Pikh*).

Morphological data on seven quantitative traits and one qualitative trait was recorded in the  $BC_2F_1$  plants with resistance

genes. Based on the seven quantitative traits (plant height, number of tillers, number of productive tillers, panicle length, grain L/B ratio, thousand grain weight and days to maturity) Euclidean coefficient of dissimilarity was assessed in comparison with the recurrent parent, Uma. Based on the Euclidean distance and percentage recovery of the recurrent parent genome, five plants were identified from each of the three crosses as potential Near Isogenic Lines (NILs) for the three blast resistance genes *Pi2*, *Pi1* and *Pikh*. The genotype A-5-1 with a recurrent parent genome recovery of 95.83% and Euclidean distance of 5.22 with Uma was identified as the most potential NIL of Uma for the gene *Pi2*. Similarly B-27-1 (Euclidean distance - 4.72, % genome recovery - 97.06) and C-17-3 (Euclidean distance - 4.72, % genome recovery-94.12) were identified as potential NILs for *Pi1* and *Pikh* genes. Selfed seeds ( $BC_2F_2$ ) were collected from the identified potential NILs. This research could identify NILs of Uma for three blast resistance genes viz., *Pi1*, *Pi2* and *Pikh* with more than 94% recurrent parent genome recovery with two backcrossing through marker assisted selection. This confirms the utility of marker assisted backcross breeding in recurrent parent genome recovery. The NILs can be used in intermating programmes to develop pyramided lines of Uma with all the three blast resistance genes (*Pi1*, *Pi2* and *Pikh*) to ensure durable and broad spectrum resistance to the blast pathogen.

**Name of Project Coordination Group : – (02)  
Spices and Plantation Crops (including Palms)**

**Compiled by:  
Dr. V.S.Sujatha, Protect Coordinator**

**Plan & External Aided Projects**

**Concluded Projects- 2 Nos.**

**Ongoing Projects - 36 Nos.**

**Post Graduate Projects**

**Concluded Projects - 4 Nos.**



**Concluded Project****Cardamom****1. Subproject 5: CAR/CP/6. Pest and Disease Management Trial**

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Assistant Professor  
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[dhanya\\_mk2000@yahoo.co.in](mailto:dhanya_mk2000@yahoo.co.in)

a) CAR/CP/ Nematode pest management in cardamom using bio-control agents and organic supplements

The result of the pooled analysis showed that application of *Pochoniachlamydosporia* @ 50g/clump at monthly intervals registered least aerial symptom (5.150%) with maximum reduction (87.64%) over untreated check followed by the sole application of *P. lilacinus*, neem cake + *Paecilomyceslilacinus* and cartap hydrochloride (least leaf narrowing symptoms viz., 7.13%, 7.64% and 8.06% respectively). The root infection and the number of knots in 5g root sample revealed that, the least root knots were found with the sole applications of *P. chlamydosporia*, *P. lilacinus* and combined applications of neem cake + *P. lilacinus* and they were on par with each other

**Cashew****1. Evaluation of biointensive technologies in the management of tea mosquito bug, *Helopeltisantonii* Signoret in cashew.**

Dr. Satheesan.N.V.  
Associate Professor  
[satheesan.nv@kau.in](mailto:satheesan.nv@kau.in)

The project mainly focused to evaluate the prospects of indigenous plant extracts and botanical oils for tea mosquito bug management in cashew and to compare yield performance and pest status in bio intensive and conventional methods. Among the aqueous extracts and botanical oil emulsions tested against tea mosquito bug *Helopeltisantonii* on cashew under laboratory conditions, pongamia oil at 5% concentration showed both insecticidal and antifeedant property. *Acoruscalamus* rhizome powder showed antifeedant property at 5 % concentration and exhibited both antifeedant and insecticidal property at 10 % concentration. In the second year field experiments were laid out with promising botanicals-pongamia oil (5%), *Acoruscalamus* at 5% and 10%, POP and control. Three rounds of spray conducted at monthly intervals. Statistical analysis of the data revealed that *Acoruscalamus* at 10 per cent concentration found superior to all other treatments and was on par with POP recommendation. Though there was no significant difference in nut yield, POP recommendation recorded highest nut yield followed by *Acoruscalamus* (10%). There is no significant difference in case natural enemies like red ants, black ants and spiders. In *Acoruscalamus* treated trees red ant population was on par with control. Similar trend was also recorded in both spider and black ant population.

**Ongoing projects****Pepper****1. Germplasm collection, characterization, evaluation and conservation**

Dr. Ajith.P.M.  
Associate Professor  
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At present 313 cultivated types, 54 wild types and 3 exotic types of black pepper are being maintained at PRS, Panniyur. The survey work was carried out and 5 new genotypes were collected during the year. During the year 2017, the genotypes PRS 64, PRS 136 and PRS 154 were the top yielders. PRS 64 ranked first with 4.95 kg green berry yield and 1250 spikes/vine. Spike length was maximum for PRS 155 (15.2 cm). The number of developed berries/spike was more for PRS 137 (68.0). The 100 berry weight was high for PRS 154 (12.4 g). The dry recovery % was more for PRS 136 (37 %).

**2. Inter varietal hybridization to evolve high yielding varieties.**

Dr. Ajith.P.M.  
Associate Professor  
[ajith.pm@kau.in](mailto:ajith.pm@kau.in)

The hybrids PRS 160, PRS 161 and PRS 165 were found to be promising with mean green berry yield of 5.90 kg/vine, 6.32 kg/vine and 4.93 kg/vine respectively. Number of spikes/vine was higher for PRS 161 (895). Spike length was maximum for PRS 161 (18.1 cm). 100 berry weight was higher for PRS 161 (19.0).

### 3. Hybridization to evolve varieties tolerant to biotic and abiotic stresses.

Dr. Ajith.P.M.  
Associate Professor  
[ajith.pm@kau.in](mailto:ajith.pm@kau.in)

The seedlings of PRS 4 x PRS 8 and P 1 x PRS 78 were planted. Seedlings of P 1 x PRS 48 were lost due to *Phytophthora* infection. Seedlings of P1 x PRS 64 were obtained. The crosses P1 x PRS 4 and P1 x PRS 48 were carried out during the year.

### 4. Coordinated Varietal Trial (CVT) 2006 Series VI

Dr. Ajith.P.M.  
Associate Professor  
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The trial was started during 2007. During 2017, HB 20052 recorded the highest green berry yield of 4.57 kg/vine followed by Acc.no.53 (4.38 kg/ vine). The highest plant height was recorded for Panniyur 1 (4.90 m).

### 5. CVT 2015 on Farmer varieties of Black pepper Series VII

Dr. Ajith.P.M.  
Associate Professor  
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The trial was started during 2015. During 2017, all the vines except Kampukkal and Zion mundi are in the vegetative stage and there was no significant difference between the treatments for morphological characters. Kampukkal recorded a mean dry berry yield of 112 g and mean spike length of 8.56 cm. Zion mundi recorded a mean dry berry yield of 25 g and mean spike length of 8.62 cm.

### 6. CVT 2015 on Black pepper Series VIII

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The trial was started during 2015. The plants are in the vegetative stage.

### 7. Black pepper based mixed cropping system for sustainable productivity and food security

Dr. Heera G.  
Assoc.Professor  
[heera.g@kau.in](mailto:heera.g@kau.in)

During 2017-18 good yield was obtained from the intercrops in black pepper garden except arrow root and tapioca. Among the intercrops  $T_3$  - elephant foot yam recorded maximum yield of 8.53 kg followed by  $T_5$  -greater yam (7.25 kg ) from an inter space of 4m x 2 m spacing between black pepper. Colocasia ( $T_1$ ) yielded 3.18 kg and arrowroot ( $T_2$ ) - 1.87 kg (Table 4). It is difficult to maintain the intercrops tapioca and arrow root due to wild boar attack

### 8. Biological Management of slow wilt in black pepper

Dr. Heera G.  
Assoc.Professor  
[heera.g@kau.in](mailto:heera.g@kau.in)

During 2017-18 all the treatments were significantly superior in reducing the yellowing due to slow decline in black pepper except soil drenching with COC and cartap hydrochloride. Application of *Trichoderma viride* + neem cake @2kg/ vine (T1) recorded a maximum yield of 3.109 kg/vine, maximum no of spikes and minimum disease intensity of 5.63%. All the biocontrol agents were effective in managing the disease though the yield was not superior to control. The treatment T6 had a negative effect on the yield and management of the disease.

**9. Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala.**

Dr. Rini C.R.  
Assistant Professor  
[rini.cr@kau.in](mailto:rini.cr@kau.in)

Among the different treatments tested against marginal gall thrips in black pepper, Quinalphos was found to be the best treatment with minimum number of damaged leaves. This was followed by *Lecanicilliumlecani* which was on par with dimethoate.

**10. Subproject 2 - Coordinated Varietal Trial 2006 – Series VI**

Dr. Ajith.P.M.  
Associate Professor  
[ajith.pm@kau.in](mailto:ajith.pm@kau.in)

Among the characters studied, highest fresh (1.5 kg/vine) weight of berries per vine was registered for *Panniyur-1* which is on par with *Karimunda* (1.4 kg/vine) followed by HB 20052 (1.2 kg/vine). For dry weight of berries *Panniyur-1* recorded the highest value (0.494 kg/vine) followed by *Karimunda* (0.457 kg/vine). The yield attributing characters had significant difference between the accessions. Maximum spike length was recorded from ACC 53 (13.71 cm) followed by HB 20052 (14.5 cm). ACC-1090 and *Panniyur-1* were statistically on par with each other with respect to spike length. 100 berry weight was maximum for *Panniyur-1* (15.6 g) but the number of berries per spike was more in HB 20052 (46.4) which is on par with *Karimunda* (45.7).

**11. Strengthening research on Black pepper at Dept. of Plantation Crops & Spices, College of Horticulture, Vellanikkara**

Dr.V.S.Sujatha  
Professor  
[sujatha.vs@kau.in](mailto:sujatha.vs@kau.in)

Three new collections added to germplasm. 105 accessions of *Piper nigrum* field planted and labeled. Layout prepared. Nine released varieties of black pepper field planted and labeled.

**Cardamom**

**1 Subproject 3 - CAR/CI/3-Coordinated Varietal Trial**

Dr. M. Murugan  
Professor  
[murugan.m@kau.in](mailto:murugan.m@kau.in) ; [muthupeyan@gmail.com](mailto:muthupeyan@gmail.com)

a) CAR/CI/3.7. CVT of drought tolerance in Cardamom – Series VII  
The experiment was started during 2017 and plants are in their early vegetative stage.

**2. Evaluation of promising small cardamom (*ElettariacardamomumMaton*) cultivars/varieties for organic cultivation in the high ranges of Idukki district**

Dr. M. Murugan  
Professor  
[murugan.m@kau.in](mailto:murugan.m@kau.in) ; [muthupeyan@gmail.com](mailto:muthupeyan@gmail.com)

There is significant difference among varieties with respect to yield and biotic stress characters. Maximum fresh weight (1618.70 g plant<sup>-1</sup>) of capsules was recorded by PV1 which is on par with PV2 (1528.7 g plant<sup>-1</sup>) but the maximum dry weight was observed in PV2 (363.8 g plant<sup>-1</sup>). The lowest wet and dry yield was registered in GG and was significantly inferior to all others. The incidence of thrips, shoot borer and *azhukal* was more in GG whereas *Azhukal* incidence was less in PV2.

**3. Subproject 4: CAR/CI/4- Varietal Evaluation Trial (VET)**

Dr. M. Murugan  
Professor  
[murugan.m@kau.in](mailto:murugan.m@kau.in) ; [muthupeyan@gmail.com](mailto:muthupeyan@gmail.com)

a) CAR/CI/4.3 Initial Evaluation Trial 2012

There was significant difference among accessions with respect to their vegetative characters except plant height. Maximum number of tillers was produced by BEP 2 (39.3) which is followed by PV 2 (35.0). Maximum leaf length (65 cm) and leaf width (12.2 cm) was observed in PV 2 which is on par with HY 6, PPK 2 and HY 9. Number of panicle was more in GG (29.7) but the length of panicle was maximum in PV2 (41.8 cm).

- b). Subproject4: CAR/CI/4- Varietal Evaluation Trial (VET)
- c) CAR/CI/4.4. CVT Multi Location Evaluation of thrips tolerant cardamom lines

The experiment was started 2017 and plants are in early vegetative stage.

#### **4. Subproject6: CAR/CP/6.9 Evaluation of new insecticides for thrips control**

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The pooled data for the observation on thrips infestation after seven sprays revealed that, fipronil5 SC @ 0.005% applied plants showed highest per cent reduction of infestation (88.26%), whereas Imidacloprid 17.8 SL @ 0.0089% stood next (78.74%) in its effectiveness. Spinosad 45 SC @ 0.0135% and quinalphos 25 EC @ 0.05% were also found effective in reducing the infestations (75.29% and 70.31% respectively) and were on par with each other.

#### **Nutmeg**

##### **1. AICRP- Project mode centre on nutmeg**

Dr. N. Miniraj  
Professor  
[n.miniraj@kau.in](mailto:n.miniraj@kau.in)

Trial has been laid out with four farmer varieties, one local check and one national check. The genotype included are

1. PunnathanamJathi
2. KochukudyJathi
3. KadukkamakkanJathi
4. Improved nutmeg variety from Mr. Tom C.Antony
5. Local check – (KAU-Pullan)
6. National check-IISR-Viswashree

##### **2. Annual plan project “Strengthening Research on Nutmeg”**

Dr.N.Miniraj  
Professor  
[n.miniraj@kau.in](mailto:n.miniraj@kau.in)

In the first aspect of the study, collection and characterisation of elite clones of nutmeg; five superior nutmeg varieties have been released for cultivation in Kerala. A very good germplasm with 40 elite/unique clones of nutmeg has been established and maintained in the Model nursery on Spices. The germplasm has started bearing. Evaluation of the germplasm has to be initiated. Molecular characterisation of the elite clones is another pending work.

In the second aspect of the project on value addition of nutmeg rind, process standardisation was done for making diversified products from nutmeg rind. An enterprise for value added products from nutmeg rind is feasible in Kerala. The complete technology is now ready for transfer to the stake holders.

In the last part of the project on management of aflatoxins in the nut and mace, decoction treatment with anona seed extract has emerged as the best treatment in field samples and in stored samples citrus leaves was the best treatment. However the dose, time, duration etc. of the promising treatments need to be standardised by further studies.

**Cocoa****1. Germplasm collection and maintenance of cocoa**

Dr. B. Suma  
Professor  
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During the year 2015-16, 41 accessions were introduced from University of Reading, UK as bud wood. They were budded to hybrid seedlings and are field planted.

**2. Cocoa breeding**

Dr. B. Suma  
Professor  
[suma.b@kau.in](mailto:suma.b@kau.in)

**a. Heterosis breeding****a.1 Breeding for Vascular streak dieback disease resistance**

15 VSD tolerant self plants were field planted

**a.2. Breeding for *Phytophthora* pod rot resistance**

♦ **Assessment of general combining ability (GCA) of self-incompatible *Phytophthora* resistant hybrids**

For assessing the GCA, hybrids were crossed and there was no pod set.

♦ **Genetic stock development for *Phytophthora* resistance**

Germplasm GVI G included germplasm introduced from University of Reading UK which was reported to be resistance to *Phytophthora* in other part of the world. Thirty accessions of cocoa which are in the steady bearing stage serve as the material for the study.

♦ **Qualitative characters of selected accessions for floral character**

All the accessions were analyzed for qualitative and quantitative characters.

♦ **Quantitative characters of selected accessions for floral character**

Genotypes, CRU (1.47 cm), EET 397 (1.46 cm) and DOM 25 (1.42 cm) were having large flowers; where as NA 149 (0.89 cm) is with smallest flower.

♦ **Catalogue of biochemical characters**

Highest fat content is in NA 149 (59.33%). CRU12 (19.92 %) and ICS 41 (20.11 %) have good phenol content. Sodium content was above 2 % in all accessions. Potassium most of the accessions showed in a range of 6 percent but accession MATINA 1/7 recorded a high value(8.13 %) and PNG 250 recorded a low value (4.89%).

♦ **Screening for *Phytophthora* resistance**

All the accessions were lab screened for *Phytophthora* resistance and classified as highly tolerant, moderately tolerant and susceptible based on the scoring chart.

**b. Inbreeding**

♦ **Selfing of inbreds to advance the inbred generation**

Eleven different Selfing techniques were attempted to advance inbred generation.

**3. Development of black pod resistant varieties of cocoa**

Dr. B. Suma  
Professor  
[suma.b@kau.in](mailto:suma.b@kau.in)

**Confirmation of black pod resistance by pod inoculation method**

The hybrids bred under the programme breeding for *Phytophthora* resistance were field established and evaluated in the field by screening for the disease during peak season. It resulted in identification of thirty hybrids in the field which showed no symptom. It is very much necessary to confirm the resistance by artificial inoculation to prove that the disease is due to the genetic makeup and not due to environmental influence. For this pod inoculation method was carried out.

**Pod inoculation method**

Pods at full maturity but before ripening were collected, surface sterilized with distilled water and 70 per cent alcohol, inoculated under high humid condition with fresh culture of *Phytophthora* without pricking. *Phytophthora* culture disc of seven days old were used and above which wet cotton was placed. Observations were taken after ten days of inoculation

and percentage of infection calculated using the formula (Length x breadth of lesion / length x breadth of pod) x 100. Genotype SIV 1.26 x TISSA (3.8), SIV 1.26 x PII 12.11 (17.5) and GVI 216 x GVI 294 (34.6) showed 100 percent infection in non pricked condition. Hence these genotypes cannot be recommended for further evaluation. SIV 1.26 x TISSA (4.6) showed 55.87 percentage infection in non pricked condition.

#### 4. Strengthening Cocoa Research Centre, Kerala Agricultural University

Dr. B. Suma  
Professor  
[suma.b@kau.in](mailto:suma.b@kau.in)

Eleven VSD resistant hybrids were selected for clonal garden. Standardization of primary processing to reduce free fatty acids. Different methods of fermentation like basket and sack were carried out. Bean recovery was highest in heap method. Lipase activity was maximum in sack method and lowest in heap.

#### 5. ATMA-Strengthening of research on value addition of cocoa, Kerala Agricultural University

Dr. B. Suma  
Professor  
[suma.b@kau.in](mailto:suma.b@kau.in)

Four novel products were developed i.e., cocoa nutrimix, cocoa spread, cocoa choco balls and cocoa dark chocolate.

#### 6. Maximizing production through conventional breeding and molecular approaches -Screening for drought tolerant cocoa

Dr. MinimoL.J.S  
Assoc.Professor  
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Screening of newly released cocoa hybrids (CCRP 11, 12, 13, 14 and 15) to estimate its capacity to with stand drought by gravimetric method. Physiological and biochemical parameters will be estimated. Detailed work is to be continued.

#### 7. Annual Plan 16-17 Station wise funding- Standardization of *in vitro* techniques in cocoa

Dr. B. Suma  
Professor  
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Budded plants of CCRP 1, CCRP 2, CCRP 3, CCRP 4, CCRP 5, CCRP 6, CCRP 7, CCRP 8, CCRP 9, CCRP 10, CCRP 11, CCRP 12, CCRP 13, CCRP 14 and CCRP 15 are maintained in polyhouse. Different media compositions like MS, MS + NAA, MS+NAA+CW 10%, woody Plant Media and ½ MS media were tried. Explants used were Stem (Internodes). Culture initiated small sprouting in ½ MS media. More detailed works to be continued.

### Cashew

#### 1. Intercropping in Cashew

Dr.A.Sobhana  
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Objective of the experiment was to identify suitable medicinal plants that can be grown as inter crops in the initial years of cashew. The economic analysis of inter cropping in cashew with different medicinal plants revealed that *Clitoriaternate* was economical followed by *Ayapanatriplinervis*, with BC ratio 1.31 and 1.16 (Table 1) respectively. In all other medicinal plants the BC ratio was less than one which indicates that they are not economical.

#### 2. Organic Management of Cashew

Dr.A.Sobhana  
Professor  
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Seven different organic manure treatments in combination with biofertilizers were compared with recommended doses of fertilizer, to explore the possibility of increasing nut yield and quality and to find out economic feasibility over

conventional farming. The tree height did not vary significantly among treatments. However maximum tree height was observed in T 7 (5.89m). The trunk girth was maximum in T1 (74.17 cm) followed by T8 (72.08 cm). Mean canopy diameter was maximum in T6 (7.10 m). Mean canopy surface area and ground coverage by canopy (%) were highest in T2 (74.76m<sup>2</sup> and 86.40% respectively).

The treatments did not vary significantly for yield characters except annual nut yield. Highest annual nut yield was recorded in T2 (6.27kg/ha) followed by T8 (6.26kg/ha). The maximum cumulative yield was recorded in T3 (16.57kg), followed by T7 (16.13kg). However, highest B: C ratio (4.42) was observed in T8 with recommended dose of fertilizers.

### 3. New breeding approach with reduced breeding cycle

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To develop improved varieties of cashew within a short period of time, five hybrids/varieties (H-505, C2-6, H-12/05, H-2917, VRI-(CW) H1), were planted with a spacing of 3x2 m @ 5 plants/variety during 2017.

### 4. Ultra high density planting in cashew

Dr.A.Sobhana  
Professor  
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In order to identify the optimum spacing under ultra high density planting of cashew and suitable variety for UHDP for better performance and yield, the experiment was laid out in split plot design, with main plot as spacing (2.5 x 2.5, 3 x 3, 3.5 x 3.5, 8 x 8m) and sub plot as variety (Vridhachalam-3, NRCC Selection -2, Poornima), in three replications. The planting was done in 2017 and the trial is in progress.

### 5. Chemical Control of pest complex in cashew -Evaluation of insecticides for control of TMB and other insect pests

Dr. Satheesan.N.V.  
Associate Professor  
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Tea mosquito bug intensity was very low during the season. The spray was imposed only once during the flowering period. At seventh day after second spray, the damage on shoot was practically nil in all the treatments as evidenced from the score value. However, all the treatments were significantly superior to control. At 15<sup>th</sup> day of second spray, same trend was observed with the exception that thiamethoxam @ 0.1 g/l was also on par with control. On panicle, at seventh day after second spray, all the treatments except carbosulfan were significantly superior to control. At 15<sup>th</sup> day, the damage score was nil in both *Beauverabassiana*@5g/l (ICAR-IIHR formulation), carbosulfan and KAU POP. The damage score in the remaining treatments were comparatively less and they were superior to control.

Analysis of data showed a decline of black ant population in all the trees that received insecticide treatments. Control harboured significantly high red ant population during second spray. Spider activity was observed in all the trees which received insecticide sprays as well as in unsprayed there was no significant difference among treatments.

### 6. Control of cashew stem and root borer Curative control trial

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Among the insecticides tested for post extraction prophylaxis, swabbing neem oil soap suspension @ 50 ml/l resulted in recovery of 90% of treated trees followed with chlorpyrifos with 85% of trees recovered. Fipronil swabbing resulted in recovery of 75% of treated trees and same was the case with imidachloprid. Grub removal only resulted in recovery of 40% of trees.

No definite pattern of influence of physical parameters has been observed with respect to per cent recovery. However, only 64 per cent of treated of trees have been recovered after post extraction prophylaxis among trees with more than 75 per cent bark circumference damage compared to 87% recovery with bark circumference damage less than 25 per cent.

## 7. Influence of biotic and abiotic factors on the incidence of pest complex of cashew

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The correlation analysis between tea mosquito bug damage and second previous week weather factors revealed that morning and evening relative humidity had a significant negative correlation with the damage by tea mosquito bug, whereas significant positive correlation was not established with any of the weather parameters.

Monitoring of pests and natural enemies of cashew throughout the season from April 2016 to March 2017 showed sporadic nature of tea mosquito bug in the months of April and May of 2016 and January-February months of 2017. An overview of incidence of leaf miner during 2016-17 seasons showed the occurrence of infestation only during the months of September-October coinciding with flushing stage of the crop with a maximum of 9.5 per cent infestation in September month. In the case of apple and nut borer, the infestation was negligible and was to the tune of less than one per cent. With regard to other natural enemies, though the presence of spiders was observed throughout the year, high population was recorded during the month of May 2016 and from July to September 2017. Black ant population was high during March month.

## 8. Screening of germplasm to locate tolerant / resistant types to major pests of the region

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The objective of this project was to identify germplasm accessions tolerant / resistant to the major pests of the region. The insect pest infestation on fourteen accessions maintained in the germplasm collection. Tea mosquito bug infestation was very low ranged from 0.001 in ARL-1 to 0.099 in Ummannur. The other insect pests were not observed during the period. Leaf miner infestation was absent in all accessions. Thrips infestation was absent during this year. During last year, thrips infestation was absent in K-2, K-3, Kottukkal and ARL-2. Apple and nut borer incidence was negligible in all accessions during the reporting year.

### Coconut

#### 1. State Plan (17-18) Hybrid Seedling & Dwarf coconut seed production

Seednut and seedling production in progress

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Strengthening of existing coconut hybrid seed nut production programme in farmers field and distribution of quality seedlings. Identification of promising dwarf palms in farmers field for dwarf seednut production and distribution. Maintenance and further development of centenary memorial dwarf plantation and collaboration with Nileswaram Municipality for "Dwarf palm Village" Programme.

#### 2. Developing D x T hybrids using promising second generation inbred and molecular characterization of the third generation inbreds of WCT coconut (*Cocos nucifera* L.)

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Two promising and healthy palms from the IIS2 family of inbreds from WCT planted in 1961 at RARS, Pilicode were selected as the pollen parent based on reports from earlier study (Chethana, 2016). Two palms from this family were selected viz., Palm No, 313 and 225, and pollen was collected to pollinate two separate inflorescence of a superior palm of MYD at College of Agriculture, Padannakkad. Though 25-35 flowers were pollinated, the seed set was very low which may be due to the inbreeding depression in the male parent. Hybrid seednuts (5nos) collected were sown in the nursery. Simultaneously, 15 S3 seedlings from the IIS2 family which were already planted in replicated trial during 2014 in the field at RARS Pilicode were characterized and compared with other tall and dwarf genotypes using RAPD. Genomic DNA was extracted from the inbreds (S3 generation - IIS3 family) along with WCT, MYD, CGD and COD and amplified using ten selected decamer primers based on earlier studies. The data is being subjected to diversity analysis for finding the extent of similarity/difference of these 3<sup>rd</sup> generation inbreds from parental tall variety WCT and dwarf palms.

**Tamarind****1. Germplasm Evaluation of Tamarind**

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**Garlic****1. Participatory Evaluation of Garlic genotypes in Devikulam Block**

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Yield and yield contributing characters of five eco types of garlic were evaluated in the Kanthloorpanchayath of Devikulam block, Idukki

The ecotypes Yamuna safed 3, Ooty1, Mettupalayam, Singapore and Malapoondu were high yielders during the season May – September 2017. The highest yield was obtained for Ooty 1 and Malapoondu. The potential of production of big bulbs are seen in, Malapoondu and Mettupalayam as seen by the highest bulb weight data.

The oil contents are rich in Singapore, Yamuna safed and Ooty 1 ecotypes. Quantity of trisulfide is high in all analysed varieties except in Ooty 1. The quantity of OctaSulpher is more in Malapoondu. Singapore is the one with low fibre content of 1.45 % and is also having highest total sugars and better self life and suitable for stalking. The self life is maximum in Malapoondu with field tolerance to Thrips, an important pest in garlic field.

**PG Projects****Concluded projects****Ginger****1. Standardisation of agro techniques for transplanted ginger (*zingiberofficinalerosc.*)****1. Plant height**

The plant height was significantly higher for the mulch treatment,  $M_1$  (30 t ha<sup>-1</sup>) throughout the observed crop growth periods. The plant height increased from 37.48 cm to 44.84 cm from 4<sup>th</sup> to 8<sup>th</sup> month of observation in plots treated with 30 t/ha of mulch and it was the least in plots treated with 7.5 t/ha ( $M_3$ ) which varied from 28.84 to 35.76 cm during the corresponding period. The fertilizer treatment  $T_2$  (150:100:100 kg ha<sup>-1</sup>) resulted in highest plant height on all periods of observation and a plant height of 43.33 cm was recorded at 8<sup>th</sup> month in  $T_2$ . Interaction between mulch and fertilizer, was significant throughout the periods of observation and highest level of mulch and double the recommended dose of fertilizer recorded the highest plant height on all periods. The comparison of  $C_1$  as well as  $C_2$  with the treatments also indicated significant difference in the plant height in all periods of growth. A significant difference was noticed between the control  $C_1$  as well as  $C_2$ . The present study clearly indicates the difference in plant height between the different levels of fertilizers and mulches compared to the recommended package of practice of KAU.

**2. No of leaves per plant**

Significantly higher number of leaves were produced due to higher level of mulch of 30 t ha<sup>-1</sup> (230.78 in 8<sup>th</sup> month) Fertilizer treatment,  $T_2$  (150:100:100 kg/ha) recorded highest number of leaves at 8<sup>th</sup> month (210.24) and least number of leaves in (75:50:50 kg ha<sup>-1</sup>). In interaction combination of mulches @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg/ha ( $m_1t_2$ ) recorded highest number of leaves in all periods. The comparison of  $C_1$  as well as  $C_2$  with the treatments also indicated significant difference in the number of leaves on all periods of growth. A significant difference was noticed between the control  $C_1$  as well as  $C_2$

**3. Number of tillers/plant**

Organic Mulches increased the number of tillers and highest tiller was obtained in 4<sup>th</sup> to 8<sup>th</sup> month  $M_1$  of 30 t ha<sup>-1</sup> followed by plastic mulch. The number of tillers at 8<sup>th</sup> month was 14.88 for  $M_1$  and 14 for  $M_4$ . An increase in tiller was observed in treatment  $T_2$  (150:100:100 kg ha<sup>-1</sup>) at all periods of observation. Higher number of tillers at 8<sup>th</sup> months were observed from mulches @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> ( $m_1t_2$ ) which was on par with  $m_1t_{4,w}$  while in the 6<sup>th</sup> months  $m_2t_2, m_4t_2, m_4t_4$  was on par with  $m_1t_2$  (and on 8<sup>th</sup> months  $m_1t_4$  was on par with  $m_1t_2$ ). A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also has

shown a significant difference between them. This means that the treatments were in adequate quantity and was essential for good tiller production. This shows that a higher dose of fertilizer recommendation than the normal recommendation of package of practice of KAU along with 30 t ha<sup>-1</sup> of mulch was superior in increasing the number of tillers.

#### 4. Shoot weight

M<sub>1</sub> (30 t ha<sup>-1</sup>) recorded the highest shoot weight on all periods of observation and an increase in shoot weight was observed from 24.54g to 45.05g from 4<sup>th</sup> month to 8<sup>th</sup> month of observation. In sub plot T<sub>2</sub>, treatment of double the dose of fertilizer recorded highest shoot weight on all periods of observation and a shoot weight of 43.80g was obtained in the 8<sup>th</sup> month. Among the interaction mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:10:100 kg ha<sup>-1</sup> (m<sub>1</sub>t<sub>2</sub>) recorded highest shoot weight on all periods of observation. In 4<sup>th</sup> month m<sub>1</sub>t<sub>2</sub> and m<sub>2</sub>t<sub>4</sub> were on par and in the 6<sup>th</sup> and 8<sup>th</sup> months m<sub>1</sub>t<sub>2</sub> recorded highest shoot weight. Treatment effects varied significantly from both control C<sub>1</sub> as well as C<sub>2</sub>. A significant difference was noticed between the control C<sub>1</sub> as well as C<sub>2</sub>.

#### 5. Root length

The plots treated with 30 t ha<sup>-1</sup> of organic mulch (M<sub>1</sub>) recorded highest root length (32.24 cm) on 8<sup>th</sup> month as well as on all periods of growth and least root length was observed in plots mulched with 7.5 t ha<sup>-1</sup> of organic mulch i.e M<sub>3</sub>. Among sub plot treatments, highest root length was recorded by T<sub>2</sub> on all periods of observation while in 8<sup>th</sup> month T<sub>2</sub>(32.23cm) was on par with T<sub>4</sub> (32.12 cm). In interaction highest root length was observed the observation periods in treatment m<sub>1</sub>t<sub>2</sub> which is the combination of mulches @ 30 t ha<sup>-1</sup> and double the recommended dose of fertilizer as per package of practices recommendation of Kerala Agriculture University. The root length of m<sub>1</sub>t<sub>2</sub> at 8<sup>th</sup> month was 33.38cm while that for C<sub>1</sub> was only 29.78cm.

#### 6. Root weight

Main plot treatment of different levels of organic mulches and plastic mulch was significantly influenced the root weight of ginger on all periods of observation and M<sub>1</sub> recorded highest root weight of 1.17 g on 8<sup>th</sup> month. Fertilizer treatment T<sub>2</sub> of double the dose of recommended dose as per KAU POP was highest on all periods of observation and was on par with T<sub>4</sub> (100:75:75 kg ha<sup>-1</sup> + foliar application of 0.5% of 19:19:19) on 4<sup>th</sup> and 6<sup>th</sup> months. Among the interaction mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> resulted in higher root weight on all periods of observation and recorded 1.32g in 8<sup>th</sup> month while in 6<sup>th</sup> month m<sub>1</sub>t<sub>4</sub> was on par with m<sub>1</sub>t<sub>2</sub>. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of C<sub>1</sub> and C<sub>2</sub> also showed a significant difference between them.

#### 7. Root volume

Main plot treatment of 30 t ha<sup>-1</sup> resulted in higher root volume on all periods of observation and recorded 114.20 cm<sup>3</sup> plant<sup>-1</sup> during the 8<sup>th</sup> months of observation. In sub plot treatment of double the recommended dose of fertilizer resulted in high root volume on all periods of observation and recorded 112.49 cm<sup>3</sup> plant<sup>-1</sup> in the 8<sup>th</sup> month and least root volume was observed in fertilizer dose of 75:50:50 kg ha<sup>-1</sup> (110.18 cm<sup>3</sup> plant<sup>-1</sup> in 8<sup>th</sup> month). Among the combination, mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> recorded highest root volume on all periods while in 6<sup>th</sup> month m<sub>1</sub>t<sub>1</sub> was on par with m<sub>1</sub>t<sub>2</sub>, while at 8<sup>th</sup> month m<sub>1</sub>t<sub>4</sub> was on par with m<sub>1</sub>t<sub>2</sub> with root volume of 115.45 cm<sup>3</sup> plant<sup>-1</sup>. Treatment effects varied significantly with both control C<sub>1</sub> as well as C<sub>2</sub>. A significant difference was noticed between the control C<sub>1</sub> as well as C<sub>2</sub>.

#### 8. Root shoot ratio

Significant difference was noticed among the treatments of mulch in 4<sup>th</sup> and 6<sup>th</sup> month, fertilizer treatments in 6<sup>th</sup> month and their interaction was significant throughout the periods of observation. No significant difference root shoot ratio in 8<sup>th</sup> month was noted in the main plot treatments and Treatment of mulching @ 30 t ha<sup>-1</sup> recorded highest root shoot ratio in 4<sup>th</sup> and 6<sup>th</sup> months.

The root shoot ratio of sub plot treatments was insignificant in 4<sup>th</sup> and 8<sup>th</sup> month and in 6<sup>th</sup> month, T<sub>2</sub> (150:100:100 kg ha<sup>-1</sup>) recorded highest root shoot ratio of 0.029 and was on par with T<sub>4</sub>. Root: shoot ratio was inconsistent over different periods of growth

Treatment combination was significant throughout the periods of observation and combination of mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> resulted in higher root shoot ratio and in 6<sup>th</sup> month it was on par with m<sub>1</sub>t<sub>3</sub>, m<sub>1</sub>t<sub>4</sub> and m<sub>2</sub>t<sub>2</sub> while in 8<sup>th</sup> month it was on par with m<sub>1</sub>t<sub>3</sub>, m<sub>1</sub>t<sub>4</sub>, m<sub>2</sub>t<sub>2</sub>, m<sub>2</sub>t<sub>3</sub>, m<sub>2</sub>t<sub>4</sub>, m<sub>3</sub>t<sub>1</sub>, m<sub>3</sub>t<sub>2</sub>, m<sub>3</sub>t<sub>4</sub>. Treatments varied significantly with both the controls. A significant variation was observed within the controls C<sub>1</sub> and C<sub>2</sub>.

### 9. Fresh yield

The main plot treatment using mulch M<sub>1</sub> @ 30 t ha<sup>-1</sup> recorded highest fresh yield on all periods of observation and resulted in 18093.53 kg ha<sup>-1</sup> in 8<sup>th</sup> month. This was followed by plots treated with plastic mulch (M<sub>4</sub>) which recorded 17567.25 kg/ha. Treatment T<sub>2</sub> recorded highest fresh yield on all periods and obtained 17855.03 kg ha<sup>-1</sup> at harvest followed by T<sub>4</sub> (17455.58 kg/ha) T<sub>3</sub> and T<sub>1</sub> recorded 17230.35 kg/ha & 16746.15 kg/ha respectively. Among interaction, combination of mulches @ 30 t ha<sup>-1</sup> and double the recommended dose of fertilizer as per KAU package of practices (m<sub>1</sub>t<sub>2</sub>) obtained highest yield on all periods of observation and recorded 18644.40 kg ha<sup>-1</sup> in 8<sup>th</sup> month followed by m<sub>4</sub>t<sub>2</sub> (18135.30 kg ha<sup>-1</sup>) which was on par with m<sub>1</sub>t<sub>4</sub>, m<sub>1</sub>t<sub>3</sub> and m<sub>4</sub>t<sub>4</sub>. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of C<sub>1</sub> and C<sub>2</sub> also shown a significant difference between them.

### 10. Dry yield

The treatment M<sub>1</sub> mulching with @ 30 t ha<sup>-1</sup> recorded highest dry yield on all periods of observation and recorded 3828.15 kg ha<sup>-1</sup> during harvest. The dry ginger yield in plastic mulch treatment was 3564.38t/ha. The higher dry ginger yield m<sub>1</sub>t<sub>2</sub> might be due to the higher nutrient (NPK) uptake as well as better soil conditions provided by highest quantity of mulch (30 t ha<sup>-1</sup>). In subplot, treatments showed significant difference throughout the periods of observation and treatment T<sub>2</sub> recorded highest dry yield on all periods and obtained 3911.10 kg ha<sup>-1</sup> at harvest. The dry ginger yield of T<sub>4</sub> was 3587.78 kg ha<sup>-1</sup> while that for T<sub>3</sub> and T<sub>1</sub> were 3406.73 and 3319.73 kg ha<sup>-1</sup> respectively. Interaction effects were significant throughout the periods of observation and among interaction combination of mulches @ 30 t ha<sup>-1</sup> and double the recommended dose of fertilizer as per KAU package of practice (m<sub>1</sub>t<sub>2</sub>) obtained highest dry yield on all periods of observation and recorded 4316.10 kg ha<sup>-1</sup> at harvest followed by m<sub>4</sub>t<sub>2</sub> (3881.80 kg ha<sup>-1</sup>) which was on par with m<sub>1</sub>t<sub>4</sub> (3842.10 kg ha<sup>-1</sup>). The treatment combinations except m<sub>2</sub>t<sub>1</sub>, m<sub>2</sub>t<sub>3</sub>, m<sub>3</sub>t<sub>1</sub>, m<sub>3</sub>t<sub>3</sub>, m<sub>3</sub>t<sub>4</sub> and m<sub>4</sub>t<sub>1</sub> were significantly superior to conventional raising of ginger following recommended package of practices of KAU. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of C<sub>1</sub> and C<sub>2</sub> showed a significant difference between them.

### 11. Harvest index

Plants that received M<sub>1</sub> (30 t ha<sup>-1</sup>) in main plot resulted in maximum harvest index at all growth periods. A harvest index of 0.414 was recorded and least harvest index was recorded with mulching @ 7.5t ha<sup>-1</sup> (M<sub>3</sub>). Sub plot treatment, T<sub>2</sub> (150:100:100 kg ha<sup>-1</sup>) recorded highest harvest index of 0.170, 0.210 and 0.423 at 4<sup>th</sup>, 6<sup>th</sup> and 8<sup>th</sup> month respectively. The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg /ha (m<sub>1</sub>t<sub>2</sub>) resulted in maximum harvest index of 0.435 at 8 months. Thus the efficiency of translocation of assimilates to economic part was found to be increasing with increasing fertilizer levels and mulches.

A significant difference in harvest index in all periods of growth was recorded between treatment and control. The control C<sub>1</sub> as well as C<sub>2</sub> varied significantly from treatments in all periods.

### 12. Dry recovery

Higher dry recovery of ginger was retained by main plot treatment M<sub>1</sub> (30 t ha<sup>-1</sup>) in all periods of observation and recorded 21.14% obtained harvest. In sub plot treatment of fertilizers T<sub>2</sub> (150:100:100 kg/ha) recorded highest dry recovery of 21.89% at harvest. However according to Joseph (1992) dry recovery was not influenced by fertilizer levels. Interaction effect showed highest dry recovery was recorded from the combination of mulches @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg/ha (m<sub>1</sub>t<sub>2</sub>) in all periods of observation and at harvest a dry recovery of 23.15% was recorded. This was followed by the treatment m<sub>4</sub>t<sub>2</sub> (21.91) which was on par with m<sub>3</sub>t<sub>2</sub> (21.49). The dry recovery recorded by the treatment varied significantly from the control on all periods of growth. The comparison of C<sub>1</sub> as well as C<sub>2</sub> with the treatments also indicated significant difference in the dry recovery at all periods of growth. A significant difference was noticed between the control C<sub>1</sub> as well as C<sub>2</sub>.

### 13. Rhizome thickness

A significant variation in rhizome thickness was observed among the main plot treatments. The main plot treatment of M<sub>1</sub> recorded highest rhizome thickness and noted 1.69 cm followed by M<sub>3</sub> (1.62 cm) on at harvest. In sub plot treatment T<sub>2</sub> recorded highest rhizome thickness on all periods of observation and recorded 1.67cm at harvest and was significant by different from other treatments throughout the periods of observation. In interaction treatment m<sub>1</sub>t<sub>2</sub> which is the combination of mulches @ 30 t ha<sup>-1</sup> and double the recommended dose of fertilizer as per package of practices of KAU resulted in highest rhizome thickness throughout the observation periods and at harvest the rhizome thickness was 1.79cm and was on par with m<sub>1</sub>t<sub>4</sub>. The treatments were significantly different from both the controls and there was significant difference between the control as well.

#### 14. Rhizome spread

Main plot treatment of application of different mulches was significantly influenced the rhizome spread of ginger on all periods of observation and  $M_1$  recorded highest rhizome spread of 13.31cm at harvest. The sub plot treatment,  $T_2$  showed highest rhizome spread on all periods of observation and recorded 13.08cm at harvest. Among the interaction mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> resulted in higher rhizome spread on all periods of observation and recorded 14.30cm which was on par with  $m_1t_3$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also showed a significant difference in rhizome spread.

#### 15. Starch

Main plot treatment of mulching significantly influenced the starch content in all periods of observation and produced highest starch content in main plot treatment  $M_1$  (30 t ha<sup>-1</sup>) in all periods of growth and recorded 37.63% at harvest and was on par with  $M_4$  (34.34 %). In sub plot, treatment  $T_2$  was significantly higher in all periods of observation and recorded 37.72% at harvest. Interaction showed significant effect on starch content during the periods of observation and treatment combination  $m_1t_2$  (mulches @30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup>) noted highest starch content in all periods of observation. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also showed a significant difference in starch content between them.

#### 16. Fibre

A significant variation in fibre content was observed among the main plot treatments. The main plot treatment,  $M_1$  resulted in higher fibre content on all periods of observation and a fibre content of 4.25% was recorded at harvest while in 4<sup>th</sup> month main plot treatment  $M_1$  was on par with  $M_2$  and  $M_4$ . In subplot  $T_2$  treatment resulted in high fibre content on all periods of observation and resulted in 4.08% of fibre at harvest and in 4<sup>th</sup> month treatment  $T_2$  was on par with  $T_3$  and  $T_4$ . Among the combination mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup>,  $m_1t_2$  recorded highest fibre content on all periods and recorded 4.41% at harvest. Treatment effects varied significantly with both control  $C_1$  as well as  $C_2$ . A significant difference was noticed between the control  $C_1$  as well as  $C_2$ .

#### 17. Oil

Significant differences in oil content was observed throughout the crop growth periods. Plants that received  $M_1$  (30 t ha<sup>-1</sup>) in main plot resulted in maximum oil content at all growth periods. At harvest an oil content of 2.76% was recorded. Sub plot treatment,  $T_2$  (150:100:100 kg ha<sup>-1</sup>) recorded highest oil content on all periods of observation. At 8 months an oil content of 2.43% was recorded which was on par with  $T_4$ . The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg / ha ( $m_1t_2$ ) resulted in maximum oil content of 2.92% at harvest. A significant difference in oil content in all periods of growth was recorded between treatment and control. The control  $C_1$  as well as  $C_2$  varied significantly from treatments in all periods of observation. The oil content recorded between control also varied significantly.

#### 18. Non Volatile Ether Extract

Main plot treatment of mulching significantly influenced the NVEE on all periods of observation  $M_1$  recorded highest NVEE of 8.72% at harvest which was on par with  $M_4$  in all periods of observation and sub plot treatment  $T_2$  was highest NVEE on all periods of observation and recorded 8.71% at harvest. Among the interaction mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> resulted in higher NVEE on all periods of observation and recorded 9.08%. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also showed a significant difference between them.

#### 19. Dry matter production

Main plot treatments significantly affected the dry matter production of ginger throughout the periods of observation. The main plot treatment  $M_1$  with mulches @ 30 t ha<sup>-1</sup> recorded highest dry matter production on all periods and obtained 76.95 g plant<sup>-1</sup> in 8<sup>th</sup> month. In subplot treatments dry matter production were significant throughout the periods of observation and treatment  $T_2$  recorded highest dry matter production on all periods and obtained 75.67g plant<sup>-1</sup> on 8<sup>th</sup> month. Interaction effects were significant throughout the periods and among interaction combination of mulches @ 30 t ha<sup>-1</sup> and double the recommended dose of fertilizer as per package of practices of KAU obtained highest dry matter production on all periods of observation and recorded 83.70 g plant<sup>-1</sup> at 8<sup>th</sup> month. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also showed a significant difference between them.

#### 20. Net assimilation rate

Significant differences in net assimilation rate was observed throughout the crop growth periods. Plants that received  $M_1$  (30 t ha<sup>-1</sup>) in main plot resulted in maximum net assimilation rate at all growth periods. During the crop growth period

from 6 to 8 month net assimilation rate of  $0.290 \text{ g m}^{-2} \text{ day}^{-1}$  was recorded. Sub plot treatment  $T_2$  ( $150:100:100 \text{ kg ha}^{-1}$ ) recorded highest net assimilation rate on all periods of observation. At 6 to 8 months a net assimilation rate of  $0.266 \text{ g m}^{-2} \text{ day}^{-1}$  was recorded. In the interaction between main plot and sub plot, significant variation was observed throughout the periods of observation and treatments  $m_1t_2, m_1t_3, m_1t_4$  were on par for 4 to 6 month. The highest net assimilation rate of  $0.365 \text{ g m}^{-2} \text{ day}^{-1}$  was noticed during the period of 6<sup>th</sup> to 8<sup>th</sup> month. The control  $C_1$  as well as  $C_2$  varied significantly from treatments in all periods. The net assimilation rate recorded between control also varied significantly.

### 21. Crop growth rate

Main plot treatment of mulching was significant only in period of 6<sup>th</sup> to 8<sup>th</sup> month and produced highest crop growth rate in main plot treatment  $M_1$  and  $M_4$  ( $0.029 \text{ g/m}^2/\text{day}$ ). In sub plot, treatment were significant only in 4<sup>th</sup> to 6<sup>th</sup> months of observation and highest was recorded by treatment  $T_2$  and  $T_4$  which was on par with  $T_3$ . Interaction was significant during the periods of 4<sup>th</sup> to 6<sup>th</sup> months of observation and treatment combination  $m_1t_2$  (mulches @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$ ) noted highest crop growth rate on 4<sup>th</sup> to 6<sup>th</sup> months of observation which was on par with  $m_1t_1, m_2t_2, m_2t_3, m_3t_1, m_3t_2, m_4t_1, m_4t_2$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also showed a significant difference between them in 4<sup>th</sup> to 6<sup>th</sup> months.

### 22. Leaf area index

Main plot treatment, sub plot treatment and interaction had significant influence in the leaf area index at all periods of growth. Among the main plot treatment  $M_1$  ( $30 \text{ t ha}^{-1}$ ) retained significantly higher leaf area index in all periods of growth and recorded 8.64 at 8<sup>th</sup> month. In sub plot treatment  $T_2$  ( $150:100:100 \text{ kg/ha}$ ) recorded highest leaf area index of 8.11 in 8<sup>th</sup> month. Interaction effect resulted in significant difference in all periods of growth and highest leaf area index was recorded from the combination of mulches @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg/ha}$  ( $m_1t_2$ ) in all periods of observation and in 8<sup>th</sup> month leaf area index of 9.20 was recorded. Leaf area index of treatments varied significantly from the control on all periods of growth. The comparison of  $C_1$  as well as  $C_2$  with the treatments also indicated significant difference in the number of leaves in all periods of growth. A significant difference was noticed in leaf area index between the control  $C_1$  and  $C_2$ .

### 23. Relative growth rate

Relative growth rate recorded showed significant difference between main plots in 6<sup>th</sup> to 8<sup>th</sup> month and Treatment  $M_1$  and  $M_4$  recorded highest relative growth rate in 6 to 8 months ( $0.072 \text{ g/g/day}$ ). In sub plot, treatments were insignificant for relative growth rate in 4 to 6 months and  $T_2$  recorded highest relative growth rate on 6 to 8 month. Treatment combination was significant throughout the periods of observation and combination of mulching @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$  resulted in higher relative growth rate in 4 to 6 months. The relative growth rate during 6<sup>th</sup> to 8<sup>th</sup> months for  $m_1t_2$  recorded highest and was on par with  $m_1t_3$  and  $m_4t_2$ . Treatments varied significantly with both the controls. A significant variation was observed within the controls  $C_1$  and  $C_2$  as well.

### 24. Leaf area duration

Leaf area duration differed significantly among all periods of observation.  $M_1$  ( $30 \text{ t ha}^{-1}$ ) recorded highest leaf area duration on all periods. The leaf area duration of 263.39 days were obtained for  $M_1$  for the period of 6<sup>th</sup> to 8<sup>th</sup> month. In sub plot,  $T_2$  treatment recorded highest leaf area duration on all periods of observation and was significantly different from other treatment. Among the interaction mulching @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$  ( $m_1t_2$ ) recorded highest leaf area duration on all periods of observation. Treatment effects varied significantly with both control  $C_1$  as well as  $C_2$ . A significant difference was noticed between the control  $C_1$  as well as  $C_2$ .

### 25. Bulking rate

The bulking rate recorded significant variation among main plot treatments on 6<sup>th</sup> to 8<sup>th</sup> month of observation. Highest bulking rate was recorded due to main plot treatment  $M_1$  ( $30 \text{ t ha}^{-1}$ ) during this period ( $0.237 \text{ g/plant/day}$ ). In sub plot, treatment  $T_2$  was significantly higher in all periods of observation while in 4<sup>th</sup> to 6<sup>th</sup> month  $T_2$  was on par with  $T_3$ . Interaction was significant during the periods of observation and treatment combination  $m_1t_2$  (mulches @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$ ) noted highest bulking rate in 4<sup>th</sup> to 6<sup>th</sup> months and was on par with  $m_1t_4, m_2t_2$  and  $m_3t_2$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of  $C_1$  and  $C_2$  also showed a significant difference between them.

### 26. Chlorophyll content

Significant differences in chlorophyll content among main plot treatments was observed throughout the crop growth periods. Plants that received  $M_1$  ( $30 \text{ t ha}^{-1}$ ) in main plot resulted in maximum chlorophyll content in all growth periods. At 8 months chlorophyll content of  $1.33 \text{ mg g}^{-1}$  was recorded from  $M_2$ . Sub plot treatment  $T_2$  ( $150:100:100 \text{ kg ha}^{-1}$ ) recorded highest chlorophyll content on 4<sup>th</sup> and 6<sup>th</sup> months observation. While in 8 months chlorophyll content of  $1.24 \text{ mg g}^{-1}$  was

recorded for  $T_2$  and  $T_4$ . The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg /ha}$  ( $m_1t_2$ ) resulted in maximum chlorophyll content while in 4<sup>th</sup> month interactions  $m_1t_2$  was on par with  $m_1t_3, m_1t_4, m_2t_2, m_4t_2$  and  $m_4t_4$  and in 8<sup>th</sup> month interaction  $m_1t_2$  resulted higher chlorophyll content of  $1.39 \text{ mg g}^{-1}$ . A significant difference in chlorophyll content in all periods of growth was recorded between treatment and control. The control  $C_1$  as well as  $C_2$  varied significantly from treatments in all periods. Chlorophyll content recorded between controls  $C_1$  and  $C_2$  also varied significantly.

### 25. Weed count

Weed count differed significantly between all periods of observation and highest weed count was recorded from  $M_3$  ( $7.5 \text{ t ha}^{-1}$ ) on all periods. Weed count of 43.31 was obtained in the 120<sup>th</sup> day of observation. In sub plot,  $T_2$  treatment recorded highest weed count on all periods of observation and was significantly different from other treatments and weed count of 33.19 was obtained in the 120<sup>th</sup> day. Among the interaction mulching @  $7.5 \text{ t ha}^{-1}$  and fertilizer dose of  $150:10:100 \text{ kg ha}^{-1}$  ( $m_3t_2$ ) recorded highest weed count on all periods of observation. Treatment effects varied significantly with both control  $C_1$  as well as  $C_2$ . A significant difference was noticed between the control  $C_1$  and  $C_2$ .

### 25. Dry weight of weed per unit area

A significant variation in dry weight of weed per unit area was observed among the main plot treatment. The main plot treatment of  $M_3$  resulted in highest dry weight of weed of  $161.01 \text{ g/m}^2$  was recorded in 120<sup>th</sup> day. In subplot  $T_2$  treatment resulted in highest dry weight of weed all periods of observation and was on par with  $T_4$  in 45<sup>th</sup> and 120<sup>th</sup> day. Among the combination mulching @  $7.5 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$  ( $m_3t_2$ ) recorded highest dry weight of weed on all periods. While in 45<sup>th</sup>  $m_3t_2$  was on par with  $m_3t_3$  and in 120<sup>th</sup> day  $m_2t_2, m_3t_1, m_3t_2$  was on par with  $m_3t_4$ . Treatment effects varied significantly from both control  $C_1$  as well as  $C_2$ . A significant difference was noticed between the control  $C_1$  and  $C_2$  as well.

### 26. Agronomic efficiency

Main plot treatments significantly influenced agronomic efficiency of Nitrogen, Phosphorus and Potassium in all periods of growth in ginger. Highest agronomic efficiency of Nitrogen, Phosphorus and Potassium was recorded in main plot treatment  $M_1$  ( $30 \text{ t ha}^{-1}$ ) in all periods of growth. The agronomic efficiency of N, P and K recorded in main plot treatment was 20.18, 28.34 and  $28.34 \text{ kg kg}^{-1}$ . In sub plot, treatment  $T_2$  showed significant higher agronomic efficiency of Nitrogen, Phosphorus and Potassium in all periods of observation. The treatment,  $T_2$  resulted in agronomic efficiency of 18.58, 32.13 and  $32.13 \text{ kg kg}^{-1}$  for N, P and K respectively of ginger. Interaction effect on agronomic efficiency of Nitrogen, Phosphorus and Potassium was significant during the periods of observation and treatment combination  $m_1t_2$  (mulches @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$ ) noted highest agronomic efficiency for Nitrogen, Phosphorus and Potassium in all periods of observation. A significant difference in agronomic efficiency of N, P and K was observed between the treatments and the control,  $C_1$  on all periods of growth.

### 27. Partial factor productivity

Significant differences in partial factor productivity of nitrogen, phosphorus and potassium was observed among main plot treatments. Plants that received  $M_1$  ( $30 \text{ t ha}^{-1}$ ) as main plot resulted in maximum partial factor productivity of nitrogen, phosphorus and potassium. The partial factor productivity of N, P and K recorded from main plot treatment  $M_1$  was 36.75, 51.94  $\text{kg kg}^{-1}$  respectively. Sub plot treatment  $T_1$  ( $75:50:50 \text{ kg ha}^{-1}$ ) recorded highest partial factor productivity of nitrogen, phosphorus and potassium of 44.26, 66.39 and 66.39 respectively. In the interaction between main plot and sub plot, significant variation in partial factor productivity of N, P and K was noticed and treatments  $m_1t_1$  resulted in maximum partial factor productivity of nitrogen, phosphorus and potassium of 48.54, 72.81 and  $72.81 \text{ kg kg}^{-1}$  respectively. A significant difference in partial factor productivity of N, P, K was recorded between treatment and control. The partial factor productivity of N, P and K for control  $C_1$  was 46.30, 69.46 and  $69.46 \text{ kg kg}^{-1}$  respectively.

### 28. Physiological efficiency

Physiological efficiency of nitrogen, phosphorus and potassium recorded shown significant variation among main plot treatments and  $M_1$  ( $30 \text{ t ha}^{-1}$ ) recorded highest physiological efficiency of nitrogen, phosphorus and potassium of 45.37, 708.83 and  $36.58 \text{ kg kg}^{-1}$ . While in physiological efficiency of nitrogen and potassium  $M_4$  was on par with  $M_1$ . In sub plot,  $T_2$  treatment recorded highest physiological efficiency of nitrogen, phosphorus and potassium however physiological efficiency of nitrogen in treatment  $T_4$  was on par with  $T_2$ . Among the interaction mulching @  $30 \text{ t ha}^{-1}$  and fertilizer dose of  $150:100:100 \text{ kg ha}^{-1}$  ( $m_1t_2$ ) recorded highest physiological efficiency of nitrogen, phosphorus and potassium and while in physiological efficiency of nitrogen and potassium  $m_1t_2$  was on par with  $m_1t_4, m_4t_2, m_4t_4$ . However with physiological efficiency of phosphorus of the treatment combination  $m_3t_1$  was on par with  $m_1t_2$ .

**29. Soil chemical analysis**

Soils of the experimental plots before the experiment were in medium range of nitrogen and remains in medium range even after the experiment. Phosphorus range of soils in the experimental plots were in medium range and after the experiment, there was increase in phosphorus content of the soil. Potassium content of the soils were in low range and after the experiment only a slight increase in soil potassium content was noticed. The nitrogen content of experimental plot before the experiment ranged from 357.06 to 400.4 kg ha<sup>-1</sup>. The soil phosphorus content of the experimental site ranged from 16.32 to 21.88 kg ha<sup>-1</sup>. The potassium content of the experimental site from before and after the experiment ranged from 105.86 to 120.35 kg ha<sup>-1</sup>.

**30. Nutrient analysis of fym, organic mulch**

The NPK content of organic mulch used was 0.5 %, 0.4% and 0.42 % respectively . The FYM applied contained 0.5% N, 0.4% P and 0.64% K .

**31. Plant NPK uptake**

The plant NPK uptake differed significantly and main plot treatment M<sub>1</sub> (30 t ha<sup>-1</sup>) recorded highest uptake of nitrogen, phosphorus and potassium on all periods. In sub plot, T<sub>2</sub> treatment recorded highest uptake of nitrogen, phosphorus and potassium and was significantly different from other treatments . Among the interaction mulching @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup> (m<sub>1</sub>t<sub>2</sub>) recorded highest uptake of nitrogen, phosphorus and potassium . Treatment effects varied significantly with both control C<sub>1</sub> as well as C<sub>2</sub>. A significant difference was noticed between the control C<sub>1</sub> and C<sub>2</sub> as well .

**32. Nutrient balance sheet for NPK**

The nutrient balance sheet analysed revealed a higher uptake for m<sub>1</sub>t<sub>2</sub> followed by m<sub>2</sub>t<sub>2</sub> however the net loss of nitrogen was comparatively higher for all the combinations of m<sub>1</sub>, while in the all fertilizer plots treated with plastic mulch a reduction in the net loss of nitrogen was observed . The nutrient balance sheet prepared for phosphorus revealed that net loss was less for treatments with plastic mulches. The net loss of P was minimum for absolute control. The combination of plastic mulch with fertilizer dose of 75:50:50 kg ha<sup>-1</sup> recorded least net loss of P (-110.03 kg ha<sup>-1</sup>). The nutrient balance sheet prepared for potassium revealed that net loss was less for combination of plastic mulch . The K added ranged from 230 kg ha<sup>-1</sup> to 406 kg ha<sup>-1</sup>. The plant uptake of K ranged from 62.25 in absolute control to 88.33 kg ha<sup>-1</sup> in combination of mulches @ 30 t ha<sup>-1</sup> and fertilizer dose of 150:100:100 kg ha<sup>-1</sup>.

**33. Pest and disease incidence**

There was no pest incidence in the field however leaf spot was noticed in few plants one month after transplanting which could be controlled by a single dose of mancozeb @ 0.3 per cent.

**34. Benefit cost analysis**

The treatment of 30 t ha<sup>-1</sup> of mulches applied in two split doses with a fertiliser dose of 150: 100: 100 kg of NPK per hectare along with 30 t ha<sup>-1</sup> of FYM generated a higher net profit compared to all other treatment. The cost of cultivation was more for all the combinations where plastic mulch was used.

**Clove****1. Survey, characterization and evaluation of clove (*Syzygium aromaticum* (L) Merr. & Perry) accessions****1. Survey**

Survey was carried out in the major clove growing regions of Trivandrum, Kollam and Pathanamthitta districts of Kerala and Kanyakumari district of Tamil Nadu for characterisation of clove accessions and to identify superior high yielding type during the period from 2016-2018.

Twenty accessions from seven clove growing plantations were identified and named as BRC-1, BRC-2, BRC-3, BRC-4, MRC-5, MRC-6, MRC-7, MRC-8, AMC-9, AMC-10, AMC-11, AMC-12, AMC-13, MMC-14, MMC-15, BLC-16, BLC-17, BLC-18, MGC-19 and ANC-20. Passport data of selected clove accessions were collected. Twenty selected clove accessions were observed for their qualitative and quantitative characters and yield for two years viz., 2016-17 and 2017-18. Soil N, P, K, organic carbon and soil pH were recorded in the selected clove accessions and nutrients were applied based on the soil test data as per the package of practices of Kerala Agricultural University.

**2. Characterisation and evaluation of selected clove accessions**

Twenty selected clove accessions were observed for qualitative characters which included tree, leaf, bud, flower, fruit and seed characters. Considerable variation was present among the accessions for 15 out of 21 qualitative characters observed.

Characters like leaf arrangement, position of flower, colour of peduncle, mature fruit colour, ripe fruit colour and seed colour were non variable characters among the accessions and were not included for further analysis.

In the tree characters evaluated, elliptical canopy shapes were observed in 40% of the accessions followed by cylindrical (20%), conical (20%) and pyramidal shapes (20%). Semi-erect branching pattern was common (55%) followed by irregular (35%) and erect (10%). The colour of young leaf among the selected and evaluated accessions were red pinklight green tinge in 85 %, followed by yellow greenlight green tinge (10 %) and purple redlight green tinge in 5 % while that of mature leaf was dark green (65%) and the rest were green (35%). The predominant leaf lamina shape was lanceolate with acuminate leaf apex (85%) followed by narrowly elliptical leaf lamina with acute leaf apex (15%).

Bud forming season of the selected accessions was classified as early, mid and late season of which mid-season was the predominant. Majority of the accessions were having combination of 1,2,3 flower buds per cluster (85%) while the rest had combination of 1,2,3,4,5 flower buds per cluster. Medium sized buds were reported from 70% of the accessions followed by large (20%) and small (10%). The predominant hypanthium colour was light red pink (95%) while only one accession, AMC-9 exhibited dark purple red.

Flower consisted of petals of light green with pinkish tinge colour and sepal of yellow green with light green stigma in all the accessions except one accession which had green brown petals with dark purple red sepal colour and yellow green stigma. The shape of the fruit and seed obtained was oblong in 85% and elliptic in 15 %.

### 2.1 Bivariate analysis of major qualitative characters

Bivariate analysis of major qualitative characters revealed that when canopy shapes were elliptical majority of the plants were having semi-erect branching pattern (54.54%). Similarly, when colour of young leaves were red pink majority of the accessions were having light green petal (89.47%) and when colour of young leaves were red pink majority of the accessions were having yellow green sepal (89.47%). Colour of young leaves when it was red pink majority of the accessions were having yellow light green stigma (89.47%). The medium sized bud (64.29 %) were associated with dark green leaf. However, seed shape was evenly distributed with respect to the fruit shape.

Association of characters like canopy shape with bud clustering habit, bud size, fruit shape and seed shape; branching pattern with bud clustering habit, bud size, fruit shape and seed shape; colour of young leaf with bud clustering habit, bud size, fruit shape and seed shape; colour of mature leaf with fruit shape, seed shape, petal colour, sepal colour and colour of stigma; leaf apex shape with bud clustering habit, fruit shape and seed shape; leaf lamina shape with bud clustering habit, fruit shape and seed shape were found to be non significant.

According to Unweighted Pair Group Method with Arithmetic Mean hierarchial techniques twenty accessions were grouped into 13 clusters based on qualitative traits at 80 % similarity (Fig. 1). Cluster II and VIII had 3 accessions while cluster I,IV,V,VII,IX,X,XI and XIII had only single accessions. Among the thirteen clusters, Cluster I included BRC-1, Cluster II included BRC-2, MMC-15 and BRC-4, Cluster III contained MMC-14 and BLC-18, Cluster IV with MRC-7, Cluster V contained AMC-12, Cluster VI with MRC-5 and MRC-6, Cluster VII included BLC-16, Cluster VIII contained MRC-8, AMC-10 and BLC-17, Cluster IX contained MGC-19, Cluster X with ANC-20, Cluster XI contained BRC-3, Cluster XII included AMC-11 and AMC-13 and Cluster XIII with AMC-9.

### 2.2 Clustering based on qualitative characters

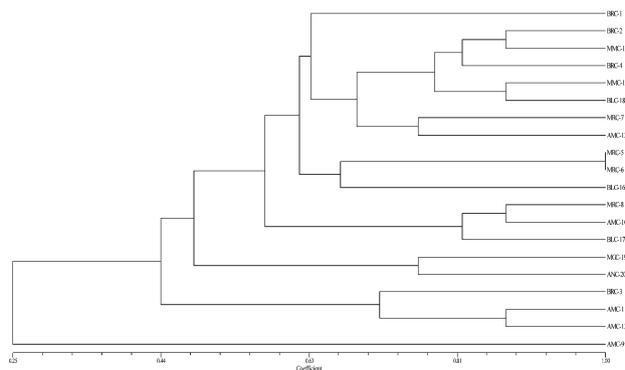


Fig. 1. UPGMA dendrogram of qualitative characteristics of clove accessions

### 3. Quantitative characterization

Quantitative characterisation carried out included tree, leaf, bud, flower, fruit and seed characters. The plant height measured between the twenty selected clove accessions ranged from 5.15 m to 15.25 m and the girth at 45 cm height ranged from 44.10 cm to 138.10 cm. The N-S canopy spread was the highest for MRC-7 while the E-W canopy spread was the highest for AMC-11. The number of branches among accessions ranged from 26 to 55. Minimum leaf length in the selected accession measured was 9.66 cm while maximum was 13.93 cm in MRC-5 and the leaf breadth of selected accessions varied from 3.55 cm to 4.72 cm. Leaf area thus calculated varied from 23.07 cm in ANC-20 to 42.93 cm in AMC-11.

The number of inflorescence /m<sup>2</sup> among the accessions varied between 155.5 to 36.25 and the number of flower buds / inflorescence from 6.05 in ANC-20 to 18.21 in MRC-6. The single bud weight (fresh) and single bud weight (dry) was the highest for BRC-3. The single bud weight dry ranged from 66.5 to 128.5g. The mature bud length varied from 14.94 mm to 19.06mm while the mature bud diameter ranged from 4.9mm to 6.41mm. The period taken from bud initiation varied from 103.8 to 118.4 days among the accessions. The pooled mean of bud yield per tree fresh varied from 2.7 to 40.25 kg. BRC-1, MRC-5, MRC-6, MRC-8, AMC-10 and MMC-15 were good yielders yielding more than 30 kg/tree as revealed from pooled mean. The length of flower ranged from 16.36 mm to 21.84mm and the breadth ranged from 9.85mm to 14.82mm. The number of sepal and petal was constant while the length of sepal ranged from 2.49mm to 3.15mm. The fruit weight ranged from 1.2 g in ANC-20 to 3.53g in BRC-3. The ratio of fruit to seed varied between 2.41 to 3.64. The seed length varied from 13.2 to 19.31mm and seed breadth from 6.11 to 9.19mm in the selected accessions. The seed weight was the highest for BRC-3 (1.18g). The time taken for harvest of fruits from flowering ranged from 86.8 to 97.6 days. The bud oil in the selected accessions varied from 12.53 to 19.6 % while the stem oil ranged from 3.6 to 6.7 %. The bud oleoresin showed a range from 16.9 to 24.3 % and the stem oleoresin from 7.1 to 12.2%. The eugenol content between accessions ranged between 54.29 and 70.77%. GC MS analysis of the bud oils of the improved clove accessions like BRC-1, BRC-3, MRC-5 and MRC-6 exhibited 25 constituents. The major constituents of the bud oil were p-eugenol, eugenyl acetate,  $\beta$ -caryophyllene,  $\beta$ -cubebene, 4-Quinolinal and  $\alpha$ -humulene.

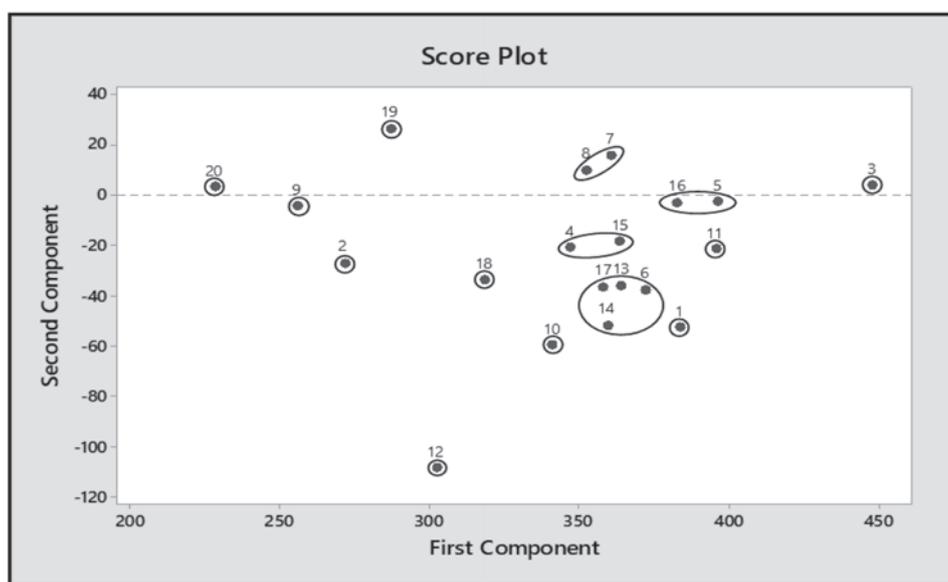
#### 3.1 Clustering based on quantitative characters

The Principal Component Analysis of quantitative characters resulted in the first two principal component explaining 88.8% variation (Table 1.)

Table 1. Component loadings for the first two Principal Components

Variables	Principal Component 1	Principal Component 2
Plant height	0.013	0.03
Girth at 45 cm height	<b>0.335</b>	-0.044
Canopy spread (N-S)	0.01	0.007
Canopy spread (E-W)	0.012	0.01
Number of branches	0.099	-0.05
Leaf length	0.015	0.014
Leaf breadth	0.003	0.003
Leaf area	0.054	0.034
Number of inflorescence/m <sup>2</sup>	0.172	<b>-0.959</b>
Number of flower buds/inflorescence	0.021	-0.021
Length of flower	0.027	0.012
Breadth of flower	0.021	-0.007
Length of petal	0.005	0.001
Length of sepal	0.002	-0.002
Single bud weight (fresh)	<b>0.87</b>	0.174
Single bud weight (dry)	<b>0.262</b>	0.163
Mature bud length	0.02	0.002
Mature bud diameter	0.007	0.001
Period from bud initiation to bud harvest	-0.01	-0.065
Bud yield per tree (fresh)	0.114	-0.101
Bud yield per tree (dry)	0.038	-0.04
Fruit weight (fresh)	0.009	0.004
Ratio of fruit to seed	0	0.003
Seed length	0.024	0.007
Seed breadth	0.011	0.005
Seed weight	0.003	0.001
Time taken for harvest of fruit from flowering	-0.013	-0.014
Bud oil	0.012	0.004
Bud oleoresin	0.008	0.003
Clove stem oil	-0.001	-0.01
Clove stem oleoresin	0.002	-0.009
Eugenol content of bud	-0.04	0.003

A score plot generated based on the first two Principal Components using Minitab version 18 identified fourteen clusters (Fig. 1). The linkage analyzed based on the biplot of Principal Component scores revealed a strong positive association



between all quantitative characters measured except, girth at 45 cm height, number of branches, number of inflorescence/m<sup>2</sup>, single bud weight fresh, single bud weight dry and fresh bud yield per tree (Fig. 2) Minimum Data Set for identifying a promising clove accession were generated. Identification of an ideotype using existing data revealed that accessions BRC-1, MRC-5, and MRC-6 had better ideotype.

## Chilli

### 1. Screening of spice chilli (*Capsicum annum* L.)

Thirty two genotypes of chilli collected from different sources and the three released varieties (Ujwala, Anugraha, Vellayani Athulya) of KAU formed the material for the study. Analysis of variation (ANOVA) revealed significant differences among the thirty five genotypes for plant and fruit characters (quantitative & qualitative). Among the genotypes, CA 22, CA 27, CA 28 and CA 29 were found taller (>100 cm) and CA 31 was found to be the shortest with a plant height of <50 cm. CA 27 had highest leaf length and CA 6 recorded the highest leaf breadth. Genotypes like CA 25 and CA 21 were early in flowering (less than 35 days) and fruiting (less than 40 days), whereas CC 1, CC 2 and CC 3 were late in flowering (more than 70 days) and fruiting (more than 75 days). Distinct variation was observed for fruit characters viz fruit length (3.9 cm -12.3), fruit width (0.16 cm- 2.32 cm), fruit weight (2.31 g-13.31 g), number of fruits per plant (11.9 -45.4), dry yield per plant (5.6 g-47.53 g), number of fruits per plant (11.9 -45.4), dry yield per plant (5.6 g-47.53g) etc. Three genotypes (CA 23, CA 29 and CA 32) performed better with individual fruit weight of more than 10 g. Number of fruits per plant is an important economic character and more than forty fruits per plant were observed in CA 7, CA 22, CA 19 and CA 25. In the present investigation, fresh yield from plant ranged from 39.72 g (CA 26) to 318.6 g (CA 32) and dry yield per plant ranged from 5.6 g (CA 14) to 47.53 g (CA 13). Among the genotypes, CA 26 recorded maximum driage (39.51 %) and minimum driage was recorded in CA 14 (7.14 %). High driage (more than 30 %) was obtained in CA 26, CA 10, CA 12 and CA 31. Considerable variability was observed with respect to qualitative characters like leaf colour (light green to dark green), mature fruit colour (light green to dark green), ripe fruit colour (light red to dark red), fruit shape (elongated and tapering to conical), fruit surface (smooth to wrinkled) and seed colour light yellow to dark yellow) where as no variability was observed for corolla colour. Bacterial wilt was the major disease observed in field and considerable variability was recorded for the disease incidence ranging from 0 % to 85 %. Most of the released varieties were wilt prone except KAU varieties while most of the local genotypes were tolerant to bacterial wilt as seen in CA 22, CA 23, CC 1, CC 2 and CC 3. The highest wilt incidence (85 %) was observed in CA 15 followed by CA 14 (70 %). Biochemical analysis revealed that CA 25 (0.95 %) and CA 16 (0.91 %) are highly pungent among *Capsicum annum* types where as among *Capsicum chinense* types, the highest capsaicin content was recorded for CC 2 (1.09 %). CA 16, CA 1, CC 2 and CC 3 had high oleoresin recovery (more than 25 %) where as CA 31, CA 30, CA 8 and CA 32 recorded high colour value (more than 100 ASTA units)

Correlation and clustering analysis was done between fruit and yield contributing characters. Correlation analysis indicated that fruit weight was significantly and positively contributed to fruit length and width, placenta length and weight, pericarp weight and thickness and dry yield. It is revealed that fruit weight and number of fruits per plant are the important yield contributing parameters.

Based on the cluster analysis, all the thirty five genotype under the study were grouped in to eight clusters with significant variation among the clusters and within clusters for different character studied. Cluster 2, cluster 4 and cluster 8 were distinct from other clusters.

Based on the study , few genotypes were found promising as spice chilli (CA 13,CA 16, CA 22, CA 25, CA 27 and CA 28), vegetable chilli (CA 3 ,CA 7, CA 8, CA 9, CA 10, CA 11 ,CA 12 , and CA 23 ) and for industrial purpose (CA 16,CA 25 , CC 1,CC2 a

## Coconut

### 1. “Characterisation of coconut palms (*Cocosnucifera* L.) showing general yellowing”

The study on “Characterisation of coconut palms (*Cocosnucifera* L.) showing general yellowing” was undertaken in selected coconut palms of Thiruvallampanchayat of Thiruvananthapuram district from March 2016 to March 2017. The objective was to evaluate the field characteristics and nutritional status of soil and coconut palms showing general yellowing and to formulate a management strategy.

Coconut palms of variety WCT showing general yellowing which advance from lower to upper whorls of leaves were identified from farmer’s field of Thiruvallampanchayat. Fifteen palms showing uniform pattern of general yellowing were selected from five fields of Thiruvallam, Pachalloor, Punkulam, Koliyoor and five healthy palms from same fields were selected as control. Field, soil, plant and management characterization were carried out in the selected palms to identify the pre disposing factors leading to general yellowing.

Observations on morphological and yield characteristics of selected coconut palms were recorded for one year at 60 days interval. Soil and plant samples were collected and analysed for macro and micronutrients. Based on soil test results the quantity of deficient macro nutrients were calculated and applied as per package of practices recommendation of Kerala Agricultural University. The soil and plant sample was again analysed six months after the application of fertilisers.

The information on field, soil, plant characteristics and management aspects were collected from the selected fields. The field characteristics had shown 100 percentage drainage in the selected fields and 80% of the fields showed an elevation of 10-50 meter above mean sea level and 20% of the fields fall in an elevation of 50-100 meter above mean sea level. Data generated on soil characterization of selected coconut fields revealed that the soil type of the all fields selected was red loam and 80% of the coconut palms showing general yellowing had medium organic matter which ranged from 0.86 to 1.29% and 20 % of the coconut palms showing general yellowing had high organic matter content with more than 1.29 per cent. All the healthy palms are under high organic matter content. The age of selected healthy palms and coconut palms showing general yellowing was grouped and 20% of the coconut palms showing general yellowing ranged between 20 to 25 and 80% of the healthy palms also came under this age group. 27% of the coconut palms showing general yellowing belonged to 26-30 age group and 53% of the coconut palms showing general yellowing came under 31-35 age group and 20% of the healthy palms in 26-30 age group.

The data collected on the management characteristics of the selected coconut palms showed that 80% of the coconut palms showing general yellowing were noticed without the application fertilizer and 20% of the coconut palms showing general yellowing were given with the fertilizer application. 60% of the palms were not provided with organic matter and 40% of palms were given organic matter. 40% of fields had irrigation facility while 60% of the fields did not have any irrigation facilities. 53% of coconut palms showing general yellowing had disease incidence and 73% had pest incidence. 47% of coconut palms showing yellowing were without disease incidence and 27% of palms were without pest incidence. 80% of the healthy coconut palms did not show any pest and disease incidence.

Physiological characters of selected palms before the application of nutrients showed significant variation in chlorophyll content, membrane integrity, relative water content. However after the application of nutrients significant increase in chlorophyll content, membrane integrity and relative water content was noticed in coconut palms showing general yellowing. There was no significant variation in auxin content between the palms showing general yellowing and healthy palms. Observations on morphological and yield characteristics of selected coconut palms were recorded for one year at 60 days interval. The morphological and yield parameters of selected palms indicated significant variation in number of leaves showing yellowing, number of bunches, number of female flowers per bunch of unfertilised open inflorescence, number of nuts set per bunch, weight of nut, weight of copra and oil content in coconut palms showing general yellowing compared to healthy palms.

Available primary nutrients in soils of coconut showing general yellowing and healthy palms before the application of nutrients were analysed and is shown in the Table 1. Soil analysis revealed a significant variation in soil available nitrogen content of coconut palms showing general yellowing and healthy palms. Soil available nitrogen content before the application of nutrients in palms showing general yellowing was 206.47 kg ha<sup>-1</sup> and for healthy palms the available nitrogen revealed was about 289.39 kg ha<sup>-1</sup>. There was no significant difference between soil phosphorus content of coconut palms showing general yellowing and healthy palms. Soil phosphorus content of coconut showing general yellowing was about 11.88 kg ha<sup>-1</sup> and in the case healthy palms was about 17.79 kg ha<sup>-1</sup>. Before the application of nutrients soil potassium content of coconut showing general yellowing was 108.80 kg ha<sup>-1</sup>, but in the case of healthy palms soil potassium content was about 175.04 kg ha<sup>-1</sup>. There was an significant difference between soil potassium content in healthy palms compared to coconut palms showing general yellowing. The coconut palm which had shown general yellowing fall in the low status while for healthy palms the soil nitrogen status was of medium. The available phosphorus content of both the category fall under the medium range (10-24 kg ha<sup>-1</sup>). The available soil potassium content of the palm showing general yellowing fall under the low status while that for healthy palms the available soil potassium contents fall under the medium category.

Table 1. Available primary nutrients in soils of coconut showing general yellowing and healthy palms before the application of fertilizers.

Treatments	N(Kg/ha)	P(Kg/ha)	K(Kg/ha)
Coconut showing general yellowing (Y <sub>-1</sub> )	206.47	11.88	108.80
Healthy palms (H <sub>-1</sub> )	289.39	17.79	175.04
t stat	3.264*	0.854	2.184*

Soil nutrient status before and after the experiment was assessed and analysed. Before the application of nutrients soil nitrogen content of coconut palms showing general yellowing was found to be 206.47Kg/ha.

Result revealed that the soil application of major nutrients of N, P and K significantly increased the soil status of these nutrients and is given in the Table 2. After the nutrients application soil nitrogen status increased to 285.82 Kg/ha and it was significantly higher from the soil nitrogen status of before application of nutrients. Significant variation in soil phosphorus content was noticed in the coconut palms showing general yellowing before and after the application of nutrients. Soil phosphorus status of fifteen palms showing general yellowing before the application of treatments was found to be 11.88 Kg/ha. Phosphorus was not deficient under these situation. After nutrient application soil phosphorus content showed an significant increase to about 23.24 Kg/ha. Soil potassium of coconut palms showing general yellowing before the application of nutrients differed significantly from the soil potassium content after the application of nutrients. Soil potassium of palms showing general yellowing before the application of nutrient was 108.80 Kg/ha and after the treatment application soil potassium status improved to 221.46 Kg/ha.

Table 2. Available primary nutrients in soils of coconut showing general yellowing before and after the application of fertilizers.

Treatments	N(Kg/ha)	P (Kg/ha)	K (Kg/ha)
Before	206.47	11.88	108.80
After (6 month after the application of fertilizers)	285.82	23.24	221.46
t stat	2.060*	3.034*	7.638*
P value	0.02924	0.00445	0.000012

Available secondary nutrients in soils of coconut palms showing general yellowing and healthy palms before the application of nutrients were analysed and is given in the Table 3. Soil calcium content of coconut palms showing general yellowing analysed (96 mg kg<sup>-1</sup>) were significantly different from healthy palms (154 mg/Kg). Soil magnesium content of coconut palms showing general yellowing (70.40 mg kg<sup>-1</sup>) showed significant variation when compared to the healthy palms (129.60 mg kg<sup>-1</sup>) Soil sulphur was analysed for selected fifteen palms showing general yellowing before the application of nutrients was 5.98 mg kg<sup>-1</sup>. It was significantly different from healthy palms which recorded 11.76mg Kg<sup>-1</sup>.

Table 3. Available secondary nutrients in soils of coconut showing general yellowing and healthy palms before the application of fertilizers

Treatments	Ca (ppm)	Mg (ppm)	S (ppm)
Coconut showing general yellowing Y <sub>-1</sub> )	96.00	70.40	5.98
Healthy palms (H <sub>-1</sub> )	154.00	129.60	11.76
t stat	2.836*	3.209*	2.246*

Available secondary nutrients in soils of coconut palms showing general yellowing before and after the application of nutrients were analysed and is shown in the Table 4. A significant increase in calcium content of soils of coconut palms showing general yellowing after the application of nutrients was noticed.

Table 4. Available secondary nutrients in soils of coconut showing general yellowing before and after the application of fertilizers

Treatments	Ca(mg/kg)	Mg(mg/kg)	S(mg/kg)
Before	96	70.40	5.98
After (6 month after the application of fertilizers)	162.67	198.13	6.60
t stat	6.580*	6.075*	0.569
P value	0.00000611	.0000143	0.26735

Before the application of treatments soil calcium content of fifteen palms showing general yellowing was found to be 96 mg kg<sup>-1</sup>. If calcium content was less than 300 mg kg<sup>-1</sup>, the soil become calcium deficient. After the application of nutrients calcium contents increased to about 162.66 mg kg<sup>-1</sup>. Soil magnesium content before and after the application of nutrients differed significantly in coconut palms showing general yellowing. Soil magnesium was analysed for selected fifteen palms showing general yellowing was 70.40 mg kg<sup>-1</sup> of soil. After the application of nutrients soil magnesium content increased to about 198.13 mg kg<sup>-1</sup>. Soil sulphur content before and after the application of nutrients differed significantly in coconut palms showing general yellowing. Soil sulphur content before the application of nutrients was 5.98 mg kg<sup>-1</sup>. While after the application of nutrients soil sulphur content increased to about 6.60 mg kg<sup>-1</sup>.

Available micro nutrients in soils of coconut palms showing general yellowing and healthy palms before the application of nutrients were analysed. Results revealed that there was no significant variation in iron content between coconut palms showing general yellowing (34.49 mg/Kg) and healthy palms (44.96 mg/Kg) and was above the critical level of iron content in the soil. A significant variation was noticed in soil available manganese content between coconut palms showing general yellowing (4.03 mg/Kg) and healthy palms (was 6.81 mg/Kg). Also in soil available boron content between coconut palms showing general yellowing (0.54 mg/Kg) and healthy palms (0.68 mg/Kg). There was no significant variation in soil available zinc content between coconut palms showing general yellowing (8.18 mg/Kg) and healthy palms (8.95 mg/Kg). No significant variation observed in soil available copper content between coconut palms showing general yellowing (0.32 mg/Kg) and healthy palms (0.30 mg/Kg). There was no significant variation in soil available chlorine content between coconut palms showing general yellowing (488.60 mg/Kg) and healthy palms (468.60 mg/Kg). Soil iron content in coconut palms showing general yellowing before (34.49 mg/Kg) and after the application of nutrients (37.75 mg/Kg) was analysed and no significant difference was noticed. There was no significant variation was noticed soil manganese content of selected fifteen palms showing general yellowing before (4.03 mg/Kg) and after the application of fertilisers (4.04 mg/Kg). No significant difference was noticed in soil zinc content of coconut palms showing general yellowing before (8.18 mg/Kg) and after the application of nutrients (8.02 mg/Kg). There was no significant difference in soil copper content of coconut palms showing general yellowing before (0.32 mg/Kg) and after the application of nutrients (0.29 mg/Kg). A significant difference was noticed in boron content of coconut palms showing general yellowing before (0.54 mg/Kg) and after the application of nutrients (0.52 mg/Kg). There was no significant difference in soil chlorine content of coconut palms showing general yellowing before (488.6 mg/Kg) and after the application of nutrients was noticed (0454.4 mg/Kg).

A significant difference was noticed in the soil organic carbon content of coconut palm showing general yellowing (0.94%) and healthy palms (1.31%). Soil chemical analysis 6 month after the application of fertilizers (1.98%) showed a significant difference in organic carbon content of coconut palms showing general yellowing compared to before the application of nutrients (0.939%). There was no significant difference in soil pH of selected coconut fields. Before the application of lime and fertilisers soil pH of coconut palms showing general yellowing was 4.71 and that of healthy palms was 5.03. The soils were in acidic range of pH. Significant difference in soil pH was noticed to the coconut palm showing general yellowing before and after the application of fertilisers. Six month after the application of fertilizers soil pH increased from acidic to near neutral condition. Soil pH of coconut palms showing general yellowing before the application of fertilizers was 4.7. Six month after the application of fertilizers soil pH of coconut palms showing general yellowing increased to 6.5.

Physical properties of soils of coconut showing general yellowing and healthy palms were observed. Among the physical properties of soils, water holding capacity showed a significant difference in coconut showing general yellowing (22.78%) and healthy palms (30.02%).

Leaf nutrient analysis was done in selected coconut palms before the application of fertilisers and represented in Table 5. There was significant difference between total nitrogen content in coconut palms showing general yellowing and healthy palms. Total nitrogen content in index leaves of coconut palms showing general yellowing was 1.50% and healthy palm was 2.76%. There was no significant difference in total phosphorus content of index leaves of coconut palms showing general yellowing and healthy palms. Total phosphorus content in index leaves of coconut palms showing general yellowing before the application of nutrients was 0.190% and the healthy palms was 0.194%. A significant variation was noticed in total potassium content of coconut palms showing general yellowing and healthy palms. Total potassium content in index leaves of coconut palms showing general yellowing was 1.00% and healthy palms was 1.59%.

Table 5. Primary nutrients in leaves of coconut showing general yellowing and healthy palms before the application of fertilizers

Major nutrients	N(%)	P(%)	K(%)
Coconut showing general yellowing (Y <sub>-1</sub> )	1.50	0.190	1.00
Healthy palms (H <sub>-1</sub> )	2.76	0.194	1.59
t stat	12.895*	0.563	4.653*

Primary nutrients in leaves of coconut showing general yellowing before and after the application of fertilizers is given in Table 6.

Table 6. Primary nutrients in leaves of coconut showing general yellowing before and after the application of fertilizers

Treatments	N(%)	P(%)	K(%)
Before	1.50	0.190	1.00
After (6 month after the application of fertilizers)	1.54	0.21	1.30
t stat	2.656*	3.303*	2.696*
P value	0.00940	0.00262	0.000156

The total nitrogen content showed a significant difference before and after the application of fertilisers in coconut palms showing general yellowing. The results showed that before the application of fertilisers total nitrogen content in index leaves was 1.50%. Leaf nutrient analysis six month after the application of fertilisers showed a significant variation in nitrogen content of index leaf tissue of coconut palms showing general yellowing and the nitrogen content after the application increased to 1.54%. The total phosphorus content in index leaves of coconut palms showing general yellowing differed significantly before and after the application of fertilisers. Total phosphorus content in index leaves of coconut palms showing general yellowing before the application of fertilisers was 0.190% and after the application of fertilisers phosphorus content in index leaves was 0.21%. There was a significant variation in total potassium content in index leaves of coconut palms showing general yellowing before and after the application of fertilisers. The results revealed that total potassium content in index leaves of coconut palms showing general yellowing before and after the application of fertilisers was 1.0% and 1.3% respectively.

Secondary nutrients were analysed in index leaves of selected coconut palms before the application of fertilizers. The results revealed that there was a significant variation in total calcium content in index leaves of coconut palms showing general yellowing and healthy palms before the application of fertilizers. Total calcium in index leaves of coconut palms showing general yellowing was 0.110% and healthy palms was 0.206%. Total magnesium content in index leaves of coconut palms showing general yellowing (0.180%) showed a significant variation compared to the healthy palms (0.320%). A significant variation was noticed in total sulphur in index leaves of coconut palms showing general yellowing and healthy palms. Before the application of fertilizers total sulphur of coconut palms showing general yellowing was 0.183% and for healthy palms was 0.23%.

Micronutrients in index leaves of selected coconut palms before the application of fertilizers were analysed. The results revealed that there was no significant variation in total iron content in index leaves of coconut palms showing general yellowing and healthy palms before the application of fertilizers. Total iron in index leaves of coconut palms showing general yellowing was 53.52% and healthy palms was 55.78%. There was no significant variation noticed in total manganese content in index leaves of coconut palms showing general yellowing and healthy palms before the application of fertilizers total manganese content of coconut palms showing general yellowing was 68.91% and healthy palms was 73.82%. There was no significant difference noticed in total zinc content in index leaves of coconut palms showing general yellowing and healthy palms before the application of fertilizers. The zinc content in index leaves of coconut palms showing general yellowing was 26.44% and healthy palms 28.37%. The results revealed that there was no significant variation in total copper content in index leaves of coconut palms showing general yellowing and healthy palms before

the application of fertilizers. Total copper in index leaves of coconut palms showing general yellowing was 223.5% and healthy palms was 259.8%. Significant variation was noticed in total boron content in index leaves of coconut palms showing general yellowing and healthy palms before the application of fertilizers. Total boron content in coconut palms showing general yellowing was 12.17 % and healthy palms was 15.43%.

Soil analysis carried out for estimating the nematode population in the fields of selected coconut palms. Nematode extraction was done in soils of selected coconut fields by cobbs sieving and decanting methods. There was no significant difference in nematode population in soils of coconut palms showing general yellowing and healthy palms before the application of fertilizers. Two nematodes were identified after the analysis *Rotylenchulus reniformis* and *Helicotylenchus*. The population of *Helicotylenchus* was 604 in coconut palms showing general yellowing and 528 in healthy palms. The population of *Rotylenchulus reniformis* was 402.73 under coconut palms showing general yellowing and less (352) in healthy palms.

Major pest and disease incidence observed in selected coconut fields were coconut eriophyid mite, coreid bug, rhinoceros beetle and leaf rot.



# **Name of Project Coordination Group – (03) Vegetables**

**Compiled by:  
Dr. S. Nirmala Devi, Protect Coordinator**



## Projects under ADVANCED CENTRE FOR TROPICAL VEGETABLE RESEARCH

Dr.P.Indira,  
Professor &Head,**1. Breeding for high yield/quality/resistance to major biotic and abiotic stresses****a. Breeding for resistance to fruit fly (*Bacterocera* spp.) in oriental picklingmelon**

Screening of 62 genotypes revealed that OP 047, OP 045, OP 051 and OP 022 were high yielding and OP 014, OP 012, OP 056 and OP 034 are resistant to melon fruitfly. Two species of fruitflies viz. *B. cucurbitae* and *B. tau* were identified

**b. Development of tropical parental lines for developing  $F_1$  hybrids in selected cucurbits and solanaceous crops**

$F_2$  population from promising 12,  $F_1$  gynoecious hybrids of cucumber were generated for identifying tropical gynoecious lines.  $F_2$  population from the cross EC 709119 x IC 538186 was observed as the most promising one. This population took only minimum days to form female flower and took minimum number of nodes to form female flower with highest number of female flowers and minimum male flowers. The 12  $F_2$  population evaluated for gynoecious trait were classified into monoecious and gynoecious character and tested for goodness of fit based on chi square test with monohybrid ratio of 3:1 being monoecy dominant over gynoecey. Out of 12 populations, 10 were found to express significant value and fit in 3:1 ratio for dominant monoecious trait. EC 709119 x IC 538186 produced maximum number of true gynoecious plants whereas seven  $F_2$  populations failed to produce even one true gynoecious plant. Gynoecey was found to be governed by single recessive gene which was already reported in cucumber. Experiment is in progress and stable lines can be identified after advancing promising generation to F5-F6 level.

**I. Development of molecular markers for complementing conventional breeding for selected traits in tropical vegetable crops.****CUCUMBER**

Twenty four SSR primers were used for amplification of cucumber genomic DNA. Among them, one primer gave satisfactory result. The banding pattern of SSR primer EC12 using 9 cucumber genotypes are shown in Table 1. The SSR primers produced different numbers of DNA fragments, depending upon their simple sequence repeat motifs. Primer EC 12 (fig.1) produced polymorphic bands with size varied from 150-250 bp. A maximum of 100% polymorphism was obtained with this SSR primer. SSRs are co-dominant markers; hence residual heterozygosity can be detected. This primer produced one extra band which is specific for gynoecious line, in both homozygous and heterozygous conditions. This specific fragment was inherited to next three generations too.

**TOMATO**

A total of ten primer combinations were used for amplification of tomato genomic DNA. Among them one primer gave satisfactory results which were used for further analysis of all tomato genotypes. SCARs (Sequence Characterized Amplified Regions) have a high reproducibility and are locus-specific. Primer Ualty 3b (fig.1) produced total five bands, of which two bands were polymorphic. The bands ranging in size from 100-900 bp were obtained. A maximum of 100% polymorphism was obtained with this SCAR primer. Due to the co-dominant nature, SCAR marker can provide a valid tool for the accurate assessment of genotype linked to bacterial wilt. In this study comparison of highly resistant and susceptible tomato genotypes was performed. Primer Ualty 3b has resulted presence of two extra bands. Extra bands that were possibly associated with bacterial wilt resistance, the fragments, sized about 650-900 bp. Both the two fragments were amplified only in the resistant genotypes. In this study molecular marker linked to bacterial wilt resistance in tomato were successfully identified.

**IV. Identification of varieties/ hybrids and standardization of agro techniques for rain shelter/ hi-tech vegetable production****1. Cabbage**

Four  $F_1$  hybrids viz. NS183, NS 43, NS 35 and Disha were evaluated initially inside rain shelter. Among them, NS 43 was found ideal for protected cultivation during off-season. Another experiment was laid out to standardize the time of planting for off season cabbage production inside rain shelter. Cabbage hybrid NS43 was planted on six planting dates (May 15<sup>th</sup>, May 30<sup>th</sup>, June 15<sup>th</sup>, June 30<sup>th</sup>, July 15<sup>th</sup>, July 30<sup>th</sup>). May 15<sup>th</sup> planting was found ideal for off-season cultivation of cabbage inside rain shelter, which recorded maximum value for head characters like net head weight (818.75g), head length (13.55cm), head breadth (15.73cm), harvest index (60.79) and also yield/ plot (11.78kg). But when compared to on-season, the net head weight and yield of cabbage were less during off-season. The two reasons attributed to this are loose head formation and incidence of internal tip burn which is a calcium related physiological disorder. Hence another experiment was laid out to evaluate more cabbage genotypes for head compactness and internal tip burn resistance

under rain shelter. Seven cabbage hybrids (NS43, Green challenger, Super Ball 50, F<sub>1</sub> Border 777, Green Voyager, Mahy 118 and Saint) were evaluated with three different calcium foliar treatments (0%, 0.5%, 1.5%). Among the hybrids Green Voyager produced very compact heads, high head weight (1005.83g), yield/plot (6.40kg) and high benefit -cost ratio (1.52). It was also resistant to internal tip burn and can be recommended for off-season cultivation under rain shelter in the central plains of Kerala.

## **2. Cherry tomato**

Evaluation of ten genotypes inside rainshelter showed that SLC-9(426g/pl.) and was on par with SLC-2.). Comparative study in open field and rainshelter also showed yield was highest inside rain shelter. All the genotypes were susceptible to bacterial wilt

## **V. Maintenance of germplasm of tropical vegetables**

Sixteen genotypes of dolichos bean were evaluated during October –January 2018. Among them yield per plot was maximum for the variety Grace (5.200kg) followed by DL-226 .Maximum pod length was recorded in DL-222 (followed by Hima. Pod girth was maximum for DL-223 followed by DL-50

Among eleven types of winged bean evaluated during October-January 2018 yield per plot was maximum for the genotype, Vellayani followed by PT-50-1-1. Maximum pod length was recorded in PT-50-1 followed by PT-35-1. Maximum girth was recorded in Revathy & PT-35-1 followed by Vellayani. Pod weight was maximum for PT-47-2 followed by PT-35-1 .

Twenty four genotypes of chilli were evaluated during May-December 2017. Among these Ujwala, Anugraha, Vellayani Athulya, Vellayani Samrudhi and white Kanthari were wilt resistant. Vellayani Samrudhi recorded maximum yield/plant (1355g) followed by CA 784 (1275g).

Among the 14 brinjal genotypes evaluated maximum yield /plant was recorded in Green Long (2.44kg) followed by SM 398 (2.3kg). But Green Long was highly susceptible to bacterial wilt. SM 391 recorded maximum fruit weight (190g).

Twenty four accessions of snakegourd were evaluated. TA 65 recorded maximum yield/pit followed by TA 1042 .TA 60-1 recorded maximum fruit length and Covai had small fruits .

Twenty four accessions of Amaranthus were evaluated. Acc.No.94 recorded maximum yield /plot(1.29kg) followed by Acc.No.18 (1.25kg) . Accessions 208,10,75,48 and 56 were late flowering genotypes.

## **II .Projects under State Network Project- DEVELOPMENT OF HYBRID VEGETABLES AND HIGH TECH PRODUCTION TECHNOLOGIES**

### **1. Development of high yielding bhindi hybrids resistant to yellow vein mosaic disease**

Dr. Beena Thomas  
Asst.Professor,

The seeds of bhindi collections viz. Thirumala local, Mallappalli local, Kattakkada local, Holavanalli local and Punjab Phalguni were crossed among themselves and the hybrids will be evaluated in summer season

### **2. Development high yielding F1 hybrids in tomato**

Dr. I Sreelatha Kumari  
Professor and Head, CoA

Based on yield and resistance to bacterial wilt LE3, LE12, LE13, LE16, LE19, LE20 , Manulakshmi, Akshaya, Vellayani Vijai and Anagha were selected for production of hybrids.

## **III. ESTABLISHMENT OF HIGH TECH SEED TESTING LABORATORY FACILITY**

Dr. T. Pradeepkumar  
Professor (Hort.)

### **1. Large scale testing of seeds from other centers of KAU and prescribing quality limits for various classes of seed.**

Seed Quality test of various crops were conducted in the High Tech Seed Testing Lab from February 2015 by the supply of seeds from two different crop production centers such as Central Nursery, Vellanikkara and Instructional Farm, Mannuthy.

During 2017-18 seeds from three different crop production centers such as Central Nursery, Vellanikkara, Instructional Farm, Mannuthy and Department of Vegetable Science, Vellanikkara were tested.

## Results

At present the quality of total twenty eight varieties of fifteen different crops were analysed. The common eleven crops received from three different centres were taken for comparison. Germination percentage, vigour index I and vigour index II of the seed lots supplied from different centers are given in table 1. Seed quality parameters of common varieties produced from different centers are given in table 2. Among the different centers Department of Vegetable Science submitted maximum seed samples for testing. Comparison of the seed quality produced from different centers revealed varying quality of seed lots.

In the case of bitter gourd variety Preethi from three different centres, seeds from instructional farm, vellanikkara exhibited highest germination percentage (90) and vigour index I (2520) and vigour index II (12). The same trend was observed in the case of ash gourd variety KAU local. By comparing brinjal variety 'Haritha', chilli variety 'Ujjwala', OP melon variety 'Mudicode local', cowpea variety 'Anaswara', pumpkin variety 'Ambili', bhindi variety 'Arka Anamika' and tomato variety 'Anagha', seed produced from Central Nursery, exhibited highest germination percentage with more vigour indexes. In the case of amaranthus variety 'CO-1', seeds from Department of Vegetable Science showed highest seed quality parameters.

## 2. Molecular characterization of vegetable varieties released by KAU

DNA isolation, quantification, PCR amplification and SSR assay was standardised for Okra and Brinjal. DNA finger printing profiles were generated for Okra varieties (Aruna, Salkeerthy, Susthira, Anjitha, Manjima, Gourishapattanam Local (P1), P4(NBPGR/TCR-874), AE400, AE401, AE416, Kashi Pragati(VRO6), Arka Anamika, Arka Abhay, Pusa Savani, Kashi Kranthi, VarshaUpahar and *A.moschatus*) and Brinjal varieties (Haritha, Soorya, Swetha, Neelima, SM 116, Ponni, SM 67, Arka kusumkar, *Solanum gilo*, *Solanum indicum*, *Solanum incanum*, *Solanum nigrum*, *Solanum torvum*, Soorya (Variant))

### Finger printing of Okra

In okra among 17 varieties unique bands were observed for AE 416, VRO 6, Pusa Sawani, *A. Moschatus* and Arka Abhay. Maximum number of unique bands was seen for VRO 6. None among the Kerala Agricultural University varieties produced a unique band. NTSYS analysis was also conducted for *Abelmoschus esculentus* genotypes based on SSR markers. Among the KAU varieties, Salkeerthy, Susthira and Varun formed a separate cluster when compared to Manjima and Anjitha.

### Finger printing Brinjal

In Brinjal 14 varieties were analyzed and unique band was observed only in *Solanum torvum*, *Solanum nigrum*, *Solanum indicum*, Haritha and Ponni. Most of the wild species involved in the finger printing profile generated unique banding pattern with SSR primers. Among the varieties released by Kerala Agricultural University only Haritha and Ponni produced unique band. Detailed NTSYS analysis was also conducted for *Solanum melanogena* genotypes based on SSR markers. Improved varieties formed a separate cluster when compared to wild species.



## **Name of Project Coordination Group – (04) Fruits**

**Compiled by:**

**Dr. M.L. Jyothi,, Protect Coordinator**

### **Plan & External Aided Projects**

**Concluded Projects- 6 Nos.**

**Ongoing Projects - 23 Nos.**

### **Post Graduate Projects**

**Concluded Projects- 5 Nos.**

**Ongoing Projects - 16 Nos.**



## Concluded projects

## Banana

## 1. Standardization of organic nutrient schedule in banana (BRS Kannara)

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Performance of Nendran banana to organic nutrient schedule was studied for five seasons. The pooled data for five years are presented below.

## Treatments

T1- FYM 10kg + Neem cake 1.25kg + Vermicompost 5kg + wood ash 1.75kg,

T2 - FYM 10kg + Neem cake 1.25kg + Vermicompost 5kg + wood ash 3.75kg,

T3 - FYM 15kg + Neem cake 1.875kg + Vermicompost 7.5kg + wood ash 625g,

T4 - FYM 15kg + Neem cake 1.875kg + Vermicompost 7.5kg + wood ash 2.625kg,

T5 – N0+K0

T6 – triple green manuring with dhaincha / cowpea,

T7 - AM (25g) + *Azospirillum* (50g) + PSB (50g) + *T. harzianum* (50g)

T8 – T1 + T6

T9 – T1 + T7

T10 – T1 + T6 + T7

T11 – Fertilizer control (300:100:300 g N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/plant)

Table : 1. Vegetative characters of banana cv. Nendran

Treatment	Plant height(cm)	Stem girth (cm)	Suckers/ plant	Phyllochron (days)	LAI	Days to bunching (days)
T1	275.69 <sup>abc</sup>	44.80 <sup>ab</sup>	5.72 <sup>a</sup>	7.95 <sup>c</sup>	2.11 <sup>c</sup>	234.92 <sup>bcd</sup>
T2	267.34 <sup>abc</sup>	43.78 <sup>bc</sup>	5.34 <sup>ab</sup>	8.06 <sup>c</sup>	2.02 <sup>cd</sup>	237.89 <sup>bcd</sup>
T3	262.61 <sup>abc</sup>	42.26 <sup>cd</sup>	5.27 <sup>ab</sup>	9.00 <sup>bc</sup>	1.71 <sup>e</sup>	238.26 <sup>bc</sup>
T4	263.43 <sup>abc</sup>	41.93 <sup>d</sup>	4.86 <sup>b</sup>	8.31 <sup>c</sup>	1.80 <sup>de</sup>	242.47 <sup>b</sup>
T5	211.50 <sup>d</sup>	34.08 <sup>f</sup>	2.79 <sup>d</sup>	10.79 <sup>a</sup>	1.22 <sup>f</sup>	279.43 <sup>a</sup>
T6	240.24 <sup>bcd</sup>	38.30 <sup>e</sup>	4.05 <sup>c</sup>	9.19 <sup>bc</sup>	1.59 <sup>e</sup>	266.74 <sup>a</sup>
T7	240.62 <sup>bcd</sup>	37.16 <sup>e</sup>	3.68 <sup>c</sup>	9.76 <sup>ab</sup>	1.61 <sup>e</sup>	267.90 <sup>a</sup>
T8	283.58 <sup>ab</sup>	44.99 <sup>ab</sup>	5.472 <sup>ab</sup>	8.44 <sup>c</sup>	2.20 <sup>bc</sup>	229.20 <sup>cd</sup>
T9	284.93 <sup>ab</sup>	44.73 <sup>ab</sup>	5.56 <sup>ab</sup>	8.08 <sup>c</sup>	2.43 <sup>ab</sup>	224.92 <sup>d</sup>
T10	233.79 <sup>cd</sup>	45.08 <sup>ab</sup>	5.55 <sup>ab</sup>	8.44 <sup>c</sup>	2.21 <sup>bc</sup>	234.83 <sup>bcd</sup>
T11	295.43 <sup>a</sup>	45.78 <sup>a</sup>	5.50 <sup>ab</sup>	8.28 <sup>c</sup>	2.51 <sup>a</sup>	234.64 <sup>bcd</sup>
SEm <sup>±</sup>	10.89	0.42	0.19	0.31	0.06	9.66
LSD at 5%	46.18	1.75	0.81	1.30	0.27	4.19
CV%	13.90	3.26	13.02	11.66	10.79	13.10

Table : 2. Bunch weight and yield of banana cv. Nendran

Treatment	Bunch weight(kg)	Yield(t/ha)	Days to harvest	Hands / bunch	Fingers / bunch	B : C ratio
T1	7.00 <sup>c</sup>	17.50 <sup>c</sup>	319.81 <sup>b</sup>	4.86 <sup>bc</sup>	45.53 <sup>bc</sup>	1.35
T2	7.45 <sup>c</sup>	18.62 <sup>c</sup>	322.68 <sup>b</sup>	4.90 <sup>bc</sup>	46.20 <sup>bc</sup>	1.45
T3	7.11 <sup>c</sup>	17.77 <sup>c</sup>	322.25 <sup>b</sup>	4.73 <sup>c</sup>	45.57 <sup>bc</sup>	1.32
T4	7.14 <sup>c</sup>	17.86 <sup>c</sup>	325.18 <sup>b</sup>	4.91 <sup>bc</sup>	44.82 <sup>c</sup>	1.24
T5	4.42 <sup>e</sup>	11.05 <sup>e</sup>	357.68 <sup>a</sup>	4.05 <sup>e</sup>	31.90 <sup>e</sup>	0.91
T6	5.20 <sup>d</sup>	13.01 <sup>d</sup>	347.69 <sup>a</sup>	4.62 <sup>cd</sup>	39.75 <sup>d</sup>	1.08
T7	4.78 <sup>de</sup>	11.94 <sup>de</sup>	349.96 <sup>a</sup>	4.34 <sup>de</sup>	38.08 <sup>d</sup>	0.98
T8	8.81 <sup>b</sup>	22.04 <sup>b</sup>	316.43 <sup>b</sup>	5.13 <sup>ab</sup>	48.09 <sup>ab</sup>	1.71
T9	9.24 <sup>ab</sup>	23.12 <sup>ab</sup>	313.94 <sup>b</sup>	5.16 <sup>ab</sup>	49.47 <sup>a</sup>	1.73
T10	9.60 <sup>a</sup>	23.99 <sup>a</sup>	320.12 <sup>b</sup>	5.30 <sup>a</sup>	50.66 <sup>a</sup>	1.78
T11	9.54 <sup>a</sup>	23.86 <sup>a</sup>	317.54 <sup>b</sup>	5.38 <sup>a</sup>	50.86 <sup>a</sup>	2.59
SEm <sup>±</sup>	0.12	0.31	3.28	0.09	0.66	-
LSD at 5%	0.52	1.30	13.89	0.38	2.82	-
CV%	5.59	5.59	3.31	6.10	4.94	-

Table : 3. Fruit characters of banana cv. Nendran

Treatment	Finger weight (g)	Finger length (cm)	Finger girth (cm)	Shelf life (days)	TSS (°Brix)	Pulp: peel ratio
T <sub>1</sub>	155.03 <sup>b</sup>	20.34 <sup>bc</sup>	11.54 <sup>de</sup>	7.30 <sup>cde</sup>	27.63 <sup>bcd</sup>	2.95
T <sub>2</sub>	155.75 <sup>b</sup>	20.07 <sup>c</sup>	11.77 <sup>bcd</sup>	8.13 <sup>ab</sup>	27.05 <sup>d</sup>	3.17
T <sub>3</sub>	149.74 <sup>b</sup>	20.06 <sup>c</sup>	11.51 <sup>de</sup>	6.97 <sup>de</sup>	28.22 <sup>ab</sup>	3.00
T <sub>4</sub>	156.93 <sup>b</sup>	20.46 <sup>bc</sup>	11.69 <sup>cd</sup>	7.28 <sup>cde</sup>	27.04 <sup>d</sup>	3.23
T <sub>5</sub>	122.992 <sup>c</sup>	16.90 <sup>d</sup>	9.69 <sup>f</sup>	7.71 <sup>bcd</sup>	26.67 <sup>d</sup>	2.77
T <sub>6</sub>	132.86 <sup>c</sup>	18.27 <sup>d</sup>	10.44 <sup>ef</sup>	8.27 <sup>ab</sup>	28.13 <sup>abc</sup>	2.96
T <sub>7</sub>	123.81 <sup>c</sup>	17.22 <sup>d</sup>	9.96 <sup>f</sup>	7.31 <sup>cde</sup>	28.27 <sup>ab</sup>	2.92
T <sub>8</sub>	187.28 <sup>a</sup>	21.94 <sup>ab</sup>	12.78 <sup>abc</sup>	7.87 <sup>abc</sup>	28.43 <sup>ab</sup>	3.29
T <sub>9</sub>	187.82 <sup>a</sup>	22.05 <sup>ab</sup>	12.93 <sup>ab</sup>	8.53 <sup>a</sup>	28.92 <sup>a</sup>	3.16
T <sub>10</sub>	188.89 <sup>a</sup>	21.870 <sup>ab</sup>	12.96 <sup>a</sup>	8.22 <sup>ab</sup>	28.93 <sup>a</sup>	3.37
T <sub>11</sub>	187.61 <sup>a</sup>	22.55 <sup>a</sup>	13.42 <sup>a</sup>	6.60 <sup>e</sup>	27.11 <sup>cd</sup>	3.07
SEm±	3.59	0.40	0.28	0.19	0.25	0.06
LSD at 5%	15.21	1.71	1.17	0.81	1.06	NS
CV%	7.48	6.62	7.84	8.31	2.99	6.46

Table 6. Soil microflora at harvest

Treatment	Total Bacteria (10 <sup>5</sup> cfu/g)	Total Fungi (10 <sup>3</sup> cfu/g)	Total Actinomycetes (10 <sup>4</sup> cfu/g)	Total <i>Trichoderma</i> (10 <sup>2</sup> cfu/g)	Total P solubilizers (MPN/g)	<i>Azospirillum</i> (10 <sup>4</sup> cfu/g)	AMF(spore count/ (100g soil)
T1	38	15	40	-	-	-	-
T2	25	8	65	-	-	-	-
T3	41	11	35	-	-	-	-
T4	32	3	62	-	-	-	-
T5	39	15	14	-	-	-	-
T6	38	12	48	-	-	-	-
T7	30	16	56	1	<3.0	0	25
T8	22	8	60	-	-	-	-
T9	50	10	52	1	>1100	1	40
T10	28	6	25	2	>1100	2	42
T11	15	8	32	0	-	0	0
Initial soil Microflora	20	16	20	0	-	0	30

Pest and disease incidence

Table 5. Eumusae leaf spot incidence (at shooting)

Eumusae leaf spot Incidence

Treatments	Infection Index
T1	21.30
T2	23.81
T3	23.36
T4	22.03
T5	22.48
T6	21.18
T7	22.11
T8	21.88
T9	19.56
T10	21.59
T11	22.64
SEm±	0.54
LSD at 5%	NS
CV%	11.57

Table 7. Soil nutrient status (at Harvest)

Parameters	Initial	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
pH	6.1	6.3	6.9	6.5	6.8	5.9	5.2	6.8	6.3	7.4	6.8	6.4
EC (dS/m)	0.2	0.1	0.4	0.2	0.3	0.1	0.1	0.2	0.2	0.3	0.2	0.2
OC (%)	0.9	1.2	1.3	1.2	1.6	0.8	1.3	1.1	1.3	1.2	0.7	1.2
Available P (kg/ha)	79.5	160.2	166.9	150.7	117.7	53.6	115.6	70.3	238.8	87.6	100.4	129.3
Available K (kg/ha)	532.0	784.0	296.8	436.8	375.2	509.6	459.2	442.4	526.4	582.4	470.4	980.0
Available Ca (mg/kg)	769.0	306.0	1164.8	417.3	1289.5	379.3	767.5	446.0	451.0	1235.3	643.5	459.5
Available Mg (mg/kg)	81.8	27.0	139.0	20.8	23.8	81.3	19.8	39.3	102.8	42.3	106.8	140.5
Available S (mg/kg)	7.1	6.0	7.9	7.1	5.5	5.2	12.3	6.5	5.5	8.4	6.0	11.0
Micronutrients												
Copper (mg/kg)	1.74	2.12	1.94	2.38	1.37	2.04	1.34	1.56	2.36	1.98	1.98	1.51
Iron (mg/kg)	33.8	58.6	55.9	49.6	33.4	25.8	46.6	39.8	47.4	48.5	34.7	58.8
Zinc (mg/kg)	9.2	3.8	9.8	9.8	8.8	5.5	5.0	9.6	8.1	9.3	8.5	5.4
Manganese (mg/kg)	102.9	141.6	133.2	80.7	90.5	38.9	121.8	86.6	105.5	87.6	76.3	162.0
Boron (mg/kg)	0.4	0.3	0.4	0.3	0.4	0.2	0.6	0.2	0.3	0.2	0.5	0.6

Table 8. Leaf Nutrient status (at shooting)

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Mn (ppm)	B (ppm)	S (%)
T1	2.09	0.17	1.13	2.45	0.22	13.40	480.60	19.40	860.00	23.59	1.42
T2	1.51	0.13	1.34	1.02	0.22	14.50	402.30	16.10	175.00	24.62	0.98
T3	2.42	0.17	1.27	1.22	0.22	15.80	465.30	18.40	620.00	19.49	1.06
T4	1.23	0.12	1.20	1.34	0.24	12.50	565.80	18.10	385.00	22.56	1.07
T5	2.04	0.18	1.39	1.35	0.20	9.80	494.60	19.60	515.00	25.64	1.02
T6	2.00	0.12	1.10	1.28	0.20	17.80	482.40	19.80	1185.00	25.64	0.91
T7	1.74	0.12	1.13	1.37	0.37	14.10	506.10	24.20	770.00	27.69	1.00
T8	1.75	0.10	0.88	1.44	0.17	15.10	480.50	19.40	470.00	21.54	1.17
T9	2.11	0.14	1.17	1.35	0.25	13.90	464.40	20.60	655.00	21.54	0.95
T10	2.60	0.12	1.17	1.25	0.30	14.80	453.10	16.60	575.00	37.95	1.03
T11	2.84	0.23	1.41	0.98	0.17	17.30	477.10	17.90	270.00	34.87	1.01

In Nendran, the treatments involving application of FYM 10 kg + Neem cake 1.25 kg + vermicompost 5 kg + wood ash 1.75 kg + biofertilizers (AMF 25g/pt + *Azospirillum* 50g/pt + PSB 50g/pt + *T. harzianum* 50g/pt) (T9), along with triple green manuring with daincha/cowpea (T10) had a comparable yield with inorganic control treatment (T11). These treatments were also on par with inorganic control with respect to plant height, stem girth, LAI, hands and fingers per bunch. Treatments T9 and T10 had better soil physico-chemical properties and soil microflora than control. No significant difference was observed among treatments for quality characters (TSS and shelf life) and sigatoka leaf spot incidence. It could be concluded that combination of FYM 10 kg + Neem cake 1.25 kg + vermicompost 5 kg + wood ash 1.75 kg + biofertilizers (AMF 25g/pt + *Azospirillum* 50g/pt + PSB 50g/pt + *T. harzianum* 50g/pt) along with triple green manuring had a comparable bunch weight and yield with that of inorganic control. The same treatment (T10) has been consistently performing over five seasons.

## 2. Yield loss assessment due to BBrMV infection in Banana (BRS Kannara)

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Impact of BBrMV infection in six banana varieties viz., Mysore poovan, Chenkadali, Yangambi KM5, Rasthali and Grandnaine was studied. Of these varieties, Rasthali recorded the maximum reduction in bunch weight (64.8%). Due to BBrMV infection, height, girth and fruit weight was decreased where as peduncle length and TSS was increased in most of the varieties (Table 1, 2 and Fig.1).

Table1. Impact of BBrMV infection on vegetative and yield parameters of banana varieties Mysore Poovan, Chenkadali and Yangambi Km 5

Sl No	Parameters	Mysore Poovan			Chenkadali			Yangambi Km 5		
		H	D	% change	H	D	% change	H	D	% change
1	Height (cm)	301.9	291.7	-3.4	360	355	-1.3	320	260	-18.8
2	Girth (cm)	55.1	54.4	-1.3	72.2	66.5	-7.9	66	43	-34.8
3	Length of peduncle(cm)	35.7	460	+28.9	57.7	61.6	+6.8	30	32	+6.7
4	Bunch weight (kg)	22.8	8.8	-62.3	13.5	6.0	-55.6	12.5	4.5	-64.0
5	Number of hands	18	11.9	-34.1	6.2	4.7	-24.4	9	8	-11.1
6	Number of fingers	180	68.4	-62.0	68.4	59.5	-13.1	134.0	147	+9.7
7	Green fruit weight (g)	65.3	60.8	-6.9	152	18	-88.2	78	14	-82.1
8	Ripe fruit weight (g)	55.3	53.2	-3.9	140	18	-87.1	140	71	-77.0
9	Pulp weight (g)	44.6	43.2	-3.1	110	14.7	-86.7	66	11.3	-82.8
10	T.S.S. (°Brix)	22.6	23.4	+3.5	25	26	+4.0	24.5	22.3	-9

Table2 Impact of BBrMV infection on vegetative and yield parameters of banana varieties Njalipoovan, Rasthali and Grand Naine

Sl No	Parameters	Njalipoovan			Rasthali			Grand Naine		
		H	D	% change	H	D	% change	H	D	% change
1	Height (cm)	265.4	225.0	-15.2	-	-	-	-	-	-
2	Girth (cm)	50.5	43.6	-13.6	-	-	-	-	-	-
3	Length of peduncle(cm)	30.1	37.3	+24.0	32.6	29.8	-8.5	-	-	-
4	Bunch weight (kg)	9.2	4.3	-54.3	11.8	4.2	-64.8	26.3	21.0	-20.2
5	Number of hands	8.5	8.8	+3.4	8.6	6.8	20.6	11.7	10.0	-14.2
6	Number of fingers	113.5	116.8	+2.8	118.0	83.6	-29.2	168	146.3	-12.9
7	Green fruit weight (g)	38.7	33.1	-14.5	87.2	59	-47.8	168	160.0	-4.8
8	Ripe fruit weight (g)	32.1	29.3	-8.8	69.4	45.4	-34.6	150.6	146.1	-3.0
9	Pulp weight (g)	26.4	22.9	-13.4	58.0	41.4	-28.6	101.7	93.7	-7.9
10	T.S.S. (°Brix)	28.9	28.0	-3.0	21.9	25.3	+15.6	20.2	22.3	+15.3

H: Healthy

D: Diseased

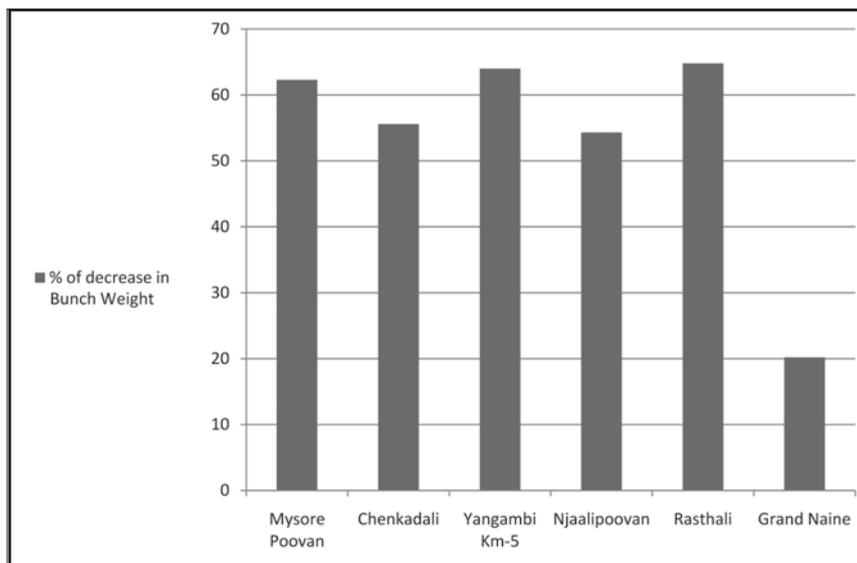


Fig1. Reduction in bunch weight due to BBrMV infection in different varieties of banana

### 3. Management of post harvest disease (BRS Kannara)

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Pre and post application of Carbendazim (0.2%) was effective for enhancing shelf life and managing post harvest diseases. Among the biocontrol agents *Trichoderma viride* was more effective than *Pseudomonas fluorescens* for enhancing shelf life and managing post harvest diseases.

Effect of treatments on shelf life and post harvest diseases of Banana var. Grand Naine

Treatment	Green Life (d)	Yellow life (d)	Shelf life (d)	Disease Score Anthracnose	Disease Score Crown rot
T <sub>1</sub>	3.80	8.20	12.00	1.54	1.32
T <sub>2</sub>	3.00	14.00	17.00	0.32	0.24
T <sub>3</sub>	3.60	15.40	19.00	0.30	0.24
T <sub>4</sub>	3.30	12.90	16.20	0.28	0.50
T <sub>5</sub>	5.00	9.00	13.60	2.48	1.70
T <sub>6</sub>	5.00	3.00	8.00	1.02	0.76
T <sub>7</sub>	5.60	10.40	16.00	0.44	1.04
T <sub>8</sub>	7.00	7.20	14.20	0.84	1.74
CD	0.56	1.02	0.93	0.19	0.23
CV	9.54	7.93	5.00	17.02	19.15

T<sub>1</sub>- Pre harvest spray with carbendazim (0.1 %) T<sub>2</sub>-Post harvest dip with carbendazim (0.1 %) T<sub>3</sub>- T<sub>1</sub> + T<sub>2</sub> T<sub>4</sub>- Pre harvest spray with *Trichoderma viride* (3%) T<sub>5</sub>- Post harvest spray with *T. viride* (3%) T<sub>6</sub>- Pre harvest spray with *Pseudomonas fluorescens* (3%) T<sub>7</sub>- Post harvest spray with *P. fluorescens* (3%) T<sub>8</sub>- Control

#### 4. Management of nematodes in ratoon and high-density planting systems (BRS Kannara)

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Data on the efficacy of various management options against the banana nematodes in high-density planting systems is presented in the table:

T <sub>1</sub>	Cartap Hydrochloride @ 20 g/clump soil application followed by half dose after 3 <sup>rd</sup> month
T <sub>2</sub>	AM @ 200g/clump soil application followed by half dose after 3 <sup>rd</sup> month
T <sub>3</sub>	<i>Pseudomonas fluorescens</i> @ 80 g/clump soil application followed by half dose after 3 <sup>rd</sup> month
T <sub>4</sub>	Growing sunhemp around the basin and incorporating before flowering
T <sub>5</sub>	Growing Coriander as around the basin
T <sub>6</sub>	Growing <i>Tagetes</i> around the basin
T <sub>7</sub>	Neem cake @ 250 g/clump followed by 250g after 3 <sup>rd</sup> month
T <sub>8</sub>	Untreated control

Treatments

Table- 1. Effect of various treatments on vegetative characters in the management of nematodes in high-density planting systems

Treatments	Plant height (cm) (vegetative stage)	Plant height (cm) (at harvest)	Plant girth (cm) (vegetative stage)	Plant girth (cm) (at harvest)	Leaves/ plant (at harvest)
T <sub>1</sub>	213.67 <sup>abcd</sup>	239.33	53.33 <sup>a</sup>	57.33 <sup>a</sup>	11.00
T <sub>2</sub>	210.67 <sup>cd</sup>	233.33	43.00 <sup>cd</sup>	48.33 <sup>ef</sup>	11.67
T <sub>3</sub>	216.33 <sup>abc</sup>	232.67	45.00 <sup>bcd</sup>	51.67 <sup>cd</sup>	12.00
T <sub>4</sub>	216.00 <sup>abcd</sup>	232.00	45.67 <sup>bc</sup>	51.00 <sup>de</sup>	11.00
T <sub>5</sub>	218.00 <sup>ab</sup>	226.67	46.00 <sup>bc</sup>	51.00 <sup>de</sup>	11.00
T <sub>6</sub>	212.33 <sup>bcd</sup>	234.33	49.33 <sup>ab</sup>	54.66 <sup>ab</sup>	12.33
T <sub>7</sub>	219.00 <sup>a</sup>	235.67	47.67 <sup>b</sup>	54.00 <sup>bc</sup>	12.33
T <sub>8</sub>	210.33 <sup>d</sup>	234.67	41.00 <sup>d</sup>	48.00 <sup>f</sup>	11.33
C.V (%)	1.54	3.49	5.36	3.29	15.54
S.E.M	1.16	0.023	4.68	0.60	0.64
L.S.D	5.77	N.S	4.35	2.99	NS

Among the vegetative characters (Table 1), only plant height at vegetative stage and plant girths at the vegetative and harvesting stages were significantly affected by the treatments. At vegetative stage, the tallest plants were recorded in T7 (Neem cake @ 250 g/clump followed by 250g after 3<sup>rd</sup> month) and the shortest in untreated control (T8).

Similarly plant girth at vegetative and harvesting stage was maximum in T1 (Cartap Hydrochloride @ 20 g/clump soil application followed by half dose after 3<sup>rd</sup> month), T6 (Growing *Tagetes* around the basin) and T7 (Neem cake @ 250 g/clump followed by 250g after 3<sup>rd</sup> month), minimum in untreated control (T8).

Table-2. Effect of various treatments on nematode infestation in the management of nematodes in high-density planting systems

Treatments	Soil nematode population (250cc of soil)					
	<i>Meloidogyne</i> initial soil population	<i>Meloidogyne</i> (vegetative stage)	<i>Meloidogyne</i> (at harvest)	<i>Pratylenchus</i> initial soil population	<i>Pratylenchus</i> (vegetative stage)	<i>Pratylenchus</i> at harvest
T <sub>1</sub>	193.33	88.00 <sup>e</sup>	30.67 <sup>e</sup>	150.67	43.67 <sup>g</sup>	39.33 <sup>e</sup>
T <sub>2</sub>	192.00	169.67 <sup>b</sup>	53.33 <sup>cd</sup>	146.67	72.33 <sup>d</sup>	64.33 <sup>c</sup>
T <sub>3</sub>	177.33	158.67 <sup>c</sup>	55.00 <sup>bcd</sup>	137.00	53.67 <sup>f</sup>	48.00 <sup>d</sup>
T <sub>4</sub>	178.33	158.33 <sup>c</sup>	68.00 <sup>b</sup>	131.33	110.33 <sup>c</sup>	112.00 <sup>b</sup>
T <sub>5</sub>	185.00	169.33 <sup>b</sup>	63.00 <sup>bc</sup>	140.00	139.33 <sup>b</sup>	67.33 <sup>c</sup>
T <sub>6</sub>	185.33	109.67 <sup>d</sup>	50.33 <sup>cd</sup>	139.67	72.67 <sup>d</sup>	64.67 <sup>c</sup>
T <sub>7</sub>	185.67	94.67 <sup>e</sup>	41.00 <sup>de</sup>	141.00	60.33 <sup>e</sup>	69.67 <sup>c</sup>
T <sub>8</sub>	175.00	246.33 <sup>a</sup>	245.33 <sup>a</sup>	138.00	153.00 <sup>a</sup>	154.00 <sup>a</sup>
C.V (%)	5.09	3.78	10.65	10.97	3.16	4.56
S.E.M	3.31	2.00	2.85	5.45	0.98	1.25
L.S.D	NS	9.89	14.14	NS	4.87	6.18

The treatments significantly reduced the population of nematodes (*Meloidogyne incognita*, *Pratylenchus sp.*) in soil at the vegetative stage and harvesting stage of the crop growth. Application of chemical pesticide (cartap hydrochloride @ 20 g/clump soil application followed by half dose after 3<sup>rd</sup> month) exhibited the best result in reducing the nematode population (54.48 and 71.01 per cent reduction of *Meloidogyne incognita* and *Pratylenchus thornei* at vegetative stage; 84.13 and 73.90 per cent reduction of *Meloidogyne incognita* and *Pratylenchus thornei* at harvest, respectively over control). Among the bioagents, application of neem cake @ 250 g/clump followed by 250g after 3<sup>rd</sup> month (T7) and growing *Tagetes* around the basin (T6) showed the best result in reducing the population of soil nematodes over control (T8).

#### 5. Biorationals for the management of nematodes of banana (BRS Kannara)

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Data presented in the Table-1 revealed that among the vegetative and yield characters, plant height was significantly higher in T 2 (*Pseudomonas fluorescens* @ 25g/m<sup>2</sup>) and T4 (*Bacillus subtilis* @ 25g/m<sup>2</sup>) at flowering with least in control (T7). Plant girth in all the treatments were significantly higher than in the control plants, but were on par with each. Number of leaves per plants were significantly higher in T6 (cartap hydrochloride @ 10g/m<sup>2</sup>), closely followed by T2 and T3. Lowest number of leaves was recorded in T7 (8.58) untreated plants. Similarly bunch weights showed significant differences with highest values recorded in T6- cartap hydrochloride @ 10g/m<sup>2</sup> (9.62 kg) and T3- *Paecilomyces lilacinus* @25g/m<sup>2</sup> (9.48 kg) with least weight in T7- untreated control (6.71 kg).

Table 1. Effect of Biorationals on the yield and yield attributing characters cv. Nendran

Treatment	Plant height at flowering (cm)	Stem girth at flowering (cm)	Leaves/ plant at flowering	Hands/ bunch	No. of fingers/ Bunch	Bunch weight (kg)
T <i>Trichoderma viride</i> @ 25g/m <sup>2</sup>	295.00 <sup>ab</sup>	41.43 <sup>a</sup>	10.58 <sup>c</sup>	5.61	52.58	7.75
T <sup>1</sup> <i>Pseudomonas fluorescens</i> @ 25g/m <sup>2</sup>	314. <sup>a</sup>	40.96 <sup>a</sup>	11.33 <sup>ab</sup>	5.64	51.58	8.46
T <sup>2</sup> <i>Paecilomyces lilacinus</i> @25g/m <sup>2</sup>	300.83 <sup>ab</sup>	42.66 <sup>a</sup>	11.33 <sup>ab</sup>	5.50	53.42	9.48
T <sup>3</sup> <i>Bacillus subtilis</i> @ 25g/m <sup>2</sup>	311.25 <sup>a</sup>	41.68 <sup>a</sup>	10.42 <sup>c</sup>	5.67	52.08	8.25
T <sup>4</sup> EPN <i>Heterorhabditis bacteriophora</i> @ 1 x 10 <sup>9</sup> IJs/ml	307.08 <sup>ab</sup>	42.37 <sup>a</sup>	10.983 <sup>bc</sup>	5.36	52.75	9.08
T <sup>5</sup> cartap hydrochloride @ 10g/m <sup>2</sup>	308.00 <sup>ab</sup>	40.91 <sup>a</sup>	11.75 <sup>a</sup>	5.42	51.83	9.62
T <sup>6</sup> Untreated control	283.33 <sup>c</sup>	36.32 <sup>b</sup>	8.58 <sup>d</sup>	5.58	52.33	6.71
C <sub>V</sub>	2.58%	4.29%	3.45%	3.29%	1.54%	2.71%
SE m ±	2.96	0.66	0.14	0.07	0.31	0.09
CD at 5 %	13.92	3.13	0.66	NS	NS	0.41

Table 2. Effect of Biorationals on the nematode populations of banana cv. Nendran

Treatment	Nematode population				Root necrosis (%)	
	250 cc soil		10 g roots		Vegetative stage	Shooting stage
	Vegetative stage	Shooting stage	Vegetative stage	Shooting stage		
T <i>Trichoderma viride</i> @ 25g/m <sup>2</sup>	135.00	165.333	24.00	38.67	17.33	21.00
T <sup>1</sup> <i>Pseudomonas fluorescens</i> @ 25g/m <sup>2</sup>	141.00	168.00	31.33	38.67	18.00	21.67
T <sup>2</sup> <i>Paecilomyces lilacinus</i> @ 25g/m <sup>2</sup>	105.67	108.667	21.67	24.33	16.00	14.67
T <sup>3</sup> <i>Bacillus subtilis</i> @ 25g/m <sup>2</sup>	165.67	135.33	49.33	44.33	27.00	34.00
T <sup>4</sup> EPN <i>Heterorhabditis bacteriophora</i> @ 1 x 10 <sup>9</sup> IJs/ml	128.67	132.00	23.33	24.67	16.67	20.67
T <sup>5</sup> cartap hydrochloride @ 10g/m <sup>2</sup>	98.67	102.67	16.33	19.67	12.00	12.33
T <sup>6</sup> Untreated control	300.33	315.33	59.00	66.67	57.33	67.00
CV	4.80%	3.27%	12.73%	8.97%	12.29%	9.43%
SE m ±	2.78	1.99	1.55	1.43	1.09	0.97
CDat 5 %	13.12	9.37	7.28	5.86	5.13	4.59

The treatment cartap hydrochloride@ 10g/m<sup>2</sup> (T6) effectively reduced the nematode population in both soil and root when observed in vegetative and shooting stages of the banana cv. Nendran. It could bring 67.15 % and 67.44 % reduction of soil population in vegetative and shooting stages. Similarly 72.32 % and 70.50% reduction of root population in vegetative and shooting stages was also observed. This was followed by *Paecilomyces lilacinus*@25g/m<sup>2</sup> with 64.82% and 65.54% reduction of soil population in vegetative and shooting stages respectively, and 63.28% and 63.50 % reduction of root population in vegetative and shooting stages respectively). With regard to root necrosis, the lowest root necrosis was recorded in T6-cartap hydrochloride @ 10g/m<sup>2</sup> (79.06 % and 81.59% at vegetative and shooting stages respectively) followed by T3- *Paecilomyces lilacinus*@25g/m<sup>2</sup> (72.09 % and 78.12 % at vegetative and shooting stages respectively).

#### 6. Biological control of banana stem weevil, *Odoiporus longicollis* Oliv. (BRS Kannara)

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Bunch weight was significantly influenced by the treatments. Highest bunch weight of 8.4 kg, 7.7 kg and 7.6 kg were recorded in T6 (Insecticide check – chlorpyrifos @ 0.1%), T3 ( EPN formulation of *Heterorhabditis* sp. spray at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) and T4 (Stem trap swabbed with *Beauveria bassiana* @ 20g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) respectively. The lowest bunch weight of 5.81 kg was recorded in control.

The least number of holes was recorded in treated check (T6: Insecticide check –chlorpyrifos application) followed by T3 ( Entomopathogenic nematode formulation of *Heterorhabditis* sp. spray at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) and T4 (Stem trap swabbed with *Beauveria bassiana* @ 20g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting). Similarly when number of weevils, grubs and pupae were considered, significant reduction of infestation was observed in comparison to the control plants.

T5 (Stem trap swabbed with *Heterorhabditis* sp. @ 1x10<sup>9</sup> IJs/ml at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) and T6 (Treated check) significantly reduced the number of weevils whereas, T3 (Entomopathogenic nematode formulation of *Heterorhabditis* sp. spray at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting ) and T6 was most effective against grubs. The treatments had significant influence on pupae, with T4 (Stem trap swabbed with *Beauveria bassiana* @ 20g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) and treated check T6 being the most effective.

T3 ( Entomopathogenic nematode formulation of *Heterorhabditis* sp. spray at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) and T4 (Stem trap swabbed with *Beauveria bassiana* @ 20g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting) were proved to be on par with treated check (T6) in its efficacy in reducing the various stages of the pseudostem borer of banana and its management.

## Ongoing Projects

### BANANA

#### 1. Collection, characterization, conservation, evaluation and utilization of germplasm (BRS Kannara)

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During the period two primary collections from Wayanad district, Kerala were made and its characterization is being done. Thirteen secondary collections were made from NRCB, Trichy. Meanwhile, ten secondary collections made during 2015-16 are established in the field and being characterized.

No. of primary collections made during 2017-18	No. of secondary collections made	Total number of collections available under conservation
Two	Total 13(NRCB,Trichy)	Total 235 AA-32 AAA- 29 AAAA-1 ABBB - 11 BRS Hybrids- 6 Exotic hybrids-15 AAB - 73 AB - 14 BB- 7 ABB - 45 (Genome of 2 primary collections to be ascertained)

#### Particulars of characterization

Characterized Attikol (BB), SimiliRadjah, Dole TjauLagada	Attikol (BB) is resistant to Eumusae leaf spot (PDI - 9.7)
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#### Particulars of conservation

Numbers newly conserved during reporting period	Numbers conserved till end of reporting period	Details conserved
Total 15 (2 primary and 13 secondary collections during 2016-17)AA-1ABBB- 11BB-1	Total collection available under conservation 235AA-32 ,AAA- 29, AAAA-1ABBB - 11, BRS Hybrids- 6 Exotic hybrids-15AAB - 73, AB - 14 BB- 7 ABB - 45	Field Gene Bank

#### Particulars of Evaluation

Numbers evaluated during reporting period	Total numbers evaluated till end of reporting period	Significant finding from evaluation
Fougamu ABB Cachaco ABB Pelipita ABB Torres Strait Island ABB Pisanglajee AA PisangMulik AA PisangKeling AAA Chinese Cavendish AAA Figue PommeGeante AAB SimiliRadjah Dole TjauLagada	Present status based on morphological characterization- 213AA- 28, AAA- 27 AAAA- 1BRS Hybrids- 6Exotic hybrids- 15 AAB - 71, AB -14BB - 6, ABB - 45	Fougamu (ABB) and Cachaco (ABB) were suited as cooking cultivars. Pisanglajee (AA) was resistant, while Fougamu (ABB), Pisang Keling (AAA), Pisang Mulik (AA) were moderately resistant to Eumusae leaf spot.Torres Strait Island (ABB), Pelipita (ABB), Figue Pomme Geante (AAB) and Chinese Cavendish (AAA) were susceptible to eumusae leaf spot.

Particulars of utilization

Accessions suitable for pseudostem sweetened juice: Palayankodan (AAB), Nendran (AAB), Popoulu (AAB), Grand Naine (AAA), Kadali (AA), Kunnan (AB).

Accessions suitable for pseudostem and rhizome pickle : Palayankodan (AAB), Popoulu (AAB), KlulaiNamwaKhom (ABB), Poovan (Rasthali, AAB).

Male flower of Yangambi km5 (AAA) and SH-3640 are ideal for pickling and as vegetable.

Accessions suitable for fibre extraction : Palayankodan (AAB), Nendran (AAB), Grand Naine (AAA), Kunnan (AB).

Accessions suitable for preparing banana flour : Popoulu (AAB), Nendran (AAB), Kunnan (AB), KudapanillaKunnan (AAB), Rasthali (AAB).

Popoulu (AAB), Nendran (AAB) and Kunnan (AB) flour ideal for making cakes and cookies.

Popoulu (AAB) fruits ideal for making flavored chips.

For Breeding/hybridization work : Matti, Cultivar Rose, Pisang Lilin

Particulars of deposition

Accessions deposited to NAGS during the period – 7 at NRCB, Trichy

Reaction of new accessions towards banana pseudostem weevil

Moderately susceptible	Susceptible	Moderately Resistant
Kasaska (AA)	Pisang Madu (AA)	Leite (AAA)
Uzhakan (AAB)		
Akpakpak (AAB)		

Classification of germplasm accessions to Eumusae leaf spot disease based on four years of screening

Resistant

AA: Calcutta 4, H4, Pisang liliin, Sannachenkadali, Tongat,

AAB : Kalibow

ABB: PeyKunnan, Udayam

Hybrid: FHIA-18 [AAAB], FHIA-3 [ABBB], SH 3640 [AAAB], TMB 3 X 15108-6, TM-5295-1 [AAAB]

Moderately Resistant

AA : BRS I, BRS II, Paka, PisangJaribuaya, PisangMadu

AB : Agniswar, Kalyan Bale, Kunnan, NattuPoovan, Njalipoovan, Poomkalli, Rasakadali

Rasagalli, ValiyaKunnan

AAB : ManjeriNendran, PisangKeling, PisangNangka, Popoulu, Vannan

ABB : Fougamu, VellaPalayankodan

AAA : Manoranjitham, PisangMulik

Hybrid : FHIA-23 (AAAA), FHIA-3436 -9 (AAAA), FHIA-01 [AAAB], FHIA 17 [AAA]

Nendran Hybrid

Susceptible

AA : Sikuzani, Matti, Namrai, Calcutta 4, H4, PisangLilin, Sannachenkadali, Nanipoovan

Pacha Bale

AAB : Figue PommeGeante, Krishna Vazha, Ladies Finger, Navral, PisangRadjah, Velipadathi, Chakkarakeli, Mysore Ethan, PisangCeylan

ABB : Blue Java, Pelipita

AAA : Chinese Cavendish, High Gate, Lacatan, Monsmarie, Pachakappa, Robusta

Highly Susceptible

AA : Anaikompan, Erachivazha, Leite

AAA : Grand Naine, Gros Michel, SapumalAnamalu, Wather

## 2. Evaluation of new introductions of banana (MLT – 2) - Selection Popoulu vs. Manjeri Nendran and Nendran (BRS Kannara)

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Bunch weight was significantly higher in Popoulu (15.91 kg/ plant), followed by Manjeri Nendran (13.35 kg/ plant) and Nendran (10.69 kg/ plant). This can be attributed to higher hands per bunch (6.78) and finger weight (217.72 g) in Popoulu than Manjeri Nendran (5.66 and 184.19g respectively) and Nendran (5.65 and 174.35 g respectively). Finger girth (17.70 cm) and pulp weight (156.61 g) was also significantly higher in Popoulu than the local checks. TSS and Shelf life after ripening was on par among the three varieties. Popoulu also had the maximum B:C ratio of 2.65. Days to bunching in Popoulu (241.25 days) was on par with Nendran (235.14 days) but early than Manjeri Nendran (280.98 days) by almost 40 days. Earliness in bunching has resulted in early harvest as well. Popoulu came to harvest 58 days early than Manjeri Nendran. Days to harvest (bunching to harvest) was significantly shorter in Popoulu. While Manjeri Nendran and Nendran recorded 89.55 and 85.84 days respectively from bunching to harvest, Popoulu took only 64.40 days for the same. Pseudostem girth in Popoulu was significantly higher than Manjeri Nendran and Nendran. It is much more rigid than the local Nendran checks and hence propping, which is a high investment cultural practice followed in Nendran could be avoided for growing Popoulu.

### NRCB Selection 10 vs. Karpooravalli

NRCB Selection 10 registered a significantly higher bunch weight (17.82 kg/ plant) than local check Karpooravalli (14.10 kg/plant) giving an additional yield of 26%. Finger weight (119.06g), finger girth (13.28 cm) as well as pulp weight (81.75g) was also higher in NRCB Selection 10 than local check (84.22g, 11.38 cm and 55.50g respectively). Days to bunching was early in NRCB Selection 10 by 32 days than local check. Similarly, earliness in harvest by 27 days was observed in NRCB Selection 10 compared to Karpooravalli. NRCB Selection 10 had a plant height of 249.57 cm which is shorter by 115 cm than local check Karpooravalli (364.63 cm). Hence this variety could be recommended for wind prone areas. Leaves per plant (13.78) and leaf area in NRCB Sel. 10 (17.31 m<sup>2</sup>) is significantly higher than Karpooravalli (12.01 and 14.09 m<sup>2</sup> respectively). TSS and Shelf life after ripening is on par among the two varieties.

## 3. Assessment of phenology, productivity and incidence of insect pests and diseases in banana grown under varying climatic conditions (BRS Kannara)

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Year 2017-18 received a normal rainfall, but concentrating towards the fag end of the South-West monsoon. A normal crop growth in terms of bunching and duration was observed. Increase in intensity of diseases was noticed for Eumusae leaf spot, *Fusarium* wilt, rhizome rot and viral diseases like Banana Bract Mosaic and Infectious chlorosis compared to 2016-17. Among the insect pests attacking banana, the incidence of banana skipper butterfly decreased, while that of pseudostem weevil, lace wing bug, slug caterpillars (*Miresadecendens*), aphids and mites increased during the year. Increase in incidence of rhizome rot and *Fusarium* wilt observed can be attributed to the higher intensity of rainfall received this year during the fag end of the bunch maturing phase (August-September 2017).

## 4. Enhancing input use efficiency in banana (BRS Kannara)

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The treatment (T2) drip irrigation + fertigation + micronutrient foliar spray (Banana Shakti 2%) + SOP bunch spray (2%) recorded the maximum bunch weight (26.85 kg/plant) and yield (80.55 t/ha), with a B:C ratio of 3.08. The same treatment also had the maximum fingers/ bunch (151.99), finger weight (163.95g) and finger girth (13.23cm). This gives an additional yield of 38.4 % as well as additional net profit worth Rs. 2.65 lakhs/ha respectively from T2 compared to control (19.4 kg bunch weight/plant and yield 58.2 t/ha).

Drip irrigation + Fertigation + Micronutrient foliar spray (2%) + SOP bunch spray (2%) + Polyethylene mulching (T1) was the earliest in bunching (183.48 days), days to harvest (86.14 days) and crop duration (269.39 days), which was on par with T2. The earliness in the best treatment was by 29 days compared to control which had a crop duration of 298.84 days. With respect to fruit quality characters, drip irrigation + fertigation + micronutrient foliar spray (Banana Shakti 2%)

+ SOP bunch spray (2%) (T2) had significantly higher TSS (22.53 °B) and shelf life (6.38 days) compared to control. The treatments T1 and T3 were on par with T2 for TSS and shelf life.

The treatment (T2) drip irrigation + fertigation + micronutrient foliar spray (Banana Shakti 2%) + SOP bunch spray (2%) was found to be the best treatment with respect to bunch weight, yield and B:Cratio.

#### 5. Assessment of post-harvest loss in banana (BRS Kannara)

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Post-harvest loss at farm level, during transportation, wholesale market, retail market, storage/ripening was assessed drawing a fixed quantity of produce at random. The stage of the crop at harvest was 90% maturity of the crop.

At farmer's field:

Due to pseudostem weevil attack, the peduncle breaks close to the bunch before complete maturation. This leads to poor bunch weight and quality, fetching lower price and rejections in the market.

Bunch covering not strictly followed. Bird damage is very common.

Improper nutrient management leading to fruit splitting.

The last immature/ under developed hands, bird attacked and split fruits are rejected at farmer's field.

Harvested in mature green stage.

Improper handling of bunches - Harvested fruits are placed on ground. Carried manually and assembled at farm road for lifting. This creates bruises and injuries on fruits.

Cleaning, grading and sorting not followed.

Dehanding is not followed and handled as bunches as a whole only.

Delay in sale by one day at low harvest create bunch weight loss by 1 kg.

Transportation from farmer's field to market

Transported mostly to local whole sale and retail markets, VFPCK auction centres.

Transported mostly in goods auto, trucks loaded manually by dumping. One layer banana leaves placed at bottom and sides of the vehicle to minimize damage. Bunches are stacked usually in 4-5 layers.

Fruits get detached easily from the bunches during transport. In whole sale and retail markets, loose fruits which are sound and good are sold separately at a lower price. They are also sought after for chips making.

Manually transported by hanging the bunches on both side of the polls and carrying in shoulders at the centre of polls.

Whole sale market

Loading and unloading by dumping causing bruises and injuries.

Bird attacked, split fruits, last under developed hands and damaged ones during transport are rejected.

Means of transport from whole sale to retail are usually goods auto or lorry. Banana leaves are used to line the bottom and sides of the vehicle to minimize damage. Bunches are stacked in layers.

Retail market

Bunches arrive from whole sale markets as well as from local farmers.

Split fruits, damaged and bird attacked fruits are rejected.

Transportation from whole sale markets done in goods auto. Banana bunches are transported along with vegetables and other commodities purchased from whole sale market. Hence use of cushioning material for transportation is not much practiced

Loading and unloading by dumping.

Fruits with blemishes remain unsold. Over ripening and decay are also reasons for unsold fruits.

Storage and ripening

Use of Ripening chambers for cold storage and controlled ripening of banana is very limited. Owing to the high power consumption, these ripening chambers are not being used for storage of banana under controlled atmosphere. They are currently used for ripening only. All banana varieties are stacked separately within the same chamber as whole bunches and ripened using ethylene. Since bulk of banana is being marketed in the state as whole bunches, dehanding and ripening in baskets is not done.

Smoking chambers are used commonly for storage and ripening in retail and large whole sale markets on a limited scale. Smoking done by burning paddy straw or coconut husk kept in pot or using agarbathi. Exposure to smoke done for 24hrs for ripening (color breaking) the next day. Rats cause damage to both green and ripe fruits inside smoking chamber, which are rejected after ripening. All banana varieties are stacked as whole bunches in smoking chamber and ripened.

Post harvest loss in Nendran banana from farmer's field – whole sale – retail markets comes to an average of 19.61 % in Thrissur district and 25.37 % in Palakkad, including the stage of storage and ripening.

## 6. Survey on emerging insect pests of banana (BRS Kannara)

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### Fixed plot survey

In the reporting period, incidence of pseudostem borer and rhizome weevil (major pests) along with leaf eating caterpillars viz., *Spodoptera litura* and *Pericallia ricini* were regularly present in the fixed plots. Sucking pests viz., mirid bugs, lacewing bugs, whiteflies etc. were seen sporadically with higher number in rainy season. The gregarious infestation of defoliators (*Pericallia ricini* and *Spodoptera litura*) started from pre-monsoon and progressed through post monsoon period. Their maximum infestation was recorded during the months of June, July and August, which received maximum rainfall. Infestation by pseudo stem borer (PSB) was observed intermittently and their number rose with the age of the plants (ascertained from stem traps). Incidence of Banana skipper butterfly (*Erionota torus*) was observed from pre-monsoon through post monsoon during 2017. Peak leaf roll formation was seen in the months of June to August coinciding with monsoon in Kerala, later subsiding during dry periods.

### Roving surveys

Nineteen different insect pests were observed infesting banana in Kerala during the survey period. During the survey, location specific difference in pest attack and intensity in attack was observed.

Major pests of banana viz., pseudostem and rhizome weevils were observed to infest banana in all the surveyed areas with severe incidences recorded from Thrissur, Malappuram, Ernakulam and Kozhikode districts in cv. Nendran.

Slug caterpillar (*Miresa descendens*) infestations were observed at Thrissur, Wayanad, Idukki, Alappuzha and Kottayam districts on cv. Nendran and Njalipoovan. Severe attacks were seen in Nendran plots in Kottayam district, sometimes causing 10-20% yield decline. Intermittent rain and sunny days with night temperatures of less than 24° C is favouring their incidences. As reported in previous year, cv. Popoulu recorded very high susceptibility to fruit fly attack, when bunches started ripening in Thrissur, Palakkad and Kollam districts. Heavy incidences of hairy caterpillars (*Pericallia ricini*) were seen in surveyed areas especially from Thrissur, Ernakulam and Kozhikode districts, leading to defoliation. Similarly incidences of Skipper butterfly infestation were seen in parts of Idukki, Wayanadu, Kannur and Kasargod districts with more infestation in Nendran varieties.

Infestation of mealy bug (*Ferrisia virgata*) and white flies (*Dialeurodicus disperses*) were seen in Idukki, Wayanad, Kannur, Kozhikode and Kasargod districts. Infestations of root mealy bug (*Geococcus sp.*) were observed only at Malappuram and Kannur districts in cv. Nendran. During the rainy months of June and July, 2017 high population build up of banana spittle bugs (*Phymatostetha deschampis*) was recorded sporadically from most of the surveyed areas especially Malappuram, Pathanamthitta, Idukki, Ernakulam and Thrissur districts with high incidences in July- September, 2017. Severe incidences of root mealy bug, *Dysmicoccus sp.* were recorded at plots of Wayanad, Thrissur and Ernakulam districts.

There were heavy infestations of Banana Leaf Thrips (*Helionothrips kadaliphilus*) and Lace wing bugs (*Stephanitis typicus*), with clear feeding damage symptoms associated with these pests in the surveyed areas of Malappuram, Thrissur, Palakkad, Alappuzha, Kozhikode districts. There were scattered incidences of Rugose Spiralling Whitefly along with some mirid bugs in banana intercropped with coconut.

Red spider mite infestation was observed from Thrissur, Palakkad, Malappuram, Idukki and Kozhikode districts. The intensity of the attack was high during the reporting period compared to previous year. *Stethorus sp.*, a mite predatory black beetle was collected and recorded from Thrissur district.

**7. Integrated management of banana pseudostem weevil (*Odoiporus longicollis*) (BRS Kannara)**

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Among the treatments, T1 (Swabbing chlorpyrifos 0.05% (2.5ml/litre) at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> months after planting) and T2 (Pseudostem trapping with EPF, *Beauveria bassiana* (1x 10<sup>7</sup> spores/ml) 15 g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> months after planting), recorded the highest bunch weight of 8.928 kg and 8.863 kg respectively, which were significantly higher than control.

There was significant variation with respect to number of holes/ plant, number of weevils and grubs per plant and number of life stages of the pest (weevils, grubs and pupae). Highest significant increase in number of holes/plant was observed in T5-control (17.47), where as the least number was recorded in T1 (5.93)-Swabbing chlorpyrifos 0.05%. The second least formation of symptoms of PSB infestation was recorded in T2-Pseudostem trapping with EPF, *Beauveria bassiana* (9.07).

Number of weevils and pupae per plant was least in T1 (Swabbing chlorpyrifos 0.05%) and T2 (pseudostem trapping with EPF, *Beauveria bassiana*), which were on par. Swabbing chlorpyrifos 0.05% (T1) was found to be the best management for reducing the number of grub stages in the plants.

When number of various live stages of pseudostem weevil/plant was taken (weevils, grubs and pupae altogether), the best treatment was T1 (Swabbing chlorpyrifos 0.05%), which was on par with T2. Maximum infestation (7.46) was in Control (T5).

The above results proved that T1- Swabbing chlorpyrifos 0.05% and T2-Pseudostem trapping with EPF, *Beauveria bassiana* are the suitable management options for the control of pseudostem weevil infestations.

**8. Survey of plant parasitic nematodes associated with banana (BRS Kannara)**

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Survey of nematode pests of banana was conducted across the state of Kerala for *Radopholus similis*, *Pratylenchus* sp., *Helicotylenchus multicinctus*, *Meloidogyne* sp. and *Heterodera oryzicola*. Major banana nematodes viz., *Meloidogyne incognita*, *Radopholus similis*, *Helicotylenchus multicinctus*, *Pratylenchus penetrans*, *Heterodera oryzicola* were recorded at Thiruvananthapuram, Pathanamthitta, Kollam, Palakkad, Thrissur, Ernakulam, Wayanad, Idukki, Alappuzha and Kottayam districts.

Severe incidences of *Meloidogyne spp.* was observed in banana monoculture or in banana plants intercropped with tubers and vegetables in the surveyed areas of Thiruvananthapuram, Kollam, Alappuzha, Wayanad, Idukki, Thrissur, Ernakulam, Kottayam, Kozhikode, Malappuram and Palakkad districts. *M. incognita* was predominant in Dhanuvehapuram, Kattakada and Vellayani (Thiruvananthapuram district) where as *M. javanica* was predominant in Balagram, Pampadumpara and Thovalappady (Idukki district). New record of *M. arenaria* from banana in Chazhoor and Thalikkulam of Thrissur district was made in this survey. The incidences of *Radopholus similis* was mostly low to negligent as compared to previous years. But they were seen more at Wayanad and Idukki districts closely followed by Thrissur and Kottayam districts as isolated cases. Banana spiral nematode, *Helicotylenchus multicinctus* was more at Palakkad district. The incidence of *Pratylenchus coffea* was more at Thrissur, Malappuram, Kozhikode, Ernakulam (Central and North Kerala, Idukki, Kottayam and Wayanad districts (hilly tracts) and also in Alappuzha, a coastal district. A scattered incidence of banana cyst nematode (*Heterodera oryzicola*) was recorded from the soil samples collected from Kollam district. A combined infestation of *Meloidogyne* sp. and *Radopholus similis* was observed in Aryankavu area (Kollam district) where multilayer cropping of Arecanut, black pepper and banana was followed. *Radopholus similis* was observed to heavily infest banana roots along with *Pratylenchus* sp. in Thrissur District.

**9. Management of banana skipper butterfly-*Erionota torus* (BRS Kannara)**

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To study the effect of different treatments on controlling banana skipper butterfly, (*Erionota torus*) formation of the leaf

rolls were recorded as the indicator of damage symptoms. The data recorded 30 days after first round of treatment application showed that there was no significant effect of the treatments on the formation of leaf rolls.

#### 10. Evaluation of bio control agents for the management of banana nematodes (BRS Kannara)

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Maximum plant height of 300.42 cm was recorded in T5 (cartap hydrochloride @ 10g/plant at the time of planting and 3 MAP) closely followed by T4 (*Paecilomyces lilacinus* + *Pseudomonas fluorescense* each @ 12.5g/ plant at the time of planting and 3 MAP) and T1 (*Paecilomyces lilacinus* @25g/plant at the time of planting and 3 MAP) with 297.19 cm. Lowest height was recorded in T6 (control). Maximum plant girth at harvesting stages were recorded in T5 (cartap hydrochloride @ 10g/plant at the time of planting and 3 MAP) and T1 (*Paecilomyces lilacinus* @25g/plant at the time of planting and 3 MAP) whereas the least plant girths were recorded in untreated control (T6).

When yield was considered, highest bunch weight was recorded in T5 (9.13 kg) and T4 (8.22 kg) with least bunch weight of 5.97 kg in T6 (control).

#### 11. Biological management of nematodes in tissue culture banana (BRS Kannara)

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The treatments significantly reduced the population of nematodes (*Meloidogyne incognita*, *Pratylenchus sp.*) in soil at the harvesting stage of the crop in comparison to initial nematode population taken at the time of planting. Application of chemical pesticide (T5- cartap hydrochloride @ 10g/plant at the time of planting and 3 MAP) exhibited the best result in reducing the nematode population (74.87 and 61.30 per cent reduction of *Meloidogyne incognita* and *Pratylenchus thornei* at harvest, respectively over control).

Among the biocontrol agents, application of *Paecilomyces lilacinus* + *Pseudomonas fluorescens* each @ 12.5g/ plant at the time of planting and 3 MAP (T4) and EPN *Heterorhabditis sp.* @  $1 \times 10^9$  IJs/ml at the time of planting and 3 MAP (T3) showed the best result in reducing the population of soil nematodes over control (T<sub>0</sub>). There were 66.02 and 52.09 and 56.97 and 49.74 per cent reduction of *Meloidogyne incognita* and *Pratylenchus thornei* respectively at harvest in comparison to initial nematode population in T4 and T3.

#### 12. Diagnosis of banana viruses in germplasm and planting materials used in experiments (BRS Kannara)

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Out of 220 germplasm accessions, five accessions were infected with BBTv, six accessions were infected with BBrMV and one accession Mottapoovan was infected with BSV. CMV infection was not recorded from any accessions. In TC planting materials of major cultivated varieties, infection of BBTv and BBrMV varied between 0 to 33.3% and that of CMV varied between 0 to 7.6%.

Virus indexing of TC planting materials for BBTv, BBrMV and CMV were carried out for popular banana varieties and the per cent infection was recorded. The maximum infection of BBTv and BBrMV was recorded in Kluwai Namwakhom (33.30 %) and CMV in Njalipoovan (7.60%).

#### 13. Integrated management of Fusarium wilt disease of banana (BRS Kannara)

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Treatments:

- T1 : Disease free suckers from disease free fields + application of Neem cake @ 250g /plant .
- T2 : T1 + dipping in Carbendazim (0.2%) for 45min.
- T3 : T1 + dipping in carbendazim (0.2%) for 30min followed by Carbendazim

drenching 0.2% solution 2<sup>nd</sup>, 4<sup>th</sup> and 6<sup>th</sup> month after planting )and carbendazim

injection @ 3ml of 2% solution (3<sup>rd</sup>, 5<sup>th</sup> and 7<sup>th</sup> month after planting )

T4 :T1+Soil application of *Trichoderma viride* +*Pseudomonas fluorescense*@ 50g/ sucker three times(0,2 and 4 months after planting )

T5: POP Recommendation

T6 :ControlMaximum plant height was observed in T4 (253.5cm) and this was on par with T3 and T2. Maximum plant girth was observed in T4 (28.6cm) and this was on par with T3. The disease index external was significantly low in T3 (43.3) and this was on par with T2. The disease index internal was also significantly low in T3 (32) and this was followed by T2 (40.9). All treatments except T1 was on par in bunch yield and the maximum bunch yield was observed In T2 (9.1kg)

#### 14. Management of sigatoka or prevalent leaf spot disease with oil based formulations (BRS Kannara)

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Professor

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Disease index (PDI) was on par for all treatments except control at 6 MAP and at flowering. The treatment application significantly reduced the disease index /severity by 58.79 to 68.88% over control. Significant difference was also noticed in youngest leaf spotted (YLS) at 6 MAP and at flowering. At 6 MAP, the highest value of YLS was recorded for T5 (mineral oil) (8.60) which was on par with T3 (Chemicals + Mineral oil) and T2 (Propiconazole (0.05%) + Mineral oil(1%)) 3 sprays @25days interval. At flowering, YLS of all treatment were on par except control. There was no significant influence for the treatments with respect to vegetative and yield characters except number of fingers and bunch weigh. Maximum number of fingers was recorded in T2 (62.80) which was on par with T3 and T5. Significant difference was recorded in bunch weight of treatments and control. All the treatments are equally effective in disease management.

#### 15. Survey of fungal, bacterial and viral diseases of banana (BRS Kannara)

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No new diseases were recorded during the period under the report. The incidence of Emmusae leaf spot, Fusarium wilt, Rhizome rot and viral diseases except BBTV was more in the current year compared to last year. This may be due to favourable weather condition (well distributed rainfall, high temperature) varietal susceptibility and ratoon cropping and intensive cultivation. The major diseases of banana observed in the survey were Emmusae leaf spot Fusarium wilt, Rhizome rot, Banana bract mosaic and Bunchy top and Infectious chlorosis .

#### 16. Screening of germplasm (BRS Kannara)

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##### Emmusae Leaf Spot

Of the 140 accessions screened against Emmusae leaf spot, 28 accessions were resistant with PDI zero to ten. 55 accessions were moderately resistant with PDI 10.1-20.0, 42 accessions were susceptible with PDI 21.0-30.0 and 15 accessions were highly susceptible with PDI more than 30.

##### Fusarium wilt

Of the 140 germplasm accessions , natural incidence of Fusarium Wilt was observed in 7 accessions viz., Senna chenkadali, Highgate, Nanipoovan, Rasthali, Poomgali, Kluai Namwakhom and Agniswar.

##### BBTV

Of the 140 germplasm accessions incidence of BBTV was observed in 3 (Anaikompan(AA) , Namrai(AA) and Karim Kadali(AAB)).

##### Rhizome rot

Of the 140 germplasm accessions, incidence of Rhizome rot was observed only in 1 accession (Klauai Namwakhom).

## Mango

### 1. Collection, conservation and evaluation of pickling mangoes (RARS, Pattambi)

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77 accessions of local collections are maintained. 25 accessions produced fruits during this season. Quantitative and quality characters of fruits were recorded. Tender mango and cut mango pickles were prepared. Skin content of ripe fruits varied from 13.39% to 30.4%; pulp content from 41.9% to 71.0%; stone content from 9.39% to 27.47% and juice content of fruit pulp from 22.2% to 76.1%.

## Pineapple

### 1. Breeding for yield and quality of pineapple

Dr. P.P.Joy,  
Professor  
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Fourteen accessions were selected and replanted. Accession 932 recorded the highest fruit weight (3.4kg) followed by 3795 (2.4kg), 4243 (1.98kg) and 800 (1.93kg).

### 2. Organic versus inorganic nutrient management of pineapple varieties for safe and sustainable production

Dr. P.P.Joy,  
Professor  
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Second year results showed that Amritha and Mauritius varieties recorded more or less similar for various phenological events such as flowering, fruit formation and maturity. Maximum yield was obtained for Muaritus receiving integrated treatment (23.93t/ha). All the quality parameters were significantly influenced by the varieties. Mauritius had relatively better fruit colour and taste while MD2 had the best aroma. Mauritius was the overall acceptable pineapple variety.

## Jack fruit

### 1. Collection, characterisation, conservation, evaluation and utilization of jackfruit germplasm (BRS Kannara)

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The survey was conducted at Thrissur, Wayanad, Palakkad (Western Ghats) and Kottayam districts to identify jackfruit types with early bearing characters, extended cropping period, high yield with more number of attractive flakes. The flake characters considered were their weight and colour. The suitability for product preparation was also studied.

Among the 15 accessions identified from different parts of Kerala, seven (KJ – 1/17, KJ – 2/17, KJ – 3/17, KJ – 10/18, KJ – 12/18, KJ – 13/18 and KJ – 15/18) were early bearing types. KJ – 2/17 and KJ – 3/17 are red fleshed types with good colour and are found ideal for table purpose and product preparation (jam, jelly, bar, halwa etc.). KJ – 1/17 and KJ – 12/18 possess extended cropping period with very good yield. These types are ideal for cooking purpose and preparation of chips.

A jack fruit type KJ – 10/18 from Wayanad (Poothady panchayath) recorded maximum fruit weight (32.4 kg) among the collections made during 2018. This was due to more flakes per fruit (983) and more flake weight (7.9 g). Weight of flake without seed (6.2g) was also high in this accession. Maximum fruit length, width, vertical length and central core length was recorded for KJ – 9/17.

The quality analysis of the 10 accessions has shown that accession KJ – 1/17, KJ – 2/17 and KJ – 3/17, KJ – 6/17 and KJ – 9/17 possessed reducing sugar more than 3 per cent. Accession 9/17 possessed highest reducing sugar. Total sugar was also high in these accessions which were more than 9.5 per cent. Highest TSS was recorded by KJ – 9/17 followed by KJ – 10/17. Chips recovery was high for the accessions KJ – 6/17 and KJ – 9/17. These two types scored maximum value for cooking characters. Based on the evaluation of different types accessions KJ – 1/17, KJ – 2/17, KJ – 3/17, KJ – 6/17 and KJ – 9/17 were selected for conservation.

**2. Varietal trial on jackfruit** (BRS Kannara)

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Four new varieties were added : Kokkan Prolific, Swarna, G-IIa, G-65a  
Muttom Varikka and Pechiparai-1 are vigorous growing than other varieties. Number of fruits were high in MuttomVarikka, followed by Pechiparai-1. Vegetative growth was significantly superior in Pechiparai-1 and MuttomVarikka. Fruits per tree during 2017 was maximum for Muttomvarikka (58), followed by Pechiparai 1 (42). Flowering and fruiting is earlier in Pechiparai-1 and MuttomVarikka. Stem bleeding was a problem observed in some of the trees for which control measures were taken. Maximum fruit weight was recorded for Velipara (9.68Kg) and Pechipara (8.26Kg). Fruit weight was very less for Gumless Jack (5.60 Kg). Maximum yield tree was for MuttomVarikka (454.72 kg) followed by Pechipara (386.40 kg). Accordingly the per hectare yield was also high for these varieties.

## MLT II

The maximum height recorded was for G-11a (394.61cm). Girth of stem was maximum for Sindoor (18.72 cm) which was on par with G-11a. Variety Sindoor also had maximum plant spread ( 157.25 EW and 158.12 NS respectively).

**3. Survey and incidence of disease in jackfruit** (BRS, Kannara)

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Leaf spot caused by *Colletotrichum gloeosporioides* was the pre dominant disease of Jack in Kerala. Fruit rot caused by *Rhizopus sp* and *Botrydiploia sp* are responsible for yield loss in Jack.

**4. Survey for new and emerging insect pests of jackfruit** (BRS Kannara)

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## Roving survey

Surveys were done at Thiruvananthapuram, Kollam, Pathanamthitta, Thrissur, Ernakulam, Idukki, Wayanadu, Palakkad, Alappuzha, Kottayam, Kasargod and Kannur districts of Kerala.

*Acalolepta nivosa* White, 1858 (Coleoptera: Cerambycidae) was recorded as a new pest of Jackfruit. *Artocarpus heterophyllus* and *Artocarpus altilis* were recorded as preferred hosts of *Epepeote suncinatus*, along with studies on its life cycle in the hosts.

Lepidopteran and Coleopteran defoliators/stem borers were observed sporadically with severe incidences in jackfruit growing locations. Severe incidence of leaf eating cerambycid beetles (*Olenecamptus bilobus*) was observed during the monsoon period. They feed alone or in groups of 3-4 beetles and severely defoliate the jack plants across the surveyed locations.

*Glenea multiguttata*, a cerambycid beetle was observed to cause damage to Jack leaves by severing the veins leading to drying of leaves and young shoots. This beetle was reported from Thiruvananthapuram, Pathanamthitta, Thrissur, Ernakulam, Idukki, Wayanadu, Palakkad, Kottayam and Alappuzha districts. Incidence of *Oberea artocarpi* was recorded from Central zone (Thrissur and Palakkad districts) mainly from trees less than 5 years old. Jack fruit aphid (*Greenidia artocarpii*) and spittle bug (*Clovia lineaticollis*), which are mild but regular pests appear whenever new shoots are formed and causes crinkling of leaves in young shoots. Defoliation by Katydid and leaf caterpillar was of regular occurrence. Infestation by the tingid bug was wide spread but of mild nature.

Bud weevil (*Ochyromera artocarpi*) heavily feed on young and tender jack fruits. Rodents like 3 banded common squirrel, Malabar giant squirrel, and birds have a special preference for ripening fruits. The combined attacks of these pests cause appreciable yield loss.

## Fixed plot surveys

Gregarious infestation of Leaf beetle (*Olenecamptus bilobus*) coincides with the profuse flushing especially during the

monsoon period. This was closely followed by infestation of Leaf caterpillar (*Margaronia bivitalis*). Isolated incidences of Breadfruit mealy bug (*Icerya aegyptica*) and jack aphid (*Greenidia artocarpii*) were also recorded. Incidence of defoliators like *Oberea artocarp*, *Epepeotes uncinatus* were recorded from October, 2016- September, 2017, with a break in peak summer. Attack of stem borer, *Batocera rufomaculata* was noticed on trees during monsoon and post monsoon period (July-September). Attacks of long horned grasshoppers (katydids) were high. Gregarious chrysomelid beetles of orange colour were found severely attacking the leaves during the months of June and July, 2017. *Acalolepta nivosa* White, 1858 (Coleoptera: Cerambycidae) was recorded as a new pest of Jackfruit. Similarly *Artocarpus heterophyllus* and *Artocarpus altilis* were recorded as preferred hosts of *Epepeotes uncinatus*. *Epepeotes uncinatus* is emerging as a noticeable pest jack fruit in the fixed plot survey, whereas the Long horned beetle complex consisting of *Olenecamptus bilobus*, *Oberea artocarp*, *Epepeotes uncinatus*, *Glenea multiguttata* and stem borer, *Batocera rufomaculata* are causing appreciable loss to jackfruit both as defoliators in the adult stage and trunk borers in the grub stages.

## Concluded PG Projects

### 1. Characterization of Kuttiaattoor mango (*Mangifera indica* L.) cultivar of Kannur district, Kerala

The investigation on 'Characterization of Kuttiaattoor mango (*Mangifera indica* L.) cultivar of Kannur district, Kerala' was undertaken to characterize Kuttiaattoor mango cultivar grown in Kuttiaattoor Panchayath and the nearby Grama Panchayaths viz., Kolachhery, Mayyil, Koodali, Munderi and Malappattam and to characterize the similar mango cultivar of the area. Preliminary survey revealed that Kunjimangalam mango cultivar found in Kunjimangalam Grama Panchayath was a similar cultivar to the Kuttiaattoor cultivar.

Kuttiaattoor cultivar was noted to have an attractive semi-circular crown shape. Generally, all the trees were tall and found to have spreading type of tree growth habit. Tree height ranged from 13.50 m to 16.10 m with an overall mean of 14.82 m. Trunk circumference ranged from 129.00 cm to 164.20 cm with an overall mean of 144.22 cm. The crown diameter ranged from 10.90 m to 15.90 with an overall mean of 13.12 m. The tree characters did not vary significantly in trees across the Panchayaths.

Kuttiaattoor cultivar showed medium intensity of anthocyanin colouration in young leaves. Colour of young leaves were light green with brownish tinge. Mature leaves were dark green in colour without leaf blade twisting. Leaf base was obtuse and leaf tip was acuminate. The petiole attitude in relation to shoot was perpendicular. Leaf characters except petiole length did not show significant variation in tree from Panchayath to Panchayath including Kunjimangalam.

Broad elliptic shape in cross section, green colour of skin, medium colour contrast between lenticels and skin, absence of roughness of surface, medium depth of stalk cavity, rounded outward shape of dorsal shoulder, rounded upward type of ventral shoulder, absence of neck, absence of bulging on ventral shoulder, absence of sinus and absence of bulging of proximal styler scar where the typical qualitative mature fruit characters. The qualitative characters did not vary across the Panchayaths including Kunjimangalam. Fruit length ranged from 8.78 cm to 9.18 cm and the fruit width ranged from 8.11 cm to 8.30 cm. Ratio obtained by dividing the fruit length by fruit width ranged from 1.07 to 1.10 with an overall mean of 1.08. The size of lenticels ranged from 134.78  $\mu$ m to 137.28  $\mu$ m with an overall mean of 136.20  $\mu$ m. Diameter of stalk attachment recorded an overall mean of 4.46 mm. Density of lenticels and diameter of stalk attachment of fruits varied slightly across the Panchayaths.

The other fruit quantitative characters did not vary significantly across the Panchayaths. Yellow-orange colour of skin, medium orange colour of flesh, absence of skin speckling were the characters shown by ripe fruits. The characters viz. adherence of skin to flesh, firmness of flesh, juiciness, texture of flesh, amount of fibre attached to stone and amount of fibre attached to skin were recorded as 'medium' in fruits from all Panchayaths including Kunjimangalam. The thickness of skin ranged from 1.02 mm to 1.09 mm with an overall mean of 1.06 mm.

Relief of stone surface was ridged and the seed shape was reniform. The cultivar was highly polyembryonic. 89.66 per cent of the nuts exhibited polyembryony whereas 10.34 per cent exhibited monoembryony.

Biochemical characterization revealed that TSS ranged from 12.62° Brix to 15.4° Brix with an overall mean of 14.45° Brix. TSS was very similar to that obtained for Muvandan in earlier studies. Titrable acidity ranged from 0.14 percent to 0.21 per cent with an overall mean of 0.18 per cent and carotenoids ranged from 4.48 mg/100g to 7.66 mg/100g with an overall mean of 6.47 mg/100g. Ascorbic acid ranged from 37.65 mg/100g to 50.98 mg/100g and the crude fibre ranged from 2.56 per cent to 5.05 per cent. TSS and crude fibre showed slight variation in mangoes across the Panchayaths.

Cluster analysis grouped 55 trees into two clusters. It was observed that trees from same Panchayath were distributed to both the clusters. Majority of trees from Kunjimangalam were distributed in Cluster I, which had most of the trees of Kuttiattoor, indicating that, the trees identified from Kunjimangalam had close similarity to the trees from Kuttiattoor and nearby Panchayaths.

## 2. Precision farming in banana (*Musa AAB Nendran*) for productivity enhancement

The project was conducted with the objective of assessing the influence of land management practices and lime application on growth and yield of banana, to standardize the fertigation schedule for yield improvement, to work out the economics and to study the nutrient dynamics under soil and fertigation systems of nutrient application

The project was conducted as two different experiments.

a. Soil management and fertigation studies in banana

b. Nutrient dynamic studies in banana

Precision management practice improved growth attributes (LAI and total dry matter production) and yield attributes like number of fingers in D hand and number of fingers per bunch. Quality attributes like TSS and total sugars were also improved by the treatment. Basal application of lime significantly improved the second year yield and pooled yield. It also resulted in higher LAI. Fertigation of 60%RD of N and K significantly improved yield. Pooled yield was higher with fertigation of 100% and 140%RD of N and K (28.68t/ha and 27.63t /ha respectively)

All treatment combinations resulted in improved growth and yield over control. Precision land management and basal application of lime with fertigation of 60, 100 or 140% RD of N and K recorded higher yield. Fertigation treatments and adhoc recommendation resulted in yield improvement by 30.83% and 21.61% respectively.

Application of entire quantity of lime as basal enhanced water use efficiency. Drip irrigation enhanced water use efficiency and water productivity over basin irrigation. Compared to soil application of 100% RD of N and K, fertigation with the same nutrient level resulted in higher nutrient use efficiency and agronomic efficiency.

Precision land management with basal application of lime and fertigation with 60% RD of N and K recorded higher B:C ratio (3.75).

An increasing trend in NO<sub>3</sub> –N content in soil was observed from initial stage to harvest stage of the crop. An increasing trend in OC and p contents was also observed in the soil. In general build up of Ca and Mg in the soil was noticed after two years.

The results of the study revealed that precision land management practice (deep ploughing to a depth of 50 cm, raised beds to a height of 30cm, taking pits and planting) along with basal application of FYM, P (based on soil status) and lime (based on soil pH) and fertigation of 60% RD of N and K is the best management practice to increase the yield and profitability in banana. Fertigation can be given at weekly intervals starting from first month of planting. Soil nutrient dynamics was found to be influenced by rainfall pattern, growth stage of crop and nutrient interactions. Fertigation improved nutrient availability over soil application.

## 3. Performance evaluation of ecotypes of banana (*Musa AAB Plantain subgroup*)

The study revealed that considerable variability existed between different ecotypes of banana. The ecotypes varied significantly with respect to all the clonal characters studied, except the number of ridges. Ecotype Mettupalayam Nendran had high yield but it had long duration. It was followed by Myndoli and Big Ebanga. Perumatti Nendran had the shortest crop duration, followed by Kaliethan. Zanzibar and Big Ebanga were superior in terms of finger characteristics. Based on organoleptic parameters, Changalikodan was found to be the best followed by Big Ebanga. Characters like number of fingers and bunch weight with high heritability coupled with high genetic gain can be used for selection. The genotypes having high yield like Mettupalayam Nendran, Myndoli etc can be used in further crop improvement programmes to develop high yielding nendran varieties.

## Strawberry

### 4. Evaluation of promising strawberry (*Fragaria x ananassa Duch.*) varieties for Wayanad

Performance of five strawberry varieties viz., Crystal, Winter Dawn, Sweet Charlie, Sabrina and Eliyana were evaluated under open and polyhouse conditions at Regional Agricultural Research Station, Ambalavayal, Wayanad. Maximum plant height (32.31 cm), number of leaves (26.20) and plant spread (31.41 cm) were recorded in variety Winter Dawn followed by Sweet Charlie under both growing systems. Number of flowers (16.24) and number of clusters per plant (10.13) was significantly higher in variety Winter Dawn followed by Sweet Charlie. Minimum days to first flowering were observed in

the variety Crystal (45.21). Maximum number of fruits (12.04), yield (139.51 g) and earlier harvest of the fruits (63.40 days) were observed in variety Winter Dawn under both growing systems. Biochemical characters viz., highest TSS (11.54 °B), lowest acidity (0.65 %), TSS/acidity ratio (11.3) and total sugars (6.70 %) and overall sensory score were highest in the variety Sweet Charlie followed by Winter Dawn. However, the variety Winter Dawn had better appearance and flavour. Among five varieties evaluated under two growing systems viz., open condition and polyhouse, Winter Dawn and Sweet Charlie were found to be better in yield and quality. Therefore, these varieties can be recommended for commercial cultivation in agroclimatic conditions of Wayanad, Kerala.

### 5. Nutrient management in Strawberry (*Fragaria x ananassa* Duch.)

Performance of strawberry variety Winter Dawn was evaluated at Regional Agricultural Research Station, Ambalavayal under nine treatments and a control in the open field viz., FYM 10 t ha<sup>-1</sup> + NPK 50:20:50 kg ha<sup>-1</sup> (T1); FYM 10 t ha<sup>-1</sup> + NPK 75:30:75 kg ha<sup>-1</sup> (T2); FYM 10 t ha<sup>-1</sup> + NPK 100:40:100 kg ha<sup>-1</sup> (T3); FYM 20 t ha<sup>-1</sup> + NPK 50:30:100 kg ha<sup>-1</sup> (T4); FYM 20 t ha<sup>-1</sup> + NPK 75:40:50 kg ha<sup>-1</sup> (T5); FYM 20 t ha<sup>-1</sup> + NPK 100:20:75 kg ha<sup>-1</sup> (T6); FYM 30 t ha<sup>-1</sup> + NPK 50:40:75 kg ha<sup>-1</sup> (T7); FYM 30 t ha<sup>-1</sup> + NPK 75:20:100 kg ha<sup>-1</sup> (T8); FYM 30 t ha<sup>-1</sup> + NPK 100:30:50 kg ha<sup>-1</sup> (T9) and an absolute control (T10), without any nutrient application. Among the different nutrient combinations evaluated, T7 (FYM 30 t ha<sup>-1</sup> + NPK 50:40:75 kg ha<sup>-1</sup>) with a BC ratio of 3.06 can be recommended for further optimization and refinement.

### Ongoing PG Projects

#### Ph.D. Projects

*College of Horticulture, Vellanikkara*

1. Evaluation of hybrids and clonal variants in pineapple (*Ananas comosus* L.)
2. Production technology and crop improvement of passion fruit (*Pssiflora edulis* Sims.)
3. Response of banana *Musa* (AAB) 'Nendran' to nutrient sources
4. Production dynamics of strawberry (*Fragaria x ananassa* Duch.) in Kerala

*College of Agriculture, Vellayani*

1. Fertigation studies in papaya
2. Evaluation of propagation techniques and root stock studies of mango (*Mangifera indica*)
3. Ecophysiology and screening for climate change resilience in mango (*Mangifera indica*) genotypes

#### M.Sc. projects

*College of Horticulture, Vellanikkara*

1. Morpho-physiological characterization of avocado (*Persea americana* Mill.)
2. Effect of crop regulation on yield and quality of mango (*Mangifera indica* L.) under high density planting system in Kerala
3. Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha
4. Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.)

*College of Agriculture, Padannakkad*

1. Evaluation of promising accessions of papaya for cultivation in northern zone of Kerala
2. Standardisation of patch budding in jack fruit (*Artocarpus heterophyllus* Lam)
3. In vitro nitrogen sources and acclimatisation studies in TC banana cv. Nendran

*College of Agriculture, Vellayani*

1. Nutrient standardization in Banana (*Musa* AAB. Popoulu)
2. Effect of pre harvest treatment on fruit drop and fruit quality of Rambutan (*Nephelium lappaceum* L.)

**Name of Project Coordination Group– (05)  
Pulses, Oil seeds, Fodder crops &  
Green manure crops**

**Compiled by:**

**Dr. Elizabeth K. Syriac, Project Coordinator**

**Plan & External Aided Projects**

**Concluded Projects - 12 Nos.**

**Ongoing Projects - 8 Nos.**

**Post Graduate Projects**

**Concluded Projects- 5 Nos.**

**Ongoing Projects - 7 Nos.**



## Concluded Projects

### 1. Evaluation of stable and high yielding black gram cultures

In this plan project conducted at CoH, Vellanikkara, the cultures, 4.6.1, 4.5.1, 4.5.6, 4.5.8 and 4.5.18 were evaluated along with Syama and TNAU 1. Flowering duration of the cultures were between 43 to 58 days while the varieties flowered in 40 to 53 days. Plant height of the cultures ranged between 60 to 139 cm while the check varieties were having height ranging from 45 to 59 cm. Yield per plot(20 m<sup>2</sup>) ranged between 0.844 kg to 4.44 kg in cultures while the yield of check varieties ranged between 0.78 kg to 1.02 kg/plot.

### 2. Farm development to strengthen research and production of planting materials in cereals, tuber and fodder crops

The project was intended to strengthen farm infrastructure for the production of planting materials in the department of Agronomy, especially cereal crops, tuber crops and fodder crops. Under this programme, construction of a threshing floor was done and wild boar proof fencing (70.5 m) was undertaken.

### 3. Impact of Magnesium and Boron on nutrient uptake, quality and yield of Hybrid Napier.

Application of 80kg MgSO<sub>4</sub> along with RDF (200:50:50kg NPK and 25t/ha of FYM) to bajra napier hybrid is recommended for higher fodder yield and better quality fodder. The technology resulted in production of upto 2100 q green fodder with higher crude protein content and net returns of upto Rs. 94,000, B:C ratio of 2.35.

### 4. Studies on the effect of additives on silage quality of different grasses

Both BN hybrid and guinea grass were found to be equally suitable and remunerative for silage preparation. Addition of tapioca flour@1% on the fresh weight basis is recommended for quality organic silage preparation from cultivated perennial grasses.

### 5. Initial Varietal Trial in fodder Rice bean

Among seven varieties, IVTRB-3 and IVTRB-6 recorded highest green fodder yield (167q/ha).

### 6. Advanced Varietal Trial in fodder Rice bean

Among five varieties, AVTRB-1 recorded highest green fodder yield of 117 q/ha.

### 7. Initial Varietal Trial in fodder Cowpea

Among 11 varieties, IVTC-6 and IVTC-10 recorded highest green fodder yield of 347 q/ha.

### 8. Advanced Varietal Trial-1 in fodder cowpea

Among six varieties, AVTC-3 recorded highest green fodder yield of 300 q/ha.

### 9. Advanced Varietal Trial-2 in fodder cowpea

Among eight varieties, AVTC-2 and AVTC-4 recorded highest green fodder yield of 150 q/ha.

### 10. Advanced Varietal Trial-2 (seed) in fodder cowpea

Among eight varieties, AVTC-2 recorded highest seed yield of 105 kg/ha.

### 11. Initial Varietal Trial in fodder Oats

Among eleven varieties, IVTO-SC-5 recorded highest green fodder yield of 244 q/ha.

### 12. Advanced Varietal Trial in fodder Oats

Among ten varieties, AVTO-SC-8 recorded highest green fodder yield of 381 q/ha.

## Ongoing Projects

### Pulses and Oil seeds

#### 1. AINP on Arid Legumes (2017-18) - RARS, PATTAMBI

##### Breeding Trials:

##### a) Summer cow pea 2017

Fourteen entries of cow pea were sown on 7.03.2017 in RBD design with three replications with the spacing of 45×10cm. The result showed that the cow pea entry CP-7 (GC 1203) recorded the maximum yield of 2774 kg/ha.

##### b) IVT on Cowpea 2017-18

Fourteen entries of cow pea were sown on 11.01.2018 in RBD design with three replications with the spacing of 45×10cm. The result showed that the cow pea entry CP-9 recorded the maximum yield of 1019 kg/ha.

### c) Summer cow pea 2018

Seventeen entries of cow pea were sown during summer 2018 in RBD design with three replications with the spacing of 45 X 10cm. The result showed that the cow pea entry CST-7 recorded the maximum yield of 792 kg/ha.

### d) IVT on Horse gram 2017-18

Ten entries were sown on 11.01.2018 in RBD design with three replications with the spacing of 45×10cm. The result showed that the entry HG-3 recorded the maximum yield of 1264 kg/ha.

### e) Summer green gram 2017 & 2018

Four varieties of green gram were sown on 24.01.2018 in RBD design with five replications with the spacing of 30 x 15cm. The result showed that the variety LGG 460 recorded the maximum yield of 1571.71 kg/ha. The mean yield data over 2017 and 2018 also showed that the variety LGG 460 recorded maximum yield of 2074.76 kg/ha.

### f) Summer black gram 2016, 2017 & 2018

Six varieties were sown on 24.01.2018 in RBD design with four replications with the spacing of 30 x 15cm. The result showed that the variety Vamban 6 recorded the maximum yield of 1116 kg/ha. The mean yield data over 2016, 2017 and 2018 showed that the Vamban 6 recorded maximum yield of 1283.04 kg/ha.

### g) Breeding programme in cow pea carried out during 2017

Thirty one successful crosses were obtained in the cow pea breeding programme during the year 2017 and the F1 generation seeds were harvested for raising the F2 generation. The details of the successful crosses are given below:

PL-4 X Kanakamony	Kanakamony X PL-1	Kanakamony X RC101	KBC 8 X KBC 9
RC101 X KBC 7	DCS47-1 X PL-4	PL-1 X DC-15	PL-3 X Kanakamony
PL-4 X RC 101	PL-4 X KBC 7	GC-3 X RC 101	PL-1 X PL-5
DC-15 X RC101	PL-3 X KBC 9	Krishnamony X Kanakamony	KBC 8 X PL-4
PL-2 X Kanakamony	Kanakamony X PL-4	DCS 47-1 X RC 101	PL-1 X Kanakamony
PL-4 X PL-3	PL-2 X PL-4	DC-15 X Kanakamony	PL-4 X KBC 9
KBC 9 X PL-4	PL-4 X PL-1	PL-1 X PL-3	RC 101 X PL-1
Kanakamony X PL-3	RC101XKanakamony	PL-2 X RC 101	

### h) Farm trials on cow pea entries PGCP-23, KBC-4 and PTBCP-4

Farm trial on cow pea promising new entries viz., PGCP-23, KBC-4 and PTBCP-4 were laid out in RBD with five replications along with the local check Kanakamony at different locations of Palakkad, Thrissur and Malappuram districts. The trials at various locations were harvested and the results showed that PGCP-23, KBC-4 and PTBCP-4 recorded more yield than the local check Kanakamony.

### i) Farm trial proposal on new cow pea entries KBC-7, KBC-8 and KBC-9

Pooled data over three seasons (2014-IVT, 2015- AVT-1 and 2016-AVT-2) showed that the new cowpea entries viz., KBC-9, KBC-8 and KBC-7 recorded yield of 1361, 1343 and 1230 kg/ha respectively whereas the local check Kanakamony (PTB-1) recorded 808 kg/ha. KBC-9, KBC-8 and KBC-7 are having the yield advantage of 68.35, 66.17 and 52.15 per cent respectively over the local check Kanakamony (PTB-1).

### Plant Protection Trials:

#### a. Farm trial on Management of seed mycoflora of cowpea

Farm trial on management of seed mycoflora of cowpea with the treatments viz., Carbendazim 12% + Mancozeb 63% WP @ 2g/kg of seed (T1), Carbendazim @ 2g/kg of seed (T2), Mancozeb @ 3g/kg of seed (T3) and control (T4) were laid out in RBD with five replications at different locations of Palakkad, Thrissur and Malappuram districts. The trials at various locations were harvested and the results showed that seed treatment with Carbendazim 12% + Mancozeb 63% WP @ 2g/kg of seed (T1) recorded good germination and reduction in dry root rot incidence and significantly more yield over the other treatments.

#### b. Farm trial on Efficacy of different *Rhizobium* cultures on Cowpea

Farm trial on efficacy of different *Rhizobium* cultures on cowpea with the *Rhizobium* cultures viz., RCW 33 b @ 10 g/kg of seed (T1), RCW 33 c @ 10 g/kg of seed (T2), KAU released culture (check) @ 10 g/kg of seed (T3) and control (T4) were laid out in RBD with five replications at different locations of Palakkad, Thrissur and Malappuram districts. The trials at various locations were harvested and the results showed that seed treatment with RCW 33 b @ 10 g/kg of seed (T1) and RCW 33 c @ 10 g/kg of seed (T2) recorded more yield over the other treatments.

**c. Farm trial on Management of cowpea aphid**

Farm trial on management of cowpea aphid with the treatments viz., Dinotefuran @ 0.4g/litre (T1), Ethiprole + Imidacloprid @ 0.3g/litre (T2), Azadirachtin 1000 ppm @ 2.5ml/litre (T3) and control (T4) were laid out in RBD with five replications at different locations of Palakkad, Thrissur and Malappuram districts. The trials at various locations were harvested and the results showed that Dinotefuran @ 0.4g/litre (T1), Ethiprole + Imidacloprid @ 0.3g/litre (T2) and Azadirachtin 1000 ppm @ 2.5ml/litre could manage the aphid effectively.

**Evaluation of native *Rhizobium* cultures on cow pea**

Eight native *Rhizobium* cultures were evaluated along with the *Rhizobium* culture released from COA, Vellayani as check in RBD with three replications during rabi 2017 - The result showed that the *Rhizobium* culture from COA, Vellayani (RH2) recorded the maximum yield of 493.95 kg/ha.

**a. Evaluation IVT cow pea entries for diseases**

Eighteen cow pea entries evaluated for diseases in the CRD with three replications during kharif 2017 showed that three entries viz., CP-1, CP-3 and CP-4 were free from anthracnose disease where as CP-9 recorded resistant reaction.

**b. Evaluation of IVT horse gram entries for diseases**

Thirteen horse gram entries evaluated for diseases in the CRD with three replications during kharif 2017 showed that the entry, HG-14 showed resistant reaction to YMV where as HG-1, HG-8 and HG-11 showed moderately resistant reaction to YMV.

**c. Evaluation IVT cow pea entries for pests**

Eighteen cow pea entries were evaluated for pests in the CRD with three replications during kharif 2017 showed that three entries viz., CP-13, CP-15 and CP-16 recorded nil incidence of aphid and it was followed by CP-9 with the incidence of five numbers of aphid/leaf.

**d. Evaluation of IVT horse gram entries for pests**

Thirteen horse gram entries evaluated for pests in the CRD with three replications during Kharif 2017 showed that the entries viz., HG-1, HG-2, HG-5, HG-10, HG-13 and HG-14 recorded minor incidence of leaf folder and the rest showed nil incidence.

**e. Evaluation of IVT guar entries for pests and diseases**

Fourteen entries of guar evaluated for pests and diseases in the CRD with three replications during kharif 2017 showed that all the entries were free from pests and diseases.

**f. Evaluation of moth bean entries for pests and diseases**

Nine entries of moth bean evaluated for pests and diseases in the CRD with three replications during kharif 2017 showed that all the entries were free from pests and diseases.

**g. Survey of pests and diseases of cow pea**

Survey conducted in frontline demonstration fields of PGCP-23 during rabi 2017-18 (promising cow pea entry) in Palakkad, Malappuram and Thrissur districts showed that there was no incidence of pests and diseases.

**2. Genetic improvement of local sesame variety "Ayali" (*Sesamum indicum*) suite to the drought conditions of Onattukara**

Result of comparative yield trials with ASS-7, ASS-10 and ASS-11 revealed the superiority of ASS-11 in terms of yield. The same was presented in the ZREAC meeting of problem areas conducted at RARS, Kumarakom and the same was approved and ASS-11 was recommended for farm trial. Seeds of ASS-11 was distributed to five farmers in Muthukulam and Bharanikkavu panchayats. The crop is raised in the field along with the check varieties Thilak and local variety and the culture is performing well.

**3. Evolution of high yielding variety of cowpea (*Vigna unguiculata*) with synchronized maturity suited to the summer rice fallows of Onattukara**

Breeder seed production of two released varieties sreya and hridya was undertaken.

Germplasm consisting of 11 accessions were raised in the field during summer season for characterisation and evaluation. Evaluation and selection of the segregants will be carried out during the Rabi season of 2018.

4. Intensive production through Agase based cropping system under protective irrigation
5. Studies on carbon sequestration in perennial grass based cropping system.
6. Studies on performance of Top feeds under varied planting geometry with and without inter crop
7. VTBN-2015 Varietal Trial in Bajra Napier Hybrid (Perennial)
8. VTD-2016-Varietal Trial in Desmanthes (Perennial)

## PG Projects

### Concluded Projects

#### 1. Magnesium nutrition in hybrid napier

The study was conducted at the College of Agriculture, Vellayani, Thiruvananthapuram during the period from May 2016 to April 2017 to assess the influence of magnesium on the growth, yield and quality of hybrid napier. The growing conditions and magnesium application significantly influenced the number of tillers, total green fodder yield and total dry fodder yield. In general, tiller number, green fodder yield and dry fodder yield were significantly higher in open condition compared to coconut garden in all the harvests and the percentage increase in total green fodder yield and total dry fodder yield in open with respect to coconut garden was 44.16 per cent and 47.42 per cent respectively.

Application of  $\text{MgSO}_4$  @  $80 \text{ kg ha}^{-1}$  produced the highest number of tillers, total green fodder yield and total dry fodder yield and the increase in green fodder yield and dry fodder yield was 13.18 per cent 18.74 per cent over control treatment. Among the interactions,  $s_1m_4$  (open condition with  $80 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ) produced the highest tiller number (Table 2), total green fodder yield ( $257.95 \text{ t ha}^{-1}$ ) (Table 4) and dry fodder yield ( $75.29 \text{ t ha}^{-1}$ ). Under coconut garden, application of  $100 \text{ kg MgSO}_4 \text{ ha}^{-1}$  registered the highest tiller number, total green fodder yield ( $152.27 \text{ t ha}^{-1}$ ) and dry fodder yield ( $43.07 \text{ t ha}^{-1}$ ).

Growing co

nditions and magnesium application significantly influenced the quality parameters viz. crude protein content and crude fibre content. The quality attributes of fodder grown in coconut garden were more than that under open; high crude protein content (9.82 %) and lower crude fibre content (36.83%) was observed in coconut garden (Fig 3).

The crude protein content of hybrid napier increased with increase in level of magnesium. The treatment  $M_5$  ( $100 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ) recorded the highest crude protein content (9.33 %) and it was on par with  $M_6$  ( $120 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ) and  $M_4$  ( $80 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ).

The crude fibre content of hybrid napier reduced with increase in level of magnesium and the lowest crude fibre content (35.46%) was obtained in  $M_6$  ( $120 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ) which was on par with  $M_5$  ( $100 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ) and  $M_4$  ( $80 \text{ kg MgSO}_4 \text{ ha}^{-1}$ ).

From the results of the study, it can be concluded that higher yield of hybrid napier is obtained in the open condition with a Mg dose of  $80 \text{ kg MgSO}_4 \text{ ha}^{-1}$  in addition to the POP recommendations of KAU ( $25 \text{ t ha}^{-1}$  FYM and  $200:50:50 \text{ kg ha}^{-1}$  NPK). In coconut garden, the productivity can be enhanced by applying  $100 \text{ kg MgSO}_4 \text{ ha}^{-1}$  along with the POP recommendations of KAU.

#### 2. Induced mutagenesis for delayed flowering and high tillering in guinea grass (*Panicum maximum* Jacq.)

Experiment was conducted to develop high yielding guinea grass types with delayed flowering and high tillering through induced mutagenesis.

Two non flowering types PGG 208 (60 Gy) and MS-4600 (60Gy) were identified which had delayed flowering, more plant height, no of tillers/hill, green fodder yield and dry fodder yield.

#### 3. Tillage and water saving techniques for black gram in rice fallows

The study was conducted during the year 2016-2017 at Agricultural Research Station, Mannuthy. The experiment was aimed to study the effect of reduced tillage practices on growth, yield, uptake of nutrients as well as the economics of production of black gram in rice fallows and to test the feasibility of mulch cum drip irrigation practices under conservation tillage in rice fallows. The results revealed that the mulched plots under conventional tillage had the tallest plants. The conventional tillage with mulching also recorded higher number of branches at different growth phases of black gram and it was on par with the treatment of reduced tillage with mulching. Drip irrigation at 80% EP recorded the highest plant height and number of branches per plant at all stages of growth. The leaf area index of the treatment conventional tillage with mulching was significantly superior to all other tillage treatments. Drip irrigation at 40% EP showed the largest LAI and the life saving irrigation showed the lowest. The conventional tillage with mulching achieved maximum biomass and dry matter production and lowest from reduced tillage without mulching. Tillage or mulching failed to

produce significant effect on early flowering. Maximum number of pods per plant and seeds per pod were produced by the plants in the mulched plots with conventional tillage. Significantly longer pods were observed in plots of reduced tillage with mulching which was on par with conventional tillage with mulching. Plots with drip irrigation at 80% EP recorded maximum number of pods per plant, seeds per pod and pod length. Mulched plots with conventional tillage had the highest yield followed by mulched plots with reduced tillage. Among the drip irrigation levels, highest yield was recorded from plots with drip irrigation at 80% EP. The maximum soil moisture content was recorded under reduced tillage without mulching at 5, 10 and 15 cm depth during the growth phase of the crop. The soil moisture content at 15, 30 and 60 DAS recorded maximum from the treatment drip irrigation at 80% EP and at 45 DAS it was from life saving irrigation. Among the tillage treatments highest water use efficiency was exhibited by conventional tillage with mulching and from drip irrigation levels highest water use efficiency was exhibited by drip irrigation at 80% EP. Reduced tillage without mulching recorded highest water holding capacity. While lowest bulk density was observed in the treatment of conventional tillage without mulch. The available nitrogen, phosphorus, potassium and organic carbon contents of soil was highest from reduced tillage without mulching. The uptake of nitrogen, phosphorus and potassium were comparable from the mulched plots under conventional tillage and reduced tillage. Among the drip irrigation levels, drip irrigation at 80% EP recorded the highest uptake of N, P and K. Though the cost of production was lowest for reduced tillage without mulching, it resulted in significantly lower yields and hence a lower B:C ratio. Conventional tillage with mulching and drip irrigation at 80% EP had the highest net returns resulting in higher B:C ratio.

Conventional tillage with mulching and drip irrigation at 80% EP was found to be better option in terms of yield and net returns in black gram for cultivation in summer rice fallows. The effect of reduced tillage can be considered on a long term perspective in the context of soil health and moisture conservation.

#### **4. Evaluation of cowpea [*Vigna unguiculata* (L.) Walp.] genotypes for yield and resistance to pulse beetle [*Callosobruchus* spp.]**

In no choice confinement test under experiment-I, seeds of all the thirty genotypes of cowpea with three replications were used to evaluate the resistance of these genotypes to pulse beetle. Even though none of the genotypes were completely resistant to pulse beetle attack, there were significant differences among the genotypes in terms of oviposition, percentage seed damage and percentage seed weight loss. The genotype T<sub>2</sub> (Kayamkulam local-1) had the least egg load while, more eggs were laid on seeds of T<sub>29</sub> (Sreya) and T<sub>1</sub> (Ambalappuzha local). The lowest percentage seed damage and percentage seed weight loss were observed for the genotype T<sub>7</sub> (Dhavengarae local) whereas, the highest percentage seed damage and the highest percentage seed weight loss were recorded for T<sub>13</sub> (Hridya) and T<sub>27</sub> (Bijapur local) respectively.

In the experiment-II, seed morphological and biochemical factors associated with resistance to pulse beetle were studied in five relatively resistant genotypes viz., T<sub>4</sub> (Kulashekarapuram local), T<sub>7</sub> (Dhavengarae Local), T<sub>9</sub> (Nenmara local), T<sub>14</sub> (Alathur Local) and T<sub>18</sub> (Clappana local) and five relatively susceptible ones viz., T<sub>11</sub> (Belagum local), T<sub>13</sub> (Hridya), T<sub>15</sub> (Kanakamani), T<sub>27</sub> (Bijapur local) and T<sub>29</sub> (Sreya) which were identified through experiment-I. It was found that the total phenol content was having significant negative correlation with percentage seed weight loss. However, seed coat texture, seed coat colour and protein content in the seeds were found to have no influence on resistance to pulse beetle. The percentage seed weight loss and percentage seed damage were found to be increased with increase in moisture content of the seed, while germination percentage was found to be decreased with increase percentage seed weight loss and percentage seed damage.

An index score was worked out to find out the genotypes with good yield and relative resistance to pulse beetle. It was observed that the genotype T<sub>7</sub> (Dhavengarae local) had the highest index score followed by T<sub>14</sub> (Alathur local), T<sub>18</sub> (Clappana local), T<sub>4</sub> (Kulashekarapuram local) and T<sub>9</sub> (Nenmara local).

The present study revealed that the genotype T<sub>7</sub> (Dhavengarae local) was found to be a good yielder with relative resistance to pulse beetle followed by the genotype T<sub>14</sub> (Alathur local). Hence these genotypes can be recommended for future resistance breeding programmes.

#### **5. Pedigree breeding in early segregating generations of cowpea (*Vigna unguiculata* (L.) walp)**

##### **Experiment 1:**

The experimental material consisted of three parents (Anaswara, PKB 3 and PKB 4) and F<sub>2</sub> population of cross H 10 (Anaswara x PKB 3) and cross H 11 (Anaswara x PKB 4). Two hundred seeds of each F<sub>1</sub> population, along with their parents were sown in the experimental field. The segregating generations showed high mean performance over parents for all the characters studied, except for number of branches per plant and protein content, irrespective of crosses and generations. In general, the segregating populations showed high variance for almost all characters studied. This shows high level of variability in the segregating generation. Comparing, the F<sub>2</sub> and F<sub>3</sub> generation, the variability was high in F<sub>2</sub> generation

and gradually, decreased in  $F_3$  generation. Based on the genetic parameter estimation, a selection criteria had framed to select best lines to forward to  $F_3$ . By this, eight lines from H 10 family and fifteen lines from H 11 family were selected and forwarded to  $F_3$  generation.

#### **Experiment II:**

The experimental material consisted of  $F_3$  population along with its three parents (Anaswara, PKB 3 and PKB 4).

#### **Selection of lines to be advanced to next generation**

1. Pedigree selection from segregating  $F_2$  generation

Based on the genetic parameters estimated, a selection criteria was framed as follows

No. of pods per plant : > 45

Grain yield/ plant : > 145 g

Protein content : > 28 per cent

Totally, 8 lines from H 10 family and 15 lines from H 11 family were selected and forwarded to  $F_3$  generation

2. Pedigree selection from segregating  $F_3$  generation

After evaluation of  $F_3$  progenies, a selection criteria was framed based on their genetic performance as follows

Grain yield/ plant : > 160 g

Protein content : > 25 per cent

#### **Ongoing Projects**

1. Genetic analysis of yield and quality in fodder cowpea (*Vigna unguiculata* L. Walp)
2. Intercropping fodder legumes in palisade grass (*Brachiaria brizantha* (Hochst) Ex. A. Rich) Stapf.)
3. Standardisation of spacing and nutrient levels for fodder rice bean (*Vigna umbellata* (Thunb.)
4. Nutrient optimization for grain cowpea in high phosphorus soils
5. Genotype x Environment interaction in Hedge Lucerne (*Desmanthes virgatus* (L) Wild.) for yield and quality
6. Performance of green gram (*Vigna radiata* (L.) Wilczek) cultivars under different tillage methods
7. Effect of hydrogel and mulching on maize in sandy soil

# **Name of Project Coordination Group – (06) Floriculture**

**Compiled by:  
Dr.U.Sreelatha Protect Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 6 Nos.**

**Ongoing Projects - 2 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 7Nos.**

**Ongoing Projects - 4 Nos.**



## Concluded Projects

### 1. Additional support for landscaping

Dr. Geetha C.K.,  
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Maintained the lawn in the College of Horticulture and in front of the Headquarters by weeding, mowing, rolling, watering, application of fertilizers and plant protection chemicals. The ornamental trees/ shrubs/ palms adjacent to building, entrance, main junction, road sides were maintained by regular pruning, weeding etc. Areas along the central circle near to the Administrative Block and college of Horticulture were maintained. Procured high value ornamental plants for use as indoor plants. Landscaped the Central circle of the main campus with perennial shrubs and maintained it. Interior landscaping were done in the blocks of College of Horticulture. Hedge and edge plants along the road were pruned regularly. Extended the irrigation facilities. Maintained avenue trees by pruning. The lower branches of avenue trees are to be regularly pruned to permit traffic. The over grown branches are also to be pruned to avoid hazard. Purchased consumables like pots, media, PP chemicals, organic and inorganic fertilizers and other aids for the maintenance of plants in the landscape.

### 2. Network project on seed and nursery programme-Planting material production

Dr. Sudhadevi P.K  
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The funds were released in December 2016. This was utilized for the purchase of mother plants and consumables for implementing large scale multiplication of high value ornamental plants by *in vivo* methods. Purchased mother plants of high value ornamentals and foliage plants. Ornamental plants were purchased for large scale multiplication and also for landscaping the premises. Mother plants of perennial and annual flowers were purchased and started multiplication of the same. New varieties of fruit plants like pulasan (*Nephelium mutabile*), rambutan (*Nephelium lappaceum*), sweetlime (*Citrus limetta*), sweet ambazham (*Spondias mombin*), hybrid chamba (*Syzigium jambos*), durian (*Duriozibethinus*) and star fruit (*Averrhoa carambola*) purchased during 2013-14 were established and started flowering and fruiting. Purchased consumables like pots, media, PP chemicals, organic and inorganic fertilizers and other aids for the maintenance and propagation of plants. Maintained and extended the available irrigation facilities.

### 3. Network project on seed and nursery programme- Planting material production

Dr. Sudhadevi P.K  
Professor  
[sudhadevi.pk@kau.in](mailto:sudhadevi.pk@kau.in)

During the period plants of Mosambi layers and Malasianthaichampa (in small poly bags and grow bags). Budding of rambutan was not successful. Purchased consumables like pots, media, PP chemicals, organic and inorganic fertilizers and other aids for the maintenance and propagation of plants. Maintained and extended the available irrigation facilities.

### 4. Strengthening production of quality planting materials and bio inputs in KAU

Dr. Sreelatha. U  
Professor  
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Introduced about 20 new types in ornamentals. Drip & fertigation facility in 800 sq. m area for seed production in seasonal flowers. Produced planting material 2000 No.s and 1 Kg flower seeds.

### 5. Introduction, evaluation and large Scale Production of exotic cut flowers and foliage

Dr. Geetha C.K.,  
Professor  
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Fifty five *Vanda* varieties/hybrids grown in hanging baskets (basket vandas) were evaluated for commercial purposes and

landscape use. V. Pathum Gold, V. Lumpini Red x V. Taweewan and V. Anek Neostylis Lou Sneary, *Rhynchorides* Bangkok Sunset, Vasco Blue Bay Blue, Vasco Blue Bay White, Vasco Blue Bay Pink, Ascda Sirichai Fragrance, *Vascostylis* Crownfox Red Gem, Ascda Peggy Foo x *Rhyn. coelestis* Blue, Ascda. Udomchai, *AeridesquinqueVulnera* Rhy. *Coelestis* were identified as suitable for cut flowers. Among the evaluated types, V. Pachara Delight Pink and V. Prapawan and *Rhynchorides* Bangkok Sunset, *Neostylis* Lou Sneary, Vasco Blue Bay Blue and Vasco Blue Bay Pink are excellent pot plants. V. Pathum Gold, V. Lumpini Red x V. Taweewan, V. Pachara Delight Pink, V. Apec Blue, V. Prapawan, V. Urbchitrx V. Bitz's Heartthrob and V. Thailand Beauty were identified as suitable for cut flower production and as pot plants. Fragrance scoring was also done based on intensity and diffusiveness, newness and beautifulness of fragrance. Fragrance was observed in 24 vandaceous orchids and fragrance were categorized based on different notes such as floral, fruity, spicy, green, sweet and miscellaneous. *Neostylis* Lou Sneary and Vasco Blue Bay White can be recommended for fragrant garden and moon garden.

Developed the protocol for post-harvest handling of Heliconias. Forty one species/varieties of ornamental gingers belonging to six different genera, namely, *Alpinia*, *Costus*, *Etilingera*, *Zingiber*, *Curcuma* and *Tapeinochilos*, were evaluated during the period. Among the evaluated species, *Etilingera* sp., *Costus* sp. and *Zingiber* sp. are tall growing and found suitable as accent plants for background planting, foundation planting, screening for privacy, corner planting and border planting. *Costuscurvibracteatus* and *C. osa* having different coloured foliage, can be planted in attractive combinations. *Curcuma* sp. and *Costus* sp. were suitable for border planting. Inflorescences of *Etilingera* sp., *Zingiber* sp., *Alpinia* purpurata and *Curcuma* sp. were ideal for use as cut flowers in bouquets and flower arrangements. None of the ornamental gingers was suitable for use as loose flowers. Performance of foliage plant species, viz, *Cordyline*, *Aglonema*, and *Philodendron* for use as cut foliage was done. Twenty seven *Philodendron* varieties \ species were evaluated based on qualitative and quantitative characters to assess the suitability for commercial exploitation. Their suitability for outdoor and indoor landscaping and also for use as cut foliage was evaluated. Thirty two species \ varieties of *Aglaonema* were evaluated for commercial exploitation ie for use as cut foliage \ indoor or outdoor landscaping. All most all were attractive. Three types of *Aglaonema* species \ varieties could be noticed based on petiole colour pink, green and white. Based on the qualitative and quantitative characters, the suitability of *Aglaonema* varieties / hybrids in floriculture \ landscaping were also evaluated. Twenty four species/varieties of *Cordyline/Dracaena* were evaluated for their use as cut foliage/fillers. Almost all were attractive and their visual scoring and vase studies were also done. Almost all of the species/varieties were having attractive multi coloured leaves. The visual scoring revealed the superiority of *Dracaenafragrans* 'Massangeana' among them, followed by *Cordylineterminalis* 'Rainbow', *Cordylineterminalis* 'Carnival', and *Cordylineterminalis* 'Surprise'. Maximum vase life was for *Dracaenafragrans* 'Massangeana', followed by *Pleomelereflexa* and *Cordylineterminalis* 'Calcutta' and *Dracaenasanderiana*. All of them are very attractive and could be very well used as fillers in flower arrangements and bouquets. Maintained the post quarantine shed and the existing demonstration units and other green houses in the project for keeping the exotic plants. Exotic varieties of high value ornamentals like orchids (*Vanda*, Fragrant vandaceous orchids, *Kagwara*, *Mokara*, *Aranda*, *Renanthera*, *Oncidium*, *Phalaenopsis*,) and *Gerbera* were evaluated. The vegetative and floral characters of the trigenic orchids viz., *Kagwara* and *Mokara*, bigenic orchids viz *Aranda*, monopodial orchids (*Renanthera*, *Phalaenopsis*) and *Oncidium* were evaluated. Nine *Gerbera* varieties viz, Salvadore, Goliyath, Dana Ellen, Submarine, Jaffana, Balance, Rosalin, Silvester and Intense are evaluated during the period in different containers (mud pot and grow bags) and potting media (sand, soil and cowdung (1:1:1) and cocopeat). The vegetative characters and floral characters of the varieties as influenced by containers and media. On comparing growth and yield character performance of gerbera varieties grown in cocopeat in mud pots was better as compared to ordinary potting mixture. Trainings were conducted to unemployed youth and farmers on production technology of new ornamentals, production technology on loose flowers and production technology of dry flowers

## 6. AICRP on Floriculture (EAP)

Dr. P.K. Sudhadevi (upto 31<sup>st</sup> December, 2017)  
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 Dr. Sreelatha U (from 01/01/2018 continuing)  
 Professor  
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### 6.1 Collection and evaluation of under - exploited ornamentals

Fifteen varieties of heliconia viz; *Heliconia stricta* - Bucky, *Heliconia bihai* - Emerald Forest, *Heliconia bihai* - Kamehameha, *Heliconia bihai* - Island Yellow, *Heliconia psittacorum* - Halloween, *Heliconia psittacorum* - Sassy pink, *Heliconia bihai* X *Heliconia caribaea* - Hot Rio Nights, *Heliconia bihai* X *Heliconia caribaea* - Yamakawa-Chocolate, *Heliconia rostrata*, *Heliconia chartacea* - Sexy Pink, *Heliconia longissima* - Red wings, *Heliconia orthotricha* - Oriole Orange, *Heliconia orthotricha* - Orange Marmalade, *Heliconia orthotricha* - Macas pink, *Heliconia imbricata* x *latispatha* - José

Abalowers were evaluated for growth, flowering and post harvest characters as well as landscape and commercial uses. Variety Red Wings was superior in terms of vegetative characters like plant height, spread, leaf length and breadth. Petiole length was more in varieties Red Wings, Halloween, Island Yellow and less in varieties Sassy Pink and Maccas Pink. Number of suckers per clump was maximum in variety Oriole Orange. Flower behaviour was different (seasonal / free flowering) among the varieties. July – November was observed to be the main flowering season in all the varieties. Free flowering was observed in varieties Orange Marmalade, Bucky, Red Wings and Island Yellow. Pendent type of inflorescence was observed in varieties *Heliconia rostrata*, Red Wings and Sexy Pink. Inflorescence was erect in all other varieties. Among erect type spike length was maximum in varieties, Hot rio nights and Halloween (43.42 cm and 43.12 cm respectively) and minimum in variety Sassy Pink (13.67 cm). Maximum length of flower stalk was observed in variety Sassy Pink (53.67). Among pendent type, highest spike length and length of flower stalk were observed in variety Red Wings (71.97 cm and 38 cm). Maximum number of bracts were observed in variety Red Wings (16). With regard to postharvest characters, fresh weight of the inflorescence was maximum in variety Halloween (137 gm). Vase life was maximum (9 days) in varieties Emerald Forest, Jose Abalo, Kamehameha, Halloween, Island Yellow and Oriole Orange. Based on their performance identified heliconias for various purposes. Flowers of varieties Emerald Forest, Kamehameha, Halloween and Island Yellow can be recommended as cut flower for export. Varieties Bucky, Oriole Orange, Orange Marmalade, Sassy Pink, Hot rio nights and Yamakawa Chocolate have flowers suitable as cut flower for local markets. In landscapes, varieties Oriole Orange, Orange Marmalade and Bucky can be recommended as pot plants, for corner planting etc. and Halloween, Red wings, Hot rio nights, Kamehameha and Emerald Forest for screening purpose in gardens.

### 6.2. Collection and evaluation of fillers

The objective of the study was to evaluate the performance of fillers and to identify those that can be recommended for commercial cultivation in the region. Eleven species of ferns belonging to different genera viz; *Adiantum tenerum*, *Asplenium nidus*, *Asplenium longissimum*, *Asplenium scolopendrium*, *Diaplazium macrostichoides*, *Nephrolepis biserrata* 'Furcans', *Nephrolepis exaltata* 'Chidisi', *Nephrolepis exaltata* Botoniensis Compacta, *Nephrolepis cordifolia*, *Nephrolepis biserrata* - *Miniata* and *Pteris sensiformis* were evaluated for based on their growth pattern and other attributes for various landscape and commercial uses during 2016-17. Vegetative characters like plant height and spread was more in *Asplenium nidus* and maximum number of leaves were observed in *Adiantum tenerum*. Based on growth pattern they were classified into tall, medium and dwarf. All species evaluated were found to be suitable as pot plants. *Nephrolepis biserrata* - *Miniata*, *Nephrolepis biserrata* 'Furcans', *Nephrolepis cordifolia*, *Asplenium nidus* and *Diaplazium macrostichoides* can be recommended as indoor plants. *Nephrolepis biserrata* - *Miniata*, *Nephrolepis biserrata* 'Furcans' and *Nephrolepis cordifolia* can be used as border plants in landscapes. *Nephrolepis exaltata* Botoniensis Compacta, *Asplenium longissimum*, *Pteris sensiformis* were observed to be attractive in hanging baskets. *Nephrolepis biserrata* - *Miniata*, *Nephrolepis exaltata* 'Chidisi', *Nephrolepis exaltata* Botoniensis Compacta and *Diaplazium macrostichoides* are suitable for bouquet and making in flower arrangements.

### 6.3. Effect of organic supplements on growth and flowering of Orchids

The objective of the experiment was to study the influence of different organic manures on growth, flowering and post harvest characters of orchid. Experiment was laid out and treatments were applied. The experiment consisted of seven different treatment combinations of organic manures with three replications in CRD. *Dendrobium* variety Burana Jade was used for the study. There was no significant effect for any of the treatments with respect to vegetative as well as floral characters.

### 6.4. Effect of biofertilizers on growth and flowering of Orchids

The study aimed to evaluate the effect of bio fertilizers on growth and flowering of orchids. The experiment consisted of nine different treatments with three replications in CRD. *Dendrobium* variety Ms. Singapore was used for the study. No significant variation in vegetative parameters could be observed among the treatments. However, a treatment combination of Vermicompost 500 g + Azospirillum 2g/pot + AMF 2g/pot (T<sub>3</sub>) was found to be the best for increasing spike length and number of flowers in the spike.

### 6.5. Effect of micronutrients on growth and flowering of Orchids

The experiment was aimed to study the effect of different micronutrients on growth and flowering of orchids. The experiment consisted of thirteen different treatments of micronutrients in various concentrations *Dendrobium* variety Ms. Singapore was used for the study. There was no significant variation in vegetative as well as floral characters during the period of observation. However fortnightly application of Zn @ 0.05 ppm along with weekly spray of NPK @ 30:10:10 was observed effective for improving quality of spikes when compared to other treatments.

### 6.6. Efficacy of media incorporated with Pusa hydrogel on growth and production of quality foliage plants

The experiment intended to assess the efficacy of Pusa hydrogel incorporated in potting media on the quality and

performance of *Philodendron xanady*, a foliage plant suitable for both as cut foliage and indoors. Physico chemical characters of the media were observed before planting. Four different levels of Pusa hydrogel (10, 20, 30 and 40 g/pot containing 5 Kg media) were applied. Irrigation was given at four and seven days intervals for each level of pusa hydrogel. Plant characters were observed at monthly intervals. From the analysis of vegetative characters, it could be observed that media incorporated with 30 g Pusa Hydrogel per 5 Kg potting media with four days irrigation interval was found to maintain compact growth in *Philodendron xanadu*.

### 6.7. Standardization of glycerinization for increasing shelf life of cut foliages

The experiment aimed to standardize optimum concentration of glycerine solution for increasing shelf life of cut foliage leaves. Leaves of *Cordyline terminalis* was subjected to uptake method with 10%, 20 % and 40 % glycerine solution. Overall acceptance in terms of texture, brittleness, shape, colour retention and glossiness were significantly high in 40 % glycerine solution with a score of 15.90 out of 20.

### 6.8. Effect of holding solutions on keeping quality of orchid stems

The objective of this experiment was to standardize a suitable holding solution for orchids. The experiment consisted of five different treatments viz., Control - Distilled water ( $T_1$ ), Sucrose (4%) + 8HQS (100ppm) + Citric acid (150ppm) ( $T_2$ ), Glucose (4%) + 8HQS (100ppm) + Citric acid (150 ppm) ( $T_3$ ), Lime juice (30ml) + Sugar (10g) + NaOCl (0.2% per litre) ( $T_4$ ), Coconut water (50%) + Sucrose (4%) + NaOCl (0.2%) ( $T_5$ ). The flower spikes of *Dendrobium* variety Sonia with uniform length and floret number at all bud open stage were harvested and placed immediately in water and then pre-cooled at 12°C for 6hrs. The vase life was evaluated in the above mentioned solutions. The treatment  $T_2$  which consisted of Sucrose (4%) + 8HQS (100 ppm) + Citric acid (150ppm) was found to be superior in terms of vase life.

## Ongoing Projects

### 1. Standardization of production package for selected seasonal flowers in Kerala

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Objectives of the study are to evaluate African marigold (Varieties/ F1 hybrids/local collections) for cultivation in Kerala, to select suitable genotypes in African marigold and other *Tagetes* sp. against bacterial wilt. Precision farming techniques in African marigold. Twenty five genotypes of *Tagetes erecta* and 2 other *Tagetes* sp. viz. *T. minuta*, *T. patula* are planted in the bacterial sick plot for evaluation

### 2. Developing a conservation strategy for Indigenous herbs in the hillocks of Kerala by domestication and exploiting their potential ornamental & medicinal value

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Objectives of the study are survey of lateritic hillock flora in Thrissur district, evaluation of ornamental value of selected flora and collection of potential ornamentals, refinement in domestication package for *Exacumbicolor*, initiation of crop improvement in *Exacum bicolor*. Seeds of 14 genotypes sown for evaluation. Started surveys in various parts of Kerala and collected of native ornamentals were started.

## PG Projects

### Concluded

#### 1. Evaluation of African Marigold (*Tagetes erecta* L.) hybrids/varieties for yield and resistance to bacterial wilt

- All genotypes showed considerable variation with respect to yield and resistance to bacterial wilt. The genotype P-4 was found to be promising with high yield, large sized flowers and moderate susceptibility to bacterial wilt.
- The genotype M-1 was 100 per cent resistant to bacterial wilt while the genotype Sakura 031 was found to be 100 per cent susceptible. The genotype M-1 can be used as rootstock for grafting susceptible genotypes. Grafting the susceptible genotypes on resistant rootstock found to be an effective tool to combat the bacterial wilt.
- Grafting significantly increased the yield in susceptible genotypes without affecting the flower quality attributes.

#### 2. Refinement of nutrient management practices in *Dendrobium* orchids

##### *Dendrobium* variety Yellow Splash was used for the study

- Bioinoculants + benzyl adenine (along with POP recommendation) gave best results in both vegetative and floral parameters

- Dominance in vegetative characters observed in *Azospirillum* inoculated plants and AMF followed PGPR Mix – 1 in combination with 100 – 150 ppm BA
- Floral characters – best results from AMF inoculated plants followed by *Azospirillum* and PGPR Mix -1 inoculation along with BA (100 – 150 ppm)
- POP + AMF + 150 ppm BA was found to be the best

### 3. Evaluation of fragrant vandaceous orchids for ornamental traits

- *Vascostylis* Crownfox Red Gem recorded maximum plant height, spread, intermodal length and leaf length. *V. PranermPrai* x *V. tessellata* showed maximum shoot girth, leaf area, leaf number and root length.
- Among floral characters, Number of spikes produced was maximum (11.50) in *Neostylis* Lou Sneary and was significantly superior to all other varieties and was followed by *Ascda* Sirichai Fragrance (6.43) and *Vascostylis* Crownfox Red Gem (4.54).
- *Aerides* *quinqueVulnera* *Rhy. Coelestis* recorded the maximum spike length (33.17 cm) and was significantly superior to all other varieties except *Vascostylis* Crownfox Red Gem (32.73 cm).
- *Aerides* *quinqueVulnera* *Rhy. Coelestis* recorded the maximum (22.23 cm) rachis length followed by *Ascda*. Udomchai (20.43cm), *Vascostylis* Crownfox Red Gem (19.80cm) and *Vasco* Blue Bay Blue (19.33cm).
- Maximum number of florets was noticed in *Vasco* Blue Bay Pink (44.33) followed by *Vasco* Blue Bay White (40.33) and *Vasco* Blue Bay Blue (39.67). Minimum number of florets was recorded in *V. PranermPrai* x *V. tessellata* (4.83).
- Maximum flower size (83.23 cm<sup>2</sup>) was recorded in *V. Rothschildiana* followed by *Ascda*. Suksamran Sunlight Yellow (78.27 cm<sup>2</sup>) and *V. PranermPrai* x *V. tessellata* (72.00 cm<sup>2</sup>). Fragrance was observed in all varieties except *V. Rothschildiana*.
- While considering the blooming periods more number of varieties were flowered during the months of May to July whereas flower production was minimum during February to March.
- Plant quality rated on the basis of fullness, growth and visual appearance, flower colour and pigmentation, spike longevity, shape and arrangement of foliage during the growth period. *Vasco* Blue Bay Pink had highest mean total score (44.8), followed by *Vascostylis* Crownfox Red Gem (44.7), *Vasco* Blue Bay Blue (44.6) and *Rhynchorides* Bangkok Sunset (44.5).
- *Neostylis* Lou Sneary, *Rhynchorides* Bangkok Sunset, *Vasco* Blue Bay Blue, *Vasco* Blue Bay White, *Vasco* Blue Bay Pink, *Ascda* Sirichai Fragrance, *Vascostylis* Crownfox Red Gem, *Ascda* Peggy Foo x *Rhyn. Coelestis* Blue, *Ascda*. Udomchai, *Aerides* *quinqueVulnera* *Rhy. Coelestis* were found to be suitable for cut flower purpose and these can be recommended for cut flower purpose.
- *Neostylis* Lou Sneary and *Vasco* Blue Bay White can be recommended for fragrant garden and moon garden.
- *Rhynchorides* Bangkok Sunset, *Neostylis* Lou Sneary, *Vasco* Blue Bay Blue and *Vasco* Blue Bay Pink are excellent pot plants.
- While taken the overall qualitative and quantitative attributes, *Vascostylis* Crownfox Red Gem, *Vasco* Blue Bay Blue, *Rhynchorides* Bangkok Sunset, *V. Mimi* Palmer, *V. JVB* X *Ascocenda* Yip Sum Wah and *Vasco* Blue Bay Pink were excellent for both cut flower as well as pot plants.
- Fragrance was observed in all varieties except *V. Rothschildiana*. Fragrance were categorized based on different notes such as floral, fruity, spicy, green, sweet and miscellaneous.

### 4. Evaluation of selected underutilized flowers of Kerala for commercial exploitation

- All species evaluated were found not suitable for use as cut flower.
- Four ornamental species viz. *Antigonon leptopus*, *Barleria obtusa*, *Calicopteris floribunda*, *Cassia fistula* and *Clerodendrum paniculatum* were evaluated for suitability as dry flower using five drying methods like shade drying, embedded drying, microwave oven drying, hot air oven drying and press drying. Among the species evaluated *Cassia fistula* (embedded drying-12.84) scored high cumulative score followed by *Antigonon leptopus* (Microwave oven drying-11.64), *Barleria obtusa* (Press drying - 10.28) and *Calicopteris floribunda* (Press drying - 10.22). *Clerodendrum paniculatum* was not found suitable for dry flower.
- Three fragrant ornamental flower species viz. *Gardenia jasminoides*, *Plumeria* spp. and *Quisqualis indica* were evaluated for recovery of concrete which is an indication of essential oil content in flower crops. The experiment was laid out in CRD with five replications. Solvent extraction method using food grade hexane was used for extraction. Among the species evaluated maximum recovery of concrete was observed in *Gardenia jasminoides* which was significantly superior over others.
- Four ornamental flower species viz. *Caesalpinia pulcherrima*, *Cassia fistula*, *Clerodendrum paniculatum* and *Delonix regia* were evaluated for extraction of pigments. The experiment was laid out in CRD with eight treatments and three replications. Method of extraction was solvent extraction for two hours using hexane:acetone in 7:3 ratio with 0.5 % NaOH pretreatment for 48 hours and without pretreatment. Solvent extraction with pre treatment yielded more pigments than solvent extraction without pre treatment. *Clerodendrum paniculatum* yielded maximum pigment yield under both methods. Lowest pigment yield was observed in *Caesalpinia pulcherrima*. Identification of carotenoids

and anthocyanins was done using spectrophotometer. Highest carotenoid yield was observed in *Cassia fistula* (70.04mg/100 g) and highest anthocyanin yield was in *Clerodendron paniculatum* (574.76mg/100g).

- Components of different floral oils & pigments were identified by GC-MS analysis and Spectrophotometry. 12 compounds were identified in *Gardenia jasminoides*, 11 compounds identified in *Plumeria* spp and 6 compounds identified in *Quisqualis indica*.

### **5. Induction of genetic variability in phalaenopsis orchids through hybridization and embryo culture**

Among the morphological characters studied Phalaenopsis parents varied significantly with respect to total number of leaves, leaf area, and shoot height. Statistical analysis showed that varieties varied significantly for floral characters i.e number of days from first flower opening to last flower opening, days for wilting of the first flower, days for wilting of the last flower, flower size, spike length. Flower size was observed to be biggest in Winter Spot and smallest in Elegant Yellow. Flowers of six selected varieties bloomed between the month of March to November. All varieties bloomed once in a year except Winter Spot which came to flowering twice in a year. Dendrogram generated based on phenotypic characters grouped the selected varieties into different clusters between similarity coefficient of 0.10 to 1.00. At 20 per cent similarity coefficient bifurcation occurred which showed that all the varieties were distinctly variable from each other and shared only 20 per cent similarity. Anthesis time of the flowers ranged from 5:00 am to 2:00 pm among the varieties. Elegant Yellow opened earliest of all (5:00 am -8:00 am) whereas Violet was observed to open from 11:00 am - 2:00 pm. Maximum number of days for stigma receptivity was observed in Winter Spot (3-12 days) and Violet had minimum (1-5 days). Palynology results of parents revealed that there were no significant difference between varieties for pollen fertility percentage, length of pollen tube and pollen production per pollinium. Whereas significant difference was observed in pollen germination percentage and pollen diameter. Pollen germination percentage was maximum (100 %) in Elegant Yellow and minimum in Elegant Purple (47.2%). Pollen diameter was maximum in Winter Spot (107.68  $\mu$ ) and minimum in Pink (84.58  $\mu$ ). Out of 13 ISSR primers screened, seven primers gave maximum number of clear and reproducible bands. 100 per cent polymorphism was obtained by UBC 841. Dendrogram generated based on molecular data clustering had similarity coefficient between 0.56-0.78. Three different clusters were observed in which Elegant Purple and Pink were most closely (78 %) related to each other. Inter varietal crosses made in all possible cross combinations between the selected varieties resulted in pod set of six crosses. They were Winter Spot X Elegant Purple, Winter Spot X Pink, Elegant Purple X Pink, Pink X Winter Spot, Pink X Elegant Purple and Violet X Elegant Purple. Pod set percentage ranged between 0 – 66.6 per cent among the varieties. Embryo culture was done with seeds from successful crosses in MS and Knudson-C basal media with and without growth regulators. Seeds from the crosses Winter Spot X Pink, Elegant Purple X Pink and Pink X Elegant Purple germinated maximum (50 %) in half MS medium supplemented with 1 mg l<sup>-1</sup> BA, 0.1 mg l<sup>-1</sup> NAA and 0.5 per cent activated charcoal and in Knudson-C (40 %) basal medium supplemented with BA 3 mg l<sup>-1</sup> and NAA 0.3 mg l<sup>-1</sup>. Germinated seeds developed into protocorms in the crosses between Pink x Elegant Purple and Elegant Purple x Pink. Protocorms when sub cultured to half MS basal medium supplemented with 1 mg l<sup>-1</sup> each of BA and NAA exhibited leaf differentiation from the cross Pink x Elegant Purple. Therefore, plantlets emerging from these crosses have to be further grown for assessing the genetic and phenotypic variability generated.

### **6. Genetic improvement through induced mutation in dahlia (*Dahlia variabilis* Desf.)**

The per cent sprouting and survival at 15 days (%) decreased with increase in dose of gamma rays which was exhibited by all the three varieties in the same fashion. A gradual decrease in plant height was recorded with increase in dose of gamma rays which was evident in data recorded at 30, 60, 90 and 120 days after planting. The range in plant spread among the treatments showed that there was a significant reduction in plant spread at higher doses of gamma rays as compared to lower doses. A gradual decrease in number of branches was recorded with gradual increase in dose of gamma rays. As dose of gamma radiation increased the length and width of leaf decreased. Internodal length, thickness of internode and thickness at node were found superior in control plants than the plants treated with gamma rays in all the three varieties studied. Days to flowering however, was earlier at 5 Gy (63.89 days) as compared to control (64.94 days). As dose of radiation increased the days to flowering also increased. Number of flowers plant<sup>-1</sup> and size of flower (cm) were inversely proportional to mutagen dose. The number of flowers got significantly reduced with increasing rate of gamma irradiation. Significant reduction in floret number at higher doses of gamma rays was noticed. The longevity of flower was reduced and there was disharmony of ray floret opening at higher doses. The delay in flowering resulted in a reduced longevity period both in intact and cut flower condition. In M1V1 generation Amb - white and Amb - purple produced mutants for flower colour at 5 Gy and 10 Gy dose of radiation. Flower colour mutant obtained from Amb-white variety at 5 Gy was WM1 which showed a change in colour from wood colour in control flower to yellow colour in the central disc region. In WM2 mutant in Amb-white, the central disc was enclosed by a whorl of ray florets presenting an unopened spherical appearance of ray florets in the centre. Towards the periphery, the ray florets were broad and arranged in a haphazard manner. The mutant from Amb-purple PM1 showed white tips with purple base, whereas control flower was single solid purple colour. Length of tuber was found to be the highest in plants treated with 5 Gy dose as

compared to untreated plants. As doses were increased the tuber length showed a diminishing trend. Fresh weight, length and breadth of tubers were inversely proportional to mutagen dose. Three mutants showing prominent flower character mutations were isolated from M1V1 generation. They include WM1 showing flower colour and form variation isolated from Amb-white, WM2 showing form variation isolated from the same parent and PM1 showing colour variation isolated from Amb-purple. They were carried forward to M1V2 generation for stability screening. Both WM1 and WM2 showed a tendency to revert back to the original flower form and colour, denoting that they were not stable. PM1, the colour mutant isolated from Amb-purple, showed stable performance in M1V2 generation. Although prominent plant architecture mutations were not observed, significant size reduction at higher doses was prevalent in all the three varieties in M1V1 and M1V2 generations.

#### **7. Effect of growth retardants on growth and yield of African marigold (*Tagetes erecta* L.)**

The study entitled “Effect of growth retardants on growth and yield of African marigold (*Tagetes erecta* L.)” was conducted at College of Agriculture, Padannakkad during 2015-2017 with the objective to assess the response of marigold in terms of growth, yield and carotenoid content as influenced by foliar application of growth retardants Alar and Cycocel. The experiment was laid out in split plot design during two seasons viz., monsoon and pre-monsoon. The data was subjected to statistical analysis to find out the effect of growth retardants on different parameters. The experimental material comprised of PusaNarangiGaiinda and Maxima Yellow F1 varieties of African marigold and their response to growth retardants was evaluated with treatments viz., C1 : Alar 500 ppm, C2 : Alar 1000 ppm, C3 : Alar 1500 ppm, C4 : Cycocel 1000 ppm, C5 : Cycocel 1500 ppm, C6 : Cycocel 2000 ppm and C7 : Water spray (control). The analysis of data regarding different plant characters revealed that the varieties and growth retardants resulted in significant differences with vegetative, floral and yield characters and pigment contents in flowers. Growth retardants significantly influenced plant height, plant spread, number of branches, internodal length, and stem girth, number of flowers, flower yield and carotenoid content. There was no significant difference noticed on days to first flowering, days to 50 % flowering, flower length, pedicel length, flower diameter and flower weight. The effects of growth retardants on leaf area, SCMR, total biomass, crop duration, flowering duration and post-harvest longevity varied with seasons. On comparing the two varieties during two seasons, Maxima Yellow F1 performed better for most of the growth and floral characters and recorded highest flower yield in monsoon season. From economic point of view, Maxima Yellow F1 can be recommended during monsoon season in Kerala to meet the high demand of flowers during Onam. Among the growth retardants, Cycocel 1000 ppm can be recommended for better growth, higher yield and carotenoid content in PusaNarangiGaiinda and Maxima Yellow F1 varieties of African marigold during monsoon season and pre-monsoon seasons.

#### **Ongoing projects**

- 1. Evaluation of rose varieties for commercial cultivation under the warm humid tropics of Kerala**
- 2. Standardization of grafting techniques in African marigold (*Tagetes erecta* L) for combating bacterial wilt.**
- 3. Nutrient management in gerbera (*Gerbera jamesonii* Bolus.) grown under naturally ventilated polyhouse.**
- 4. Vegetative propagation in African Marigold (*Tagetes erecta*) hybrid.**



**Name of Project Coordination Group : – (07)  
Aromatic & Medicinal Plants**

**Compiled by:  
Dr. N.Miniraj, Project Coordinator**

**Plan & External Aided Projects  
Ongoing Projects - 6 Nos.**

**Post Graduate Projects  
Concluded Projects- 4 Nos.**



## Concluded Projects

### 1. Propagation techniques and *ex situ* conservation of *Coscinium fenestratum* (Gaertn.) Colebr. - an endangered medicinal plant

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#### 1. Collection and *ex situ* conservation of lines/land races from Western Ghats region of Kerala

Surveys were conducted at Western Ghats region of Kerala and for this appropriate site supporting viable populations of the species were located, and the location monitored in order to collect seeds and other reproductive plant parts at the optimum stage of maturity in suitable season. None of the identified plants flowered during this period. Plants collected from the forest were established in the nursery. It is a slow growing plant and will take minimum of one year for transplanting to the field. Representative sample from each location were planted in the field as an *ex vitro* conservatory for the species.

#### 2. Studies on morphology and floral biology of the domesticated plant

Studies on flowering behavior, seed structure, dormancy, germination, seed viability of the domesticated plants were undertaken and observations were completed for two seasons. Study on plant growth characters of the liana revealed the colour of young and mature shoot as brown with spiral phyllotaxy with the shoots being yellow internally. Branchlets were brown and tomentose at the young stage, later becoming glabrous with disciform petiole-scars. The quantitative characters of stem of the male and female plants showed no significant difference. Anatomical studies revealed that the epidermis is single layered with certain ridges at regular intervals and covered with uniseriate multicellular hairs and cortex consists of rectangular and polyhedral, thin walled, collenchymatous cells consisting of very prominent bands of hard stone cells with crystals inside. The number of vascular bundles was found to vary in the male stem (21) and female stem (22). Just above each vascular bundle, arches of 15-18 layered sclerenchymatous cells with lysigenous cavities were seen opposite to the phloem in definite patches. In between the arches, 2-4 layers of chlorenchymatous tissue were present. The 1-2 layered interfascicular cambium originated in between the bundles, in line with the fascicular cambium, resulting in a ring of 2-6 layered cambium.

Leaf in both the male and female plants had tomentose petiole with pulvinus. The ovate leaf lamina was seen as dark green on the glabrous adaxial surface and light green on the minutely tomentose abaxial surface and lamina had acuminate tip and slightly cordate base with a reticulate-multicostate divergent type venation. The length of leaf petiole and lamina were found to be significantly different in the male plant (10.28 cm and 21.13 cm, respectively) and female plant (12.02 cm and 17.95 cm, respectively). The lamina breadth and life-span of leaf showed no significant difference. Anatomical studies of leaf revealed epidermis as single layered with lower region possessing large number of multicellular and uniseriate trichomes. It was seen that mesophyll consists of 1-2 layered, thick walled, highly chlorophyllous palisade tissue and 2-4 layered, thin walled and spongy tissue with abundant intercellular spaces. Vascular bundle was seen encircled by a wavy ring of 2-10 layers of sclerenchymatous tissue and collenchyma and parenchyma cells present.

The type of inflorescence in *Coscinium fenestratum* was found to be a compound raceme, with the globose heads borne on long peduncle developing on old leafless stems in the axils of fallen leaves as cauliflorous clusters. The flower heads on the long peduncles were seen arising in an acropetal fashion. The peduncle colour was noticed as brown in female and light yellow brown in male inflorescence and softly hairy in texture.

The female inflorescence (11.13 cm) was observed to be longer than the male inflorescence (7.15 cm) showing a significant difference. The number of flower heads in a male inflorescence was recorded as 8.2 and 7.9 in a female inflorescence which showed no significant difference. The number of florets in a flower head was observed as eleven on an average. The diameter of the male floret was measured as 0.22 cm and that of a female floret was 0.32 cm showing significant difference. It was recorded that the life-span of male flower head was 33 days and that of female flower head was 34.5 days and differed significantly. The duration of opening of flower head in male inflorescence was noted as 7.1 days whereas in female flower head, as 8.7 days differing significantly. The number of days required by the male flower head to reach 50% flowering recorded, was two days lesser (3.7 days) than the female flower head (5.7 days) and had significant difference.

The zygomorphic male floret was observed as globose, sessile and whitish yellow in colour. The tepals were seen as densely hairy on the outer surface and glabrous on the inner surface. The tepals in the innermost and middle whorls appeared slightly fused whereas those in the outermost whorl were noticed as free. It was found that the anthers were

small, oval in shape and adnate. The male floret was found to be having nine tepals in three whorls with varying sizes in each whorl. In the male floret, three out of the six stamens were found connate to the middle and the others remain free. The outer anthers were observed as single celled and the inner ones two-celled. The length of anther-lobe was measured as 0.42 mm while that of filament was measured as 0.74 mm. The floral formula of male floret was thus derived as % B & P<sub>3+(3)+(3)</sub> A<sub>3+3</sub> G<sub>zero</sub>

The female floret was noticed similar to the male floret in shape and colour with the tepals having dense hairs on the outside and glabrous surface on the inside. It was noticed that the floret lacked a distinct style, and the branched stigma being attached directly to the densely hairy superior ovary. The type of placentation was observed as axile, with the ovules attached to the trilocular ovary.

It was observed that the female floret consists of nine tepals in three whorls surrounding the pistil differing in length and breadth in each whorl. The floral formula of female floret was thus derived as % @ & P<sub>3+(3)+(3)</sub> A<sub>zero</sub> G<sub>(3)</sub>

Studies on reproductive biology revealed that the flowering season of male plant was noticed from late August to late February with the peak anthesis between 7.00 a.m. - 8.00 a.m. Anther dehiscence was found to occur for a period of 20 and a half hours. The flowering season of female plant was observed from early October to mid-March with the peak anthesis between 7.00 a.m. - 11.00 a.m. The stigma was seen receptive for a period of 26-28 hours. *Coscinium fenestratum* is anemophilous with a pollen fertility of 57.45%. The pollen diameter and exine thickness were measured as 68.95 µm and 5.56 µm respectively.

The tomentellous fruit was found to be a one-seeded drupe, globular in shape and dark brown in colour. The fruit weight, length and breadth were recorded as 8.53 g, 2.36 cm, and 2.36 cm respectively. With a high fruit set of 93.00%, the per cent of fruits carried to maturity was noted as 27.33% only. It was observed that the number of days taken for fruit maturity from the day of flower opening was 150 days.

Kidney shaped seed of greenish brown colour was seen surrounded by the dark brown pulp inside the fruit. The seed weight, length and breadth were noted as 1.7 g, 1.52 cm, and 1.14 cm respectively. The germination percentage of fresh seeds with a moisture content of 21.13% was recorded as 50%. Developmental study of carpels and fruits revealed that the condyle (distinctive feature corresponding to the placentary region) identified was of Menispermum type. Additionally, endocarp ornamentation observed in this study is a common feature in many Menispermaceae species. The bright yellow coloured embryo was located on a region nearby the hilum. Seeds displayed good viability during tetrazolium test.

### 3. Standardisation of différent conventionnel propagation techniques and micro propagation technique

#### 1. Conventional propagation techniques

**A. Cuttings:** Vegetative propagation of *Coscinium fenestratum* through cuttings was commonly not effective. Mature hardwood stem cuttings of brownish black colour and about 25cm were used for vegetative propagation. Three different treatments were tried with IBA 100ppm, cow dung and cow urine for root induction. In each treatment, cuttings were dipped for 15 minutes and then planted in polybags filled with different potting media. Among the treatments, cuttings planted in Sand + Cior pith + cow dung + soil(1:1:1:1) after cowdung dip showed root induction and was found during September- October

**B. Air layering:** Vegetative propagation of *Coscinium fenestratum* through air layering was found to be successful. One year old brown coloured axillary branches of 1cm thickness were selected for air layering. The bark of inter nodal region was removed and tied with potting media. Root initiation depends on the prevailing climate condition. Usually it takes about 7 -9 months .Favorable season for air layering was noted during the period of December to January.

**C. Seed propagation:** In seed propagation, mature fruits of 7 month age were collected and then seeds were obtained after removing the fruit pulp and then thoroughly washed. Later these were dried and then manually scarified. These scarified seeds were later tried with different seed treatments for better germination. Among these treatments GA<sub>3</sub> 4000ppm proved to be the best with maximum germination percentage.

#### 2. Micro propagation technique

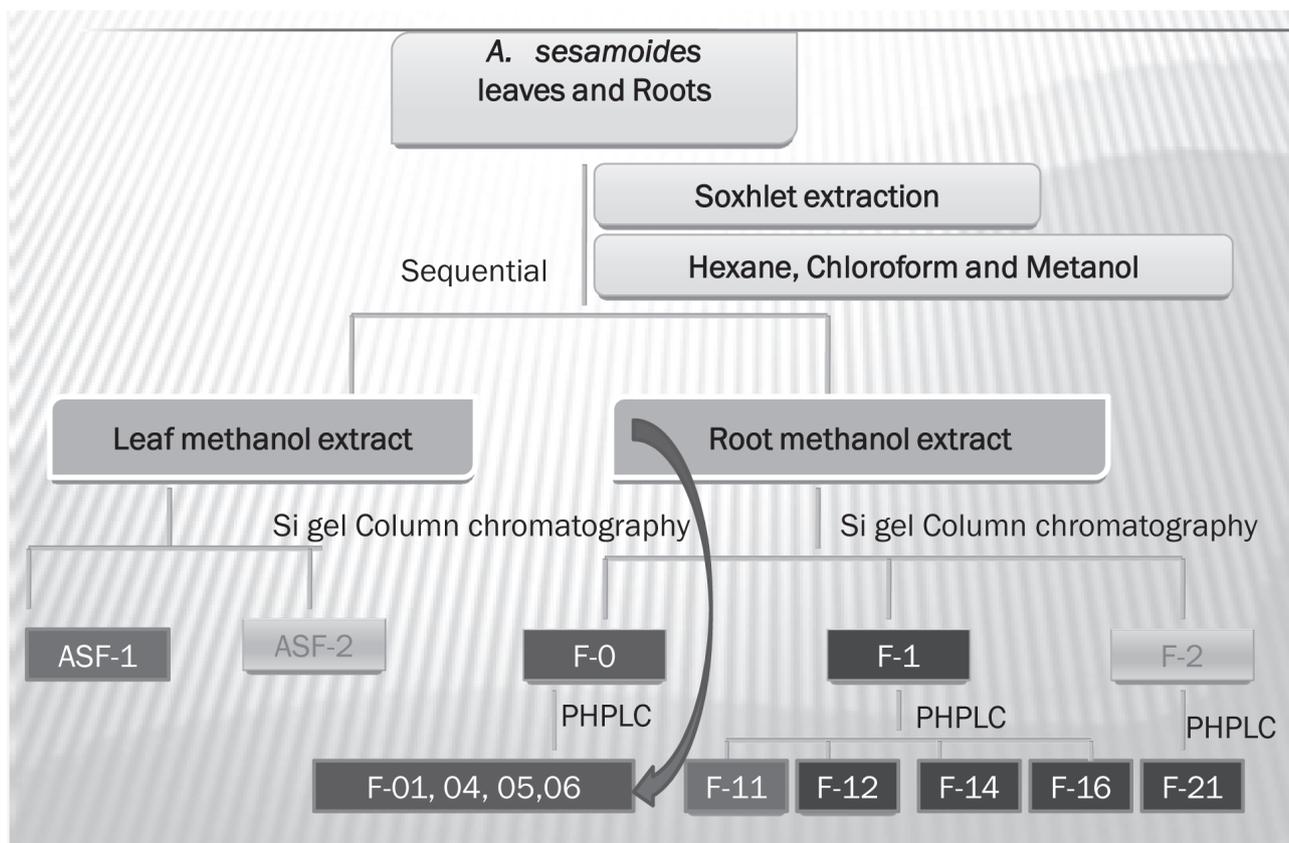
**A. In vitro seed propogation. :** Media composition and seed sterilization technique were standardized for the *in vitro* germination of seeds. Media composed of sterile sand found to be the best medium compared to MS basal media recorded a germination percentage of 20%.

**B. Organogenesis:** Different media composition and explants were tried. Cultures without contamination were obtained. It is a slow growing and low response species under natural condition. The same will be shown under *in vitro* condition also. Among the different media tried for culture establishment, full MS media supplemented with growth regulators kinetin 0.2 ppm and 0.4 ppm proved to be the best with maximum (60%) culture establishment. The period for culture establishment and shoot induction was found to be minimum in these media and also showed a high percentage of leaf emergences.

## 2. Extraction and purification of antioxidant principles from selected medicinal plants

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Phytoconstituents are extracted from the root of *Artanemesamoides* by sequential solvent extraction with hexane, chloroform, and methanol and sequential methanolic extractives were subjected to column chromatography using Silica gel 100-200 mesh using appropriate solvent system. Similar column fractions were pooled and subjected to preparative HPLC. Four new compounds were newly isolated and characterized by UV spectra, HRMS, LC MS/MS, I D,  $^2D$  H NMR & C NMR & in comparison with the literature



As highlighted within the arc, four compounds from pooled column fraction F0 ie, F01, F04, F05, F06, were isolated and characterized

In addition to seven compounds namely, Acteoside, Isoacteoside, Artanemoside, Leucoseptoside A, Martynoside, Plantainoside and Luteolin-7-O-rutinoside isolated and identified from anti-inflammatory, antioxidant fraction of methanolic extracts earlier, additional four compounds namely, Oraposide/ Crenatoside/ Orobanchoside, 3<sup>o</sup>-O-Acetylmartynoside, 2<sup>o</sup>-O-Acetylmartynoside and Clerodenside A were isolated from pooled column fractions F0, by preparative HPLC by developing appropriate solvent system for chromatographic separation. The isolated peaks were subjected to NMR and MS analysis for its structure elucidation and based on the I D,  $^2D$  H NMR (400 MHz) and  $^{13}C$  NMR (100 MHz) spectral data and HRMS, LC MS/MS and in comparison with literature, the compounds were identified.

### 3. Evaluation of antioxidants activity, cytotoxicity and phenol composition of selected anti-inflammatory plants

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#### Screening against plant pathogenic fungi

Sequential methanolic extracts at 500 ppm were screened against *Phytophthora capsici*, *Fusarium oxysporum* and *Rhizoctonia solani* by poison food method in PDA medium. Methanolic extractives of 26 plants were tested of which a few such as Manjakoova, Erikku mango leaf, thippali fruit showed significant broad spectrum activity against all the three fungi tested

#### In vitro screening against human pathogens

Sequential methanolic extracts from selected plants were screened *in vitro* against four human pathogens viz. *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Klebsiella pneumonia* and *Escherichia coli* by poison food method in appropriate medium and extracts with broad-spectrum activity against all the four tested micro-organisms were identified. The 29 plants were screened against human pathogens and eight of them showed broad spectrum activity against all the four bacterial pathogens tested

#### In vitro screening against mosquito

In vitro screening of different crude powders and extracts of medicinal plants against mosquito larvae, pupae and adults of *Aedes* was carried out. Out of 24 crude powders, five powders showed 100 % mortality of larvae at 24 hours at 0.2% concentration. Different solvent extracts of promising raw drugs were tested against both larvae and pupae in different adsorbents and carriers. Formulations and dosages for sachet application were attempted. A few of them showed good activity when introduced in sachet into contained water. Selected extracts are being progressed for field application

### 4. Collection, maintenance and evaluation of germplasm of medicinal and aromatic plants

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- The existing valuable collection of aromatic germplasm and medicinal plant species maintained in micro plots, pots and fields were maintained by replanting/ proper cultural operations.
- The vast area under medicinal tree collection was conserved properly by undergrowth clearing, need-based pruning and training, manuring and plant protection measures.
- The programme on enrichment of the collection by adding newer species of rare and endangered plants was continued.
- This served as a demonstration for a large number of visitors including students, researchers, farmers and general public. Seeds and planting materials as well as crude drugs were made available from this source.
- Generated information on propagation methods of a number of medicinal and aromatic plants.

#### Observations on seed

Name of Plant	Days to germination	germ %	Viability (months)	Dormancy	Thousand seed weight
Amukkuram	5-8	90 - 95	10 - 12	nil	1.8-2.0 g
Arayal	15-24	50-55	12	nil	0.9-1.0g
Chappangam	5-6	70 - 80	10 - 12	nil	520-550g
Cheruvazhuthina	7-14	70 - 75	10 - 12	2-3	2.5-3.0g
Chuvannamandharam	5-6	90 - 100	6	nil	170.0-190.0g
Gnathinarakam	7-8	90-100	3	nil	95.0-100.0g
Idampirivalampiri	3-5	90 - 100	12	nil	3.0-2.5g
Lemongrass	3-10	25-30	4	8 weeks	0.4-0.5
Kaanjiram	30	90 - 95	12	6 weeks	1.5-1.8g
Kattuchunda	10	40-45	8	2 months	12.0-12.5g
Kattupadavalam	7-10	50 - 60	9 months	nil	95.0-100.0g
Kudakappala	7-8	75-80	12	nil	30.0-32.0g
Kurupparuthi	5-8	80-90	7-8	nil	40.0-45.0g
Manithakkali	8-11	60-65	18	nil	0.3-0.4g
Manjamandharam	5-8	65 - 70	12	nil	60.0-70.0g
Neermaruth	20	85-90	7	nil	2.5-3.0g
Neermulli	15-20	90 - 95	7	nil	0.6-1.0g
Neervalam	7-8	60-70	6	nil	140.0-145.0g
Putharichunda	5-10	60 - 65	6	nil	2.5-2.7g
Thanni	30-40	90 - 100	12	nil	4.5-5.0 kg
Thathiri	10-20	60 - 75	6	Nil	0.3-0.4 mg
Valliuzhinja	8-15	50 - 60	16	nil	34.0-35.0g

**Seed treatment techniques were standardised for the following plants.**

Thathiri : Overnight soaking in water, 2 stage transplanting

Sandal : Acid scarification with concentrated sulphuric acid for 30 minutes

Neermaruthu: Dipping the seeds in water for 96 hours and the soaked seeds are kept in heaps covered with moist gunny cloth in shade, till germination

Karinjotta : Removal of outer coat

Lemongrass, Kiriyaath, Vathamvaratti, Palakappayyani: No treatment, direct sowing in germination medium

**Protocol for seedling production in Thathiri**

- Germinate seeds in Sterilized coir pith compost medium
- Uproot 1 week old seedlings and plant in protrays filled with Sterilized coirpith compost
- Keep the trays under sunlight in rain shelter
- Spray vermiwash 5% or 19:19:19 NPK 0.2% weekly
- Transplant to poly bags containing soil and coir pith compost in 4:1 ratio at 6-8 leaf stage at 1 month age
- 2-3 months old, 15-20 cm tall, polybagged seedlings ready for field planting

The data gathered is being published as a 'Manual on propagation of medicinal and aromatic plants' (vol 1).

**5. Evaluation of vetiver (*Vetiveria zizanioides*) accessions for superior genotypes**

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**I. Evaluation of vetiver accessions in the station farm****a. Non flowering and vigorously growing types – suitable in soil conservation**

Accession - 7 is identified as a non-flowering type of vetiver specifically suited for hedge planting in soil conservation systems.

In the 39<sup>th</sup> Zonal Research and Extension Advisory Committee meeting of Central zone held at RARS, Pattambi on 28-07-2017, the accession was recommended for POP workshop and it was proposed that demonstration of the type can be undertaken in KAU stations. Accordingly, the accession was given for multilocational testing at ARS, Chalakudy, ARS, Mannuthy and AICRP (M&AP).

It is reported that Acc. 7 is non flowering and has better tillering and vegetative growth compared to ODV-3 at all the locations.

**b. Types with high root and oil yield**

The selected accessions viz. ODV 7, 24, 27 and 33 were compared with ODV-3.

**Observations at 12 months after planting**

Accession No.	Plant height (cm)	Tillers per hill	Root yield per plant (g)	Oil yield %
ODV 7	145	148.6	125	1.10
ODV 3	124	90.6	197	0.69
ODV 24	120	133.2	133	0.30
ODV 27	128	75.2	259	1.15
ODV 33	154	59.2	288	1.04

Observations at 12<sup>th</sup> month showed that ODV-27 and ODV-33 produces higher root yield as compared to ODV-3. Percentage of oil was higher in ODV-7, ODV-27 and ODV-33. Experiment is continued.

**2. Demonstration trial of selected accessions in the coastal sandy tracts of Kerala (Chavakkad & Ponnani Taluks) for identifying superior types suited to the situation**

Selected accessions viz. Acc. 7, 24, 27 and 33 were planted in large area plots in the field of Sri Haneefa, Mannalamkundu in comparison with the local type. Local type was infested with mealy bugs and hoppers in the early stages, whereas accessions from Odakkali were pest free. Out of the accessions tested, Ac 33 is best in terms of farmer acceptance. Though yield is lower than local type, root is very long and fine with good aroma. Hence it is preferred for making handicraft items and hence fetches premium price. Acc. 33 is planted in larger area during December 2017 to confirm its adaptability and superiority.

Acc.No	No. of tillers hill 7MAP	Length of root	Root yield kg/ha
3	11.7	80	18500
7	17.7	85	9358
24	10.0	76	33858
27	23.3	89	32751
33	17.7	110	24333
Local	8.3	75	40555

## Performance of vetiver accessions in farmers' fields (2017-18)

### 6. AICRP on Medicinal plants

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#### 1. PGR management (PGR collection, evaluation, registration and others)

Centre maintains a herbal garden with 400 numbers of medicinal plants including rare and endangered plants endemic to Western Ghats.

#### Germplasm maintained in the centre - 7 species as below

Sl.No	Common Name	Scientific Name	No: of Accessions	IC numbers
1.	Long pepper	<i>Piper longum</i>	25	IC 612534 - 612558
2.	Chitrak	<i>Plumbago rosea</i>	25	IC 566499 - 566523
3.	Asoka	<i>Saraca asoca</i>	42	IC 566454 - 566498
4.	Brahmi	<i>Bacopa monnieri</i>	29	IC 566427 - 266455
5.	Neelamari	<i>Indigofera tinctoria</i>	21	IC 0613875 - 0613895
6.	Kattupadavalam	<i>Trichosanthes cucumerina</i>	19	N/06-141 -
7.	Orila	<i>Desmodium gangetium</i>	25	IC255388

#### 2. Crop improvement (entries for mlt, varieties released and others)

##### 1. Variety released

*Plumbago rosea* accession TCRPR 521, with high root yield and moderate plumbagin content recommended for variety release in the name SWATHI by the Kerala State Variety Evaluation Committee in this year.

##### SWATHI



Plant height : 95.09 cm  
No. of branches/ plant : 19  
Root length: 61.09 cm  
Root girth: 3.94 cm  
No. of roots/ plant: 33  
Root weight (fresh)/plant :165.80g  
Root weight (dry)/plant:72.20g  
Plumbagin content : 0.51%

#### MULTI LOCATIONAL TRIALS

##### A) Evaluation of promising lines of Lal Chitrak (*Plumbago rosea*) in MLT

Plant propagules of two high yielding lines of *Plumbago rosea* identified - TCRPR 516 and TCRPR 521 along with two local checks are under evaluation in MLT by the participating centers viz; TNAU and VR Gudam

##### B). MLT Evaluation of promising lines from other centres

##### 1.Kalmegh (*Andrographis paniculata*)

MLT evaluation of promising lines of Kalmegh (*Andrographis paniculata*) for high yield and quality was done with 39 entries (AK 1 to AK 39) obtained from DMAPR. Observations on yield parameters like plant height, plant spread, days to reproductive phase, days to 50% flowering, number of primary branches/plant, leaf length, leaf width, leaf/ stem ratio, leaf yield, length of the spike and biomass yield were taken. Entries AK 18 (6408 Kg/ha) and AK 9 (6264 kg/ha) performed well with respect to biomass yield under our conditions. Data sheet and dried plant samples were sent to DMAPR for chemical analysis as per the directions.

## 2. Long pepper (*Piper longum*)

Evaluation of promising lines of long pepper was done with three accessions (ALP 01, ALP 02 and ALP 03). The observations on morphological and yield parameters like leaf length, leaf breadth, length/breadth, leaf tip, leaf margin, leaf base, leaf colour, internodal length, catkin number, catkin length, catkin breadth, catkin colour and piperine content recorded and data sheet submitted to DMAPR.

## 3. Bach (*Acorus calamus*)

Evaluation of promising accessions of bach (*Acorus calamus*) was done with five entries (AC 01 to AC 05) in 4 replications in a randomized block design. The data recorded on yield attributes like plant height, number of leaves/plant, rhizome weight (g/plant), rhizome length (cm) and rhizome diameter.

### Other crop improvement programmes

**1. Characterisation and evaluation of *Desmodium gangeticum* germplasm :** Twenty five accessions of *Desmodium gangeticum* were evaluated for morphological and yield parameters. Variations noticed in morphological as well as yield attributes. Biometric observations include plant height, shoot weight, root length, root thickness, number of roots and root weight. Majority of the accessions are medium tall. Among the twenty five accessions tested TCR DG 9, TCR DG 12, TCR DG 14 and TCR DG 24 recorded superior root yield. Experiment is continuing.

**2. Development of DUS descriptors for Lal chitrak (*Plumbago rosea*):** Twenty five accessions of *Plumbago rosea* maintained at the centre were evaluated for morphological and biometric characters. Variations noticed on biometric and morphological characters. Experiment is continuing for flower and root characters

**3. Development of DUS descriptors for Neelamari (*Indigofera tinctoria*) :** The experiment to develop DUS descriptor for the 21 available accessions of *Indigofera tinctoria* in the centre was started during 2015-16. Observations were recorded on general growth characters, leaf characters, inflorescence and flower characters, pod and seed characters, yield and quality characters. Variations noticed in plant height, canopy spread, number of branches, leaflet shape, leaflet base, leaflet colour, leaflet size, indican content, herbage yield, length of inflorescence, number of flowers/ inflorescence, flower colour, number of pods/ panicle and pod shape.

Based on these characters the accessions were grouped.

### Grouping of accessions for important characters

Character	Expression	Accessions
Plant height	Tall (>60 cm)	TCRIT 4
	Medium (40cm-60 cm)	TCRIT 1, TCRIT 3, TCRIT 6, TCRIT 7, TCRIT 8, TCRIT 9, TCRIT 10, TCRIT 11, TCRIT 12, TCRIT 13, TCRIT 14, TCRIT 15, TCRIT 16, TCRIT 17, TCRIT 18, TCRIT 19, TCRIT 20, TCRIT 21
Canopy spread	Short (<40cm)	TCRIT 2, TCRIT 5
	Widely spread (>70 cm)	TCRIT 7, TCRIT 12, TCRIT 15, TCRIT 18
Number of branches	Medium (50cm-70cm)	TCRIT 3, TCRIT 4, TCRIT 6, TCRIT 8, TCRIT 9, TCRIT 10, TCRIT 11, TCRIT 13, TCRIT 14, TCRIT 16, TCRIT 17, TCRIT 19, TCRIT 20
	Low (<50cm)	TCRIT 1, TCRIT 2, TCRIT 5, TCRIT 21
	Large (>10)	TCRIT 7, TCRIT 12, TCRIT 15, TCRIT 18
Leaflet shape	Medium (8-10)	TCRIT 1, TCRIT 4, TCRIT 6, TCRIT 8, TCRIT 9, TCRIT 10, TCRIT 11, TCRIT 13, TCRIT 14, TCRIT 16, TCRIT 17, TCRIT 19
	Small (<8)	TCRIT 2, TCRIT 3, TCRIT 5, TCRIT 20, TCRIT 21
Leaflet base	Oval	TCRIT 3, TCRIT 7, TCRIT 10, TCRIT 14, TCRIT 20
	Oblong	TCRIT 2, TCRIT 6, TCRIT 8, TCRIT 11, TCRIT 13, TCRIT 15, TCRIT 16, TCRIT 18
Leaflet colour	Ovate	TCRIT 1, TCRIT 4, TCRIT 5, TCRIT 9, TCRIT 12, TCRIT 17, TCRIT 19, TCRIT 21
	Rounded	TCRIT 3, TCRIT 4, TCRIT 5, TCRIT 8, TCRIT 9, TCRIT 10, TCRIT 11, TCRIT 13, TCRIT 14, TCRIT 16, TCRIT 17, TCRIT 18, TCRIT 19, TCRIT 20
Leaf size (LxB)	Acute	TCRIT 1, TCRIT 2, TCRIT 6, TCRIT 7, TCRIT 12, TCRIT 15, TCRIT 21
	Green	TCRIT 2, TCRIT 3, TCRIT 13, TCRIT 17, TCRIT 19, TCRIT 20, TCRIT 21
	Dark green	TCRIT 4, TCRIT 5, TCRIT 7, TCRIT 9, TCRIT 10, TCRIT 12, TCRIT 18
Indican content	Bluish green	TCRIT 1, TCRIT 6, TCRIT 8, TCRIT 11, TCRIT 14, TCRIT 15, TCRIT 16
	Big (>40cm <sup>2</sup> )	TCRIT 4, TCRIT 6, TCRIT 7, TCRIT 8
Herbage yield	Medium (30-40 cm <sup>2</sup> )	TCRIT 1, TCRIT 2, TCRIT 3, TCRIT 9, TCRIT 10, TCRIT 13, TCRIT 14, TCRIT 15, TCRIT 16, TCRIT 17, TCRIT 18, TCRIT 19, TCRIT 20, TCRIT 21
	Small (<30cm <sup>2</sup> )	TCRIT 5, TCRIT 11, TCRIT 12
	Low (<0.5%)	TCRIT 12, TCRIT 13, TCRIT 20
Herbage yield	Medium (0.5-0.9%)	TCRIT 1, TCRIT 3, TCRIT 4, TCRIT 5, TCRIT 19, TCRIT 21
	High (>0.9 %)	TCRIT 2, TCRIT 6, TCRIT 7, TCRIT 8, TCRIT 9, TCRIT 10, TCRIT 11, TCRIT 14, TCRIT 15, TCRIT 16, TCRIT 17, TCRIT 18
Herbage yield	Low (<60)	TCRIT 3, TCRIT 18
	Medium (60- 100g/pt)	TCRIT 1, TCRIT 5, TCRIT 6, TCRIT 7, TCRIT 8, TCRIT 9, TCRIT 10, TCRIT 11, TCRIT 12, TCRIT 13, TCRIT 16, TCRIT 17, TCRIT 19, TCRIT 20, TCRIT 21
	High (>100)	TCRIT 2, TCRIT 4, TCRIT 14, TCRIT 15

Character	Expression	Accessions
Length of inflorescence	Long (>10cm)	TCRIT 5, TCRIT 6, TCRIT 20
	Medium (5-10cm)	TCRIT1, TCRIT2, TCRIT3, TCRIT4, TCRIT9, TCRIT10, TCRIT 11, TCRIT12, TCRIT13, TCRIT17, TCRIT18, TCRIT 19, TCRIT 21
No. of flowers/ inflorescence	Short (<5cm)	TCRIT7, TCRIT8, TCRIT14, TCRIT15, TCRIT 16
	Large (>20)	TCRIT7, TCRIT8, TCRIT9, TCRIT10, TCRIT11, TCRIT 13, TCRIT 21
	Medium (15-20)	TCRIT 3, TCRIT 5, TCRIT12, TCRIT 15, TCRIT 18, TCRIT 19, TCRIT 20,
Flower colour	Small (<15)	TCRIT1, TCRIT2, TCRIT4, TCRIT6, TCRIT14, TCRIT16, TCRIT 17
	Light pink	TCRIT 1, TCRIT 4, TCRIT 10, TCRIT 13
Pod shape	Pink	TCRIT 2, TCRIT 3, TCRIT 5, TCRIT 6, TCRIT 7, TCRIT 8, TCRIT9, TCRIT11, TCRIT12, TCRIT14, TCRIT15, TCRIT16, TCRIT17, TCRIT18, TCRIT 19, TCRIT 20, TCRIT 21
	Cylindrical	TCRIT 1, TCRIT3, TCRIT 4, TCRIT 5 TCRIT 7, TCRIT 8, TCRIT9, TCRIT 10, TCRIT11, TCRIT 13, TCRIT15, TCRIT16, TCRIT 19
	Falcate	TCRIT 6, TCRIT12, TCRIT17, TCRIT18
	Curved	TCRIT 2, TCRIT14

#### 4. Reproductive biology and pollination studies of bitter snake gourd (*Trichosanthes cucumerina*)

*Trichosanthes cucumerina* is a highly cross pollinated monoecious vine, entomophilous and honey bees as pollinating agents. Pollination studies were conducted during rainy, summer and winter seasons. Artificial pollination was done by hand. On each plant half the number of pistillate flowers available were artificially pollinated by hand. Half retained as such for natural pollination. Fruits harvested separately in artificial and natural pollination. Artificial pollination yielded 25.9, 27.6 and 17.1 percent more number of fruits than natural pollination during rainy, summer and winter season respectively.

#### 5. Development of minimum seed certification standards

Minimum clone certification standards of three important medicinal plants (*Saraca asoca*, *Piper longum* and *Plumbago rosea*) of Kerala developed

Specifications	<i>Saraca asoca</i>	<i>Piper longum</i>	<i>Plumbago rosea</i>
Propagules	Air layers	2,3 noded semi hardwood stem cuttings	2,3 noded semi hardwood stem cuttings
Land Requirements	Free from volunteer plants , Avoid ill drained soils		
	-	Provide 30% shade	Provide 25% shade
Mother Plant	<ul style="list-style-type: none"> <li>Should be healthy, true to type and free from pests and diseases</li> <li>Should be certified for the specific varietal characters by the Certifying Agency</li> <li>Two/four inspections shall be made for morphological characters, health, genetic purity and pests and diseases</li> </ul>		
Important diseases	Die back	Leaf spot, Leaf blight, Nematodes , Mealy bug, Virus	Leaf blight, Damping off
Foundation clone - Field standards			
Isolation	<ul style="list-style-type: none"> <li>Fields of other varieties (5m)</li> <li>Fields of the same variety not conforming to varietal purity requirement for certification (5m)</li> </ul>		
Spacing	0.75 m x 1.50 m	0.5 m x 0.5 m	0.5 m x 0.5 m
Rotation	Should be rotated to other plots every three years		
Specific Requirement	<ul style="list-style-type: none"> <li>Off-types maximum (0.1%)</li> <li>Infested with die back (None)</li> </ul>	<ul style="list-style-type: none"> <li>Off-types (0.1- 0.2)</li> <li>Symptoms of leaf spot &amp; leaf blight (0.1 - 0.5)</li> <li>Plants infested with nematodes, mealy bug and virus (None)</li> </ul>	<ul style="list-style-type: none"> <li>Off-types maximum (0.1%)</li> <li>Symptoms of leaf blight and die back (None)</li> </ul>
Size and age of the planting stakes from which cuttings / layers are taken	Age of the crop : 6 to 9 months	Age of the crop : 7-12 months	Age of the crop : 12 to 15 months
Certified clone standards	<ul style="list-style-type: none"> <li>Diameter of layer : 1.0-1.5 cm at 10 cm above ground level</li> <li>Height of the layers: 30-50cm</li> </ul>	<ul style="list-style-type: none"> <li>Diameter of the stem : 0.3 - 0.5 cm</li> <li>Length of the stem : 6 - 10 cm</li> <li>No. of nodes : 2-3</li> </ul>	<ul style="list-style-type: none"> <li>Diameter of the stem : 0.3 - 0.5 cm</li> <li>Length of the stem : 20 - 30 cm</li> <li>No. of nodes : 2-3</li> </ul>

### 3. Crop Production

#### POP recommendations

**Technology recommended for PoP :** Shade requirement for *Indigofera tinctoria* (25 per cent shade to open condition ideal for better yield and quality)

#### 1. Integrated nutrient management for higher yield and quality of *Indigofera tinctoria*

From the results of three years of experiment, application of FYM 5 t/ha + NPK @ 45:60:45kg/ha can be recommended for better herbage yield, indican yield and B:C ratio. Manurial management with FYM 10 t/ha + NPK @ 45:60:45kg/ha was the next best alternative for better B:C ratio. Compared to plots with integrated nutrient management, the yield recorded from the plants which received inorganic fertilizers alone or farmyard manure alone was very low.

## 2. Effect of method of crop establishment and shade level on yield and quality of *Desmodium gangeticum* (Orila)

The root yield per plant and per hectare were highest when the crop was transplanted under 75 per cent shaded condition. Growing plants under 50 per cent shaded condition by transplanting was the next best alternative for higher root yield.

## 3. Standardization of organic production technology for kalmegh

Combination of farm yard manure with biofertilisers and jivamrut gave higher yield 4173 and 4387 kg/ha during first and second year of study. Among integrated nutrient managed plots combination of NPK at 80:40:20 kg/ha along with biofertilisers and jivamrut gave higher herbage yields. Total alkaloid content was higher in treatment combinations with farm yard manure followed by combinations with castor cake during both the years, while application of vermi compost resulted in lower total alkaloid.

## 4. Standardization of organic farming practices for acorus

The plants which received FYM @ 15 t/ha gave the highest rhizome yield of 1428 kg/ha during first year and 1573 kg/ha during second year. It was on par with vermi compost @ 7.5 t/ha. The plants which received fertilizer NPK @ 45:12.5:12.5 kg/ha recorded the highest rhizome yield of 1772 kg/ha during first year and 1944 kg/ha during second year.

## 5. Studies the performance analysis of medicinal plants under banana plantation

Medicinal plants, neel and bala performed well under banana intercropping system without any negative effect on yield of either main or intercrop

## 4. Phyto Chemistry

### 1. Experiment title: Comparative quality evaluation of different *Tinospora* species found in Kerala

Results: Three different *Tinospora* species are commonly found in Kerala namely *Tinospora cordifolia*, *Tinospora malabarica* and *Tinospora crispa*. They were collected and grown in our experimental field. The external appearance and morphology of *T. cordifolia* and *T. malabarica* are almost alike but the stem and leaves of *T. malabarica* are bigger in size. Scanty tubercle protuberances are more in the papery bark of *T. malabarica* compared to *T. cordifolia*. In the very young stage, morphological differentiation is difficult. In the case of *T. crispa* the stem bark is crowded with large blunt protuberances even in very young stages of the plant, hence morphological identification is very easy in *T. crispa*. *T. cordifolia* is found in wide distribution while *T. crispa* and *T. malabarica* are wild and found in limited areas. *T. cordifolia* is preferred by ayurvedic practitioners of Kerala.

The comparative study of three different species showed marked variation in antioxidant activity (AOA), berberine content (active ingredient) and fibre content also. *T. crispa* showed very high AOA and phenol content followed by *T. cordifolia*. Berberine was found more in *T. malabarica* compared to *T. cordifolia*. Berberine was not detected in *T. crispa*. GCMSD analysis also showed variation in the chemical profile of three different species. HPTLC and TLC profiles of these three species reflected variations in chemical composition. Heavy metal analysis of the samples were carried out using ICP-AES method. All three species were free of heavy metals arsenic, cobalt, molybdenum and cadmium whereas the iron, lead, nickel and chromium were found in traces but more in *T. malabarica* followed by *T. crispa*. GCMSD analysis showed variation in the chemical profile of three different species.

### Total antioxidant activity, phenol and crude fibre content in three species of *Tinospora*

	Total antioxidant activity (mg AA /g)	Total phenol content (mg TA/g)	Crude fibre content (%)	Berberine content (%)
<i>T. cordifolia</i>	7.86	45.20	24	0.19
<i>T. malabarica</i>	5.78	35.33	22	0.22
<i>T. crispa</i>	12.78	59.71	20	Not detected

### Heavy metal content in three species of *Tinospora* (ppm)

	As	Cd	Co	Pb	Ni	Cr	Fe
<i>T. cordifolia</i>	ND	ND	ND	0.008	0.014	0.010	1.666
<i>T. malabarica</i>	ND	ND	ND	0.015	0.025	0.013	5.724
<i>T. crispa</i>	ND	ND	ND	0.008	0.020	0.010	2.500

### 2. Experiment title: Quality assessment of traded crude drug *Tinospora* from different markets of Kerala

Results: Market samples of *Tinospora* raw herbal drug (30 numbers) were collected from various markets of Kerala. Genuine samples of three different *Tinospora* species were also collected from the campus and identified and used for the study as reference standards. Stem samples were used for analysis. A reference TLC fingerprint was developed with genuine samples of three different species of *Tinospora* (chloroform, methanol in Silica gel 60F<sub>254</sub>, UV-L). The TLC fingerprints of market samples developed in the same way were compared with the reference fingerprints to assess the genuineness of

the market samples. The result revealed that out of thirty samples analysed so far, 28 samples were found to be that of true type i.e. *T. cordifolia* and the rest two were of *T. malabarica*. No samples proved to be *T. crispa*. This shows that though *T. cordifolia* is preferred by ayurvedic practitioners of Kerala, if not available, *T. malabarica* is used instead as an alternate drug.

## PG - Concluded Projects

### 1. Developmental morphology of tuberisation and phytochemical profiling in milk yam (*Ipomoea digitata* L.)

1. Assessment of optimum maturity and quality evaluation of milk yam.
2. Nutrient analysis and protocol development for nutritional supplements.

The major findings are summarized as follows

The right stage of harvesting milk yam tubers for ensuring optimum product was assessed through comprehensive analysis of tuber formation and maturity based phytochemical profiling. Pharmacological characteristics of the tubers were envisaged in the study. Nutrient composition of the tubers were analysed and standardised a protocol for the development of a dietary supplement.

#### Assessment of optimum maturity and quality evaluation of milk yam

Optimum maturity and the right stage of harvesting milk yam tubers were finalized by studying the developmental morphology viz., vine morphology, root morphology, tuber morphology and macroscopic features of milk yam tubers all throughout its growth stages from three to twenty four months after planting at monthly intervals. Storage roots started producing from third MAP and tubers started to develop by about fifth MAP. All biometric characters studied except number of leaves increased with maturity (Figure 1.). Number of leaves decreased during vegetative growth and decreased during reproductive and senescence stages.

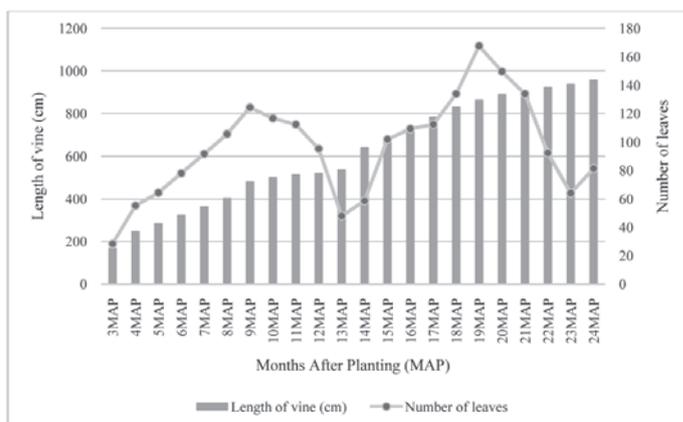


Figure 1. Development morphology of aerial parts of milk yam (*Ipomoea digitata* L.) plants

Morphological features recorded during 24 MAP were vine length (956.67 cm), root length (34.67 cm), root girth (2.97 cm), number of storage roots (3.00), number of tubers (2.33), length of tuber (35.38 cm), girth of tuber (25.13 cm) and weight of tuber (2028.33 g) respectively. Milk yam tubers were having pale brown outer surface during initial stages of growth (five to ten MAP) and it turned brownish afterwards whereas it had got white inner portion and a characteristic agreeable odour during the entire stage of tuber growth. The tubers were slightly pungent except during 10-12 MAP and 20-23 MAP when the tubers were slightly sweet. Milky white latex was present when the tubers were cut during vegetative growth period (five to eleven MAP, 15-20 MAP and 24 MAP) and only slightly present during the reproductive stages (12-14 MAP and 21-23 MAP). Developmental morphology of the plants revealed that the plants as well as the tubers are in a continuous state of growth and hence exhibited no dormancy. Number of storage roots (3.00) and economically beneficial tuber number (2.33) got stabilized from 20 and 21 MAP respectively. Moreover, pungency of tubers and latex content got reduced by 20 and 21 MAP respectively but during 24 MAP both the characteristics adversely increased. A laconic conclusion derived through developmental morphology analysis is that milk yam tubers could be harvested ideally between 21-23 MAP.

Milk yam tubers are said to be root modification owing to its radially arranged vascular bundles (pentarch during initial stages (one MAP) that turned polyarch on maturity) and exarch xylem. Tuber initiation occurred in milk yam during two MAP with the development of cambium initials in between xylem and phloem elements. As tuber enlarged these cambium initials joined together with cells proliferated from pericycle to form a complete cambium cylinder (during 12

MAP) and was assumed to be the first and oldest growth ring (Plate 1.).

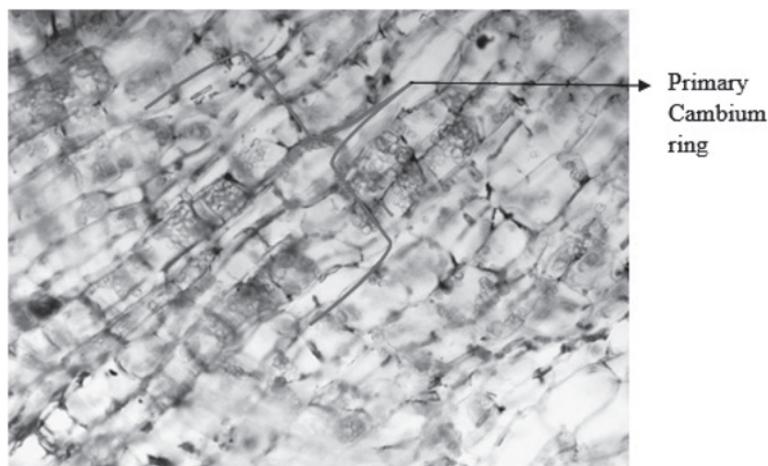


Plate 1. Microscopic view of primary cambium ring

The cambium cylinder on due course turned meristematic to produce secondary xylem and parenchyma cells centripetally and sieve elements, companion cells and parenchyma cells centrifugally. Secondary phloem parenchyma or secondary cambium (anomalous cambium) started to appear as bands or circles around secondary xylem scattered throughout the tuber circumference (Plate 2).

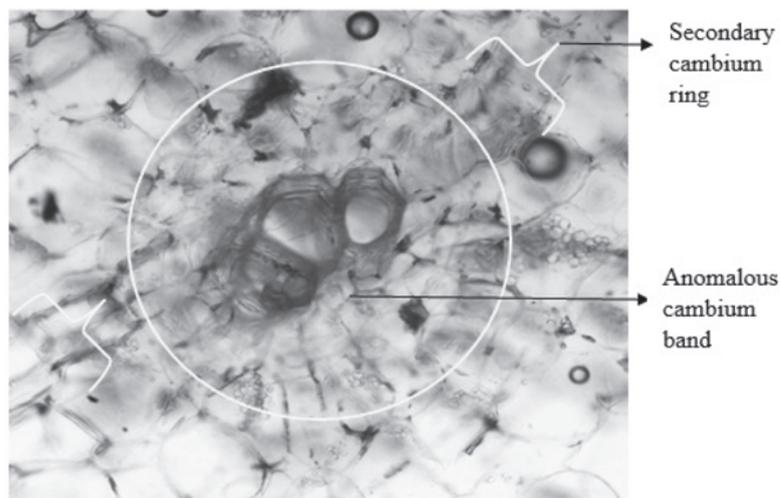


Plate 2. Microscopic view of anomalous cambiums

Secondary cambium joined with parenchyma cells and cells developed form pericycle to form second annular ring (during 19 MAP). Third annular ring was observed in tubers obtained during 36 MAP. Each annular ring was made of four to five layers of radially disposed older and spirally thickened vascular elements, latex vessels etc. pulled out by the starch filled parenchyma cells in both the directions. It is seen that starch deposition started from three MAP and as tuber matured starch deposition increased. Thus it is clear that tuber development in milk yam happened through anomalous cambium activity, development of supernumerary cambiums coupled with starch deposition in parenchyma cells. Milk yam tuber of more than 19 months maturity reported to possess all the characteristic anatomical features of a mature tuber viz., first and second annular ring, anomalous cambium bands, superficial periderm, spirally thickened older xylem vessels, tyloses attached to older xylem vessels, calcium oxalate crystals, obliterated latex vessels near to old annular ring. By 23 MAP fiber development started and was found to be higher during 24 MAP. Hence, 19-22 MAP could be considered as ideally mature for harvesting.

Proximate composition including physical standards, extractive values in different solvents and phytochemical screening were done at tri-monthly intervals from third to twenty four MAP. Moisture content decreased with maturity. Higher moisture content was recorded during initial stages of plant growth (three MAP, 95.43 per cent) and all along the vegetative growth phases counteract with less moisture content for the tubers harvested during senescence stages (12 MAP, 61.60 per cent and 21 MAP, 57.80 per cent). Total ash and water soluble ash content of milk yam tubers found to increase in all the growth stages except during the period when the plants resumed its vegetative growth (15 MAP, 3.08 and 1.99 per cent respectively; 24 MAP, 3.69 and 2.17 per cent respectively) (Figure 2.). Acid insoluble ash increased all along the

tuber development stages and reached maximum (0.62 per cent) during 24 MAP which was on par with 21 MAP (0.60 per cent) both satisfied the standards put forward by AYUSH (2006).

Crude fiber content in milk yam tubers shoot up during 12 MAP (3.95 per cent), 15 MAP (5.85 per cent) and 24 MAP (7.30 per cent) coincided with crop regrowth whereas, any phenomenal increase in crude fiber content was noticed during the vegetative growth period. Crude fiber content of tubers having 18 months or more maturity [18 MAP, 6.16 per cent; 21 MAP, 6.19 per cent and 24 MAP, 7.30 per cent] could be considered as a good competitor of other edible tubers for fiber content. Starch content and pH value recorded an inverse relationship (Figure 3.). pH value of milk yam tubers were acidic at all stages of tuber growth.

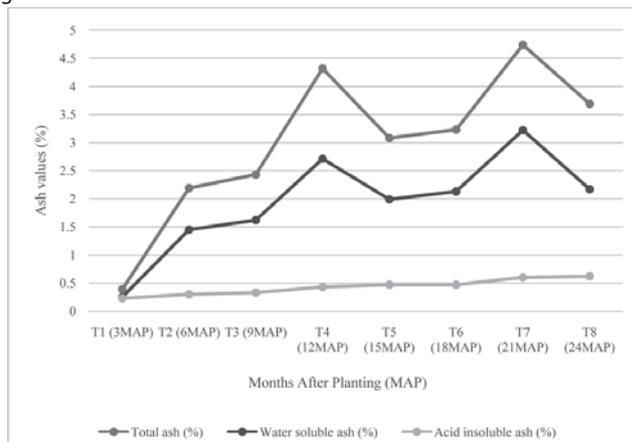


Figure 2. Change in ash value of milk yam tubers during different maturity stages of milk yam (*Ipomoea digitata* L.) tubers

Starch content found to increase during different stages of tuber growth except vegetative regrowth stages during 15 MAP (27.27 per cent) and 24 MAP (34.10 per cent) as a consequence pH value was vice versa. Starch content recorded from nine MAP onwards could meet the standards put forward by AYUSH (2006). Highest starch content was recorded during 21 MAP (39.17 per cent) and its pH value was 5.29. Optimum physical standards viz., minimum moisture (57.80 per cent), high total ash and water soluble ash (4.74 and 3.22 per cent respectively), high acid insoluble ash (0.60 per cent), optimally less crude fiber content (6.19 per cent), high starch (39.17 per cent) and pH value (5.29) were recorded to be optimum for tubers harvested at 21 MAP.

Extractive values of milk yam tubers during different stages of its growth analysed at tri-monthly intervals in different solvents viz., petroleum ether, chloroform, acetone, ethanol, methanol and water revealed that extractive value in polar solvents were higher compared to non-polar solvents. Maximum extractive value was recorded by water extracts (17.62 per cent) and the minimum was recorded by petroleum ether extracts (0.86 per cent). Extractive value was highest during 21 MAP (6.47 per cent) and the least was recorded during six MAP (5.60 per cent)

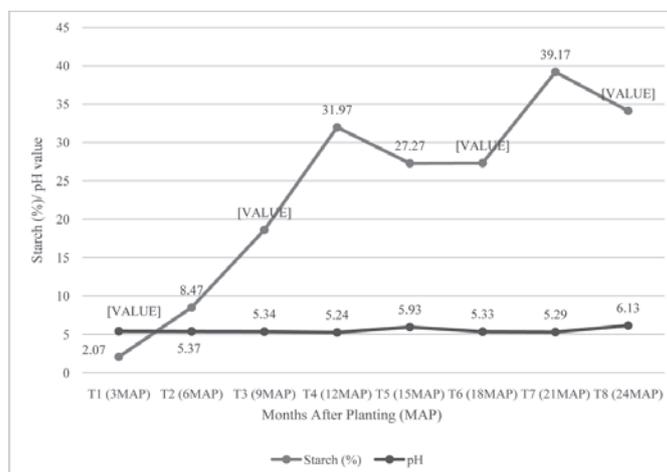


Figure 3. Change in starch content and pH value of milk yam (*Ipomoea digitata* L.) tubers during different maturity stages

Water soluble extractive of three month old tubers recorded the highest yield (23.04 per cent) and least was recorded by petroleum ether extracts of 12 MAP (0.66 per cent). Higher alcohol (ethanol+methanol) soluble extractive, 20.87 per cent

and lower water soluble extractive, 12.53 per cent recorded during 21 MAP (satisfy the standards of AYUSH, 2006) indicated the presence of more polar constituents like phenols, alkaloids, sterols etc. and less water soluble sugars. Hence, 21 MAP can be transiently considered as optimally mature.

Qualitative and quantitative estimation of phyto-constituents at trimonthly intervals revealed the presence of primary metabolites viz., carbohydrates, protein, fats and oils secondary metabolites viz., alkaloids, glycosides, flavonoids, saponins, phytosterols and resins. Primary metabolite concentration varied on maturity. Higher carbohydrate concentration was recorded during 12, 18, 21 and 24 MAP, protein was higher during 3 MAP and fats and oils were higher during 15 MAP. Highest carbohydrate content was observed during 21 MAP ( $68.25 \text{ g } 100 \text{ g}^{-1}$ ), protein content during three MAP ( $28.08 \text{ g } 100 \text{ g}^{-1}$ ), fats and oil content during 15 MAP ( $4.09 \text{ g } 100 \text{ g}^{-1}$ ). Carbohydrate and protein content found increasing on maturity except during 15 and 24 MAP as it were possibly used up for respiration during regrowth whereas fats and oil contents followed opposite pattern of accumulation during maturity. Optimum concentration of primary metabolites viz., higher carbohydrate ( $68.25 \text{ g } 100 \text{ g}^{-1}$ ), reasonably good protein content ( $6.63 \text{ g } 100 \text{ g}^{-1}$ ) and optimally low fats and oil content ( $0.81 \text{ g } 100 \text{ g}^{-1}$ ) were recorded during 21 MAP.

Secondary metabolites observed at varied concentration in milk yam tubers during different stages of its growth and development. Alkaloids, glycosides and saponins were higher at highly immature stage three MAP ( $1.45 \text{ mg AE g}^{-1}$ ,  $2.60 \mu\text{g g}^{-1}$  and  $7.14 \text{ mg DE g}^{-1}$ ). Alkaloids and glycosides decreased during the following vegetative and reproductive growth phases (six to twelve MAP) and shoot up with vegetative regrowth whereas saponin concentration decreased from six to nine MAP and raised during the reproductive growth phase (12 MAP,  $7.14 \text{ mg DE g}^{-1}$ ). Alkaloids followed the increment up to 18 MAP ( $1.35 \text{ mg AE g}^{-1}$ ) and reduced during the rest of the growth stages (21 MAP,  $0.83 \text{ mg AE g}^{-1}$  and 24 MAP,  $0.53 \text{ mg AE g}^{-1}$ ). Glycosides and saponins again rolled back during 18 ( $1.53 \mu\text{g g}^{-1}$ ) and 15 ( $6.03 \text{ mg DE g}^{-1}$ ) MAP onwards respectively and recorded a further increment during 24 ( $1.73 \mu\text{g g}^{-1}$ ) and 21 ( $9.50 \text{ mg DE g}^{-1}$ ) MAP respectively. Alkaloid concentration reported from 15-21 MAP were appreciably higher than the reported values. Cardiac glycoside content of milk yam tubers at all stages of maturity were within the safe limits and hence, older tubers harvested during 21 and 24 MAP could be considered as optimally mature. For higher saponin yields it was equally good to harvest at 21 or 24 MAP. Flavonoids found to increase from three to six ( $0.43\text{-}0.57 \text{ mg QE g}^{-1}$ ) MAP and decreased up to 18 MAP ( $0.52\text{-}0.32 \text{ mg QE g}^{-1}$ ) followed by a hike during 21 MAP ( $0.54 \text{ mg QE g}^{-1}$ ) and 24 MAP ( $0.58 \text{ mg QE g}^{-1}$ ). Hence, optimally mature tubers having high flavonoid concentration could be obtained during 21 ( $0.54 \text{ mg QE g}^{-1}$ ) and 24 ( $0.58 \text{ mg QE g}^{-1}$ ) MAP. Phytosterols found increasing all along the growth stages and reached maximum value during 24 MAP ( $1.45 \text{ mg g}^{-1}$ ). Higher phytosterols concentration might had favoured higher fiber production hence, optimum phytosterol yield was supposed to be obtained during 21 MAP ( $1.18 \text{ mg g}^{-1}$ ). Resin concentration was higher in milk yam tubers during vegetative growth phase (three to nine MAP and 15-18 MAP) and was lower during the reproductive and senescence stages (12 and 21 MAP). Optimum quantity of phytochemicals particularly, higher alkaloids, saponins and flavonoids ( $0.83 \text{ mg AE g}^{-1}$ ,  $9.50 \text{ mg DE g}^{-1}$  and  $0.54 \text{ mg QE g}^{-1}$  respectively), moderate glycosides and phytosterols ( $1.40 \mu\text{g g}^{-1}$  and  $1.18 \text{ mg g}^{-1}$  respectively) and low resins were recorded by tubers harvested during 21 MAP and hence, tentatively selected as optimally mature.

Morphological, anatomical and phytochemical investigations of milk yam tubers during its growth stages at regular intervals revealed that milk yam tubers were optimally mature at 21 MAP. Milk yam tubers of 21 MAP were having more than two (2.33) number of tubers; length, 29.50 cm; breadth, 21.90 cm; fresh tuber yield  $\text{plant}^{-1}$ , 983.33 g and dry tuber yield  $\text{plant}^{-1}$ , 414.97 g.

Optimally mature milk yam tubers (21 MAP) was compared with immature (six MAP) and over mature (36 MAP) tubers for the quantity of bio-active compound Umbelliferone using HPLC (Table 1.) and HPTLC (Table 2.) analytical tools. HPLC and HPTLC techniques revealed the presence of Umbelliferone in all the tuber samples and it was quantified to be higher in over mature tubers ( $0.44$  and  $0.42 \mu\text{g g}^{-1}$  respectively), followed by optimally mature ( $0.31$  and  $0.22 \mu\text{g g}^{-1}$  respectively) and immature tubers ( $0.20$  and  $<0.11 \mu\text{g g}^{-1}$  respectively).

**Table 1. HPLC quantification of Umbelliferone in milk yam (*Ipomoea digitata* L.) tubers of different maturity stages**

Milk yam tuber sample	Retention time(minutes)	Area(mV.s)	Area(per cent)	Amount( $\mu\text{g g}^{-1}$ )
Standard	1.88	1565828	100.00	-
Immature tuber	1.83	630183	72.29	0.20
Optimally mature tuber	1.84	972683	87.48	0.31
Over mature tuber	1.84	1363514	93.19	0.44

**Table 2. HPTLC quantification of Umbelliferone in milk yam (*Ipomoea digitata* L.) tubers of different maturity stages**

Milk yam tuber sample	Retention time(minutes)	Area (AU)	Area(per cent)	Amount(ig g <sup>-1</sup> )
Standard	0.48	-	-	-
Immature tuber	0.47	7770.70	100.00	<0.11
Optimally mature tuber	0.47	10319.60	100.00	0.22
Over mature tuber	0.48	12436.30	100.00	0.42

GC-MS profiling of the bio-active compounds present in optimally mature (21 MAP) milk yam tubers revealed the presence of sixteen compounds including five hydrocarbons, three fatty alcohols, three fatty acid esters, two fatty acids, one phenol, one aldehyde and an amide (Figure 4.). The hydrocarbons identified were, 1-Hexadecene; 1-Nonadecene; Cyclotetracosane; 10-Heneicosene (c,t) and 2,6,10,14,18,22-Tetracosahexaene, 2,6,10,15,19,23-hexamethyl-, (all-E)- or Squalene. 9-Octadecen-1-ol, (Z)- or Oleyl alcohol; 1-Eicosanol and 1-Octadecanol or Sipol S or Stearyl alcohol were the fatty alcohols. 9-Octadecenoic acid (Z)-, methyl ester; 1, 2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester and cis-4,7,10,13,16,19-Docosahexaenoic acid, trimethylsilyl ester were the fatty acid esters. Octanoic acid or Caprylic acid and Decanoic acid or Sebacic acid were the two fatty acids identified. 2-tert-Butyl-4-isopropyl-5-methylphenol; E-15-Heptadecenal and Octanamide were the identified phenol, aldehyde and amide compounds respectively. Among these phytochemicals, 2-tert-Butyl-4-isopropyl-5-methylphenol was abundantly present (8.03 percent). E-15-Heptadecenal and 1-Nonadecene were also found in higher amounts (4.94 and 4.31 percent respectively), all other compounds followed it and 9-Octadecen-1-ol, (Z)- or Oleyl alcohol identified as scarce (0.39 percent).

Pharmacological properties viz., *in vitro* antioxidant activity (DPPH radical scavenging activity, nitric oxide radical scavenging activity and reducing power) and *in vitro* anti-diabetic activity of immature (six MAP), optimally mature (21 MAP) and over mature tubers (36 MAP) of milk yam significantly varied among themselves. DPPH radical scavenging activity and nitric oxide radical scavenging activity of optimally mature milk yam tubers recorded least IC<sub>50</sub> values,

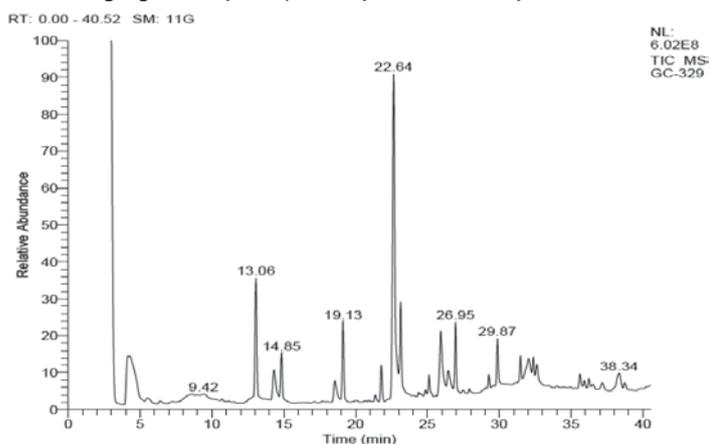


Figure 4. A typical Gas Chromatogram of methanolic crude extract of mature milk yam tubers

1040.00 µg ml<sup>-1</sup> and 355.00 µg ml<sup>-1</sup> respectively. Reducing power of optimally mature milk yam tubers observed as absorbance at 400 µg ml<sup>-1</sup> concentration was 0.118 nm. Dominant *in vitro* anti-diabetic activity measured as alpha amylase inhibition activity of milk yam tubers were recorded by aqueous extracts, 89.40 per cent and over mature tubers, 88.70 per cent. Ethanolic extract of optimally mature tubers recorded superior *in vitro* anti-diabetic activity (99.20 per cent). Cost incurred for cultivating milk yam cuttings in a single polybag under organic management for a period of twenty four months was calculated as ₹ 158.20/-.

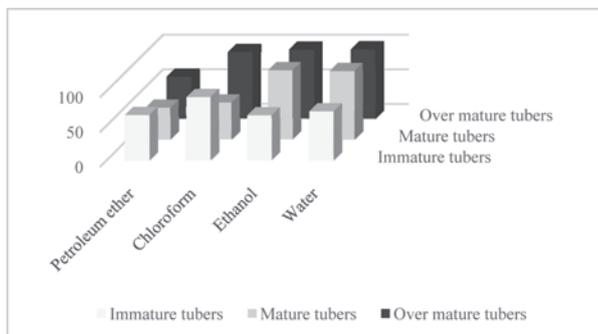
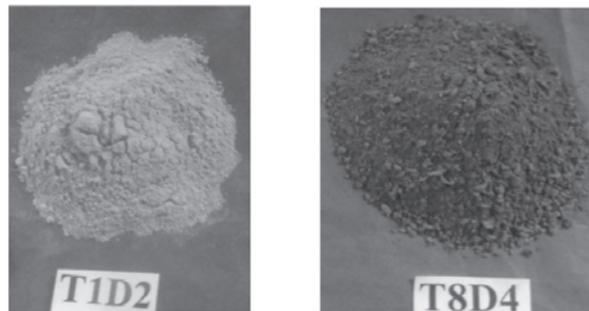


Figure 5. Alpha amylase inhibition activity of milk yam (*Ipomoea digitata* L.) tuber extracts

**Nutrient analysis and protocol development for nutritional supplements**

Physical, nutritional and sensory quality parameters of milk yam tuber powder prepared by adopting several pre-treatments viz., peeling and non-peeling the tubers and washing the tuber shreds (three times, two times, single time and no washing) and drying it by sun drying or oven drying at 60 °C, 70 °C and 80 °C varied significantly among themselves. Milk yam powder prepared using peeled tuber shreds washed for three times recorded moderate yield (21.23 per cent), high moisture (7.19 per cent), drying time (14.13 hours) and crude fiber (7.08 g 100 g<sup>-1</sup>) content. Carbohydrate, vitamin A and vitamin C content were maximum for non-peeled and non-washed tuber shreds, 60.47 g 100 g<sup>-1</sup>, 8.58 g 100 g<sup>-1</sup>, 476.67 µg 100 g<sup>-1</sup> and 5.18 mg 100 g<sup>-1</sup> respectively. High protein content was recorded by peeled tuber shreds washed for two times (9.50 g 100 g<sup>-1</sup>). Minerals viz., calcium, iron and sodium content in milk yam tuber powder were not affected by the pre-treatments applied. Maximum ash content was recorded by non-peeled tubers washed for single time, 5.26 g 100 g<sup>-1</sup>. Hot air drying at 60 °C recorded least moisture content (6.15 per cent), moderate drying time (11.29 hours), moderate yield (21.18 per cent), high carbohydrate, protein, vitamin A and vitamin C (57.07 g 100 g<sup>-1</sup>, 11.63 g 100 g<sup>-1</sup>, 588.33 µg 100 g<sup>-1</sup> and 7.23 mg 100 g<sup>-1</sup> respectively). Peeling of tubers resulted significantly less carbohydrate (50.98 g 100 g<sup>-1</sup>) and vitamin A (436.98 µg 100 g<sup>-1</sup>) than the non-peeled ones. Crude fiber, ash and mineral content didn't affect by drying methods adopted. Milk yam tuber powder prepared using peeled and three times washed tuber shreds, dewatered by keeping in bamboo basket and dried in hot air oven at 60 °C (T<sub>1</sub>D<sub>2</sub>) recorded least moisture content (4.60 per cent), moderate yield (23.27 per cent), moderate time period for drying (12.33 hours), moderate carbohydrate (50.82 g 100 g<sup>-1</sup>), high protein (4.04 g 100 g<sup>-1</sup>), high vitamin A and vitamin C (613.33 µg 100 g<sup>-1</sup> and 7.43 mg 100 g<sup>-1</sup> respectively). Fats and oil, crude fiber, ash, calcium, iron and sodium content of T<sub>1</sub>D<sub>2</sub> were 1.33 g 100 g<sup>-1</sup>, 7.13 g 100 g<sup>-1</sup>, 3.56 g 100 g<sup>-1</sup>, 136 mg 100 g<sup>-1</sup>, 4.95 mg 100 g<sup>-1</sup> and 25.33 mg 100 g<sup>-1</sup> respectively. Milk yam tuber powder prepared by adopting the treatment combination T<sub>1</sub>D<sub>2</sub> recorded superior overall visual quality (288.55) too (Plate 3. A. & B).

Nutrient composition of T<sub>1</sub>D<sub>2</sub> (100 g) was higher than that of the fresh milk yam tubers (100 g) whereas anti-nutrient components viz., tannins, phytic acid, oxalates and trypsin inhibitor were less than the fresh ones. Fresh milk yam tubers (100 g) when processed to milk yam tuber powder using the standardized protocol yielded only 24.30 g. Hence, on drying the fresh tubers



A. Milk yam tuber powder scored excellent OVQ B. Milk yam tuber powder scored bad OVQ

Plate 3. Milk yam tuber powder scored (a) excellent OVQ and (b) bad OVQ

(100 g) energy, carbohydrate, protein, fats and oil, crude fiber, ash, calcium, sodium, iron, vitamin A and vitamin C got reduced by 62.41 per cent, 34.60 per cent, 47.11 per cent, 64.00 per cent, 49.43 per cent, 33.46 per cent, 58.04 per cent, 78.53 per cent, 48.02 per cent, 31.40 per cent and 38.10 per cent respectively (Figure 6). By adopting the standardized protocol, fresh milk yam tubers (100 g) when made into dried powder (24.30 g), anti-nutrients viz., tannins, phytic acid, oxalates and trypsin inhibitor got reduced by 69.84 per cent, 81.02 per cent, 94.69 per cent and 86.83 per cent respectively.

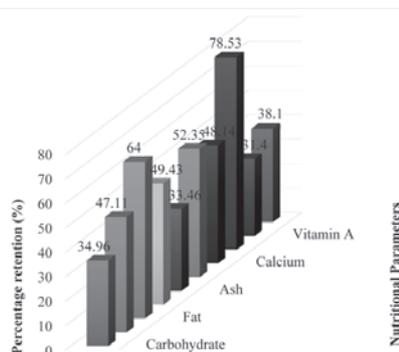


Figure 6. Percentage retention of nutrients in milk yam (*Ipomoea digitata* L.) tuber powder

Out of the twenty two standard amino acids, eighteen amino acids were estimated from one gram milk yam tuber protein and it included nine essential amino acids (150.62 mg), three non-essential amino acids (75.80 mg) and six conditional amino acids (85.21 mg). Valine (32.96 mg), leucine (28.90 mg), phenyl alanine (20.90 mg), threonine (19.29 mg), isoleucine (17.68 mg), lysine (16.08 mg), histidine (8.04 mg), methionine (5.63 mg) and tryptophan 1.10 mg) were the essential amino acids. Milk yam tuber powder could meet 57.18 per cent and 51.62 per cent RDA of total essential amino acid uptake for adults (>18 years) and children (one to two years) respectively. It could contribute 40.23 per cent RDA of sulphur containing amino acids (Meth+Cys) uptake of adults. Milk yam tuber powder could satisfy 35.73 per cent and 30.92 per cent RDA of lycine as well as 18.33 per cent and 14.86 per cent RDA of tryptophan, the two essential amino acids which are limiting in cereals.

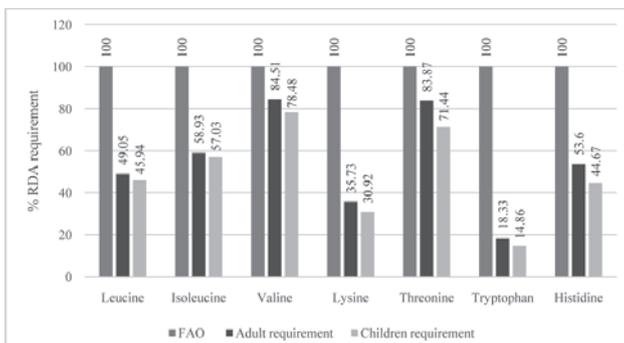


Figure 7. Percentage RDA of essential amino acids contributed by milk yam (*Ipomoea digitata* L.) tuber powder

Nutritive value of composite flour made out of milk yam, ragi, ground nut and green gram in various proportions viz., T<sub>1</sub> (50: 20: 10: 10), T<sub>2</sub> (45: 25: 10: 10), T<sub>3</sub> (40: 30: 10: 20), T<sub>4</sub> (30: 30: 10: 30) and T<sub>5</sub> (35: 25: 10: 30) recorded maximum amino acid score for tryptophan. Lysine was found limiting (chemical score) in all the samples except T<sub>4</sub> and T<sub>5</sub>. Net Dietary Protein Calories per cent was higher for T<sub>4</sub> than the other composite flours. Porridge made using T<sub>4</sub> was supported with high sensory quality attributes viz., colour (45.20), odour (45.50), consistency (43.35), mouth feel (45.40), taste (45.35) and over all acceptability (45.20) too (Plate 4).

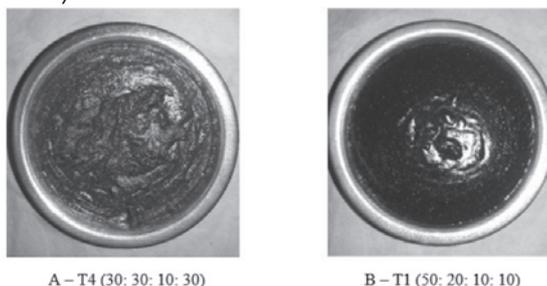


Plate 4. Porridge scored superior (A) and inferior (B) sensory quality attributes

Nutritional profile of the composite flour (30 milk yam: 30 ragi: 10 ground nut: 30 green gram) could sufficiently meet RDA of an adult man (>51 years). Higher protein (15.45 ± 0.13 g 100 g<sup>-1</sup>), fat (3.27 ± 0.36 g 100 g<sup>-1</sup>), calcium (186.63 ± 2.22 mg 100 g<sup>-1</sup>), iron (12.21 ± 0.61 mg 100 g<sup>-1</sup>), less carbohydrate (58.78 ± 1.00 g 100 g<sup>-1</sup>) and sodium content (28.27 ± 0.06 mg 100 g<sup>-1</sup>) along with similar energy value (333.84 ± 1.49 kcal) than the commercial product Quaker Oats Plus indicated the superiority of milk yam dietary supplement (MYDS). Crude fiber, ash, vitamin A, vitamin C and moisture content of the developed dietary supplement were, 4.27 ± 0.40 g 100 g<sup>-1</sup>, 5.54 ± 0.29 g 100 g<sup>-1</sup>, 333.27 ± 2.98 µg 100 g<sup>-1</sup>, 2.35 ± 0.13 mg 100 g<sup>-1</sup> and 10.10 ± 0.35 per cent respectively (Figure 8).

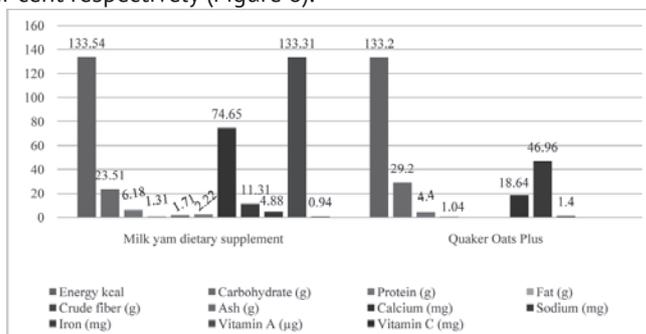
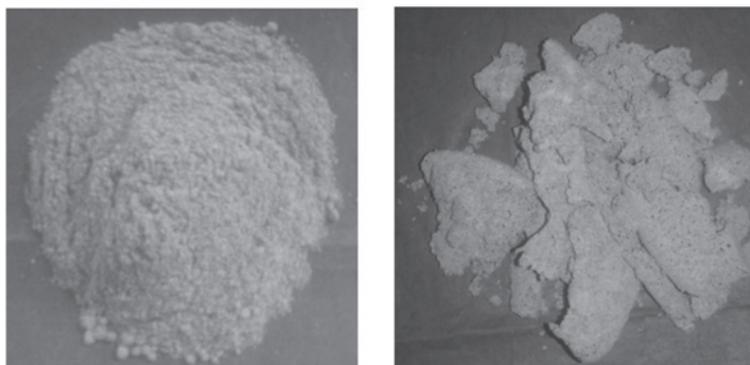


Figure 8. Nutrient composition of one serving size (40 g) of milk yam (*Ipomoea digitata* L.) dietary supplement versus commercial product

Milk yam dietary supplement (MYDS) packaged in different packaging materials viz., LDPE covers, PP covers, aluminium foil covers and PET containers and stored under ambient and refrigerated storage conditions recorded significant difference in physical, chemical, microbial and sensory quality parameters. Packaging material used, storage conditions adopted as well as their interactions significantly influenced moisture content, peroxide value, fungal population and bacterial population of MYDS during three MAS. During three MAS, MYDS packaged in aluminium foil covers recorded least moisture content (12.20 per cent), peroxide value (9.48 meq.O<sub>2</sub> kg<sup>-1</sup>), fungi (3.92 x 10<sup>5</sup> cfu g<sup>-1</sup>) and bacterial population (10.67 x 10<sup>7</sup> cfu g<sup>-1</sup>). Among the storage condition used during three MAS, MYDS stored under refrigeration recorded least moisture content (11.90 per cent), peroxide value (9.11 meq.O<sub>2</sub> kg<sup>-1</sup>), fungi (2.33 x 10<sup>5</sup> cfu g<sup>-1</sup>) and bacterial population (10.67 x 10<sup>7</sup> cfu g<sup>-1</sup>). MYDS packaged in aluminium foil covers and stored under refrigeration recorded least moisture content (10.93 per cent), peroxide value (7.73 meq.O<sub>2</sub> kg<sup>-1</sup>), fungi (0.67 x 10<sup>5</sup> cfu g<sup>-1</sup>) and bacterial population (1.00 x 10<sup>7</sup> cfu g<sup>-1</sup>) moreover, it scored highest overall visual quality (65.00) (Plate 5).



(A) Aluminium foil packaging and refrigerated storage

(B) PET packaging and ambient storage

Plate 5. Milk yam dietary supplement scored superior (A) and inferior (B) sensory quality three months after storage

Cost of production of one kilogram milk yam dietary supplement using the composite flour of milk yam: ragi: ground nut: green gram (30: 30: 10: 30) was calculated as 192.50/-.

15. Technology or academic findings generated:

- Milk yam tubers of optimum quality (morphology, anatomy, proximate characteristics) can be obtained when harvest at 21 MAP.
- Phytochemical profile using methanolic crude extract of optimally mature milk yam tubers revealed 16 bio-active compounds.
- Optimally mature tubers (21 MAP) have superior pharmacological characteristics (anti-oxidant and anti-diabetic activity).
- Milk yam tuber powder can be prepared using peeled tuber shreds, washed three times and dried in hot air oven at 60 °C.
- Milk yam dietary supplement with superior nutritional value and sensory quality can be prepared by adding milk yam powder with ragi, ground nut and green gram in the ratio 30: 30: 10: 30
- MYDS packaged using aluminium foil covers and stored under refrigeration had better shelf stability up to three months.

## 2. Evaluation and characterisation of promising hybrids of long pepper (*Piper longum* Linn.)

This project was carried out by Sruthy K under the guidance of Dr.Sujatha.V.S, at the Department of Plantation Crops and Spices, College of Horticulture.

The study entitled 'Evaluation and characterisation of promising hybrids of long pepper (*Piper longum* L.) was done with the objective of evaluating four promising hybrids in pots under different shade levels, evaluation of their performance in field condition and characterisation of hybrids along with the parents using molecular markers. The experiments on evaluation of the hybrids were laid out at Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara and characterisation was conducted at the Department of Plant Biotechnology, College of Agriculture, Padannakkad. The findings of the investigation are summarised below.

Variations were observed in vegetative and reproductive characters of *Piper longum* genotypes grown in pots under different shade levels. Spike orientation was erect in all the accessions studied.

Significant variation was observed among hybrids at different shade levels for vegetative characters like plant height,

number of primary branches per plant and time taken for production of first lateral. Variation was also observed in yield attributes like number of spikes per plant and fresh and dry weight of spikes per plant.

Flowering and fruiting were higher at zero per cent and 25 per cent shade compared to 50 per cent shade level. At zero per cent shade, Pl 9, Pl 63 and Pl 140 were on par with respect to number of spikes per plant and fresh spike yield (g) per plant. For dry spike yield, Pl 9 (7.37 g) and Pl 63 (8.14 g) were on par.

At 25 per cent shade, significant difference was observed among hybrids in number of spikes per plant. Pl 140 and Pl 63 were on par with respect to number of spikes per plant. Maximum fresh yield of spikes was for Pl 140 (12.06 g) followed by Pl 9 (5.79 g). For dry spike yield, Pl 9 (0.95 g), Pl 63 (1.05 g) and Pl 140 (2.01 g) were on par. However, at 50 per cent shade, yield was maximum in Pl 9 (1.10 g dry spike yield). Yield was higher at lower shade level (zero per cent) compared to higher (25 per cent and 50 per cent).

At zero per cent shade, Pl 9 showed maximum oleoresin (15.2 per cent) and piperine (3.47 per cent). Essential oil was uniform (0.8 per cent) in all genotypes except Pl 140 (0.83 per cent). At 25 per cent shade Pl 140 had maximum essential oil (0.86 per cent) and oleoresin (9.23 per cent).

Significant variations were observed among field planted *P. longum* genotypes in number of primary branches, internodal length of orthotropic as well as plagiotropic shoots and leaf area. Maximum vine length was observed in female parent (221.75 cm). Viswam produced maximum number of primary branches per plant (31.67). Hybrids Pl 9 and Pl 63 produced maximum number of laterals per plant (45) compared to all other genotypes studied. Characters like pedicel length, spike length, spike girth and yield in terms of number of spikes per plant, fresh weight per plant and dry spike yield per plant also differed significantly. Hybrid Pl 9 produced maximum yield (44.87 g fresh spike per plant) followed by Pl 63 (30.57 g fresh spike per plant). Hybrids Pl 9 and Pl 63 were statistically on par with respect to number of spikes per plant and dry spike yield. Number of laterals and number of spikes per lateral branch had highly significant correlation with yield. Correlation analysis revealed that number of primary branches per plant and spike length also had significant influence on yield.

Among the four promising hybrids evaluated, Pl 9 followed by Pl 63 were found to be more promising as they were significantly higher yielders compared to other hybrids, female parent and Viswam.

In field, high variability with respect to quality characters such as oleoresin and piperine content was observed. Essential oil content was uniform (0.8 per cent) in all accessions except Pl 140 (0.83 per cent). Maximum oleoresin and piperine content were recorded in Pl 9. Pest like papaya mealy bug and diseases like leaf spot and fusarium wilt were observed in field. However, the attack was not severe.

Characterisation of the four selected accessions of *Piper longum* along with parents and Viswam was done using RAPD markers. Among thirty decamer primer screened, ten primers showed difference all other hybrids whereas it was found to be closer to the parents than others.

### 3. Evaluation of Neikumbalam (*Benincasa hispida* Thunb.) collections for yield and quality

Ash gourd [*Benincasa hispida* (Thunb.) Cogn.] is a member of the family Cucurbitaceae which is mainly grown for its fruits. *Vaidyakumbalam* or *neikumbalam* is a specific ecotype of ashgourd in Kerala with hard pulp, long keeping quality and size slightly larger than a cricket ball. It is the principal ingredient used in the preparation of the Ayurvedic medicine "*Kooshmanda rasayanam*" and "*poosanilehyam*", a similar preparation made by the Siddha medicine physicians. The availability of this special type of ash gourd is scarce at present. And, not much is known about the morphology and biochemistry of *neikumbalam*. The present study has been undertaken in this context.

Sixteen types of *neikumbalam* (medicinal ash gourd) were collected from different locations in Southern, Central and Northern Kerala. These were evaluated along with a vegetable ash gourd variety 'Indu' used as check, for various morphological, yield, fruit, seed and biochemical characters.

Morphological characters were recorded at four growth stages, viz. pre-flowering, flowering, fruiting and harvest. Medicinal ash gourd accessions were less vigorous in growth, producing lower number of branches and leaves and smaller leaves when compared to the vegetable ash gourd variety 'Indu'. Among the *neikumbalam* types, highest vine length was recorded in BH 11 at all the four growth stages (172.85 cm, 212.55 cm, 245.84 cm and 289.46 cm respectively). The leaf area among the accessions ranged from 67.16 cm<sup>2</sup> to 158.8 cm<sup>2</sup>.

With respect to flowering, a few of the *neikumbalam* accessions recorded early opening of both male and female flowers. The accessions BH 13, BH 14, BH 15 and BH 16 were early in female flower opening and also produced female flowers at lower nodes than other accessions. The first female flower was produced at a lower node (4.75) in the accession BH 13. Also, all *neikumbalam* accessions had a sex ratio lesser than the check variety 'Indu' (9.37). The lowest sex ratio was recorded in BH 2 (3.5).

With respect to yield characters, the medicinal ash gourd accession BH 7 produced highest number of fruits per plant than other accessions and the check variety 'Indu'. However, due to low single fruit weight (1250 g in BH 7), the yield per plant was less in medicinal ash gourd than 'Indu' in which the individual fruit weight was significantly high (2380 g). There was variation in the number of days taken for fruit maturity and crop duration among the medicinal ash gourd accessions. The crop duration ranged from 102.66 days to 153 days.

Variability was observed in all the qualitative fruit characters studied. Oblong, spherical and conical shaped fruits were observed. The check variety 'Indu' also produced oblong fruits. The intensity of hairiness and waxiness varied among the accessions and they were categorized as low, medium and high. There was variation in rind colour also among the accessions, viz. dark green, bright green, yellowish green and light green. The keeping quality of fruits ranged from 6 weeks to 11 weeks under ambient conditions.

Fruit size exhibited variation among the accessions. The fruits of medicinal ash gourd were significantly smaller in size and lesser in weight (349 to 1250 g) than vegetable ash gourd fruits. Rind thickness was significantly lower in the medicinal ash gourd accessions than the check variety 'Indu'. The *neikumbalam* fruits also recorded significantly less flesh thickness and major part of the fruit volume was occupied by seeds.

Seeds of *neikumbalam* were small compared to Indu, the check. However, most of the *neikumbalam* accessions recorded more number of seeds per fruit (739 seeds in BH 7) than 'Indu' (523 seeds). Weight of seed coat, seed kernel and hundred seed weight were significantly less in *neikumbalam* accessions. Seeds of all accessions and the check variety 'Indu' recorded more than 96 % viability after two months.

Fully mature fruits were screened for various phytochemicals after which they were subjected to biochemical estimation. Most of the biochemical characters showed variation among the accessions. Acidity in fruits of *neikumbalam* was significantly higher than the vegetable ash gourd. Protein content and total sugar content in the *neikumbalam* accessions were significantly lower than that in the check variety 'Indu'. But, the *neikumbalam* collections recorded high amount of free amino acids which is an indication of the rejuvenating property of the fruits. Total phenol content and tannin content showed significant variation among the accessions. But a definite pattern could not be drawn between the *neikumbalam* accessions and the check 'Indu'. The ethanolic extract of *neikumbalam* fruits exhibited significantly high antioxidant activity (1.315 to 2.595) than the check variety 'Indu' (1.109) as indicated by the IC 50 value.

Results of the present study indicate that this unique type of ash gourd is morphologically different from the vegetable type ash gourd in growth pattern, flowering nature, fruiting and yield characters. *Neikumbalam* which is considered as a *medhya* (rejuvenating) drug contained higher amount of free amino acids and had high antioxidant activity. This might be one of the factors responsible for its reported medicinal properties.

#### **4. Influence of storage environment and packing materials on seed germination and viability of *Desmodium gangeticum* (L.) dc. and *Indigofera tinctoria* (L.)**

All the seed quality parameters were significantly influenced by the individual treatments of moisture levels, packing materials and storage environments and by the combined interaction of these three factors except seedling fresh weight, seedling dry weight and 1000 seed weight at some weeks after storage.

Seeds of 8% moisture content recorded higher germination percentage for both crops, higher seedling root length and shoot length for *Indigofera tinctoria*. Among the packing materials, polythene bag stored seeds of *Desmodium gangeticum* showed higher thousand seed weight, germination and seedling shoot length at the same time cloth bag stored *Indigofera tinctoria* seeds recorded higher thousand seed weight, germination and seedling root length. Seeds stored under refrigerated condition showed higher thousand seed weight, germination percentage, seedling root length and seedling shoot length for both crops.

Significant positive and negative relationships were observed due to the influence of weather parameters (maximum temperature, minimum temperature and relative humidity) on seed quality. Maximum temperature and relative humidity showed a positive relationship with majority of the seed quality parameters except seedling fresh weight of *Indigofera*

*tinctoria* and seed moisture content of *Desmodium gangeticum*. Most of the seed quality parameters (thousand seed weight, seed moisture content, germination percentage, seedling shoot length and seedling fresh weight) were negatively influenced by minimum temperature.

Results of the investigation implies that, to enhance the germination of seeds over a period of 12 weeks of storage it is better to dry the seeds to 8% moisture content and pack in polythene bags for *Desmodium gangeticum* seeds, cloth bags for *Indigofera tinctoria* seeds and store under refrigerated environment.

# **Name of Project Coordination Group – (08) Biotechnology, Biochemistry, Plant Physiology**

**Compiled by:**

**Dr. M.R. Shylaja, Project Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects- 3 Nos.**

**Ongoing Projects - 2 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 38 Nos.**

**Ongoing Projects - 76 Nos.**

## Concluded Projects

### Biotechnology

#### 1. Metabolome analysis in ginger and product development using gingerol

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The project on PPP mode was officially launched at KAU on 18<sup>th</sup> August 2014 with participation of KAU- Arjuna Natural Extracts Ltd., Alwaye (ANEL) and DBT-BIRAC, New Delhi. The major activities in the project were gingerol product development using already identified high gingerol yielding somaclones, stability studies for retention of gingerol in the product, analysis and separation of 6-gingerol from other gingerols, detailed animal toxicity studies of the extract and screening somaclones for gingerol content.

Kerala Agricultural University, Thrissur in association with Arjuna Natural Extracts Ltd., Aluva with DBT-BIRAC funding has developed a stable gingerol product with 8 per cent total gingerol from already identified high gingerol yielding somaclones of KAU with stability of gingerol for a period of one year. Provisional Indian patent number received for the stable gingerol product developed from the high gingerol yielding variety Karthika. Acute and subchronic toxicity studies of the developed product in animal models showed that there were no adverse effects for the product. 6-gingerol could be separated from total gingerols using silica gel column with a mixture of dichloromethane and hexane. 6-gingerol was found stable in nitrogen atmosphere at low temperature. Screening new set of somaclones (210 Nos. regenerated through indirect organogenesis/ embryogenesis and *in vitro* mutagenesis) for gingerol content for three years could locate ten clones of Maran and twelve clones of Rio de Janeiro with high gingerol recovery of >15g/kg ginger powder. When yield and quality parameters were taken into consideration, nine clones with high gingerol recovery of >15g/kg could be located. Two somaclones were the highest yielders recording >22 percent total gingerol. Four somaclones of the new set (CPBMB161, 162, 163, 164) could be advanced up to plant batch trials and recorded the same recovery of gingerol as that of variety Karthika in plant batch. Evaluation of aroma constituents in selected high gingerol yielding clones could locate three clones (CPBMB 176, 166 and 182) with high aroma constituents. Kerala Agricultural University, Thrissur in association with Arjuna Natural Extracts Ltd., Aluva with DBT-BIRAC funding has developed a stable gingerol nutraceutical product with 8 per cent total gingerol from already identified high gingerol yielding somaclones of KAU with stability of gingerol for a period of one year. Provisional Indian patent number received for the stable gingerol product developed from the high gingerol yielding variety Karthika.

#### 2. Molecular characterisation of spike branching trait in black pepper (*Piper nigrum* L.)

Dr.Swapna Alex  
Assoc.Professor

The objectives were to identify and functionally characterize the genes conferring spike branching trait in black pepper. Morphological, biochemical, hormonal and molecular analyses of spike branching trait and to hybridise 'Pepper Thekken' with Panniyur variety for transfer of spike branching trait. In this study Three nucleotide sequences related to Floral architecture isolated from branching type black pepper were isolated and the sequences were deposited in GenBank (Accession Numbers: KX518738-KX518740). Identification of Integrase Core Domain within the homologous sequence of *ra 3* gene in black pepper type 'Thekken', suggests a possible role of retroviral integration in differential expression. Study reveals possible role of *pin1* gene through auxin regulation in spike branching.

#### 3. Molecular marker aided selection for novel traits in Komadan coconut palms

Dr.Jayalekshmi  
Professor

The objectives of the study were identification of a molecular marker for detection of Komadan cemicaracters in Komadan mother palms, evaluation of the segregating progenies from the crosses with Komadan as a parent for analyzing the segregation of Komadan traits, molecular analysis of the segregating population to confirm the marker, along with the long-term objective to evaluate the hybrids with Komadan as a parent. 135 hybrid seedlings developed from the crosses with Komadan as one of the parent in four combinations (Komadan X WCT, WCT X Komadan, Komadan X CGD, Komadan selfing) were planted for long term evaluation. RAPD analysis of the hybrids from the four cross combinations was done with five identified polymorphic primers OPC20, OPP3, OPP2, OPP5, OPA5 and OPD3. SSR analysis of the parents and hybrids with 4 SSR primers (CNZ1, CAC10, CnCirH4 and CnCirG11) with specific marker for komadan was done. SCAR marker specific to Komadan was developed from the polymorphic RAPD marker OPC20 and was used for screening the

hybrids. The hybrids showed polymorphism for the molecular markers studied. Marker analysis showed segregation of Komadan specific markers in the hybrids. The seedlings from Komadan selfing did not show any genetic variation in the molecular analysis suggesting homozygous nature due to predominant selfing of Komadan palms. Screening of the hybrids with the Komadan specific SCAR marker showed that 50 per cent of the hybrids showed the presence of marker specific for Komadan.

## Ongoing Projects

### Biotechnology

#### 1. Centre of Excellence in Biotechnology and Secondary Agriculture at CPBMB

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Research on centre of excellence and secondary agriculture focused on development of regeneration protocols in recalcitrant species like coconut and nutmeg, gender identification in nutmeg through molecular marker analysis, *In silico* screening and molecular docking of compounds from nutmeg, pepper, pineapple against major diseases. For coconut embryo culture, better response was observed in Y3 medium supplemented with different levels of auxins and cytokinins. Bulging of embryos and germination started in few cultures. Out of 848 embryos inoculated, 172 embryos showed bulging. Trials on somatic embryogenesis using plumular region is in progress. Of the 42 media combinations tried for multiple shoot induction in nutmeg, multiple shoots could be observed in two cultures @ 2 shoots/culture in SH medium supplemented with BA, NAA and Casein Hydrolysate. RAPD primer OPBD 20 gave polymorphic band in female plants. Further validation of the primer and development of scar marker are in progress. Identified eight phyto compounds (Malabaricone B, Butylformate, Vanillin, Cymenol, Pellitorine, Coumaperine, Undecanone and Methyl octanate) from the crops studied against diabetes which passed ADMET analysis and eight phyto compounds (Vanillin, Theobromine, Malabaricone B, Cymenol, Undecanone, Coumaperine, Pellitorine, and Methyl cinnamate) against cancer which passed ADMET analysis. Docking studies of compounds of pineapple, nutmeg and black pepper against receptor proteins for arthritis and cardiovascular diseases are in progress.

#### 2. Commercial micropropagation of high demand high value crops as per National Certification System for Tissue Culture Plants (NCSTCP)

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The project aimed at developing a well designed commercial micropropagation unit at CPBMB as per NCSTCP, advanced facility for virus indexing at CoA, Vellayani, well designed micropropagation facilities at four satellite centres (BRS Kannara, RRS Vyttila, RARS Pattambi and CoA Padanakkad), operational capacity building of the units in a revolving fund mode at later stages, need based development of micropropagation protocols on new high demand crops and refinement of already developed protocols for commercial application, capacity building of entrepreneurs on commercial plant tissue culture, virus indexing and clonal fidelity testing. Establishing demonstration plots of tissue culture derived plants at lead and satellite centres are also aimed in the project.

During the period, project was in operation at eight network centres. The production of TC plants was continued at different centres in RF mode. The allotted fund @ Rs. 0.5 to 1.25 lakhs/centre was utilized for purchase of research materials/meeting labour wages. During 2017-18, 3.7 lakhs TC plants were produced in various centres generating an income of Rs. 72.00 lakhs.

## PG Projects

### Concluded Projects

#### 1. Validation of apomixis and transcriptome analysis for detection of the genes related to apomixis in black pepper (*Piper nigrum* L.)

The objectives of the study were to validate apomixis in black pepper varieties Panniyur-1 and Panniyur-2 through controlled pollination studies and to identify differentially expressed genes associated with apomixis through transcriptome analysis.

Studies were conducted on bush pepper plants of the selected varieties viz., Panniyur-1 and Panniyur-2 and floral biology was studied. In Panniyur-1 and Panniyur-2 the active female and male phase was separated by 10 and 8 days, respectively.

Attempts were made to confirm apomixes by allowing berry development in controlled condition by bagging of spike initials. Berry development occurred under bagged condition. Upper six berries were considered as apomictic and lower six berries were considered as pollinated. *In vitro* embryo culture resulted in embryo germination and multiple shoot induction in SH medium with hormones. *Ex vitro* germination of seedlings were carried out. Histological examination results revealed that in case of pollinated berries, the sexual fertilization occurs and embryo develops inside the embryo sac in the micropylar end. So, it can be concluded that facultative apomixes exists in black pepper varieties P1 and P2 and the embryo developed parthenogenetically. The molecular characterization of apomictic and non-apomictic seedlings was done through Inter Simple Sequence Repeats (ISSR) and Simple Sequence Repeats (SSR) assay. In ISSR and SSR assay certain primers showed polymorphism among mother plant, apomictic and pollinated progenies. RNA mediated transcriptome analysis of the apomictic and pollinated berries was done for identification of genes. The sequence analysis showed homology to NADH dehydrogenase subunit J, acetyl-CoA-benzylalcohol, acetyltransferase and purine permease 4.

## **2. Metabolite profiling and gene expression analysis for gingerol production in selected somaclones of ginger (*Zingiber officinale* Rosc.)**

The investigation aims to completely profile the metabolites in selected ginger somaclones using high throughput analytical platforms and to analyse the gene expression with respect to gingerol production in selected somaclones. Metabolite profiling of selected somaclones was completed and gene expression analysis for gingerol production is in progress. Clone to clone variation was observed in the number and quantity of aroma components and pungency principles profiled using GC-MS and HPLC respectively. Aroma and pungency principle accumulation was observed at the rhizome formation stage of five months after planting. Total volatile oil components separated from fresh and dry ginger rhizomes were 148 and 104 respectively. Good quality total RNA was isolated from ginger sprouts exhibiting a ration ( $A_{260}/A_{280}$ ) of greater than 1.8 with a concentration of 1.58 $\mu\text{g}/\mu\text{l}$ . Highest *Chalcone synthase* gene expression was observed in somaclone B3 (54%). Modified protocol adopted for RNA isolated could yield better quantity (2.55 to 2.93) and quality of total RNA (1.92 to 2.05) from ginger rhizomes fresh and frozen at -80°C. Modified protocol adopted for RNA isolation from leaves could yield better quantity (1.09 to 1.21) and quality of total RNA (2.13) from young ginger leaves. Twenty four rhizome ESTs and nineteen leaf ESTs were developed. Functional annotation using Blast2GO annotation tool revealed no differentially expressed genes for gingerol production in rhizome ESTs. Eleven differentially expressed proteins were found in rhizome ESTs viz. for signaling response (Protein kinase domain), protein trafficking (ADP-ribosylation factor), photosynthesis (Photosystem 1 PsaA/PsaB), ATP formation (ATP synthase subunit beta) and transposon mediated mutations (Retrotransposon and integrase protein). One differentially expressed gene for gingerol production was found in leaf ESTs viz. *3-ketoacyl CoA thiolase* (ACAA1). Eighteen other differentially expressed proteins were found in leaf ESTs viz. for transportation of plant secondary metabolites and their intermediates (Glutathione S-transferase), mobilization of sucrose into metabolic pathways (Sucrose synthase 3-like protein), lipid biosynthesis (Glycerol-3-phosphate acyltransferase 3), transportation of cellular material to microtubules (Kinesin-like-protein) and biogenesis of metabolic pathways in Calvin cycle (Phosphoribulokinase protein).

## **3. QTL mapping for yield traits in vegetable cowpea**

The objective was to map the SSR markers and to identify the quantitative trait loci for yield components in the genome of vegetable cowpea. A modified DNA isolation protocol was designed based on the standard CTAB DNA isolation method. One hundred SSR primer pairs were initially screened among the two parents to check for their ability to generate polymorphism. Out of which, 30 clearly polymorphic SSR markers were selected and used for genotyping the 94 samples in mapping population and the band patterns were scored. A linkage map spanning 908 cM with two linkage groups was constructed. Linkage group 1 had eight linked SSR markers and Linkage group 2 had five linked markers. This linkage map was further used for QTL analysis. QTL map was developed using ICIMapping software using both single marker analysis and additive linkage analysis strategies. Data from SMA was used to confirm the results of additive linkage mapping. Two significant QTLs, each having two bracket markers and an anchor marker for traits days taken for flowering and plant weight was identified. Two suggestive QTLs with two bracket markers each for traits branch number and root length was also identified. Three SSR markers, CLM0177, CLM0083 and CLM0244 were declared anchor markers for traits days taken for flowering, individual pod weight and total dry pod yield and plant weight respectively. Two significant QTLs for the traits "days taken for flowering" and "plant weight" were identified. Two suggestive QTLs for "branch number" and "root length" were also identified. Anchor markers for the traits "days taken for flowering", "individual pod weight", and "total dry pod weight" were also identified.

## **4. Characterization of PR proteins in selected calli clones of black pepper in relation to *Phytophthora* foot rot disease**

The objective was to characterize PR proteins in selected calli clones of black pepper in relation to *Phytophthora* foot rot disease. Detached leaf symptom bioassay at 24, 48 and 72 hours after inoculation revealed that, CKCC 27 showed the least lesion diameter depicting tolerance reaction.  $\beta$ -1,3-glucanase assay showed that, KLCC 89 recorded the earliest (at

24 hours after inoculation) and highest specific activity of  $\beta$ -1,3-glucanase among the 11 calliclones and susceptible variety Panniyur-1. In KLCC 89, at 24 hours after inoculation, the 16.5 kDa protein band corresponding to  $\beta$ -1,3-glucanase was found over expressed as compared to other calliclones and Panniyur-1. Proteome analysis by two-dimensional gel electrophoresis revealed that, tolerant KLCC 89 expressed 167 spots differentially as compared to Panniyur-1 at 24 hours after inoculation, of which four spots were selected for MALDI-TOF analysis (Spot 1, Spot 2, Spot 3 and Spot 4). MALDI-TOF analysis followed by MASCOT search revealed three hit peptides for Spot 1, six hit peptides for Spot 2, five hit peptides for Spot 3 and one hit peptide for Spot 4. *In silico* analysis of the 15 protein hits using BLAST2GO tool identified eight sequences of *Nicotiana tabacum*, four sequences of *Oryza sativa* japonica group, three sequences of *Nicotiana sylvestris* and one sequence each belonged to *Nicotiana benthamiana* and *Piper nigrum*. The enhanced expression of plastocyanin protein, TRAF-like family proteins, RUBISCO dependent glycolate and glyoxylate metabolism, light dependent ROS production during photorespiration, F-box proteins, synthesis of antimicrobial metabolites and retrotransposition activity were observed in the tolerant calliclone KLCC 89 as defense related responses. Plastocyanin is involved in regulation of photosynthesis to meet the requirements of nutrient competition by the *P. capsici* whereas the TRAF-like family proteins is involved in regulation of programmed cell death. The increment in RUBISCO, regulates the glycolate and glyoxylate metabolism for  $H_2O_2$  production. F-box proteins are involved in regulation of jasmonate regulated defense-related pathways.

### 5. DNA barcoding of spider mites (Prostigmata: Tetranychidae) on major crop plants of Kerala

The objective of the study was to generate DNA barcode for different species of spider mites on major crops of Kerala and to find out the genetic variability among them. The spider mites associated with ten different crops were collected from eleven different locations from mainly four districts of Kerala namely, Thrissur, Palakkad, Ernakulam and malappuram. Sixteen accessions were maintained as isolines and species identification was done using both morphological and molecular methods (*ITS2* and *COI* loci). Three different species of spider mites were morphologically identified *viz.*, *Tetranychus truncatus*, *T. okinawanus* and *T. udaipurensis* were found associated with ten different crops from eleven different locations. The study recorded new host records for all the three species. Pumpkin, banana, tapioca were new host records for *T. truncatus*; papaya, cowpea, ashgourd and brinjal were new host records for *T. okinawanus* and banana, okra and tapioca were new host records for *T. udaipurensis*. The size of amplicons obtained for *ITS2* and *COI* loci were in the range 600- 700 bp and 800- 900 bp, respectively, which were in the expected range and were suitable for barcoding and the results of BLASTn analysis of both *COI* and *ITS2* were in consensus with the morphological identification. The barcode gap analysis of *COI* and *ITS2* sequences confirmed the existence of barcode gaps at both the loci to differentiate *T. truncatus* from *T. udaipurensis* as well as *T. okinawanus*. The pairwise distance analysis of the sequences revealed that the intraspecific nucleotide divergence was less than one. The distance between *T. truncatus* and *T. udaipurensis* was 0.140 – 0.142, while between *T. truncatus* and *T. okinawanus* was 0.113, while distance summary analysis of sequences revealed that the divergence (%) within species for *ITS2* and *COI* loci were in the range of 0.00 - 0.31 and 0.96 - 2.88 respectively. Phylogeny analysis of *COI* and *ITS2* sequences revealed that the same species within a monophyletic group formed a single clade and points out point out that *T. truncatus* is closely related to *T. udaipurensis* as well as *T. okinawanus*. The study brought to light the predominance of *T. truncatus* and *T. okinawanus* from the crops sampled for spider mite. *Tetranychus okinawanus* which was first reported from *Adenium* in Kerala, was seen to have expanded its host range and was reported from four new hosts indicating its potential to widen its host range and is also suggestive that this alien species may turn invasive. Present study validates and confirms the earlier reports that both *ITS2* as well as *COI* as reliable tools to differentiate closely related species of spider mites.

### 6. Molecular characterization of *Erwinia* species causing rhizome rot in banana

Objective was to characterize *Pectobacterium carotovorum*, the pathogen causing rhizome rot in banana in terms of phenotypic, biochemical, molecular characters and variability. The variability of the isolates were evaluated by cultural, morphological, biochemical, physiological and molecular methods. The rhizome rot infected samples were collected from banana fields of 14 different locations in the districts Thrissur, Palakkad, Ernakulam, Kollam and Trivandrum of Kerala and also from four different locations in the districts Kanyakumari, Madhurai and Tuticorin of Tamilnadu. Isolation of pathogen from the samples by the standard tissue maceration method yielded 18 isolates. The bacterial colonies were small, cream to yellowish in colour, slightly raised and mucoid with a diameter in the range of 2.3 to 2.5mm and pathogenicity of 18 isolates were proved. Morphological characterization of the bacterium was carried out by staining *viz.*, Gram staining, capsule staining, flagellar staining and the bacterium was gram negative, non capsular with peritrichous flagella.

Biochemical characterization was carried out by various test *viz.*, solubility in KOH, potato and carrot soft rot test, pectate degradation, growth in NaCl containing medium, pectate degradation and catalase test. Physiological characterization was done by growing the bacterium at different temperature and pH. The maximum growth was recorded at 27°C followed by 29°C after 48h of incubation. The bacterial growth was very low at 37°C. The maximum growth was recorded at pH 7.0 followed by pH 7.5 after 48h of incubation. The most favorable pH for the growth of *Erwinia/ Pectobacterium* spp. was observed as 7.0. Differences were observed in OD value of isolates under varying temperature and pH. Based on the results

of cultural, morphological, biochemical and physiological characterization dendrogram was constructed and the 18 bacterial isolates were grouped into six groups.

Total genomic DNA isolated was subjected to PCR analysis using universal 16S rRNA primers produced amplicons of 1.5Kb size. Sequencing of the amplicons of representative isolates of six groups were carried out and the sequences obtained are used for homology analysis, phylogenetic analysis and phylogenetic tree construction. All the six groups of bacterial isolates were belonged to *Erwinia carotovora*/*Pectobacterium carotovorum* but variation was observed at subspecies level of the six groups, two subspecies viz., *Pectobacterium carotovorum*ssp. *carotovorum* and *Pectobacterium carotovorum*ssp. *brasiliense* were observed. Barcode gap of *Pectobacterium carotovorum* ssp. *carotovorum* and *Pectobacterium carotovorum* ssp. *brasiliense* was also assessed by aligning the six sequences using 'Clustal W' software. The phylogenetic tree was constructed and two subspecies of *Erwinia carotovora* / *Pectobacterium carotovorum* were discriminated in the phylogenetic tree.

### **7. Genome walking for putative phytic acid (InsP<sub>6</sub>) unigene in black pepper (*Piper nigrum* L.)**

Objective was to sequence the flanking regions of unigene *Pnc135* coding for Phytic acid (InsP<sub>6</sub>) by primer walking and validation of the gene and detection and quantification of InsP<sub>6</sub> and its derivatives [inositol pyrophosphates (PPx-InsPs)], if any, in black pepper. Three sets of primers (PNC F5/PNCR5, PNC F6/PNC R6, PNC F7/PNC R7) were designed based on the multiple sequence alignment of putative unigene (*Pnc135*) showing similarity to *ipk1* gene obtained in a previous study, with the selected sequences of 28 different crops. Among the six PCR products sequenced, F6R5 obtained by primer set PNC F6/PNC R5 gave an amplicon of 394 bp. This PCR product (F6R5) showing similarity to *ipk1* gene was used for performing genome walking for the flanking regions using the protocol by Reddy *et al.* (2008). The forward and reverse locus specific primers and the corresponding nested primers were designed based on the sequence of F6R5. From the nested PCR amplification, four PCR products A3F1, A2F1, A4R1 and A4R2 were sequenced and genome walking towards 3' flanking region of F6R5 using the primer NLSP F1 gave aPCR product of 933 bp size (A3F1) showing similarity to *ipk1*. The total length of the assembled sequences of F6R5 and A3F1 was 1072 bp (*PN-ipk1*). The assembled sequence (*PN-ipk1*) was analysed for the coding region (Open Reading Frame) and was found to be having 522 bp coding for 173 amino acids. The nucleotide sequence as well as the amino acid sequence was used for the phylogenetic analysis using *ipk1* sequences of other crops showing similarity in BLAST search. The analysis showed that *PN-ipk1* was evolutionarily closer to sequences of plants like *Phaellenopsissequistris*, *Musa acuminata*, and *Phoenix dactylifera*. Polyacrylamide gel electrophoresis (PAGE) analysis was carried out to detect the presence of InsP<sub>6</sub> in panniyur-1 leaf sample. The leaf extract as well as phytate standards were loaded onto gels and the corresponding band intensities of each concentration of phytate standard and samples were recorded using the software GelQuant.NET. Quantity of phytate in the sample was estimated to be 620 nmoles/g fresh weight in the leaf tissues. The study has given the confirmation of the presence of *ipk1* gene in black pepper and was able to decipher a total sequence length of 1072 bp by genome walking towards the 3' end of the 394 bp amplicon obtained from var. Panniyur1. Identification of the sequence towards the 5' end to get the full length gene will help to understand the role played by the gene in biotic and abiotic stress resistance in black pepper.

### **8. Transcriptome analysis of *Phytophthora capsicii* tolerance in black pepper (*Piper nigrum* L.)**

To understand the differential expression of genes during *Phytophthora* infection in susceptible and tolerant black pepper cultivars through DDRT-PCR analysis on mRNA. Two black pepper varieties, IISR Subhakara (susceptible variety) and IISR Shakthi (tolerant variety) were employed in the study. Total RNA before and after *Phytophthora capsicii* inoculation were isolated using TRIzol method and were converted into cDNA using oligo-dT primers and reverse transcriptase enzyme. DDRT PCR was carried out using anchor and arbitrary primers. Transcriptome profile was analysed on 6 per cent Urea polyacrylamide gel electrophoresis. The differentially expressed bands were identified and sequenced. Standardized method for the isolation of high quality RNA from black pepper. Two genes, *premnaspirodiene oxygenase* and *phosphoserine phosphatase* and their metabolic pathways were identified which were differentially expressed in tolerant black pepper varieties. Few identified expressed fragments from tolerant varieties after inoculation were annotated to various domains involved in resistance mechanism viz., *cytochrome P450* (detoxification pathway), *flavonoid 3-monooxygenase* (antioxidant flavonoid biosynthesis), MAP kinase and kinase super family (extra nuclear transcriptional regulation of nuclear genes), ankyrin and KH domains (anti-apoptotic effect by the regulation of caspases), *heme oxygenase* (regulation of ROS), adhesion GPCRs (cleavage of signal peptides) and RRM domains (regulates the level of RNA metabolism). Expression of *premnaspirodiene oxygenase* sequence was validated through eNorthern analysis and found the maximum expression level at 48 hours after inoculation in *Arabidopsis thaliana*.

### **9. Pyramiding of bacterial leaf blight resistance genes in rice variety Jyothi (PTB39) through Marker Assisted Selection**

The project aimed to pyramid three bacterial leaf blight resistance genes (*xa5* + *xa13* + *Xa21*) in rice variety Jyothi (PTB 39) using functional STS markers, RG556, RG136 and pTA248 and generate backcross population (BC<sub>3</sub>F<sub>1</sub> and BC<sub>2</sub>F<sub>5</sub>) introgressed with the resistance genes. Two R genes (*xa5* and *xa13*) pyramided BC<sub>2</sub>F<sub>4</sub>s were identified through foreground

selection. Out of 50 Rice Microsatellite (RM) markers, thirty-four background markers exhibited variable banding pattern in the selected BC<sub>2</sub>F<sub>4</sub>s while, 16 RM markers showed monomorphic banding pattern with recurrent parent Jyothi. Recovery of recurrent parent genome was found highest in Plant No.5 (92.20%) while it was low in the 2-R gene pyramids (58.80% and 64.60% in Plant No.9, Plant No.21 respectively). Clustering based on marker data, showed that R genes (*xa5* and *xa13*) introgressed BC<sub>2</sub>F<sub>4</sub>s *i.e.* Plant No.9 and Plant No.21 were more dissimilar to Jyothi. Wide variability in morphological characters were observed among the BC<sub>2</sub>F<sub>4</sub>s. The dendrogram generated out of the morphological characters grouped the two 2-R-genes pyramids, Plant No.9 and Plant No.21 into a single cluster along with donor parent ISM. The selected BC<sub>2</sub>F<sub>4</sub>s individuals *i.e.*, Plant No.5, Plant No.9, Plant No.21, Plant No.25 and Plant No.27 were backcrossed individually to both recurrent parent Jyothi and donor ISM to obtain BC<sub>3</sub>F<sub>1</sub>s (63 Nos.) and BC<sub>1</sub>F<sub>1</sub>s (56 Nos.) respectively.

#### 10. Induction of genetic variability in *Phalaenopsis* orchids through hybridization and embryo culture

The objective was to induce genetic variability in *Phalaenopsis* by hybridization and embryo culture. Genetic relationship among the parents was assessed by using ISSR molecular marker system and genetic variability was induced by intervarietal hybridization. Seed culture of the hybrid pods was done by embryo culture technique by using MS and Knudson-C media.

All the selected *Phalaenopsis* varieties varied from each other with respect to morphological and floral characters. Significant difference was found in shoot height, total number of leaves, leaf area, days taken from first flower opening to last flower opening, days taken for wilting of first flower, days taken for wilting of last flower, flower size and spike length. Cluster analysis showed only 20 per cent similarity among parents with respect to phenotypic characters. Flower anthesis time of Winter Spot was observed between 5.30 am – 8.00 am and Violet 11.00 am – 2.00 pm. Maximum stigma receptivity was observed in Winter Spot at 3-12 days after opening and minimum number of days for receptive stigma was observed in Violet *i.e* 1 - 5 days after opening. Palynology studies showed significant difference with respect to pollen germination and pollen diameter. 100 per cent pollen germination was recorded in Elegant Yellow. Pollen diameter was maximum in Winter Spot (107.68 microns). Seven out of 13 ISSR molecular markers were selected. 100 per cent polymorphism was observed with UBC 841. Dendrogram generated showed that Elegant Purple and Pink were most closely related (78 %) to each other. Crosses made between Winter Spot X Elegant Purple, Winter Spot X Pink, Elegant Purple X Pink, Pink X Winter Spot, Pink X Elegant Purple and Violet X Elegant Purple were successfully matured into pods. Successful pods were used for embryo culture. Maximum germination percentage (50%) was observed in ½ MS + 1 mg l-1 BA + 0.1 mg l-1 NAA + 0.5 per cent activated charcoal and among Knudson-C media combinations used KC + 3 mg l-1 BA + 0.3 mg l-1 NAA gave maximum (40 %) germination percentage. Seed from the cross Winter Spot X Pink, Elegant Purple X Pink and Pink X Elegant Purple exhibited greening. Protocorms were observed in Pink X Elegant Purple and Elegant Purple X Pink. Protocorms sub cultured in ½ MS + 1 mg l-1 BA + 1 mg l-1 NAA media got differentiated into leaves in the cross Pink X Elegant Purple.

#### 11. Bulk segregant analysis for heat tolerance in segregating generation of rice (*Oryza sativa* L.) using SSR marker

The objective was to identify the SSR markers linked to the gene/s for heat tolerance in rice through bulked segregant analysis (BSA). Two rice varieties, N22 (heat tolerant) and Uma (heat susceptible) and the F<sub>3</sub> progenies of the cross Uma × N22 were employed in the study. SSR markers were used to find the polymorphism between N22 and Uma. BSA and single marker analysis were performed to find the linkage between marker and trait. Genomic DNA samples of the two parental lines (Uma and N22) were screened with 197 Rice Microsatellites (RM) markers and 41 RM markers were identified as polymorphic between the two parents. Total 49 F<sub>3</sub> plants were screened for heat tolerance along with two parents, Uma and N22. Seven most tolerant and seven most susceptible F<sub>3</sub> plants were selected for BSA, based on spikelet fertility. DNA samples from selected tolerant individuals were used to constitute the tolerant bulk and DNA from the selected susceptible individuals were used to constitute the susceptible bulk. Polymorphic SSR markers identified between Uma and N22 were used to screen the tolerant bulk, susceptible bulk, tolerant parent (N22) and susceptible parent (Uma) and BSA was performed. RM5749 showed polymorphism between tolerant bulk and susceptible bulk as well as parents during BSA and this marker was considered as a putative marker for heat tolerance. A quantitative trait loci (QTL) was identified based on significant LOD value (LOD= 6.86) of RM5749 marker associated with spikelet fertility percentage under high-temperature stress through single marker analysis. The position of RM5749 was reported to be at 22.80 Mb on chromosome number 4 (Gramene Database).

#### 12. DNA fingerprinting of promising selections of jack (*Artocarpus heterophyllus* Lam.) using molecular markers

To characterize popular jack varieties/ cultivar and six superior jack selections identified by RARS, Kumarakom from Kuttanad tract using SSR and ISSR markers. Popular jack variety Sindhur, cultivar Muttom varikka and six superior jack selections (Velloor varikka-1, Velloor varikka-2, Pathamuttom varikka-1, Pathamuttom Varikka-2, Kavanar Varikka-1 and Chengalam varikka) identified at RARS, Kumarakom from Kuttanad tract were used for the study. Fifty each ISSR and SSR primers were screened with bulked DNA of jackfruit genotypes and selected 10 ISSR and 11 SSR primers with good polymorphism for further analysis. Unique band was not observed in Velloor varikka-1, Velloor varikka-2 and Kavanar

varikka-1. Maximum of six unique bands were observed in Pathamuttom varikka-1, Pathamuttom varikka-2 and Chengalam varikka. The variety Sindhur generated minimum (3) unique bands. The specific DNA fingerprints developed for the jack variety Sindhur, cultivar Muttom varikka and promising selections Pathamuttom varikka-1, Pathamuttom varikka-2, Kavanar varikka-1 and Chengalam varikka could be utilized for varietal identification and settling IPR issues. Since the Fingerprints obtained for Veloor varikka-1 and Veloor varikka-2 were identical more primers have to be screened for developing specific fingerprints for these selections.

### **13. Tagging of Phytophthora pod rot resistance gene in cocoa (*Theobroma cacao* L.) using ISSR markers**

The objective was to tag the gene(s) conferring resistance to *Phytophthora* pod rot disease in cocoa and enable marker assisted selection for developing pod rot resistant varieties.

High variability was observed for the characters viz., pod weight, length and breadth of pod, wet bean weight per pod and single dry bean weight among the progeny of same cross. Based on the detached pod inoculation, three each of resistant and susceptible hybrids were selected. BLASTn analysis of the sequence Oligo ISSR 04 had shown 96 per cent identity with *Theobroma cacao* genome assembly, chromosome: IX (LT594796.1), and 98 per cent with predicted: *T. cacao* histidine-containing phosphotransfer protein 1 (HPT). HPTs also play an important role in propagating cytokinin signal transduction and in disease resistance. The BLASTn analysis of marker UBC 810 also showed 99 per cent identity with *Theobroma cacao* genome assembly, chromosome: IX (LT594796.1). It also resulted in 99 per cent sequence identity with predicted *T. cacao* phospholipid: diacylglycerol acyltransferase 1 mRNA (XM\_018128234.1). Marker UBC 810877 is found to be located on the chromosome nine with SSR marker mTcCIR30 and mTcCIR166 present either side. Genes associated with this region are Regulatory protein NPR1, probable disease resistance protein At1g12280, Mitogen-activated protein kinase (MAPK) 2, Phosphatase 2C 77, trans-membrane signaling protein genes, etc. The marker UBC 826535 was bracketed by SSR markers mTcCIR136 and mTcCIR182 on chromosome six. This marker was linked with probable disease resistance protein At1g12290, Reticuline oxidase-like protein, Flavin-dependent oxidoreductase FOX1/2/5, etc. Location of marker 857839 on chromosome four was sandwiched by SSR marker mTcCIR183 and mTcCIR107 on the left while marker mTcCIR221 on the right side. This region is rich in disease associated genes like, Transcription factor MYB75, GDP-L-galactose phosphorylase 1, Serine/threonine-protein kinase CDL1, etc.

### **14. Micropropagation of seedless watermelon hybrids**

### **15. Development and validation of novel EST-SSR markers in black pepper (*Piper nigrum* L.)**

Objectives were to develop EST-SSR markers in black pepper, validation of the developed EST-SSR markers in different genotypes of black pepper and to study the genetic relationship among different *Piper* species.

Different genotypes (53 No.) including nineteen varieties and sixteen cultivars of black pepper and eighteen different species of *Piper* were included in the study. Simple sequence repeats (SSR) were mined from the expressed sequence tags (EST) expressed during berry development stage of black pepper. The microsatellite identification tool, MISA was used for detecting SSRs from 1048 unigenes. Seventy SSRs were detected from 68 unigene sequences which accounted for 6.49% of total sequences. Ten microsatellites including six trinucleotides, two dinucleotides and two compound SSRs were selected and primers were designed based on the corresponding unigene sequences to amplify these regions in the genomic DNA. Out of nine primers designed five primers (PNS1, PNS3, PNS4a, PNS6 and PNS8) were selected for further validation based on the specificity of the amplification.

Genomic DNA isolated from the 53 genotypes of *Piper* spp. were amplified with the selected primers for validation. In total, 34 alleles were obtained for the five loci amplified by the five primer sets. The average number of alleles per locus was 6.8. All the five primers were successful in amplifying the corresponding locus in *P. nigrum* genotypes as well as in other *Piper* spp. Among the 34 alleles, seven were found only in *P. nigrum*, 18 were specific to other *Piper* spp, and nine were shared by both groups. PIC value was in the range of 0.16 to 0.87. Cluster analysis (DARwin version 6) showed dissimilarity values in the range of 0.08 to 0.87. In the dendrogram, 53 genotypes were grouped into different clusters based on the similarity between genotypes. The present study demonstrated that the genotyping of *Piper* sp with EST-SSR markers reveal the genetic diversity among different genotypes and can be successfully used in breeding programmes for marker assisted selection.

### **16. Evaluation of systemic acquired resistance and induced systemic resistance on the suppression of foliar blight disease of amaranthus (*Amaranthus tricolor* L.)**

Modifications in the dose, concentration and time of application of P.indica and the chemical activator can be useful in better understanding of its combined effect in the suppression of foliar blight. The results can be used to exploit its further use in disease management of amaranthus on a large scale.

**17. Comparative and functional genomics analysis of starch biosynthesis pathways in cassava**

Objective was to study the starch biosynthesis pathways in cassava using data integration and temporal gene expression pattern during different growth stages. Five potential gene candidates were found out which had a major role in starch biosynthesis pathway in cassava. One among the genes was a negative regulator of starch synthesis in cassava which was a break through. The output data were integrated together to construct a pathway using Cell illustrator version 4 which created a better model for visualization.

**18. Validation of antiinflammatory, antinociceptive and diuretic potential of neeralar (*Marsilea quadrifolia* L.)**

Objective was to scientifically validate the traditional claims of neeralar for its anti-inflammatory, antinociceptive and diuretic effects in experimental animal models. Antiinflammatory effect of EMQ was significant with the drug doses of 150 and 450mg/Kg compared to the reference drug aspirin and thus it can be considered as the effective dose.

**19. *In silico* evaluation of anti-cobra venom activity in selected fruit crops**

Objective was to study cobra venom detoxification activity and identification of potential lead molecules in common 5 fruits crops through *in silico* methods. Results showed that *Mangifera indica* can inhibit all the 14 cobra venom proteins. Many lead molecules had multi protein inhibitory activity and the results substantiated the traditional use of these plants as antidote to cobra venom.

**20. Genetic diversity analysis of *Phytophthora colocasiae* using SSR markers**

The objective of this study was to analyse the genetic variation in *Phytophthora colocasiae* population using SSR markers. Thirty-seven isolates of *Phytophthora colocasiae* from all over the country along with ten isolates collected from ICAR-CTCRI taro fields at fine spatial scale were selected for the characterization. Isolates from odisha showed higher degree of virulence in the pathogenicity test. Three isolates can withstand temperature above 30 °C. Genetic diversity analysis indicated that isolates from odisha were found highly diverged from other isolates.

**21. Isolation and characterization of ADP-glucose pyrophosphorylase (AGPase) enzyme in high and low starch variety of cassava**

Objective was to design AGPase gene specific primers and cDNA amplification of AGPase genes in cassava and to sequence AGPase gene and assess the variations in the AGPase genes from low and high starch cultivars of cassava. Sixteen candidate primer based on the conserved sequence of AGPase cDNA sequence were screened. Among these 3 primers showed amplifications of AGPase gene fragment in both parents. Comparison of each primer amplicon from high and low starch lines showed difference in 27 base pair and amino acid comparison showed no changes.

**22. Phytochemical diversity of *Cinnamomum verum* J. Presl in South India**

The objective of the study was to scientifically enumerate distribution status of plant for the purpose of conservation and investigation of intra species diversity of *cinnamomum verum* J. Presl distributed in South India. Preliminary phytochemical screening of leaves of *Cinnamomum Verum* had shown the occurrence of secondary metabolites like carbohydrates, terpenoids, steroids, flavonoids, coumarins and saponins and these phytochemicals, may play a vital role in different kinds of biological activities. Cinnamaldehyde was the major compound identified in most bark accession and eugenol in leaves. The present study revealed that *Cinnamomum verum* is a potential spice having antioxidant properties due to rich source of phytoconstituents.

**23. Identification of lead compounds with anti-cobra venom activity in common spices through *in silico* methods**

Aim was to identify lead compounds with anti-cobra venom detoxification activity in common species of Kerala through *in silico* methods. A total of 26 leads were resulted by the study. Among them curcuminoid, Beta sitosterol, Beta cubebene showed highly potential anti toxic effects. The study substantiates the traditional knowledge of the anti dote activity of the spices of Kerala.

**24. Evaluation of direct antagonism by phylloplane bacteria, and induced systemic resistance by *Piriformospora indica* on the suppression of foliar blight disease of amaranthus (*Amaranthus tricolor* L.)**

Objective was to evaluate the potential of a combination of the root colonizing fungus *Piriformospora indica* and bacterial isolates from amaranthus (var. Arun) phyllosphere in suppressing the foliar blight disease by the pathogen *Rhizoctonia solani*. Prominent colonization was found in amaranthus plant cocultured with *P. indica* in artificial media like PDA, MS and PDA-MS. *P. indica* could increase the plant growth parameters like shoot length, number of leaves, fresh, and dry weight of shoot and roots. *P. indica* colonized treatments showed elevated defense enzyme levels after inoculation with the pathogen.

**25. Molecular characterization of Sweet Potato Feathery Mottle Virus**

The study was undertaken with an objective to identify different strains and characterise Sweet Potato Feathery Mottle

Virus (SPFMV). . The study conducted using sweet potato germplasm maintained in ICAR-CTCRI showed high symptom severity and increased aggressiveness for potyviruses but SPFMV infection got decreased compared to earlier years. From the phylogenetic tree constructed, it was observed that the sequences of samples showed high variability even though lies within the group.

#### **26. Identification of duplicates in the germplasm of sweet potato (*Ipomoea batatas* (L.) Lam.) using morphological and molecular markers**

The objective was to identify duplicates in the sweet potato germplasm based on morphological and molecular markers. Identification and elimination of these common redundant materials will enhance the germplasm viability. In this study only two duplicates were identified and in future more specific markers may be used for core collection development and to eliminate duplicates.

#### **27. Association mapping for cassava mosaic disease (CMD) resistance in cassava using SSR marker**

The objective was an association mapping analysis to identify the markers which were closely associated with CMD resistance. Results showed that there are eight sub populations in the cassava population used. Based on the output obtained from Evanno's method a bar diagram was constructed which showed the distribution of genotype in different sub population.

#### **28. Molecular characterization of rice genotypes having variability in heat tolerance**

The objective was to study the variation in rice genotypes for heat tolerance using microsatellite markers. A dendrogram was generated with the aim of analyzing the relationships between the 10 genotypes tested. 10 genotypes were clustered into two distinct clusters.

#### **29. *In silico* analysis of carotenoid biosynthesis pathway in cassava (*Manihot esculenta* Crantz.)**

The objective was to identify the genes involved in the carotenoid biosynthesis pathway in cassava, construction of the carotenoid biosynthesis pathway, regulatory sequence analysis of carotenoid genes in cassava and visualization of the constructed carotenoid pathway. 39 carotenoid genes were identified from cassava through comparative genomic analysis and BLAST-p search. Functional annotation of carotenoid genes was done using E2P2ntool and NCBI conserved domain analysis tool. The identified genes were used for the regulatory sequence analysis.

#### **30. Molecular characterization of Taro *Bacilliform Virus* (TaBV)**

The objective was to clone and characterize the TARO bacilliform virus and analyse the phylogenetic relationship with other members implicated in mixed infection of Taro. Taro samples with virus infection symptoms were collected from the germplasm repository of CTCRI Trivandrum and Bhubaneswar. The phylogenetic analysis revealed that the sequences obtained in this study belong to Taro bacilli form CH virus isolates of TaBCHV-1 and TaBCHV-2.

#### **31. Characterization of selected accessions of cassava germplasm using morphological and molecular markers**

The objective of the study was to combine morphological and molecular data for understanding the distribution and range of genetic dissimilarity present within the selected cassava accessions collected from different states of south India. The genetic diversity on molecular basis was evaluated using 10 SSR primers. All the primers showed polymorphism. Morphological characterization was based on 20 qualitative and 10 quantitative traits. Clustering based on molecular markers and morphological descriptors was done. Mantel's test proved that there was no correlation between morphological and molecular data.

#### **32. Molecular characterization and *in vitro* conservation of taro (*Colocasia esculenta* (L.) Schott)**

Objective was to analyze the genetic diversity of taro using SSR markers and to maintain them in slow growth. 36 taro accessions were screened with 10 SSR markers. SSR primers were found to be highly polymorphic across the 36 accessions. *In vitro* conservation of taro was done. Half strength MS media surplus TDZ (0.1mg/L) produced high average number of shoots.

#### **33. Scientific validation of anti inflammatory, antinociceptive and antioxidant potential of malavirinji (*Actinodaphne bourdillonii* Gamble)**

The objective of the study was to scientifically evaluate the anti-inflammatory, antinociceptive, antioxidant potential of leaves of an ethnomedicinal plant *Actinodaphne bourdillonii* Gamble. Treatment with different ethanolic extracts of leaves of *A. bourdillonii* at 50,150,450 mg/kg body weight, significantly inhibit the inflammation to a greater extend. Treatment with ethanolic extract of leaves of *A. bourdillonii* at 50,150,450 mg/kg of body weight significantly reduced the pain in test animals.

**PHYSIOLOGY****34. Evaluation of CO<sub>2</sub> enrichment effects on resource utilization in cowpea (*Vigna unguiculata* L.) and amaranthus (*Amaranthus tricolor* L.)**

Objectives of the study were to evaluate the impact of CO<sub>2</sub> enrichment on cowpea (variety Lola and Vellayani Jyothika) and amaranthus (Arun) under varying moisture, temperature and nutrient regimes. Four sets of experiments were conducted at elevated CO<sub>2</sub> concentration in Open Top Chamber (OTC) system and under open field condition. Pot culture experiments were conducted. Both the varieties performed better under elevated CO<sub>2</sub> condition with respect to yield and other physiological and biochemical attributes. In cowpea, Vellayani Jyothika, performed better under elevated CO<sub>2</sub>. The CO<sub>2</sub> enrichment had a role in improving the stress tolerance with different soil moisture levels in both the crops. Elevated CO<sub>2</sub> treatment increased photosynthetic rate and activation of defense mechanisms associated with oxidative stress. It also increased the nutrient use efficiency.

**35. Enhancing morpho-physiological vigour of sesame seedling for improving productivity and weed competitiveness**

The study aimed to understand the effect of seed treatments on germination, vigour and productivity of sesame and the influence of early vigour on improving weed competitiveness of sesame. Priming treatments improved the germination, shoot length, root length, vigour index and speed of germination of all the sesame varieties. The varieties Thilak and kayamkulam-II showed maximum response to most of the priming treatments studied. The study revealed that seed priming with MnSO<sub>4</sub> or Tank mix can contribute to 30 per cent control of weed growth in crop. Hence, the treatment can be used as a component in the integrated management of weeds in sesame

**36. Physiological effects of growth stimulants on yield and quality of okra (*Abelmoschus esculentus* L.)**

The study aimed to understand the influence of growth stimulants on morpho-physiological changes, yield and quality in Okra (*Abelmoschus esculentus* L.) with respect to soil fertility management. Soil test based nutrient management with growth stimulants application resulted in higher fruit length, fruit diameter, fruit weight and number of fruit per plant than treatments which received standard POP with growth stimulants followed by 50% standard POP with growth stimulants. Regarding the quality parameters like crude fibre, ascorbic acid, mucilage and total protein content of fruit was higher in plants receiving growth stimulants like humic acid, cytozyme and potassium silicate along with soil test based nutrient management system followed by standard POP with growth stimulants and 50 per cent standard POP with growth stimulants

**37. Physiological investigations on temperature induced spikelet sterility problems of rice in different agro ecological zones and development of management interventions**

The study envisaged to assess the cause of spikelet sterility and grain filling problems in rice under different agro ecological zones like Kole, Kuttanad, Kari and Kaipad conditions and also to develop suitable management technologies to tackle the field problems.

The maximum temperature was in the range of 33.5 to 35.8°C during January to February 2016 which coincided with flowering and grain development stage of the crop in the field. The sun shine hours were also maximum during this period. This caused a decline in physiological and yield related characters in rice. The damaging effect was partially alleviated by the foliar application of ecofriendly chemicals like Boron, Potassium silicate, Zinc sulphate, IAA and, salicylic acid. The effect of these chemicals were also compared with water spray.

The yield decline in absolute control plot indicated that the crop experienced high temperature during flowering and grain filling period and adversely effected pollen viability percent, grain filling rate, number of filled grains per panicles, sterility percent and thousand grain weight. The physiological characters also significantly decreased in untreated plots when compared to plots treated with chemicals. When day temperature exceeded above 33.0 °C it caused poor grain filling and spikelet sterility. Further grain formation under high ambient air temperature depended on successful pollination and fertilization. The pollen viability studies showed a lower pollen viability percent in absolute control plots.

All the chemical could alleviate the damaging effect of high temperature. Among chemicals boron at both concentration (0.25 and 0.5%) were significantly superior and enhanced yield upto 88% when compared to absolute control. Foliar application of Boron also enhanced chlorophyll content, photosynthetic rate, and decreased fluorescence emission (enhanced Fv/Fm value) by protecting photosystem II. Boron also favored high pollen viability percent, grain filling rate, more number of filled grains per panicle and reduced spikelet sterility. Boron is an essential micronutrient for vegetative and reproductive development. It is also essential for pollen viability, germination and grain development. The high grain filling rate observed in boron applied crop might be due to assimilate mobilization efficiency of boron from leaves and other plant parts to developing sink. Next to boron Salicylic acid @ 50ppm enhanced yield to 74% followed by SA 25 ppm and water spray treatment which also could partially alleviate temperature stress by enhancing yield to 61%

### **38. Identification of microsatellite markers associated with root traits for drought tolerance in rice (*Oryza sativa* L.)**

The objectives of the study were to validate the role of root traits for drought tolerance in rice and to identify the microsatellite markers associated with drought tolerance in rice using Bulk Line Analysis. In the first experiment, 35 rice genotypes consisting of improved varieties and landraces were evaluated for their performance for physio-morphological traits under water stress condition. All the yield parameters were significantly reduced under water stress compared to control. Correlation study revealed that grain yield under stress exhibited highly positive correlation with root traits such as root length and root shoot ratio. In irrigated condition grain yield showed positive correlation with root length, root shoot ratio and root dry weight. Physiological parameters such as photosynthetic rate, transpiration rate and stomatal conductance showed positive and significant correlation with grain yield under both conditions. Morphological and yield parameters such as plant height, days to 50% flowering and panicle length were negatively correlated with yield where as spikelet fertility percentage and 1000 grain weight were positively correlated with yield under both conditions. In Bulk Line Analysis, SSR primer, RM 474 produced polymorphism between the tolerant and susceptible bulks. The same primer produced similar product size for all the individual lines forming the bulks. The genomic region flanked by this marker has been identified to be associated with various drought tolerant traits such as root dry weight, leaf rolling, grain yield and spikelet fertility in rice. Thus, the rice genotypes evaluated under water stress condition showed significant variation for physio-morphological and plant production traits. Genotypes having higher root characters were found to tolerate drought. The genotypes identified as drought tolerant viz Ptb-29, Ptb-30, Ptb-15, Ptb-1, Ptb-55 etc. can be used in breeding programmes to improve drought tolerance in rice. Microsatellite marker RM 474 which could distinguish drought tolerant and susceptible bulks can be used for marker assisted selection for drought tolerance in rice.

### **Continuing Projects**

#### **1. Molecular marker analysis for cassava mosaic disease resistance**

The study aimed to identify reliable molecular markers linked with mosaic disease resistance in tapioca. The study is in progress

#### **2. Validation of ant tuberculosis activity in selected vegetable crops through docking and *in vitro* assay techniques**

The objective of the study was to validate ant tuberculosis activity in selected vegetable crops through *in silico* docking of selected phytochemicals against identified targets for tuberculosis and through *in vitro* assay techniques. The study is in progress

#### **3. Differential expression of pathogenesis related genes by plant growth promoting rhizobacteria in controlling taro leaf blight**

To study aimed the selection of plant growth promoting rhizobacteria (PGPR) for taro leaf blight (TLB) management, its characterization and study of the differential expression of pathogen related genes in susceptible and tolerant varieties of taro, consequent to application of PGPR. The study is in progress

#### **4. *In vitro* synthesis of gingerol and analysis of Expressed Sequence Tags for gingerol production in ginger (*Zingiber officinale* Rosc.)**

Gingerol synthesis at various growth stages of microrhizomes in three ginger varieties viz Athira, Karthika and Aswathy and two parent cultivars viz. Maran and Rio-de-Janeiro were studied using HPLC analytical platform. Sequencing and sequences analysis of available ESTs for gingerol synthesis and further validation, establishment of callus cultures and elicitation with biotic and abiotic elicitors are in progress.

#### **5. Physiological approaches for manipulating male sterility in thermo- sensitive genic male sterile system for hybrid rice seed production**

The objectives were to evaluate the environmental conditions required for complete male sterility of TGMS plants and to manipulate the male sterility by using plant growth regulators and to understand the molecular mechanism associated with TGMS system. The project is in progress.

#### **6. Physiological, biochemical and molecular studies in medicinal rice (*Oryza sativa* L.) Njavara, as influenced by abiotic stresses**

The objective was to elicit information on the physiological, biochemical and molecular attributes associated with secondary metabolites accumulation due to abiotic stresses viz. shade, drought, and UV-B stress in medicinal rice njavara. The project is in progress.

#### **7. Development of resistance against banana bract mosaic virus in *Musa* spp. var. Grand Naine using small interfering RNA (siRNA)**

The objective was to develop resistance against *Banana bract mosaic virus* in banana var. 'Grand Naine' using siRNA mediated technology. The project is in progress.

**8. Isolation, characterization and evaluation of PINI and BP genes in relation to inflorescence architecture in black pepper (*Piper nigrum* L.)**

The objectives were to isolate and characterize PINI (*Pinformedi*) and BP (*Brevipedicellus*) genes in black pepper (*Piper nigrum* L.) and to evaluate the role of these genes in branching of spikes by studying their differential expression in branching and non-branching varieties of black pepper. The project is in progress.

**9. DNA barcoding in genera *Benincasa* and *Praecitrullus***

Species specific DNA barcodes were developed in *Benincasa* and *Praecitrullus* using matk and ITS2 loci. The barcode gap generated by ITS2 loci gave a perfect picture of difference between both the species as compared to matK primer.

**10. Physiological investigations on high temperature induced spikelet sterility in rice (*Oryza sativa* L.)**

The objective was to study the morphological, biochemical and physiological basis of high temperature induced spikelet sterility in rice during anthesis and the role of calcium channel as thermo-sensors. The project is in progress.

**11. Physiological, phytochemical and molecular studies on abiotic stress mediated production of secondary metabolites in the brahmi *Bacopa monnieri* (L.) Wettst.**

The objective was to enhance the production of secondary metabolites in medicinal plant *Bacopa monnieri* (L.) by providing various abiotic stress factors and to study the physiological, biochemical and molecular changes associated with it. The project is in progress.

**12. Identification of macrosatellite markers associated with root traits for drought tolerance in rice (*Oryza sativa* L.)**

The objective was to validate the role of root traits in rice for drought tolerance and to identify the macrosatellite markers associated with root traits for drought tolerance in rice. The project is in progress.

**13. Cryoconservation of koovalam (*Aegle marmelos* L. Corr.) by encapsulation-dehydration technique**

The proposed research programme aimed at the standardization of cryopreservation protocol using encapsulation and dehydration technique in *Aegle marmelos*, a redlisted medicinal tree of Kerala. The genetic fidelity assessment of plantlets recovered and regenerated from cryostorage will also be assessed using molecular markers. The project is in progress.

**14. Establishment of *in vitro* regeneration systems from callus and protoplast in *Capsicum frutescens* L.**

The objective was to study the establishment of callus culture from different explants in *C. frutescens*. Protocol for protoplast isolation, protoplast culture and plant regeneration from callus/leaf mesophyll will also be established. The project is in progress.

**15. Evaluation of siRNA mediated banana bract mosaic virus (BBrMV) resistance in banana**

The objective was to evaluate siRNA mediated resistance against *Banana bract mosaic virus* (BBrMV) in transgenic banana (*Musa* spp. Var. Nendran) plants developed using ihpRNA construct for replicase gene by artificial infection and to confirm the expression of siRNA products in infected plants. The project is in progress.

**16. Physiological and molecular analyses of flowering response in amaranthus (*Amaranthus* spp.) and cowpea (*Vigna* spp.) under elevated CO<sub>2</sub> environment**

The objective was to study the physiological, molecular and biochemical basis of elevated CO<sub>2</sub> mediated modifications in the flowering responses of amaranthus and cowpea. The project is in progress.

**17. Somatic embryogenesis in black pepper (*Piper nigrum* L.)**

The objective was to standardize a reliable protocol for somatic embryogenesis in black pepper (*Piper nigrum* L.) var. Panniyur 5). The project is in progress.

**18. Isolation and characterization of antioxidant peptides from curry leaf (*Murraya koenigii* L.)**

To isolate and characterize antioxidant peptides from curry leaf (*Murraya koenigii* L.) using proteomic tools and bioinformatics approaches. The project is in progress.

**19. Inheritance of molecular markers linked to vascular streak dieback disease resistance in hybrid progenies of cocoa (*Theobroma cacao* L.)**

To study the inheritance of identified ISSR and SSR markers linked to VSD resistance in hybrid progenies of cocoa (*Theobroma cacao* L.).

**20. Molecular basis of acaricide resistance in *Tetranychus truncates* Ehara (Prostigmata: Tetranychidae) infesting vegetable crops**

To investigate the status, biochemical and molecular bases of acaricide resistance in *Tetranychus truncates* (Ehara).

**21. Marker assisted backcross breeding in rice for drought tolerance**

To improve drought tolerance of rice variety PTB 39 (Jyothi) through marker assisted backcross breeding.

**22. Molecular cloning and characterization of virus causing leaf curl disease of *Capsicum* spp.**

To study the incidence and symptomatology of leaf curl disease of chilli and capsicum, and to clone and characterize the coat protein gene of *Chilli leaf curl virus*.

**23. Elicitation mediated carotenoid production and *Capsanthin capsorubin synthase* gene expression in Byadagi chilli (*Capsicum annum* L.)**

To study elicitation mediated carotenoid production and *Capsanthin capsorubin synthase* gene expression in Byadagi chilli(*Capsicum annum* L.)

**24. Low cost alternatives in commercial micropropagation of banana (*Musa* spp.)**

To reduce the cost of production in commercial micropropagation of banana

**25. Developing dwarf specific SCAR marks from WCT inbreds of coconut (*Cocos nucifera* L.)**

To develop and validate dwarf specific SCAR markers for screening superior inbreds with dwarfing trait in WCT inbreds of coconut

**26. *In vitro* studies on morphogenesis and plant regeneration in elite clones of cocoa (*Theobroma cacao* L.)**

The project is in progress

**27. Development of doubled haploids for iron toxicity tolerance in rice (*Oryza sativa* L.)**

To develop doubled haploids in rice for iron toxicity tolerance.

**28. Marker assisted backcross breeding for pyramiding genes conferring resistance to bacterial blight in rice variety Uma**

The project aims to identify BC<sub>2</sub>F<sub>1</sub> lines pyramided with genes *xa5*, *xa13* and *Xa21* imparting resistance to bacterial leaf blight (BB) and to produce advanced breeding generations.

**29. Standardization of *in vitro* male bud culture in banana *Musa* (AA) 'Kadali'**

To standardize a protocol for mass multiplication of banana *Musa* (AA) 'Kadali' through *in vitro* male bud culture. Study was undertaken in three parts

**30. Validation of Temperature Induction Response (TIR) technique for inducing drought and heat stress tolerance in rice (*Oryza sativa* L.)**

To study the effect of Temperature Induction Response (TIR) for combined drought and heat stress tolerance in rice

**31. Physiological and biochemical studies on growth, development and yield of ginger (*Zingiber officinale* Rosc.) as influenced by bioinoculants and phosphorus fertilization**

To elicit information on the physiological, biochemical attributes on plant growth, development and yield of ginger as influenced by bioinoculants such as mycorrhiza and trichoderma combined with phosphorus fertilization.

**32. Enhancement of phenyl propanoid glycosides in *Artanema sesamoides* Benth (vathomvaretti) by hairy root induction**

To scale up the production of phenyl propanoid glycosides in *Artanema sesamoides* by inducing hairy roots using *Agrobacterium rhizogenes*

**33. Computational prediction of miRNAs in banana (*Musa* spp.) and evaluation of their role in virus infection.**

The objectives of the study include prediction of miRNAs in banana, their validation and expression analysis during *Banana Bract Mosaic Virus* infection.

**34. Physiological approaches for alleviating the effect of water stress in upland rice (*Oriza sativa* L.)**

To standardize suitable physiological approaches to mitigate the effect of water stress in upland rice.

**35. Green synthesized silver nanoparticles for suppression of algal rust pathogen, *Cephaleuros* sp.**

To synthesize silver nanoparticles using leaf extracts of plants having antialgal property and to evaluate their potential for the inhibition of algal growth.

**36. Efficacy of silver nanoparticles as delivery system in genetic transformation**

To evaluate the efficiency of silver nanoparticles for gene delivery in plants (biolistic method) and microbes.

**37. Assessment of water stress tolerance in selectively fertilized coconut (*Cocos nucifera* L.) hybrids.**

Physiological and molecular assessment of water stress tolerance in selectively fertilized coconut hybrids and to screen coconut genotypes for water stress tolerance through critical water potential for pollen germination.

**38. Identification of molecular markers and Quantitative Trait Loci (QTLs) associated with drought tolerant and plant production traits in rice (*Oryza sativa* L.) using association genetic analysis**

To identify molecular markers, Quantitative Trait Loci (QTLs) associated with drought tolerance and plant production traits in rice under drought condition.

**39. IhpRNA mediated resistance for *Banana bract mosaic virus* in *Musa* spp. by targeting replicase and movement protein genes**

To develop multiple ihpRNA constructs against replicase and movement protein genes of *Banana bract mosaic virus* and to evaluate their silencing potential in banana variety Grand Naine.

**40. Evaluation of CO<sub>2</sub> enrichment on growth, development and soft rot tolerance in ginger (*Zingiber officinale* Rose**

To assess the impact of elevated CO<sub>2</sub> on rhizome development, yield, quality and tolerance to soft rot in ginger through morphological, physiological, biochemical and molecular analysis.

**41. Characterization of selected *Curcuma* species germplasm using morphological and molecular markers**

To analyze the genetic variation existing in *Curcuma* species germplasm based on morphological and molecular markers (SSR)

**42. Prediction of SSR and SNP markers for anthracnose resistance in yam using bioinformatics tools and their validation**

Objective is the prediction of SNP and SSR markers for anthracnose disease resistance in Greater Yam (*Dioscorea alata*), and the verification of predicted SNP and SSR markers for anthracnose disease resistance using susceptible and resistant varieties of yam.

**43. Comparative evaluation of gene regulatory network prediction and network reconstruction using genomic data**

To compare the different computational methods for the prediction and analysis of gene regulatory networks, to reconstruct gene regulatory networks using genomic data and to develop an online visualization tool using these different methods.

**44. Molecular characterization of pathogens associated with post – harvest diseases in elephant foot yam**

To isolate, characterize and identify the pathogens that cause post-harvest diseases in elephant foot yam by adopting pathogenicity tests, morphological and molecular characterization

**45. Evaluation of miRNA prediction tools and *in silico* analysis of micro and long non coding RNAs in sweet potato.**

The objective is to compare different miRNA and target prediction tools and *in silico* analysis of the miRNA and lncRNA in sweet potato

**46. Development of infectious clones of *cassava mosaic virus* and their validation**

To develop infectious clones of *Cassava mosaic virus*, their confirmation and validation in propagative host (*Nicotiana benthamiana*)

**47. Cloning and expression of coat protein gene of *Sweet potato leaf curl virus* (SPLCV)**

To clone the coat protein gene of *Sweet potato leaf curl virus* and its expression in bacterial system.

**48. Genetic diversity analysis of sweet potato (*Ipomoea batatas* L. Lam.) germplasm using morphological and ISSR markers.**

To analyse the genetic diversity in the sweet potato germplasm collections from the eastern states of India maintained in the National active germplasm site (NAGS) at ICAR-CTCRI, Sreekariyam, Thiruvananthapuram using morphological and molecular markers.

**49. Development of molecular markers for blight disease resistance in taro using bioinformatics tools.**

To (i) develop and evaluate various Single Nucleotide Polymorphisms (SNPs) and Simple Sequence Repeats (SSRs) marker prediction pipelines. (ii) Computational prediction of SNPs and SSRs in taro (*Colocasia esculenta*) and verification of co-segregated SNP and SSR markers for taro leaf blight disease resistant and susceptible breeding lines.

**50. Identification and evaluation of endophytes from tropical tuber crops against *colletotrichum gloeosporioides* (Penz.) Sacc. causing anthracnose in greater yam (*Dioscorea alata* L.)**

The objective is to Identify and evaluate the endophytes from tropical tuber crops against *Colletotrichum gloeosporioides* (Penz.) Sacc. causing anthracnose in greater yam (*Dioscorea alata* L.)

**51. In silico screening and identification of lead molecules with anti-hepatitis B activity in selected spices.**

To identify lead compounds with anti-hepatitis B activity in major spices of Kerala viz *Elettaria cardamom* (L.) Maton, *Curcuma longa* L. and *Zingiber officinale* Roscoe.

**52. Development of functional SSR markers for D-Limonene content and analysis of genetic polymorphism in cardamom (*Elettaria cardamomum* Maton)**

The objective of this study is to develop and use functional SSR markers to assess the genetic polymorphism with respect to D-Limonene content in cardamom germplasm

**53. Development of functional EST-SSR and analysis of genetic diversity in *Centella asiatica***

To develop and use functional molecular markers such as EST-SSR for analysis of genetic diversity in *Centella asiatica* in relation to the content of triterpenoids.

**54. Genome wide marker assay for the recovery of recurrent parent genome in rice (*Oryza sativa*).**

To estimate the reconstitution of genome of Aiswarya rice variety in the BC<sub>2</sub>F<sub>2</sub> plants pyramided with genes for resistance to Bacterial Leaf Blight through molecular markers covering the entire genome of Aiswarya.

**55. Assessment of anti-inflammatory and antioxidant properties of *Chlorophytum laxum* R. Br.**

To evaluate anti-inflammatory and antioxidant potential of an ethnomedicinal plant *Chlorophytum laxum* R.Br. (Neeruvatti)

**56. Identification of molecular markers for resistance to taro leaf bight in *Colocasia esculenta* L. schott.**

To identify molecular markers associated with leaf blight resistance in taro and to isolate the band of interest, sequencing and BLAST analysis to identify the gene.

**57. Identification of molecular markers linked to anthracnose resistance in greater yam (*Dioscorea alata* L.)**

To identify molecular markers linked to anthracnose in greater yam.

**58. Molecular screening of rice genotypes for submergence tolerance**

To phenotype the field tolerant rice genotypes under submergence and to screen them for *sub 1* QTL using SSR markers.

**59. Physiological and molecular studies on cyanogenic potential in cassava (*Manihot esculenta* Crantz) in response to nitrogen nutrition, water stress and shade.**

To study the effect of plant nitrogen status, light intensity and water stress on cyanogenesis of cassava and to determine the cyanogenic glycoside in plant tissues using novel methods such as Near-infra red (NIR) spectroscopy and High Performance Thin Layer Chromatography (HPTLC)

**60. Population structure analysis of indigenous rice varieties in Kerala using molecular markers.**

To analyse the structure of populations of traditional rice in four different agro climatic zones of Kerala using SSR and RAPD markers.

**PHYSIOLOGY**

**61. Physiological studies on enhancing growth and yield of ginger (*Zingiber officinale* L.) by Nano-NPK fertilizers and organic management.**

The study aimed to understand the influence of Nano NPK fertilizers and organic management for enhancing growth and yield of ginger.

**62. Physiology and management of *Chara* spp. in wet land rice ecosystem**

The study aimed to characterize the different algal species of the kole land ecosystem and to understand the phenology,

growth and management of *Chara* spp.

**63. Interactive effect of elevated temperature and UV radiation on rice growth and physiology**

The study aimed to understand the interactive effect of elevated temperature and UV radiation during different phenophases of rice and its effect on growth physiology and productivity

**64. Characterization of antioxidant fractions in curry leaf (*Murraya koenigii* L.) and molecular docking of selected bioactive compounds**

**65. Marker assisted backcross breeding in two R-gene pyramided lines of rice variety Jyothi for bacterial blight resistance**

**66. Molecular and biochemical characterisation of aroma in Biriyanicheera rice genotype**

**67. Expression of *Chalcone synthase* gene in ginger (*Zingiber officinale* Rosc.) as influenced by various management practices.**

**68. DNA barcoding of spider mites (*Prostigmata: Tetranychidae*) associated with ornamental plants**

**69. Cloning and characterization of *myo-inositol phosphate synthase* gene coding for phytates in *Dolichos lablab* L.**

**70. DNA Fingerprinting of selected cocoa (*Theobroma cacao* L.) varieties of Kerala Agricultural University**

**71. Somatic embryogenesis from immature inflorescence of coconut (*Cocos nucifera* L.)**

**72. RNA mediated resistance to yellow vein mosaic virus in okra**

**73. Allelic difference in the putative gene *ipk 1* sequence and phytic acid (InsP6) content in black pepper (*Piper nigrum* L.) – Padannakkad**

**74. Investigation on extraction of starch from cassava stem (*Manihot esculenta* Crantz)**

**75. Identification and characterization of bioactive leads from mangrove sediment-associated bacteria and assessment of their therapeutic potential**

**76. Meta analysis of QTLs associated with pests and disease resistant genes in cassava.**



# **Name of Project Coordination Group – (09) Soil Health and Organic Farming**

**Compiled by:**

**Dr. K.Ushakumari, Protect Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects- 20 Nos.**

**Ongoing Projects - 65 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 15 Nos.**

**Ongoing Projects - 30 Nos.**



## Concluded Projects

### 1. “Soil and water quality management for enhancing productivity of coconut based cropping systems in Vilappil Panchayath”.

The soil characteristics which represented significant soil quality indicators for the land use systems in the Vilappil panchayath were identified and a Minimum Data Set (MDS) was prepared. The MDS was used to develop a soil-quality index (SQI) for the area. Based on the data obtained from soil analysis, Soil Health Cards were prepared and distributed to the farmers of Vilappil panchayath.

Analysis of water quality revealed that the collected samples were neutral or alkaline, registering a pH above 6. A higher EC value obtained for water samples may be attributed to the comparatively high content of K, Na and Cl in the water samples as indicated by their values. The contents of all the other cationic nutrients were negligible in water samples.

Two field demonstrations were conducted in the panchayath, one at Vilappil and another at Cherukode with the objective of convincing the farmers about the effectiveness of different agronomic and nutrient management practices in enhancing nutrient use efficiency and soil and water productivity under coconut based cropping systems. With the co-operation of the VilappilKrishibhavan, three Training programs were conducted as part of the project in order to impart knowledge among the farmers on the importance of soil health and balanced nutrition for increasing productivity of crops without affecting environmental quality.

### 2. Farmer participatory approach to assess the impact of IPNS on soil health and crop yield in a typical laterite soils of Western Ghats

The experiment was conducted to understand the effect of integrated use of inorganic fertilizers and organic sources such as bio fertilizers, manures on soil chemical and biological characters and to assess the effect of IPNS on the growth, yield and yield attributes of vegetable crops in a laterite environment. From the study it is concluded that the inorganic nutrients can be substituted in the form of enriched compost by judiciously combining bioinoculants such as *Freutariaaurantia*, *Phosphobacterins*, *Azosprillum*, VAM and organic amendments such as neem cake, bone meal etc. Enrichment of vermicompost @ 2 % with *Freutariaaurantia* was found to be effective with respect to soil chemical and biological characters. Thus the application of enriched vermicompost @2% with *Freutariaaurantia* along with inorganic sources such as 100% NP and 50% NP in the form of urea and single super phosphate can be recommended to the laterite soils of the Western Ghats region. This improves the soil chemical and biological attributes thus sustaining soil health and plant yield.

### 3. GoK Plan “Rejuvenation and Conservation of Vellayani Lake”

The project was undertaken with the objective to prevent encroachment by establishing biofence around the boundary of Vellayanilake, to enhance soil and water conservation, to reduce growth of aquatic weeds, to promote the cultivation of native water plants, to reduce water pollution and to enhance the livelihood security of the local people. As a part of the project activities, biofencing work had been undertaken using native plants and bamboo seedlings in the Kayalkkara of College of Agriculture, Vellayani to prevent encroachment and to demarcate the boundary of Vellayani lake. Lotus cultivation was undertaken in the lake to reduce the growth of aquatic weeds thereby reduce biomanification and to generate employment and income to the local people. Planting of vetiver around the kayal land in the College of Agriculture was undertaken for soil and water conservation.

Vellayani lake is the sole drinking water source of Kovalam, Vizhinjam, Pachalloor, Vellayani and adjoining areas. The indiscriminate anthropogenic interventions caused great threat to the quality of water and to water spread areas. A one day seminar was conducted on 27.03.2015 by participating the local people (150 numbers) of Kalliyoor and VenganoorPanchayath for creating awareness on conservation and rejuvenation of Vellayanilake.

### 4. Micro nutrient management for sustenance of soil health under intensive cultivation in Western Ghat region

(SA-01-01-05-2011-ACV (3) WGD)

The study was conducted to develop recommendations of micronutrient fertilizers in banana in laterite soils of Southern Kerala. A formulation of micronutrient fertilizer mixture suitable for banana in the laterite soils of Southern Kerala was developed in the name “Banana micromix”. This mixture was formulated using fertilizer grade ferrous sulphate, manganese sulphate, zinc sulphate, borax and copper sulphate. Experiments conducted in farmers fields for three seasons using “Banana micromix” recorded significant increase in yield, disease resistance and increased fruit quality in banana variety nendran. Continuous use of this mixture in banana cultivation do not cause accumulation of micronutrients in soil, plant and water. The dose of application was 10 kg/ha or 4 gm per plant and the mode of application was soil / foliar and time of application was along with the second split doze of NPK as soil application and for foliar application three months after planting as 1% spray by dissolving 4 gm mixture in 400 ml water per plant.

## 5. Decomposition of leaf litter by Oriculture

The experiment was carried out to assess the degrading ability of soil dwelling oribatid mites and also to assess the manurial value of the decomposed litter. From the study it could be inferred that among the different litters tried for the isolation and mass multiplication of oribatid mites, jack litter was found to be the best one. Extraction of the mites from soil samples was not possible, instead of that extraction from jack litter was possible due to its special biochemical composition. The microflora associated with the oribatid mites showed the tannin and lignin degrading ability and also they could be able to control the major soil borne pathogens. Among the different biotic enrichments litter alone, litter + cowdung, litter+mite, litter + mite+cowdung the biotic enrichment litter+mite+cowdung was found to be the best enrichment in combination with the jack litter in terms of both the nutrient composition and also the decomposition percentage.

## 6. Green technology for rice based cropping system in Onattukara

The experiment was conducted to demonstrate and standardize the management practices for optimum production, to maintain soil health through organic farming and to improve the quality of food produced through balanced supply by organic substitution. The experiment was conducted as per approved technical programme during *virippu* (2011-13), *muntakan* (2011-13) and summer (2012-14).

The result indicated that cropping systems and practices as well as their interactions significantly influenced grain yield in *virippu*. Among the cropping system rice-rice-cowpea performed the best and was on par with cropping system rice-rice-groundnut in grain and straw yield. The same trend was observed in *muntakan* also. Package of practices as well as 50% organic +50% inorganic (integrated approach) produced higher grain and straw yield. Sesame, groundnut, cowpea and bhindi were raised during summer 2012, 2013 and 2014. Yield of above crops were influenced by different levels of nutrients.

## 7. "Income and Livelihood Improvement of Banana Farmers in Southern Western Ghat tract through soil fertility evaluation"

The experiment was carried out during 2015-16, 2016-17 and 2017-18 in the western ghat panchayats of and Chenkal in the Parassala block of Thiruvananthapuram District. The Project was funded by the Western Ghat Development Cell, Planning and Economic Affairs Department, Government of Kerala. The main objective of the project was to study the feasibility of productivity enhancement in banana in low yielding western ghat tract through the scientific soil fertility interventions including acidity management, application of magnesium and micro nutrient boron. The result of the investigation carried out during the three years in the experimental farmers field at Karode and Chenkal panchayats indicated that the nutrient management with Kerala Agricultural University Package of Practices Recommendation for Nendran banana (NPK @ 190:115:300g plant<sup>-1</sup> in 6 split doses) along with application of lime @ 1kg per plant at planting, boron @ 10 kg ha<sup>-1</sup> in two splits ( ½ basal as boraux + ½ at 4-5 months after planting through foliar spray as solubor 0.2 per cent) and soil application of magnesium sulphate @ 80 kg ha<sup>-1</sup> in two splits (½ as basal and ½ at 4-5 months after planting) resulted in an yield enhancement of 41.75 per cent compared to POP recommendation and 94.24 per cent compared to the farmer practice in southern western ghat tract of Kerala. This treatment also produced the highest net returns of Rs. 11,01,484 ha<sup>-1</sup> and benefit: cost ratio of 2.84 compared to the POP alone (net returns Rs. 6,78,714 ha<sup>-1</sup> and benefit : cost ratio of 2.20) or farmer practice (net returns Rs. 4,17,238 ha<sup>-1</sup> and benefit : cost ratio of 1.85) It could be concluded that it is technically feasible and economically viable to enhance the productivity and income from banana cultivation through the soil acidity management combined with soil application of magnesium sulphate and plus foliar application of micro nutrient boron. The project has provided that the adoption of the scientific soil fertility interventions could improve the economic status of banana in western ghat area without depleting the fragile ecosystem and natural resources.

## 8. "Evaluation of a Customized Organic Fertilizer in Relation to Labile Carbon Dynamics, Nutrient Release Characteristics and Productivity of Banana".

The study envisages physic-chemical and biochemical characterization and assessment of maturity parameters of the organic fertilizer obtained from degradable solid waste by rapid thermo chemical conversion technology and evaluation of the customized organic fertilizer in relation to labile carbon dynamics, nutrient release characteristics and productivity of banana in agro ecological unit (AEU)8 of Kerala

The organic fertilizer produced by thermo chemical treatment was, with a particle size of <4mm, neutral pH low Ec and total organic carbon. Mager nutrients were higher secondary and micro nutrients were sufficient and heavy metal content within safe limit. The humification index were higher and was non phototoxic. Fertilizing Index of 4.7 and Clean Index of 5 qualify it to be a class A marketable organic fertilizer. A field experiment to study the effect of customized organic fertilizer in crop production using Nendran banana as test crop indicated that a steady and constant supply of all essential nutrient to banana and results in profitable net returns, ensuring immediate energy source to rhizospheric microorganisms and promoting long term carbon sequestration in agro ecological 8 of Kerala

### 9. “Development of custom blended organic fertilizer for vegetables”

Vegetables viz., okra, brinjal, chilli, tomato and cucumber were treated with custom blended organic fertilizer made through Suchitha Rapid Waste Processing Technology @ 100, 125 and 150% of POP recommendation. Okra, brinjal, chilli and cucumber recorded the highest yield for the treatment receiving the NPK @ 100% POP in the form of custom blended organic fertilizer (CBOF) in powder form, followed by the same treatment combination in briquette form. The soil test based recommendation followed the above two. For tomato treatment receiving NPK @ 125% POP in the form of custom blended organic fertilizer in powder form recorded the highest yield followed by tomato treatment receiving NPK @ 150% POP in the form of custom blended organic fertilizer in powder form. The quantity and schedule of organic fertilizer application is given below:

#### Quantity and schedule of application of CBOF fortified with nutrients to crops

Crops	Quantity of CBOF plant <sup>-1</sup>	Quantity of CBOF ha <sup>-1</sup>	Schedule and time of application
Okra	350 g	12.5 t	1/3 <sup>rd</sup> as basal and remaining in 5 equal splits from 3 <sup>rd</sup> week onwards
Brinjal	600 g	12.5 t	1/2 <sup>nd</sup> as basal and remaining in 6 equal splits from 3 <sup>rd</sup> week onwards
Tomato	550 g	12.5 t	1/2 <sup>nd</sup> as basal and remaining in 6 equal splits from 3 <sup>rd</sup> week onwards
Chilli	250 g	12.5 t	1/2 <sup>nd</sup> as basal and remaining in 6 equal splits from 3 <sup>rd</sup> week onwards
Cucumber	3000 g	10.0 t	2/3 <sup>rd</sup> as basal and remaining in 5 equal splits from 3 <sup>rd</sup> week onwards

### 10. “Strengthening and maintenance of Lead Centre for Organic Farming at College of Agriculture, Vellayani”

The established Model Organic Farm at College of Agriculture, Vellayani under the Department of Soil Science & Agricultural Chemistry is being maintained as a permanent field study centre for demonstrations and training purpose in the area of organic farming. Internal training on Organic Cultivation of major crops of Kerala training and demonstration on quality organic manure production were conducted for students, women unemployed youth, farmers and other public. On-farm preparation, characterization and evaluation of liquid organic manures viz. panchagavya and fish amino acid were conducted. Both the liquid manures were acidic in nature. Fish amino acid registered very high organic carbon content and dehydrogenase activity. E-coli was not detected. Comparative study of soil and foliar application of liquid organic manures conducted on okra and cow pea proved that soil application is more effective for growth and yield. Soil health was also enhanced compared to control. Training programmes on scientific organic farming were conducted for farmers and students visited the model organic farm. Facilities in the model organic farm are being utilized by students of UG and PG programmes and Diploma course for their study purpose. Lead Centre acts as a permanent knowledge and learning centre for all aspects of Organic Agriculture & Agribusiness with a mission to build competence for organizations and individuals which will contribute to ecologically, economically and socially sustainable agriculture and livelihood system.

### 11. “Income and livelihood improvement of banana farmers in Southern Western Ghat Tract through soil fertility intervention”

The results of the investigation carried out during three years in the farmers' fields at Karode and Chenkal panchayats indicated that the nutrient management with Kerala Agricultural University Package of Practices Recommendation for Nendran banana (NPK @ 190:115:300 g plant<sup>-1</sup> in 6 split doses) along with application of lime @ 1 Kg per plant at planting, boron @ 10 kg ha<sup>-1</sup> in two splits (½ basal as borax + ½ at 4-5 months after planting through foliar spray as solubor) and soil application of magnesium sulphate @ 80 kg ha<sup>-1</sup> in two splits (½ basal + ½ at 4-5 months after planting) given in the as T<sub>7</sub> treatment resulted in highest bunch yield of 29.33 tha<sup>-1</sup> which was 41.75 per cent higher compared to POP recommendation (20.69 tha<sup>-1</sup>). The treatment also produced 94.24 per cent higher yield than the farmer practice (15.10 tha<sup>-1</sup>). The T<sub>7</sub> treatment also produced the highest net returns of Rs.11,01,484 ha<sup>-1</sup> and benefit:cost ratio of 2.20) or farmer practice (net returns Rs.4,17,238 ha<sup>-1</sup> and benefit:cost ratio of 1.85). It could be concluded that it is technically feasible and economically viable to enhance the productivity and income from banana cultivation through the soil acidity management combined with soil application of magnesium sulphate and soil plus foliar application of micro nutrient boron.

### 12. “Micronutrient management for sustenance of soil health under intensive cultivation in Western Ghat region”

Developed two multinutrient fertilizer mixtures for banana and bhindi suitable for southern region of Kerala. Accordingly a formulation of micronutrient fertilizers mixture suitable for Vegetables was developed in the Department of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani. Experiments conducted in farmers fields using the “Banana micromix” recorded 20 per cent increase in yield in Banana var. Nendran. Disease resistance and improved crop quality

was also observed. Experiments conducted in farmers fields using the “Vegetable micromix” recorded two times increase in the yield, pest and disease resistance and improved crop quality. The mixture can be used either as foliar application or soil application. For foliar application the mixture should be applied @ 5 kg ha<sup>-1</sup> as 0.5% foliar spray in two splits at 15 days after sowing and 35 days after sowing. Soil application @ 20 kg ha<sup>-1</sup> can also be done.

### **13. A comparative study on soil chemical and biological regimes under coconut ecosystem in red loam and laterite soils of Trivandrum District – A farmer participatory active research**

A general soil resource data of Trivandrum District comprising of 12 block panchayats viz. Parassala, Athiyannoor, Perunkadavila, Nemom, Thiruvananthapuram Rural, Kazhakuttam, Nedumangad, Vellanadu, Vamanapuram, Chirayinkeehu, Kilimanoor, Varkala was generated based on the soil collected in various localities. With respect to soil chemical characteristics of the 12 block panchayats a significant variation in the physical, chemical and biological properties were noticed. In general the soils are found to be moderately acidic warranting application of liming materials. Soil acidification is seen in the soils in vegetable and banana growing soils – application of lime @ 600 kg/ha is recommended. Excessive use of high input acid forming fertilizers and near absence of practice of liming in the soil has resulted in the intensification of soil acidity.

Most of the soils in Thiruvananthapuram being low activity clay soils, it is essential to maintain high levels of organic matter in the soils. The organically treated sites recorded higher values for soil biological activities thus contributing to nutrient cycling and other improved physical properties. The available phosphorus status in most of the block panchayaths are found to be high which might have been due to the residual effect of the applied phosphorus. The organic matter content of the most of the red and laterite soils are in medium to high range and highest values were noticed in the sites of organic mode of cultivation. No significant deviation in the general trend of K distribution under different cropping systems was noticed. But a general deficiency of soil available potassium was noticed in most of the block panchayats. In the case of secondary nutrients such as Ca & Mg deficiency application of Dolomite or any liming material is recommended. Deficiency of Mn and B was widely seen followed by Cu and in some places Zn. From the assessment of Biological fertility indices of various soils, the highest values were reported with the redloam soils than the laterite pockets. The highest biological fertility index was noticed in sites with highest activity of enzymes viz. dehydrogenase and cellulase. Within the redloam soils, the organically treated plots showed a distinctively higher values than the conventional plots. In general redloam soils are found to be fertile than the laterite soils. Of the various cropping system studied, Coconut + Tuber and Coconut + Fodder were found to be sustaining the soil chemical properties and physical properties. With respect to soil biological properties coconut + banana was found to be the best in respect of enzyme activities and soil respiratory activity. A correlation between the micronutrients and soil enzyme activities revealed a significant and positive correlation between them and the enzyme dehydrogenase is highly influenced by the availability of micronutrients in soil. Significant and positive correlations between soil available N, and micronutrients such as Fe, Cu, Mn and B are noticed. Among the crops selected for the study coconut + fodder have reported to have improved many of the soil physical and chemical attributes as the quantum of organic matter added or recycled to the soil is more compared to the others.

### **14. Farmer participatory approach to assess the impact of IPNS on soil health and crop yield in a typical laterite soils of Western Ghats**

A study was undertaken to understand the integrated use of inorganic fertilizers and organic sources such as fertilizers, manures on soil chemical and biological characters in typical laterite pockets of Vettikkavala Panchayat of Kottarakkara Tk. About ten locations were identified in the laterite pocket of Western Ghat region. Thirteen treatments involving the combination of inorganics and organics in the form of enriched vermicompost using bonemeal, neem cake, Azospirillum, Vesicular Arbuscular Mycorrhizae, phosphobacterins and K solubilizers *Freutaria aurantia* were tried in the farmers plots. The experiments were laid out using bitter gourd as test crop. The soil of the experimental site was a typical laterite type with a pH of 5.3. Electrical conductivity of 0.01 d Sm<sup>-1</sup>, available N 217.6 Kg ha<sup>-1</sup>, available P<sub>2</sub>O<sub>5</sub> 20.58 kg ha<sup>-1</sup> and available K<sub>2</sub>O 165.34 kg ha<sup>-1</sup>.

For the soil parameters such as pH, EC, organic carbon and available nutrient status enriched compost using Azospirillum and bone meal was found to be the best. However the organic amendments imposed a similar effect on soil pH. With regard to EC treatment involving the application of 100% Nitrogen as enriched vermicompost using neem cake has registered a highest value than the other treatments.

The composting period was also drastically reduced with the application of bio inoculants such as Azospirillum, *Freutaria aurantia*, VAM and phosphobacteria. A reduction in composting period upto 20 days was observed when compared with the addition of organic amendments alone. The most suitable bioinoculant for composting is Azospirillum.

Enzyme activity is essential in both mineralization and transformation of organic C and plant nutrients. From the study, it is inferred that with respect to soil enzymatic activities enriched vermicompost using neem cake and K solubilizer was superior to other treatments. It is observed from the trial that soil urease, phosphatase and dehydrogenase reported a comparatively higher values of 216 ppm of urea hydrolysed  $\text{g}^{-1}$  of soil  $\text{hr}^{-1}$ , 56  $\mu\text{g}$  of p- nitrophenyl released  $\text{g}^{-1}$  of soil  $\text{hr}^{-1}$  and 356  $\mu\text{g}$  of TPF hydrolysed  $\text{g}^{-1}$  of soil 24  $\text{hrs}^{-1}$  respectively than the other treatments. The substitution of nitrogen with 100% of neem cake enriched vermicompost is possible resulting in improved soil biological properties. With regard to protease activity, it is observed that the application of Azospirillum enriched vermicompost had a significant influence both at 100% and 50% substitution. The highest value for dehydrogenase activity was noticed with the application of vermicompost enriched with neem cake whereby nitrogen is substituted to a rate of 100%.

A higher fruit yield was realized when compost enriched with Pseudomonas (Pseudomonas @ 1%) + NPK fertilizer was applied ( $15.74 \text{ t ha}^{-1}$ ). The quality of the resultant compost was also influenced significantly by the application of inoculants pseudomonas 1% and 0.5% and Azospirillum (1%). This study thus clearly showed that the judicious use of bioinoculants such as Pseudomonas, Trichoderma and Azospirillum as potential source of enrichment which improves the soil parameters as well as yield of the crops.

It is also inferred that all the biological and biochemical parameters revealed similar trends over time in response to the addition of organic matter amendment had an effect on soil microbial community size and activity resulting in an increase in microbial biomass (C and N), enzyme activities and N mineralization.

### 15. Major nutrient disorders of banana (var. Nendran) in Vaikom block

Results on soil acidity showed that the intensity of acidity varied from very strongly acidic to slightly acidic. The electrical conductivity was found to be normal in these tracts at the time of sampling and organic carbon status was found to be optimum in the region. The deficiency of major as well as micronutrients were observed in the study area and this was confirmed with the help of soil and plant analysis, as well as field observation. Available phosphorus (P) was adequate in the soils, but nitrogen (N) and potassium (K) were found to be deficient. A widespread deficiency of potassium was observed in the study area and visible symptoms were prominent in the fields. Phosphorus content was found to be sufficient in the fields because of the continuous application of Factamphos and bone meal by the farmers. Among the secondary nutrients, calcium and magnesium deficiency was severe in Vaikom block whereas sulphur (S) content was found to be sufficient. Application of lime was rarely followed by the farmers and often the quantity applied was less than the crop requirement ( $<500 \text{ g per plant}$ ). The analysis data revealed that the soils were found to be deficient in Boron (B), zinc (Zn) and copper (Cu) whereas iron (Fe) and manganese (Mn) content was sufficient. Micronutrients, especially boron deficiency was very severe and field symptoms were prominent. Deficiency symptoms in banana were either due to actual deficiency or induced deficiency. In certain pockets of Vechoor and Thalayazhampanchayath, deficiency symptoms were very prominent even when the soils were having optimum boron content. This induced deficiency was observed in areas where higher levels of phosphorus was seen. This situation might have aroused from the fact that farmers were applying higher levels of phosphatic fertilizers like Factamphos and bone meal.

A widespread deficiency of potassium was observed in the study area and visible symptoms were prominent in the fields with necrosis of leaves starting from the leaf margin and extending towards the midrib. In severe cases the leaf withered and curled and affected the crop yield as well. Farmers misinterpreted these symptoms for disease incidence and often applied fungicides instead of proper nutrient application. Deficiency of calcium and magnesium was acute in the soils where field symptoms were observed. Soil analysis revealed that the areas were severely deficient in calcium and magnesium. This was influenced mainly by two factors viz. inherent soil acidity and the nutrient management practices by farmers. Farmers were unaware about the importance of application of secondary nutrients and they merely applied urea and Factamphos as sources of nutrients. Secondary and micronutrient application was not carried out by the farmers. Calcium deficiency symptom appeared as yellow-white parallel streaks in the leaf lamina parallel to the midrib accompanied by severe crinkling of leaves. In the case of magnesium deficiency leaves showed excessive yellowing and chlorosis. Yellowing started from the central zone of the lamina while the margins and midrib area remained green in colour. Soil and plant analysis data revealed that micronutrient deficiencies were also widespread in the region. Iron (Fe) and Manganese (Mn) content was sufficient in the soil as well as plant tissues. But boron, zinc and copper was found to be deficient in the area.

The symptoms of boron deficiency were prominent and plants showed delayed unfolding of leaves. Uneven and brittle leaf surface with 'ladder like' symptoms were also noticed in these plants. In severe cases leaves and fruit bunches were malformed. It was concluded that the nutrient disorders observed in field were due to deficiency of both major and micronutrients. Multi-nutrient deficiencies identified in the banana growing areas might be the major reason for decline

in productivity. Scientific nutrient management based on soil and plant health can alleviate the nutrient deficiencies and enhance the crop yield.

#### 16. Regional soil health management under the project – Soil Resource Management and Biological Soil Fertility

Experiments were conducted to monitor soil health parameters in different agro-ecosystems of Kerala, to develop location specific management technologies to improve and sustain soil health and to assess major, secondary and micronutrient status of soils periodically under different AEU's. Soil samples were collected from geo referenced sampling points under intensive agriculture from different panchayats in the districts of Thrissur, Palakkad, Malappuram, Wayanad, Ernakulam, Kollam and Kozhikode. The samples were analysed for different parameters indicating the fertility status of soil. Samples from the same locations were collected after a period of 3 years and analysed for all the parameters related to soil fertility. The analytical data were arranged into different classes based on fertility ratings. The frequency distribution of samples in each class was represented as per cent of total samples analysed with respect to each district for ease in comparing the changes that had occurred over the period.

The changes that had occurred in the soil fertility parameters over a period of three years in the geo referenced sampling points after advocating crop specific soil test based recommendations were studied and the parameters that require prioritized management have been identified for each district.

In majority of the districts covered, measures should be taken to alleviate boron and magnesium deficiency. Amelioration of acidity comes as the next factor especially in Malappuram, Wayanad and Kollam districts. Sulphur deficiency is increasing in Wayanad and Kollam districts. Available phosphorus status is abnormally high in all the districts studied. There is every possible chance of phosphorus induced zinc and boron deficiency. Skipping of application of P-fertilizers may be thought of based on soil test results. Wayanad is the district with all the above problems together – acidity, organic matter degradation and nitrogen deficiency, excessive levels of available phosphorus, increased deficiencies of potassium, calcium, magnesium, sulphur, zinc and copper. The present study clearly indicates that soil test based recommendations are showing positive trends where ever it is implemented properly.

#### 17. "Network Project on Characterization and management of soil fertility with respect to secondary and micronutrients for Agro eco systems of Kerala"

The investigation was carried out to identify the critical level of secondary and micronutrients via. Ca, Mg, Zn, Cu and B in soils and in various crops, to study the response of selected crops in identified areas for the adhoc-recommendation available for secondary and micronutrients. The experiment also aimed the standardization of fertilizer recommendations for various crops with respect to secondary and micronutrients, identification of appropriate mode of application of secondary and micronutrients, for each crop and to study the residual effect and interaction effect of application of secondary and micronutrients on soil physical, chemical and biological system.

On-farm trials to identify the critical levels of micro and secondary nutrients for the seasonal crops like rice, vegetables (Yard long Bean, Bitter gourd, Snake gourd), ginger, banana and perennial crops like coconut and pepper were laid out by the PIs of the ten centres covering 23 agro ecological units. The experiments were laid to study the response of crops to different levels of the deficient nutrient: providing all other nutrients as per adhoc recommendations based on soil test. Almost 268 numbers of field trial have been conducted and response for application of secondary and micro nutrients and significant yield increase were observed in the fields where deficiency of elements was noticed.

The salient findings are given in the tables.

Crop	Element	Critical level	
		Soil (mg kg <sup>-1</sup> )	Plant
Rice	Calcium	240	0.43%
	Magnesium	90	0.33%
	Boron	0.45	22 mg kg <sup>-1</sup>
	Zinc	2.5	29 mg kg <sup>-1</sup>
Banana	Calcium	320	0.29%
	Magnesium	78	0.15
	Boron	0.4	40 mg kg <sup>-1</sup>
	Zinc	1.3	40 mg kg <sup>-1</sup>
Vegetables Snake gourd & Bitter gourd	Magnesium	118 - 120	0.4%
	Boron	0.53	30 mg kg <sup>-1</sup>
Vegetable cowpea	Magnesium	125	-
	Boron	0.4	26 mg kg <sup>-1</sup>

**Recommendations rice**

AEU (area)	Calcium carbonate (kg ha <sup>-1</sup> )	Magnesium sulphate (kg ha <sup>-1</sup> )	Borax (kg ha <sup>-1</sup> )	Zinc sulphate (kg ha <sup>-1</sup> )	Copper sulphate (kg ha <sup>-1</sup> )
1/ southern coastal plain (Thiruvananthapuram to Ernakulam)			12.5	25	1.5
3/Onattukara sandy soils (Kollam and Alappuzha)			12.5	10-15	1
4/ (Kuttanad soils)	350				
6/ (Kole soils)	850	100	15	10	1
10/ Laterite soils of Thrissur and Palakkad districts	500		12.5	20	
22/ Soils of Palakkad central plains Alathur and Palakkad thaluks			5.5		
23/ Soils of Chitturthaluk			15		1

**Recommendations Banana**

AEU/Soil type	Calcium CaCO <sub>3</sub> (kg ha <sup>-1</sup> )	Magnesium sulphate (kg ha <sup>-1</sup> )	Borax (kg ha <sup>-1</sup> )	Zinc sulphate (kg ha <sup>-1</sup> )	Copper sulphate (kg ha <sup>-1</sup> )
1/ southern coastal plain (Thiruvananthapuram to Ernakulam)			120	2.5	15
2/ Northern coastal plain (Thrissur to Kasarcode)				10	15
3/Onattukara sandy soils (Kollam and Alappuzha)				10	10
4/ (Kuttanad soils)				5 g/L	30
6/ (Kole soils)					
8/ Laterite soils in the southern parts of Thiruvananthapuram district up to Kazhakoottampanchayat	500 to 850			5	15
9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottampanchayat) to Ernakulam district including both	500 to 850 (if pH <3.5)			5	25
10/ Laterite soils of Thrissur and Palakkad districts	500 to 850			12.5	25
11/Laterite soils of Malappuram, Kozhikode, Kannur and Kasarcode districts				10	15
15/ Northern high hills (high hill areas extending from Thrissur to Kasarcode (excluding Attappady hills)			120	12.5	15
22/ Soils of Palakkad central plains Alathur and Palakkad thaluks					25
23/ Soils of Chitturthaluk				12.5	

**Recommendations Vegetables**

AEU	Magnesium sulphate (kg ha <sup>-1</sup> )	Borax (kg ha <sup>-1</sup> )	Zinc sulphate (kg ha <sup>-1</sup> )	Magnesium sulphate (kg ha <sup>-1</sup> )	Borax (kg ha <sup>-1</sup> )	Zinc sulphate (kg ha <sup>-1</sup> )
	Snake gourd			Bitter gourd		
1/ southern coastal plain (Thiruvananthapuram to Ernakulam)	120	10	20	120		30
3/Onattukara sandy soils (Kollam and Alappuzha)		10			5	
4/ (Kuttanad soils)			25			
8/ Laterite soils in the southern parts of Thiruvananthapuram district up to Kazhakoottampanchayat	100	5		60	5	
9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottampanchayat) to Ernakulam district including both		5	30			
10/ Laterite soils of Thrissur and Palakkad districts	120	10 to 15		120	15	

## Recommendations Vegetable cow pea

AEU	Magnesium sulphate(kg ha <sup>-1</sup> )	Borax (kg ha <sup>-1</sup> )
1/ southern coastal plain (Thiruvananthapuram to Ernakulam)	120	10
2/ Northern coastal plain (Thrissur to Kasarcode)	80	
3/Onattukara sandy soils (Kollam and Alappuzha)		
8/ Laterite soils in the southern parts of Thiruvananthapuram district up to Kazhakoottampanchayat	100	2.5
9/ Laterite soils extending from Northern parts of Thiruvananthapuram district (from Kazhakoottampanchayat) to Ernakulam district including both	60	5
10/ Laterite soils of Thrissur and Palakkad districts		10
11/Laterite soils of Malappuram, Kozhikode, Kannur and Kasarcode districts	100	

## 18. Network Project on Characterization and Management of soil fertility with respect to secondary and micronutrients for Agro Ecosystems of Kerala

As a part of the project soil samples were collected from different areas of Palakkad and Malappuram districts, analysed for nutrients and field trials were done in micronutrient deficient areas. 20 experiments were done at RARS Pattambi and in farmers' fields under different Agro ecological units of Palakkad and Malappuram districts to find out the secondary & micronutrient requirement of the zone.

In banana, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 22,23) in boron deficient areas, magnesium sulphate @ 100 kg/ha in magnesium deficient areas and zinc sulphate @ 20 kg/ha in zinc deficient areas separately along with soil test based management options for other nutrients improved the bunch yield and quality. In rice, the application of borax @12.5 kg/ha (AEU 10) and @15 kg/ha (AEU 23) in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and zinc sulphate @ 30 kg/ha in zinc deficient area separately along with soil test based management options for other nutrients improved the grain yield and quality.

In Coconut, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 13) in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and Copper sulphate @1.5 kg/ha in copper deficient areas separately along with soil test based management options for other nutrients improved the average yield.

Ready to use solid micronutrient formulations for rice and banana have been prepared, tested and released for sale for foliar application.

### 19. "Establishment of centre for organic farming in Onattukara"

Demonstrations were laid out during virippu and mundakam 2014 in rice. During summer 2014 sesamum, cowpea, amaranthus and cucumber were raised in the summer rice fallows. The variety used was bhagya and dhanu during virippu and mundakan respectively. The biometric and yield data recorded during virippu and mundakan are furnished below.

Treatment	Height (cm)	Total tillers (No.)	Productive tillers (No.)	Yield (kg ha <sup>-1</sup> )	
				Grain	Straw
100% organic	96.18	10.53	8.74	2425	3431
75% organic	93.52	9.80	8.22	2388	3376
50% organic	91.20	8.25	7.34	2200	3008
Control	90.85	7.50	6.23	2210	2989

The grain and straw yield obtained by the application of 100% NPK and 75% NPK as organic were high. The yield obtained by the application of 50% NPK as organic is comparatively low.

Treatment	Height (cm)	Total tillers (No.)	Productive tillers (No.)	Yield (kg ha <sup>-1</sup> )	
				Grain	Straw
100% organic	103.52	10.23	7.25	2678	5448
75% organic	100.25	9.84	6.75	2569	5100
50% organic	100.30	8.89	5.82	2300	4427
Control	100.24	9.00	5.42	2252	4335

As in the case of virippu the yield obtained during mundakan season is also the same.

## 20. “Organic resource integration for sustainable tuber production in the selected agroforestry systems of western ghat tracts of southern Kerala”

Litter in agroforestry gardens can be exploited as a nutrient source for tuber cultivation after composting. Leaf litter vary in their allelopathic potential and the crops in which they are used for Species like jack, cashew and rubber as much exhibited positive allelopathy while Ailanthus wild jack and tamarind recorded negative allelopathy. Elephant foot yam and tannia are better suited as understory crops in agroforestry gardens. Litter compost at 50% N substitution of POP recommendation (100:50:150 kg NPK ha<sup>-1</sup>) recorded highest yields in elephant foot yam and on par with 100% organic nutrition. The two treatment have been found to best based on the crop performance influence of soil properties and economic returns. The low cost zero energy cool chambers can be used for temporary storage of tubers upto two months without any significant damage.

### Ongoing Projects

#### 1. Germplasm conservation of indigenous rice varieties and ecological restoration of rice soils

Germplasm raised during virippu 2014 and mundakan 2014 consisting of 76 and 28 entries respectively. All the entries were characterized based on IRR1 descriptor. To study drought tolerance, seedling characters of virippu entries were recorded at 20 DAS. The result revealed that varieties Onam, Bhagya, Chingam, Aiswarya, Deepthi and *Santhosh* exhibited good seedling vigour in terms of height, number of leaves, length of root and number of roots. F1 seeds of the crosses *Santhosh* x ptb-8, chuttiaryan x njavara, ptb 8 x *Santhosh*, OM2x bhagya, bhagya x kanchana were planted and F2 seeds were collected. Ten new crosses viz. Njavara x MO-8, Nandiarvattom x Chingam, MO-8 x Vandana, Njavara x Kunjukunjupriya, Vandana x Njavara, Nandiarvattom x MO-7, Kunjukunjupriya x Chingam, Njavara x Kochuvithu, Chingam x Njavara. Kochuvithu x Njavara were conducted and the F1 seeds were collected. For molecular studies DNA was isolated and marker assisted selection started. 104 germplasm lines were characterized. Ten new crosses were made and F1 seeds of five crosses were collected.

#### 2. Fertility in relation to movements, losses transformations and interactions in different agroclimatic regions of Kerala

This experiment is a Permanent Manurial Trial to find out the effect of continuous application of N, P, K and lime over incorporation of straw on soil fertility, yield, quality and incidence of pests and diseases.

The effect of treatments in the yield data is given below:

Treatments	Yield, kg/ha	
	2014 Kharif	2014-15 Rabi
1 NPK@ 0:0:0 kg/ha Without straw incorporation	2117	2375
2 NPK@ 0:0:0 kg/ha With straw incorporation	2158	2392
3 NPK @ 90:0:0 kg/ha With straw incorporation	1517	3100
4 NPK @ 90:45:0 kg/ha With straw incorporation	1442	3867
5 NPK @ 90: 0: 45 kg/ha with straw incorporation	1550	3175
6 NPK @ 0:45:45 kg/ha with straw incorporation	2225	2408
7 NPK @ 90:45:45 kg/ha with straw incorporation	1717	3817
8 NPK @ 90:0:0 kg/ha with straw incorporation+ lime	1633	3625
9 NPK @ 90:45:45 kg/ha (lime , dung), as per soil test data (with straw incorporation and dung)	2042	3583
10 Alternate fallow NPK @ 90:45:45 kg/ha	1525	3250
CD (0.05)	528	413

There was significant reduction in grain yield on avoiding fertilizer application, both in straw incorporated as well as non-incorporated plots. The treatments with N omission (T6) had significantly lower yield and was on par with the control plots (T1 and T2). Application of fertilisers based on soil test basis (T9 - NPK with dung application based on the organic carbon status of the soil) gave the grain yield as par with the NPK applied plots (T7 and T8). Skipping of K fertilizer alone did not reduce the yield even after 27 years of experimentation and the yield was on par with that in NPK fertilised fields. Straw corporation in the field might have helped to improve the K status.

The experimental results during the last 5 years revealed severe nutritional deficiency and yield reduction in the N and P omission for the last 27 years. K omission plots (with straw incorporation and NP application) for the last 25 years had almost similar yield as fertilised plots even after 27 years of K skipping, both during Kharif and Rabi seasons. Nitrogenous fertiliser application is essential in Kuttanad paddy fields (inorganic cultivation) due to the anaerobic decomposition of straw and reduced mineralisation of organic carbon.

### **3. Classification and characterization of farming systems in district wise agroecological zones of Kerala**

The above project was undertaken with the following objectives:

- Identification of major farming systems in each agro ecological zones of fourteen districts in Kerala
- Integration of background databases including natural resource database for each zone at the District and State level
- Develop agro ecological zone based level reports for fourteen districts and consolidated State level Report

Reports of all Districts have been published. The reports have been prepared after personal interaction with nearly 850 officers of State Department of Agriculture and over 1200 farmers.

The reports will be a critical input for preparing District level and State level plans and will help policy makers of the State in agricultural development in future.

Documents brought out for implementing the Lead Farmer Centred Extension Advisory and Delivery Services (LEADS) programme of the Kerala State Government (based on project work)

1. Background report for Lead Farmer Centred Extension Advisory and Delivery Services (LEADS) in Palakkad and Kollam Districts -An agro ecological zone perspective (2012) were published jointly by Kerala Agricultural University and Kerala State Planning Board.

Documents brought out for implementing the SREP (Strategic Research Extension Plan) and ATMA Plus programme of the Kerala State Government in all Districts (based on project work)

Fourteen chapters based on the project findings in the “Strategic Research Extension Plan (SREP)” based on agroecological units of all Districts of Kerala

Vital information pertaining to the following critical aspects have been generated for all districts of Kerala

- Major cropping/farming systems followed (intercropping, sequential cropping etc.) in each AEU i.e. most common crop combinations and livestock components.
- Major Pest/Diseases/Nutritional Disorder of major crops
- Location specific problems that need intervention by the researchers/extension workers
- Status of technology adoption in major crops
- Average yield and yield gap of major crops

### **4. Enhancement of production and Productivity of major crops in Onattukara**

#### **Sub Project Organic nutrition of medicinal rice Njavara in Onattukara**

The experiment was conducted to study the response of medicinal rice Njavara to organic, integrated and inorganic nutrition and to evolve an ideal management package for profitable production of Njavara.

*Virippu 2014*

The experiment was laid out as per the approved technical programme. Biometric and yield data during *virippu 2014* are furnished in table – 1

Table – 1. Biometric and yield data *Virippu* 2014

Treatment	Treatment details	Ht. of plant (cm)	Total Productive`		Yield ha <sup>-1</sup>		Benefit cost ratio
			tillers hill <sup>-1</sup> (no)	tillers kg hill <sup>-1</sup> (no)	Grain	Straw	
T1	100% N as Farm yard manure + P&K	98.10	5.40	4.48	815	1108	1.69
T2	75% N as Farm yard manure + P&K	97.25	6.20	4.25	902	1192	1.67
T3	100% N as Trichoderma enriched vermicompost + P&K	99.30	5.30	3.15	1233	1474	1.77
T4	75% N as Trichoderma enriched vermicompost + P&K	101.24	7.80	4.30	980	1128	1.68
T5	100% N as rock phosphate enriched vermicompost + P&K	100.60	7.50	4.45	1085	1305	1.73
T6	75% N as rock phosphate enriched vermicompost + P&K	100.54	6.43	3.82	1013	1374	1.71
T7	100% N as Farm yard manure + Trichoderma enriched vermicompost (1:1 proportion)+ P&K	98.58	6.41	4.62	1280	1520	1.76
T8	75% N as farm yard manure + Trichoderma enriched vermicompost (1:1 proportion)+P&K	101.24	7.50	5.21	1408	1769	1.81
T9	100% N as FYM + rock phosphate enriched vermicompost (1:1 proportion)+ P&K	99.24	7.23	5.03	1044	1432	1.72
T10	75% N as FYM + rock phosphate enriched vermicompost (1:1porportion) + P&K	98.90	6.58	4.94	1183	1309	1.74
T11	100% N as FYM + Trichoderma enriched vermicompost + rock phosphate enriched vermicompost (1:1:1 proportion)+ P&K	98.40	6.8	4.12	940	1300	1.69
T12	75% N as FYM + Trichoderma enriched vermicompost + rock phosphate enriched vermisompost(1:1:1 porportion) + P&K	100.85	7.25	4.85	920	1325	1.71
T13	NPK as fertilizers (40:20:20)	97.35	5.39	3.14	880	1298	1.68
T14	POP recommendations	97.10	5.45	3.20	820	1200	1.68
T15	Farmer's practice	98.00	5.28	3.18	790	1018	1.67
	CD(0.05)	NS	NS	0.42	125	218	0.02

The treatments differ significantly in grain yield and straw yield. Highest grain and straw yields (1408 and 1569 kg ha<sup>-1</sup>) were obtained from the plots which received 75% N as FYM and Trichoderma enriched vermicompost in 1:1 proportion with recommended dose of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O as bone meal and ash respectively. This was followed by T7 and T3 which were on par with each other. Highest BC ratio was obtained from treatment T8.

#### Mundakan – 2014

During Mundakan season also the same trend was observed as in the case of Virippu 2014 with respect to biometric observation and yield data. Highest values were recorded by T8 followed by T7.

From the results it was found that application of 75% N as FYM + *Trichoderma* enriched vermicompost in 1:1 proportion along with P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O as bone meal and ash respectively is found to be effective for optimum production of Njavara in Onattukara.

#### 5. Permanent Manurial Trial of rice in acid Saline soils under flooded condition (Pokkali tract).

The experiment was conducted to find out the long term effect of application of inorganic fertilizers on the productivity of Pokkali soils and to assess its impact on rice production.

The experiment consisted of the following treatments:

- T1 - Control (no fertilizers)
- T2 - 20 kg N ha<sup>-1</sup>
- T3 - 40 kg P205 ha<sup>-1</sup>
- T4 - N and P at 20:40 kg ha<sup>-1</sup>
- T5 - NP and K at 20:40:20 kg ha<sup>-1</sup>
- T6 - NPK 20:40:20 kg ha<sup>-1</sup>+ lime 1000 kg ha<sup>-1</sup>
- T7 - NP 20:40 kg ha<sup>-1</sup>+ lime 1000 kg ha<sup>-1</sup>
- T8 - P 40 kg ha<sup>-1</sup>+ lime 1000 kg ha<sup>-1</sup>
- T9 - NPK 20:40:20 kg ha<sup>-1</sup> (N as urea mud ball)
- T10 - NPK 20:40:20 kg ha<sup>-1</sup> (N as neem coated urea)

The yield data for 2014 showed slight yield increase for the N and P fertilizer applied plots but there was no significant increase in yield. The percent yield increase was highest 17.09 %) in the plots receiving N and P @ 20:40 kg ha<sup>-1</sup>. The plot

receiving NPK application with lime @ 1 ton ha<sup>-1</sup> has an increase of 5.67% over control. During this year the application of chemical fertilizers have shown a slight increase in rice yield though not to a significant level. The Pokkali fields are highly suited for organic farming. As a permanent manurial trial, the experiment is to be continued.

#### **6. Utilization of nutrient specific phytoextractors /accumulators for enriched compost production in organic farming**

Experiment was conducted for identification of phytoaccumulators for specific nutrients by extensive sampling and analysis Production of enriched compost from phytoaccumulators using vermin composting and field testing of enriched compost under organic farming situation to assess its efficacy.

Collected and analyzed 362 plant samples. Identified 10 hyper accumulators and the conversion efficiency of the nutrients into compost is being analyzed. Identified 10 hyper accumulator plants having high concentration of total nutrients to the tune of about 10% total nutrient contents.

Based on the nutrient content of the prepared compost and other advantages of the plants, 3 plants namely *Amaranthusspinosus*, *Canna indica* and *Mirabilis jalapa* are selected for large scale compost production and crop response study is over.

#### **7. AICRP on Long Term Fertilizer Experiments**

The results of the kharif and rabi crops 2014-15 have been analysed statistically and soil samples were analysed for the different parameters.

50%NPK+ *In situ* green manuring /FYM identified as 2<sup>nd</sup> best alternative which can reduce 50 per cent of the recommended inorganic fertilizer without compromising yield

This experiment has completed 17 years of experimentation and provides an opportunity to evaluate the sustainability of agricultural practices.

#### **8. Network Project on Characterization and Management of soil fertility with respect to secondary and micronutrients for Agro Ecosystems of Kerala**

As a part of the project soil samples were collected from different areas of Palakkad and Malappuram districts, analysed for nutrients and field trials were done in micronutrient deficient areas. 20 experiments were done at RARS Pattambi and in farmers' fields under different Agro ecological units of Palakkad and Malappuram districts to find out the secondary & micronutrient requirement of the zone.

In banana, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 22, 23) in boron deficient areas, magnesium sulphate @ 100 kg/ha in magnesium deficient areas and zinc sulphate @20 kg/ha in zinc deficient areas separately along with soil test based management options for other nutrients improved the bunch yield and quality.

In rice, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 23) in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and zinc sulphate @ 30 kg/ha in zinc deficient areas separately along with soil test based management options for other nutrients improved the grain yield and quality.

In coconut, the application of borax @ 12.5 kg/ha (AEU 10) and @ 15 kg/ha (AEU 13) in boron deficient areas, magnesium sulphate @ 120 kg/ha in Mg deficient areas and Copper sulphate @ 1.5kg/ha in copper deficient areas separately along with soil test based management options for other nutrients improved the average yield.

Ready to use solid micronutrient formulations for rice and banana have been prepared, tested and released for sale for foliar application.

Experiments for identification of critical levels of different nutrients are in progress. Micronutrient formulation for rice and banana were released into market.

#### **9. Developing systems recommendation for nutrient, disease and insect pest management in major cropping systems of Kerala (Network)**

The field experiments at Palakkad and Karamana have been completed. Summer crop was harvested in May 2015. Soil and plant analyses are in progress.

Trend: Present NPK Recommendation can be reduced by 25 % without reduction in yield in the studied cropping systems

#### **10. Developing user friendly weather based calendars for various crops in different agro ecological zones of Kerala (part of a Network project on Weather)**

This project was planned to develop user friendly weather based calendars for rice in different agroecological zones of Kerala. Crop calendar preparation has been completed. Final report preparation is in progress.

**11. AICRP Experiments: Development and Validation of On-Station Integrated Farming System models (Four sub projects)**

- a. Homestead based IFS model (0.2 ha)
  - b. Coconut based IFS model (0.2 ha)
  - c. Rice based IFS model (0.2 ha)
  - d. Banana based IFS model (0.2 ha)
- (NRM-03-00-01-2014-KAR(1) AICRP- 1)

All the four fully established models are managed scientifically to realize maximum profit. All these models were more profitable than the predominant farming system of the state. The highest net returns per hectare and employment generation were obtained from rice based IFS (Rs.3,02,775 & 699 man days) followed by homestead based IFS (Rs.2,86,550 & 402.5 man days), coconut based IFS (Rs.2,63,905 & 397.5 man days) and Banana based IFS (Rs. 1,01,815 & 437.5 man days). The predominant farming system existing in the state realized a net income of Rs.53,440/ha. Nutrient generation and recycling was highest in coconut based IFS, followed by rice based IFS, homestead based IFS and Banana based IFS.

**12. AICRP Experiments: 1a on IFS mode - Investigating rice based farming systems involving fish through suitable land modifications vis-à-vis conventional rice based cropping systems**

The experiment was conducted to study the performance of different cropping sequences in rice based integrated farming system involving fish component in terms of soil fertility, energetics and economics. The experiment consists of 7 treatments as given below:

Treatment	Kharif*	Rabi*	Summer
T <sub>1</sub>	Rice	Rice	Fallow
T <sub>2</sub>	Rice + fish	Rice + fish	Amaranthus + fish
T <sub>3</sub>	Rice alone	Rice alone	Amaranthus
T <sub>4</sub>	Rice + fish	Rice + fish	Culinary melon + fish
T <sub>5</sub>	Rice alone	Rice alone	Culinary melon
T <sub>6</sub>	Rice + fish	Rice + fish	Fodder cowpea + fish
T <sub>7</sub>	Rice alone	Rice alone	Fodder cowpea

\* The stocking density of fish (carp) will be @ 1 fingerling per m<sup>2</sup>

The (rice+fish) - (rice+fish) - (culinary melon+fish) system was most profitable (Rs.1,65,037/ ha) followed by (rice+fish) - (rice+fish) - (fodder cowpea+fish) (Rs.85007/ ha) and (rice + fish) - (rice + fish) - (amaranthus + fish) (Rs.84473/ha). Fish (channa + tilapia) when simultaneously cultured with rice, generated a gross income of up to Rs.334/- from a cent (40 sq.m).

**13. Experiment 2a- Permanent plot experiment on integrated nutrient supply system for a cereal based crop sequence**

The experiment was conducted to develop a suitable integrated nutrient supply system for a cereal based crop sequence involving more efficient use of fertilizers in conjunction with judicious combination of organic manures by their effective recycling technique, without any detrimental effect to long term soil fertility and improving crop productivity.

The treatment details are as follows:

Treatment	Kharif	Rabi
T <sub>1</sub>	No fertilizers, no organic manure (control)	No fertilizers, no organic manure (control)
T <sub>2</sub>	50% RDN* of NPK through fertilizers	50 % RDN of NPK through fertilizers
T <sub>3</sub>	50% RDN of NPK through fertilizers	100 % RDN of NPK through fertilizers
T <sub>4</sub>	75 % RDN of NPK through fertilizers	75 % RDN of NPK through fertilizers
T <sub>5</sub>	100% RDN of NPK through fertilizers	100 % RDN of NPK through fertilizers
T <sub>6</sub>	50 % RDN of NPK through fertilizers + 50 % through FYM	100 % RDN of NPK through fertilizers
T <sub>7</sub>	75% RDN of NPK through fertilizers + 25% through FYM	75 % RDN of NPK through Fertilizers
T <sub>8</sub>	50% RDN of NPK through fertilizers + 50% through crop residues	100% RDN of NPK through fertilizers
T <sub>9</sub>	75% RDN of NPK through fertilizers + 25 % through crop residues	75 % RDN of NPK through fertilizers
T <sub>10</sub>	50% RDN of NPK through fertilizers + 50 % through green manuring.	100 % RDN of NPK through fertilizers
T <sub>11</sub>	75% RDN of NPK through fertilizers + 25 % through green manuring.	75% RDN of NPK through fertilizers
T <sub>12</sub>	Farmers' practice (3t FYM, 90:22.5:22.5kg NPK ha <sup>-1</sup> )	Farmers' practice (90:22.5:22.5 kg NPK/ha)

\*RDN: Recommended dose of nutrients - (90:45:45 kg NPK/ha)

To achieve the economic optimum and highest productivity, 25 per cent nutrient must be substituted as organics during first crop season and 75 per cent nutrient applied as fertilizers during second crop season. The combination of nutrients entirely as fertilizers alone during first and second crop seasons revealed that a reduction of 50 per cent was detrimental for crop productivity.

No significant difference was observed in the N, P and K contents of soil at the end of the rabi season for the organic substituted and the purely inorganic treatments. Though the organic carbon values showed an increasing trend in the organic substituted treatments, the increase was insignificant.

#### 14. Development of organic farming package for system based high value crops

The study was conducted to critically evaluate organic farming vis-à-vis farming with integrated nutrient and pest management systems in terms of yield, its quality, soil health and economic advantages. It also envisages to increase manure production using farm wastes, its application for raising crops, pest and disease management through the use of plant based preparations.

*Crop sequence* : Cereal-Vegetable-Vegetable  
(Rice-Cucumber-Bhindi)

Variety : Rice : Aiswarya  
Cucumber : Vellayani local  
Bhindi : Varsha Upahar

The treatment details are as follows:

T<sub>1</sub> ½ NPK as fertilizers + ½ N as FYM + Micronutrients  
T<sub>2</sub> 1/3 NPK as FYM + 1/3 N as Vermicompost + 1/3 N as Neemcake  
T<sub>3</sub> 1/3 NPK as FYM + 1/3 N as Vermicompost + 1/3 N as Neemcake  
T<sub>4</sub> T<sub>2</sub> + Agronomic management practices for pest control  
T<sub>5</sub> ½ NPK as FYM + Biofert. N + Rock phosphate + PSB  
T<sub>6</sub> T<sub>2</sub> + Biofert. N + PSB  
T<sub>7</sub> Full NPK fertilizers + secondary and micro nutrients

In rice – cucumber – bhindi sequence crop yields and yield attributing characters did not show much variation among the organic treatments and integrated treatment while crop yields were the least in fully inorganic treatments. Grain yield of rice and yield of bhindi were highest in INM and lowest in fully inorganic treatment. Highest cucumber yield and rice straw yield were in the fully organic treatment supplemented with N and P biofertilizers and least in fully inorganic treatment.

The REY was highest (22.96 t/ha) in T1 receiving integrated nutrition and least (18.99t/ha) in T7 with full inorganic nutrition. It indicates the benefit of organic + inorganic nutrient combination for cereal based cropping system than fully organic or chemical treatments.

#### 15. Development of innovative farming practices to mitigate the effect of climate change

Experiment was planned to design and identify economically viable and efficient farming practices for resource conservation and counteracting adverse effects of climate change and to study the effects of resource conservation technologies on photosynthetic efficiency, biomass production, economic yield, soil hydro thermal regimes and soil health.

The treatment details are as follows:

A. Main plots ( Crop establishment methods x Cropping Systems )

(i) *Crop establishment methods*

T1 – Minimum tillage  
T2 – Conventional tillage

(ii) *Cropping Systems*

CS1 – Rice- rice- fallow  
CS2 – Rice- rice (F) + bhindi/any other vegetable (BB 105 x 30 cm)- black gram  
CS3 – Rice-rice (F) + cucumber- amaranthus (BB 105 x 30 cm)  
CS4 – Rice- - maize (cobs) + cowpea (BB 105 x 30 cm) –green gram (G+R)

B. Sub- plots ( Mulch x Fertilizer )

(i) *Mulch*

M1 – No mulch  
M2 – Crop residue mulch (crop residue to be recycled in situ especially in rabi season crops, and to be applied uniformly on inter- row space after crop seeding establishment 6 to 10 t/ha)

(ii) *Fertilizer rates*

F1 – Recommended dose of fertilizer (RDF)  
F2 - 75% RDF + 25% N through organic manure

The system productivity in terms of rice equivalent yield was better for minimum tillage, crop residue mulch application and where 25 per cent of nutrients were substituted with organics, when compared to conventional tillage, no mulch and full inorganic fertilization respectively. CS3 (Rice- Cucumber- Amaranthus) was found to be the best cropping system with respect to REY.

Kharif andrabi crops were successfully taken. During the third crop season pulses viz. green gram and black gram had set fruits but seed setting did not occur due to adverse weather condition. Vegetative growth was also excess.

#### **16. 'Optimization of organic component in the fertilizer recommendation of amaranthus'**

The experiment was planned to assess the optimum level of organic manure to be recommended for maximum economic yield in amaranthus.

The result of the experiment conducted at CSRC, Karamana during the summer seasons from 2011 to 2013 was verified through farm trials during summer 2014- '15 in three districts viz. Pathanamthitta, Kollam and Thituvananthapuram.

The following treatments are included in the experiment

1. Full NPK, no organic matter
2. Full NPK, FYM @ 50 tonnes /ha
3. Full NPK, FYM @ 37.5 tonnes /ha
4. Full NPK, FYM @ 25 tonnes /ha
5. Full NPK, FYM @ 12.5 tonnes /ha
6. Farmers' practice

From the farmers field trials it was found that the present PoP recommendation of 50 t/ha of farm yard manure for amaranthus could be reduced to 25 t/ha without any significant reduction in yield.

#### **17. Long range effect of continuous cropping and manuring on soil fertility and crop productivity**

The aim of the experiment is to study the long range effect of crop rotation with high yielding varieties at graded fertilizer levels on the yield stability and soil fertility.

From the experiment so far conducted it is revealed that though phosphorus is not generally a limiting nutrient in the acid soils of India, skipping of P fertilization for more than three years affects rice yields even under sufficient levels of nitrogen application and also affects crop response to N and K. Plant height, total and productive tillers increases significantly with increasing rates of N and P application. Withholding P fertilization for over three years resulted in a decrease in these parameters. In contrast to N, consecutive increase in P up to the third level was found to stimulate growth and tiller production significantly.

Withholding phosphorus also increases days to flowering and days to maturity of the rice crop by about two weeks and decreases the uptake of N and K. At equal levels of fertilizer addition the agronomic efficiency was more for P than for N. P levels showed positive influence on the uptake of N and K by both grain and straw. Skipping phosphorus continuously for more than three years considerably reduced the soil P levels.

Though phosphorus is not generally a limiting nutrient in the acid soils of India, skipping of P fertilization for more than three years affects rice yields even under sufficient levels of nitrogen application and also affects crop response to N and K. Plant height, total and productive tillers increases significantly with increasing rates of N and P application. Withholding P fertilization for over three years resulted in a decrease in these parameters. In contrast to N, consecutive increase in P up to the third level was found to stimulate growth and tiller production significantly. Withholding phosphorus also increases days to flowering and days to maturity of the rice crop by about two weeks and decreases the uptake of N and K. Phosphorus can be skipped for six seasons without any significant reduction in grain yield in riverine alluvium soils of medium to high in available P. P should be applied after a three year skipping period since further skipping detrimentally affects the growth and yield of rice in addition to delaying flowering and maturity for about two weeks even in the presence of adequate levels of nitrogen and potassium

#### **18. Evaluation of a customised organic fertilizer in relation to labile carbon dynamics, nutrient release characteristics and productivity of banana**

- *Characterisation of waste and the transformed organic manure*

Degradable solid waste from households were collected and manure produced through the rapid thermochemical conversion technology. Representative samples of degradable solid waste and the processed organic fertilizer were collected.

Characterisation with regard to various physicochemical parameters of both degradable solid waste as well as the manure were done. Heavy metal concentration was also determined. Fertility index and clean index of the organic fertilizer were worked out as per quality standards prescribed by IISS, Bhopal.

- *Soil test based fortification of the manure with inorganic nutrients for customised application to Nendran banana in AEU 8*  
Soil analysis of the representative site of AEU 8 was done and soil test based fertilizer recommendation of Nendran banana as per Package of Practices of KAU was selected. The processed organic manure was then fortified with required inorganic nutrients for customised application to Nendran banana.

- *Investigations on nutrient release characteristics of the customised organic fertiliser (COF)*

The laboratory soil incubation experiment to study the nutrient release characteristics of the customised organic fertiliser is in progress. Soil samples are drawn at fixed intervals from the incubation pots maintained at field capacity. Soil analysis to determine the available nutrient status of soil is under progress.

- *Effect of customised organic fertiliser on labile carbon dynamics and yield of Nendran banana*

The field experiment was laid out at the Instructional Farm, College of Agriculture, Vellayani. Manure and fertiliser application were done as per treatments specified. Soil and foliar samples were drawn and analysed for assessing the nutrient contents before each split application. Field observation of plant biometric characters and yield attributes of banana were also recorded.

## **19. Organic resource integration for sustainable tuber production in the selected agroforestry systems of western ghat tracts of southern Kerala**

The project was intended with the main objectives, to assess the biodiversity and tuber cultivation practices in selected agroforestry systems in the western ghat tracts of Kollam, southern Kerala and to examine the potentials of recycling litter as nutrient source for tuber production in the systems.

The study based on the informations collected from 165 respondents that tubers are the mainstay in agroforestry systems, preference being in the order Elephant foot yam, tannia, greater yam, cassava, taro and arrow root. Coleus and sweet potato were grown to a small extent alone as these require full sunlight for satisfactory tuber development and yields. Three agroforestry systems in the western ghat tracts of Kollam district were selected for the field study and the diversity worked out using Shannon-Weiner index. The maximum value (2.08) was recorded in the agroforestry system at Andoor, Ummanoor panchayat comprising of 40 species crops of which 29 were perennial. The diversity indices in the other two locations (Elampal, Vilakudy panchayat and Thrikkanamangal, Kottarakkara panchayat) were lower, but had more number of plants per tree species.

Litter fall from the tree components in systems ranged from 672 to 592 kg per year excluding those from coconut and rubber revealing its scope for use as organic resource in crop production. The litter were composted using earthworms (*Eisenia foetida*) and the composted material were incubated with biofertiliser PGPR Mix I and used for tuber production. Litter in agroforestry gardens can be exploited as a nutrient source for tuber cultivation after composting. Leaf litter vary in their allelopathic potential and the crops in which they are used for. Species like jack, cashew and rubber as mulch exhibited positive allelopathy while Ailanthus wild jack and tamarind recorded negative allelopathy. Elephant foot yam and tannia are better suited as understorey crops in agroforestry gardens

Litter compost at 50% N substitution of POP recommendation (100:50:150 kg NPK ha<sup>-1</sup>) recorded highest yields in elephant foot yam and on par with 100 % organic nutrition. The two treatments have been found to best based on the crop performance influence of soil properties and economic returns. The low cost zero energy cool chambers can be used for temporary storage of tubers upto two months without any significant damage

## **20. Phytoremediation of inorganic contaminants in Vellayani wetland ecosystem**

### *1. Peripatetic inventory of the catchment areas of Vellayanilake*

Water and sediment samples were collected from the major sites and the tributaries of Vellayanilake. Dominant native macrophytes were identified. Major physical and chemical parameters were analysed including Fe, Al, Pb and Cd content. Both water and sediment samples were subjected to pesticide residue analysis. Total coliform count in water samples were determined using MPN method. Plant density of major macrophytes was determined in the field itself.

### *2. Evaluation of native macrophytes for possible hyperaccumulation capacity for Al, Fe, Cd and Pb*

The metal concentration in the collected dominant native macrophytes was estimated using ICP OES. Metal as well as microbial load of the sediments were also determined. Based on the metal uptake by the plants, hyperaccumulators were identified.

### 3. Performance of selected hyperaccumulators under graded doses of toxic metals to identify their retention sites

The selected hyperaccumulators were raised in pots under varied doses of the toxic metal – three higher doses were given. Plants were grown for a period of 45 days, then uprooted, separated into shoot and root and analysed for metal content. Microbial load in the rhizosphere was also estimated.

### 4. Bioavailability of phytoextracted metals and comparison of common disposal methods

Vermicompost, ordinary compost, ash and biochar were prepared from the phytoextracted biomass. Pot culture experiment has just been started using these treatments. The test crop taken is amaranthus (variety- Arun)

### 21. RF-STL (Continuation of National project on management of soil health and fertility – Stationary Soil testing laboratory and mobile soil testing laboratory (in RF mode)

Analysed 4314 soil samples and gave fertilizer recommendations. An amount of Rs. 11,94,320/- was remitted to the KAU on this account.

### 22. Pilot plant for rapid conversion of degradable wastes to organic fertilizer.

The project was undertaken to install a pilot plant and demonstrate the process of rapid conversion of degradable wastes to organic fertilizer. Construction of building for housing the Pilot Plant is completed. Procedure for installation of machinery is progressing. Action for fabrication of small scale machine suited to residential flats was initiated.

### 23. GoK Plan project “Strengthening of Lead Centre for Organic Farming at College of Agriculture, Vellayani”

Strengthening and maintenance of Certified Model Organic Farm (area 3 acres) under the Department of Soil Science & Agricultural Chemistry, College of Agriculture as a permanent field study centre for demonstration and training purpose in the area of Organic Farming. On farm preparation and evaluation of liquid organic manures (Panchagavya and fish amino acid) on vegetables are in progress. Conducted one day training programme on Scientific Organic Farming for farmers of Southern districts of Kerala (Thiruvananthapuram, Kollam and Pathanamthitta) and 100 numbers of farmers attended the programme on 21.03.2015. Experts of College of Agriculture, Vellayani had handled the classes and demonstration on Organic Farming and Organic Certification. Distributed vegetable seeds for promoting Organic Vegetable cultivation in the farmers' fields. Experiments are going on to develop cropping system based PoP on Organic Farming

### 24. A comparative study on soil chemical and biological regimes under coconut in red and laterite soils of Trivandrum Dt – A farmer participatory active research

The project was undertaken to assess the dynamics of soil enzyme, soil physic-chemical characters under different cropping and farming situations in red loam and laterite soils of Trivandrum district. A general soil resource data was generated based on the soil collected in various localities. With respect to soil chemical characteristics of the 12 Block panchyaths a significant variation in the properties were noticed. In general the soils are found to be moderately acidic warranting application of liming materials. The status of available P is high in majority of the soils due to the high input of P fertilizers. From the assessment of Biological fertility indices of various soils, the highest values were reported with the redloam soils than the laterite pockets. Within the redloam soils, the organically treated plots showed a distinctively higher values than the conventional plots. Coconut + Tuber and Coconut + Fodder were found to be sustaining the soil biological health. Excessive use of high input acid forming fertilizers and near absence of practice of liming in the soil has resulted in the intensification of soil acidity.

Deficiency of Boron nutrition is noticed and warrants the application of Boron micronutrient. A correlation between the micronutrients and soil enzyme activities revealed a significant and positive correlation between them and the enzyme dehydrogenase is highly influenced by the availability of micronutrients in soil. Among the crops selected for the study coconut + fodder have reported to have improved many of the soil physical and chemical attributes as the quantum of organic matter added or recycled to the soil is more compared to the others. With respect to soil biological properties coconut + banana was found to be the best in respect of enzyme activities and soil respiratory activity.

### 25. Herbicide mixtures for weed management in direct seeded puddled rice (*Oryza sativa* L.)

The programme aims to study the bio-efficacy of post emergence herbicide mixtures for weed control in direct seeded rice, its effect on soil microflora and fauna, enzyme activity in soil and weed seed bank. It also intends to assess the *in-vitro* sensitivity of herbicide mixtures to soil borne pathogen (*Rhizoctoniasolani*), bio control agents (*Pseudomonas fluorescens* and *Trichoderma viride*) and bio-fertilizer organism (*Azospirillum sp.*) Screening of indicator plants for the herbicides, bispyribac sodium + metamifop and penoxsulam + cyhalofop butyl were carried out separately using the test plants, cucumber, maize and sunflower. The maize plant registered the highest R<sup>2</sup> value for all the parameters tested and hence it was selected as the best indicator plant. Among the parameters studied, shoot dry weight recorded the highest R<sup>2</sup> value and it was selected as the best parameter for the detection of herbicide residue.

Regarding the herbicide residue in soil, it can be inferred that the herbicide mixture, penoxsulam + cyhalofop butyl would not leave any phytotoxic residue in soil which can cause growth inhibition in maize crop.

## 26. Development of *SaltolSub1* mega rice varieties for flood prone salt affected areas and standardization of production technology

The project was started during 2012-13 with the objective of introgressing abiotic stress tolerant QTL/ genes (*SalTol* QTL and *Sub1* gene) into three mega rice varieties which are under wide cultivation in Kerala. The outcome of the project is expected to be an answer to the salinity intrusion and submergence consequent to climate change. The specific objectives of the project are the following.

- Introgression of *SalTol* gene into rice variety *Jyothi*
- Introgression of *SalTol* gene into rice variety *Uma*
- Introgression of *SalTol* gene into rice variety *Jaya*
- Introgression of *Sub 1* gene into rice variety *Jyothi*
- Introgression of *Sub1* gene into rice variety *Uma*
- Introgression of *Sub 1* gene into rice variety *Jaya*
- Introgression of *SalTol* and *Sub 1* genes into rice variety *Jyothi*
- Introgression of *SalTol* and *Sub 1* genes into rice variety *Uma*
- Introgression of *SalTol* and *Sub 1* genes into rice variety *Jaya*

Brief account of results:

- a) Hybridization between the recurrent parents (female) – *Jaya*, *Jyothi* and *Uma* each with donor male parents FL 478 (Salinity tolerant) and *Swarna Sub1* (Submergence tolerant) were successfully done.
- b) Phenotyping assays for salinity and submergence tolerance were done with parents of interest under study.
- c) Healthy mature  $F_1$  seeds were harvested and dried under the sun for one week and stored under  $-20^{\circ}C$ .
- d) Molecular primers have been designed and selected from public database. These primers were synthesized (sigma) and are optimized for molecular works.
- e) Among 247 SSR background markers which were completed for Parental genotyping, 141 showed polymorphism with six rice varieties under study. The background selection using SSR background markers is doing to identify background introgression. The microsatellite markers that revealed fixed (homozygous) alleles at non- target loci at one generation were not screened at the next generation.
- f) Biostatistical analysis of background screening using NTSYS pc version 2.0 were completed.
- g) Foreground and recombinant selection for salinity tolerant studies were completed.
- h) Hybridization between recurrent parent (*Jaya*) and *Jaya F1* was successfully done.
- i) Genotypic selection using *Saltol* specific foreground markers SKC 10 and AP 3206 were done with *Jaya F1* progenies.
- j) Positively selected *Jaya F1* progenies were forwarded to hybridization with recurrent parent *Jaya*.
- k) Parental genotyping using 20 *Saltol* SSR reproductive stage markers were completed. The selection using SSR markers is being done to identify *Saltol* gene introgression. The microsatellite markers that revealed fixed (homozygous) alleles at non- target loci at one generation were not screened at the next generation.
- l) Genotypic screening of *F1* progeny was done using *Saltol* foreground marker AP3206 and SKC10 to check hybridity. The progeny with *saltol* introgression were selected for backcrossing with Recurrent parent *Uma* to raise BC1F1 seeds.
- m) The panicles of selected progeny were emasculated and cross pollinated with recurrent parent *Uma*.
- n) BC1F1 seeds (For Salinity tolerance) were kept for germination and germinated seedlings were transferred to tray.
- o) Seeds of recurrent parents (*Uma*, *Jaya*) and BC1F1 seeds positive for *Saltol* locus introgression were germinated and pot planted for raising next generation (BC2F1 seeds).
- p) Out of 44 submergence specific foreground primers, genotypic screenings of 25 primers were completed. Amplification pattern of *Aiswarya*, *Jyothi*, *Jaya*, *Uma*, FR 13 A and *Swarna sub 1* with the primers *Sub1 BC3*, *SSR1A* were found to be polymorphic and can be used further in the screening of *F1* plants.
- q) In *Jaya* and *Swarna sub1* control plants a specific pattern for carbohydrate content was not observed. But in the case of *Jaya* and *Swarna sub 1* submerged plants, a decrease in the carbohydrate content was observed except for 14 th day. So the experiment will be repeated to get a specific pattern for carbohydrate content in both control and submerged plant.
- r) BC2F2 seeds (for submergence tolerance) were harvested and dried.
- s) Germinated three sets of parents and BC2F2 seeds for raising BC3F<sub>1</sub> generation.
- t) Background genotyping of BC2F2 plants (*Saltol* introgression) and *Sub1* introgression are being done.

**27. Permanent Manurial Trial- Tall**

The experiment was undertaken to study the effect of continuous application of Cattle manure, green leaves & ammonium sulphate individually and in combination with and without P and K on the yield of Tall Indica rice & the soil properties. The experiment was consisted of the following Treatments

- T1 - Cattle manure 9090 kg/ha
- T2 - Green manure 9090 kg/ha
- T3 - Cattle manure 4545 +Green manure 4545 kg/ha
- T4 - Ammonium sulphate 220kg/ha (45.45 kg N)
- T5 - Cattle manure 4545kg+Am sulphate + Super phosphate +MOP to supply 22.68kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O/ha
- T6 - Green manure 4545kg+ Am sulphate + Super phosphate +MOP to supply 22.68kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O /ha
- T7 - Cattle manure 2272 +Green manure 2272 kg/ha+ Am sulphate + Super phosphate +MOP to supply 22.68kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O /ha
- T8 - Ammonium sulphate to supply 45.45 kg N+ Super phosphate + MOP to supply 22.68kg P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha

Highest grain and straw yield was obtained from the plots which received Integrated nutrient management system. Plots which received inorganic nitrogen in the form of ammonium sulphate recorded the lowest yield followed by T8 (NPK from chemical fertilizers). Continuous application of nitrogenous fertilisers alone or NPK in the form of inorganic fertilizers alone were found to have detrimental effect on the growth and yield of rice. Biological parameters analysed indicated that there is no detrimental effects of fertilizers if applied along with enough organics.

**PMT (T) has completed 52 years of experimentation and provides an opportunity to evaluate the sustainability of agricultural practices.**

**28. Permanent Manurial Trial- Dwarf**

Experiment was find out he effect of continuous application of cattle manure, green leaves and Ammonium sulphate individually and in combination with and without P&K on the yield of dwarf Indica rice and soil properties with the following Treatments

Treatments

- T1 Cattle manure 18000 kg/ha
- T2 Green leaves 18000 kg/ha
- T3 Cattle manure 9000 + Green leaves 9000 kg/ha
- T4 Ammonium sulphate to supply 90kg N /ha
- T5 Cattle manure 9000kg, Ammonium sulphate + Super phosphate + MOP to supply 45kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O each/ha
- T6 Green leaves 9000kg, Ammonium sulphate +Super phosphate +MOP to supply 45kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O each/ha
- T7 Cattle manure 4500, Green leaves 4500 kg/ha, Ammonium sulphate + Super phosphate + MOP to supply 45kg N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O each/ha
- T8 Ammonium sulphate to supply 90 kg N + Super phosphate & MOP to supply 45kg P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O each/ha

Highest grain and straw yield was obtained from the plots which received integrated nutrient management system. Plots which received inorganic nitrogen alone in the form of ammonium sulphate recorded the lowest yield followed by NPK from chemical fertilizers. Continuous application of nitrogenous fertilisers alone or NPK in the form of inorganic fertilizers alone were found to have detrimental effect on the growth and yield of rice. Biological parameters analysed indicated that there is no detrimental effects of fertilizers if applied along with enough organics. PMT (D) has completed 42 years of experimentation **and provides an opportunity to evaluate the sustainability of agricultural practices.**

**29. Productivity and soil health of rice based cropping systems under organic management**

The project aimed to study the soil health and crop productivity under organic rice based cropping systems. The experiment was started in June, 2015 and two crops of rice were taken. The third crop will be raised during the last week of January, 2016.

**30. Shelf life of liquid organic formulations**

The project aimed to study the shelf life of liquid formulations by analyzing the chemical and biological properties and to study the effect on growth and yield of cucumber. The first experiment was started in January, 2015 and is in progress. The second experiment will be started in the last week of January, 2016.

**31. AICRP on Management of salt affected soils and use of saline water in agriculture****Experiment 1: Survey, characterization and mapping of ground water quality in the coastal areas of Kerala**

The experiment was carried out to study the chemical composition of ground water as influenced by seawater/ brackish

water intrusion, to assess the ground water quality for irrigation and to prepare geo-referenced map of salt affected areas of Kerala. The whole study area falls under eleven districts of Kerala viz. Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragode.

In this study, it was observed that the ground water samples collected from places, which are near to sea, have more salinity. It may be due to intrusion of sea water/brackish water into these places. Salinity can be reduced to a certain level by adoption of proper management techniques such as mixing up of saline water with fresh water/rain water, rainwater harvesting, use of surface or sub-surface drainage systems, bunds to prevent the intrusion of saline water, etc.

#### **Experiment 2 : Delineation and mapping of salt affected soils in the coastal areas of Kerala**

1. To survey the salt affected soils using GPS
2. To study the chemical properties of soils

To prepare geo-referenced map of salt affected soils of coastal belts of Kerala.

The places which are near to sea are under severe salinity. It may be due to intrusion of saline water into these places. Prevention and reclamation of salt affected soils require an integrated management approach, monitoring and maintenance, implementation of efficient irrigation and drainage systems and good farming practices including proper crop selection and rotation for sustainable development of agriculture in these salt affected areas.

#### **Experiment 3 : Raised and sunken bed technology for sustainable land use in Pokkali lands**

##### **Objectives:**

- To study the effect of plastic mulch on reducing salinity in Pokkali lands
- To analyse the changes in soil properties
- To find out the best vegetable crop suitable for Pokkali lands during summer

It was seen that, mulching with polythene sheet is having a significant effect on crop growth and yield of vegetables viz. cauliflower and bhindi at RRS, Vyttila. In case of cabbage and cowpea, the yield was more in treatments without mulch. The cool season vegetables did not come up well in typical *Pokkali* lands. As compared to growth performance and yield of cauliflower, growth of cabbage was very poor and more susceptible to salinity at farmer's field. There is a periodic increase in electrical conductivity of water due to brackish water intrusion. This may increase the salinity of soil and affect the crop growth and yield. By the adoption of proper management techniques to reduce this salinity, sustainable yield of crops can be achieved.

#### **Experiment 4 : Rice – prawn integration in Pokkali**

##### **Objectives:**

- To evaluate the rice-fish/prawn integration in *Pokkali* lands for maximum productivity
- To analyse the changes in soil properties
- The rice-prawn integration was found to very beneficial and successful in *Pokkali* lands. As the left over's of prawn cultivation become manure for rice cultivation, there would not be any additional application of fertilizers. It may enhance the soil qualities as well as the growth and yield of following rice crop.

### **32. Socioeconomic analysis and farmer participatory development of homestead farms of Kerala(Network project)**

The project is going on with the objective to Introduce innovative farming methods to improve production and income from unit area and transform them into beacon home gardens for propagating in the State and to suggest policy initiatives and development strategies for improving homestead farming in Kerala.

The selection of homesteads in consultation with ATMA was completed during 2014-15. Various location specific technical interventions following a system approach have been made in consultation with the farm family. The impact of the intervention are being monitored. Some innovative models will be suggested for each region by end of 2015-16.

The project is linked to an ongoing State Plan funded Project entitled "*Centre for Studies on technology society interface and policy in agriculture*" operating in the College of Horticulture, KAU, Vellankkara. The centre is in the process of undertaking the socioeconomic study.

### **33. Evaluation and development of pre seeded technology in Direct Seeded Rice**

- Organic sheets utilizing waste paper pulp, coir pith compost, dried leaf and aquatic weeds were prepared with 1x1m size and different thickness.

- Sheets with 0.8 mm thickness is found to be stable in the soil up to 60 days which is the ideal period for weed control in rice which decreased the weed infestation and showed yield advantage.
  - Yield advantage = 1450 kg/ha
  - Economic terms = Rs. 21750/ha
  - Additional expense in pre seeded sheet = Rs.12,412
  - Additional return in per seeded sheet = Rs. 21750
  - Economic advantage =21750-12412 = Rs. 9338/ha
  - If the sheet is provided free of cost the advantage= Rs. 49338/ha
- Rolling sheet technology standardized with lesser initial cost

#### 34. Capacity building for spatial planning in the agriculture and allied sectors of Kerala.

The project was undertaken with the objective of establishing pilot training facilities on GIS, GPS and Remote Sensing. Established facilities for GIS training by installing networking facility with a server computer and twenty clients in GIS laboratory. Celebrated GIS day on 14<sup>th</sup> November by conducting a seminar on applications of GIS in agriculture and released a CD in this connection. Orientation was provided to the PG students and the scientists of COA Vellayani, NARP (SR) Vellayani and the nearby research stations on use of GIS in preparation of thematic map and mapping of various attributes related to soil, climate and crop. Koliyoor micro water shed was selected for characterization of soils using GIS.

#### 35. Impact assessment of landfill on soil health and water quality in a waste disposal site

The was conducted to assess the impact of dumping Municipal Solid Waste (MSW) on soil and water quality, spatial variability in the level of biological and chemical contamination along the leachate flow zone and identification of a few bioremediators and their possible effectiveness of decontamination. Various types of samples viz. landfill, leachate, water and soil samples were collected at three consecutive seasons viz pre monsoon, monsoon and post monsoon seasons. The samples were analyzed for pH, EC, BOD, COD, Available N, P, K, organic carbon and heavy metals. Statistical analysis is in progress. Conducted sand culture experiments and pot culture experiments using different flowering plants and *Alternanthera* identified as best hyper accumulator and other works are progressing.

#### 36. Establishment of Centre for Organic Farming in Onattukara.

The project was undertaken to establish a centre for organic farming in Onattukara in a multidisciplinary approach to promote research and extension activities in the field of organic farming and to evaluate the socio-economic status of farming community by income maximization through product diversification and value addition, employment generation and create awareness on participatory approach to make the farmers self-reliant in organic management of crops.

Demonstrations were laid out during *virippu* and *mundakan* 2014 in rice. During summer 2014 sesamum, cowpea, amaranthus and cucumber were raised in the summer rice fallows. The grain and straw yield obtained by the application of 100% NPK and 75% NPK as organic were high. The yield obtained by the application of 50% NPK as organic is comparatively low. As in the case of *virippu* the yield obtained during *mundakan* season is also the same.

#### 37. Evaluation of rapid organic fertilizer (Suchitha) as a potting medium for soil less culture

The experiment was initiated during February 2018 by purchasing the inputs required for the conduct of the experiments. Field studies are yet to be started after the receipt of continuous sanction for the year 2018-19.

#### 38. KAU – KVASU Collaborative Project on 'Hatchery Waste Disposal and its effective utilization'

Hatchery waste for the experiment was collected from the Hatchery unit of the Regional Poultry Farm, Kudappanakkunnu. Different treatments were applied for processing the waste. The technology found feasible consisted of the following steps.

- Sorting: The collected hatchery waste was sorted into three separate groups (Empty egg shells, Dead in shells & Unfertilized eggs).
- A method was developed to separate egg shells and egg shell membranes (ESM) so that they could be used for industrial/pharmaceutical purposes which will fetch high price. The method is being tested repeatedly.
- A method was developed to produce organic fertilizer from the other two groups (ded-in-shell and unfertilized eggs). The method is being tested repeatedly.
- The organic fertilizer developed is being tested in laboratory for nutrient content.
- Plant growth trials are being conducted to study their effect on plants and to test whether any phytotoxicity is expressed.

### **39. Mobile and stationary Soil Testing Lab – Revolving Fund**

Soil testing services were extended to farmers, students and researchers on payment basis. During the year 2017-18, 326 – soil samples, 126 – plant samples, 11 – Manure samples, 3- compost and 1 – water samples were analysed. Soil test based recommendations to various crops were given to farmers. The total income generated through the analytical services was Rs.2,17,008/- (Rupees Two Lakhs Seventeen thousand and Eight only)

### **40. Solid Waste Management – Revolving Fund**

During 2017-18, an amount of Rs.1,25,390/- was generated through sale of waste processing kits, organic fertilizer, conducting trainings and as university share for installation of 'Suchitha' units.

### **41. "Continuation of mobile soil testing service to farmers"**

Soil testing services were extended to farmers, students and researchers on payment basis. 506 – soil samples, 7 – Manure samples, 30 – water samples and 1 liming material were analysed. Soil test based recommendations to various crops were given to farmers.

### **42. "AICRP on Long Term Fertilizer Experiments"**

Integrated nutrient management and in situ green manuring with daincha recorded higher grain and straw yields and in situ green manuring was identified as a cost effective and farmer friendly technology. In situ green manuring (Daincha) could save cost of 5 tonnes of farmyard manure. Though there was no significant change with regard to soil pH, the lime requirement of soil got reduced in the treatment which received lime since 1997. The continuous, long term application of lime and organic manures increased the pH of the soil measured in 1 M KCl and 0.01 M CaCl<sub>2</sub> after 16 cycles of the rice-rice cropping systems. The NPK balance sheet over eight seasons indicate that the K content in the soil had a negative balance even in treatment which received 150% of the recommended dose of potassium along with other nutrients. In general the soil organic carbon is higher even in control plots which could be attributed to the incorporation of stubbles and weeds into the soil. The soils collected from plots which received differential doses of fertilizers and different organic manures differed in the pools of potassium excepting total potassium. 50% NPK + in situ green manuring/FYM identified as 2<sup>nd</sup> best alternative which can reduce 50 per cent of the recommended inorganic fertilizer without compromising yield.

### **43. "Effects of herbicides and chemical characteristics of soil on microbial biomass carbon and enzyme activity"**

The project was undertaken to determine the impact of pre and post emergence herbicides on microbial biomass carbon and the soil enzymes namely dehydrogenase, phosphatase and urease and also to study the influence of chemical characteristics of soil on these biotic components.

Data on analysis of soil samples before the experiment revealed that all the physical, chemical, and biological characteristics which are more favourable for the growth of microflora are exhibited by rice soils of Kole land, Alappad. Based on the organic carbon content, the soils under study can be ranked in the order: Rice field, Kole>non-cropped, Kole>non-cropped, ARS> rice field, ARS. Adverse effect of herbicides on biological parameters can be ranked in the order: pendimethalin>bispyribac-sodium>oxyfluorfen>cyhalofop-butyl.

Chemical characteristics of the soil viz. pH, electrical conductivity, and organic carbon followed a decreasing trend towards the harvest in all the treatments. Out of the five biological parameters analysed, microbial biomass carbon showed the highest variation from control at all the sampling intervals. Results indicated that the herbicides had negative effect on microbial biomass carbon. Dehydrogenase activity also showed a decline due to the application of herbicides, but to a lesser magnitude than microbial biomass carbon. The adverse effect was pronounced only at 15 days after application of herbicides and followed the order viz. pendimethalin>bispyribac-sodium>oxyfluorfen>cyhalofop-butyl. The adverse effects were of lower magnitude in the soils of high organic matter content. Microbial biomass carbon, activity of dehydrogenase, urease, acid phosphatase and alkaline phosphatase were higher in S2 (high organic matter soil) compared to S1 (high organic matter soil). All the vegetative and yield parameters of rice were also high in irrespective of the treatment combinations. Organic carbon had highly significant and positive correlation with all the biotic components viz. microbial biomass carbon, dehydrogenase, urease, acid and alkaline phosphatase activity.

### **44. "Influence of weed management techniques on the quality attributes of soil in an Ultisol"**

The study was carried out with the objective to evaluate the changes in physical, chemical and biological characteristics of soil in an Ultisol due to different weed management practices in brinjal (*Solanum melongena* L.). The chemical characteristics of the soil viz., pH, electrical conductivity, and organic carbon followed a decreasing trend towards the harvest in all the treatments. Out of the five biological parameters analysed, microbial biomass carbon showed the highest variation from control at all the sampling intervals. Results indicated that the herbicides had negative effect on

microbial biomass carbon. Dehydrogenase activity also showed a decline due to the application of herbicides, but to a lesser magnitude than microbial biomass carbon. The adverse effect was pronounced only at 15 days after application of herbicides and followed the order viz. pendimethalin>bispyribac-sodium>oxyfluorfen>cyhalofop-butyl. The adverse effects were of lower magnitude in the soils of high organic matter content. Microbial biomass carbon, activity of dehydrogenase, urease, acid phosphatase and alkaline phosphatase were higher in  $S_2$  (high organic matter soil) compared to  $S_1$  (high organic matter soil).

All the vegetative and yield parameters of rice were also high in (high organic matter soil) irrespective of the treatment combinations. Adverse effects of herbicides on the plant characters were minimal. Organic carbon had highly significant and positive correlation with all the biotic components viz., microbial biomass carbon, dehydrogenase, urease, acid and alkaline phosphatase activity.

#### **45. “Evaluation of soil and water quality in Potta watershed of Pazhayannur block in Thrissur district”**

pH of the soil samples ranged from 3.47 to 6.80. The highest organic carbon content was recorded in the soil samples of middle reach. The CEC of the soil samples ranged from 4.16 to 8.98 cmol p<sup>+</sup> Kg<sup>-1</sup>. The highest mean available N,P,K,S were recorded for the soil samples of middle reach, where as the level of micronutrient was found to be the highest in the upper reach. The pre-monsoon water samples recorded higher pH than post monsoon samples. The EC of water samples ranged from 0.14 to 0.54 d Sm<sup>-1</sup>. The comparison between the quality of water samples collected in pre monsoon and post monsoon samples showed that there was significant difference between them with respect to the contents of calcium (8.24-20.08 me L<sup>-1</sup>) and magnesium (3.14-14.32 me L<sup>-1</sup>) with higher values in post monsoon season. Among the anions, the content of bicarbonate and chloride were higher than that of nitrates and sulphates. Results of soil analysis revealed that soils in the upper and middle reaches were in the threat of severe loss of nutrients (N, P, K, Ca, Mg, S) either by soil erosion or by leaching. The quality of irrigation water from all the sources was coming under safe category for irrigation when compared with standard values.

#### **46. “Formulation and evaluation of micronutrient mixture for foliar application in TC banana (*Musa sp.*) var. Nendran”**

The hardening studies were conducted in the mist chamber, Department of Plant Biotechnology, College of Agriculture, Padannakkad, Kerala with TC plants of uniform size multiplied from same genotype. The experiment was carried out in completely randomized design with 12 treatments and one absolute control maintaining 3 replications each and there were 4 plants in each replication.

The Highest net return (Rs.6, 94, 964) and benefit cost ratio (2:3) was registered with foliar application of 3% micronutrient mixture as three sprays ( $T_{11}$ ). The quantity of spray solution required for best treatment  $T_{11}$  on projection to one ha is 56 litres, with an additional cost of Rs.160/- litre for the mixture plus Rs.600/- day as cost of labour for application. The positive effects of the micronutrient foliar spray solution indicate the need of these nutrients on banana. This effect can be further evaluated on vegetables and other crops. On the basis of the results thus obtained recommendation can be made on adhoc basis.

#### **47. “Gypsum as a soil ameliorant for black pepper (*Piper nigrum* L.) in acid soils of Wayanad”**

To assess the performance of gypsum as a soil ameliorant in growth and development of black pepper and to evaluate its suitability in promoting root growth in deep soil layers of Central plateau of Wayanad (AEU 20). The results of investigation indicated that application of gypsum as an amendment alone or in combination with burnt lime and dolomite reduced the surface and subsurface acidity and increased the available nutrient status in the surface as well as sub surface soil layers, which might have resulted in better root proliferation favouring vigorous plant growth and development of black pepper in acid soils.

#### **48. “Silicon, boron and zinc nutrition of bittergourd (*Momordicacharantia*)”**

Both pot culture and field experiment indicated the effect of silicon and boron are more important than zinc in bittergourd. T14 (B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in the soil) found to be performing well under pot culture and field conditions respectively.

#### **49. “Magnesium and boron nutrition of black pepper (*Piper nigrum* L.) in laterite soils”**

The results of the experiment involving soil and foliar application of Mg and B clearly indicated that in the case of soil application, application of 40 g MgSO<sub>4</sub> + 4 g borax in pot experiment and 200 g MgSO<sub>4</sub> + 20 g borax in field experiment significantly influenced the available nutrient status of soil, yield and yield attributes of pepper. In the case of pot experiment involving foliar application, the use of 1% MgSO<sub>4</sub> + 0.5% borax was superior with respect to available nutrient status, yield and yield attributes of black pepper. Application of 0.5% MgSO<sub>4</sub> + 1% borax produce on par results. In the case of field experiment, the treatment receiving 0.5% MgSO<sub>4</sub> + 1% borax was superior to all other treatments.

### **50. Permanent Manurial Trial – Dwarf**

Highest grain and straw yield was obtained from the plots which received integrated nutrient management system. Plots which received inorganic nitrogen alone in the form of ammonium sulphate recorded the lowest yield followed by NPK from chemical fertilizers. Continuous application of nitrogenous fertilizers alone or NPK in the form of inorganic fertilizers alone were found to have detrimental effect on the growth and yield of rice. Biological parameters analysed indicated that there is no detrimental effects of fertilizers if applied along with enough organics.

### **51. Long range effect of continuous cropping and manuring on soil fertility and crop productivity**

The experiments were conducted to study the long range effect of crop rotation with high yielding varieties at graded fertilizer levels on the yield stability and soil fertility. Plant height, total and productive tillers increased significantly with increasing rates of N and P application. Withholding P fertilization for more than 5-6 years resulted in a decrease in these parameters. In contrast to N, consecutive increase in P up to the third level (P80) was found to stimulate growth and tiller production significantly. At harvest, P at 80 kg ha<sup>-1</sup>, produced significantly taller plants during both Kharif and rabi than the different levels of N and K. The growth-enhancing effect of N levels was significant up to N2 (80 kg ha<sup>-1</sup>), whereas further increase did not give any response. The two levels of K did not significantly affect plant growth.

Though phosphorus is not generally a limiting nutrient in the acid soils of India, skipping of P fertilization for more than three years affects rice yields even under sufficient levels of nitrogen application and also affects crop response to N and K. At equal levels of fertilizer addition the agronomic efficiency was more for P than for N. P levels showed positive influence on the uptake of N and K by both grain and straw. Skipping phosphorus continuously for more than three years considerably reduced the soil P levels.

Phosphorus can be skipped for six seasons without any significant reduction in grain yield in riverine alluvium soils medium to high in available P. P should be applied after a three year skipping period since further skipping detrimentally affects the growth and yield of rice in addition to delaying flowering and maturity for about two weeks even in the presence of adequate levels of nitrogen and potassium.

### **52. “Enhancement of production and productivity of major crops in Onattukara” Sub Project : Organic nutrition of medicinal rice Njavara in Onattukara” (NRM-09-00-02-2011-MC(25)DAK(1 to 10))**

The project was started during virippu 2012. Experiment was conducted as per the approved technical programme during virippu 2012, 2013 and mundakan 2012. The treatments differ significantly in grain yield and straw yield. Highest grain and straw yields were obtained from the plots which received 75% N as FYM and tichoderma enriched vermicompost in 1:1 proportion with recommended dose of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O as none meal and ash respectively.

### **53. Permanent Manurial Trial of rice in acid Saline soils under flooded condition (pokkali tract)**

The experiment was started during 1979. The results obtained so far indicate that the application of inorganic fertilizers with or without lime do not have any positive influence on grain yield of pokkali varieties. The low fertilizer responsiveness of the pokkali varieties and the high fertility status of the soil can be attributed to this results.

The yield data for 2014 shows yield increase for the N and P fertilizer applied plots but there is no significant increase in yield. The percent yield increase was highest 17.09 in the plots receiving N and P @ 20:40 kg ha<sup>-1</sup>. The plot receiving NPK application with lime @ 1 ton ha<sup>-1</sup> has an increase of 5.67 % over control. During the year the application of chemical fertilizers have shown a slight increase in rice yield though not to a significant level. The pokkali fields are highly suited for organic farming.

### **54. Fertility in relation to movements, losses transformations and interactions in different agroclimatic regions of Kerala**

The experiments aimed to find out the effect of continuous application of N, P, K and lime over incorporation of straw on soil fertility, yield and quality an incidence of pests and diseases.

Continuous omission of P resulted in visual deficiency symptoms from the eighth season and consequent significant reduction in grain and straw yield from the 10<sup>th</sup> year onwards. The grain yield obtained in the continuous K omission plots were on par with the treatments with K application even after 29 years. The experiment is continued as per the technical programme for the past 29 years. The experimental data during 2014-17 revealed that crop raised with continuous omission of K fertilizer for the last 30 years, gave on par yield with that fertilized on soil test basis (NPK + lime + cow dung), during both kharif and rabi. Among the different treatments, crop fertilized on soil test basis (T 9) was also on par with that done with POP recommendations (fertilizer alone with lime – T8).

During kharif and rabi seasons, NPK uptake was more in the crop fertilized based on soil test basis (with straw incorporation) and also in fields cropped during alternate seasons. NPK uptake was significantly lower in straw incorporated plots

without fertilizer application and in N, P and K fertilizer skip plots. Though the uptake in the plots with zero potassium application, the yield was comparatively high.

Soil test data during the crop season at maturity revealed that nutrient uptake was higher in NPK fertilized plots, low in the respective nutrient skip plots and control plots without fertilizer application. Grain yield during both the seasons were significantly higher in the plots fertilized based on soil test data and NPK applied and NPK with lime application.

It was noticed that the plants in all the treatments including that in the best treatment plots exhibited severe yellowing of leaves with narrow brown spots during both the seasons. The permanent plots show severe chaffing and reduction in the yield during both the seasons over a period of years which may be due to the severe nutritional deficiency including secondary and micronutrients. Depending on the climatic conditions during the season, the field had low to moderate infestation of blast even if prophylactic fungicidal sprays are done.

The experimental results during the last 30 years revealed severe nutritional deficiency and yield reduction in the N and P omission plots from the eighth season and consequent significant reduction in grain and straw yield from the 10<sup>th</sup> year onward. K omission plots (with straw incorporation and NP application) had on par yield as fertilized plots even after 30 years of K skipping. Nitrogenous fertilizer application is highly essential in paddy fields as the mineralization process is slow from the high carbon Kuttanad soils. The crop response in the plot fertilized on soil test basis reveals that INM favours better nutrient absorption and crop yield.

### **New Projects 2017-2018**

#### **55. Development and standardization of nutrient capsules for vegetable cultivation**

Compatibility of different water soluble major, secondary and micro nutrient fertilizers and their compatibility with different capsule materials were studied. Quantity of fertilizer material required to prepare nutrient capsules for vegetables grown in grow bags/containers were standardized. Purchased capsule filling machine.

#### **56. Development and evaluation of multi nutrient tablets/spikes for vegetables grown in home gardens**

Compatibility of different water soluble major, secondary and micro nutrient fertilizers with different binding agents were studied. Quantity of fertilizer material and binding agents required to prepare tablet/spikes for vegetables grown in grow bags/containers in home gardens were standardized.

#### **57. National Project on Management of Soil Health and Fertility-SSTL & MSTL**

Soil testing services were extended to farmers, students and researchers on payment basis. During the year 2017-18, 815 – soil samples, 165 – plant samples, 7 – Manure samples, 3 – water samples and one liming material were analysed. Soil test based recommendations to various crops were given to farmers. 610 soil health cards were distributed. 6 soil testing campaigns were conducted. 10 numbers of trainings were conducted to school students. Rapid Soil Test kits (PUSA MODEL) was purchased. Upgraded agri-tester software. Strengthened the facilities of soil testing lab.

#### **58. Popularization of 'Suchitha'-Rapid Waste Conversion Technology**

Implementation of the project started. Action initiated for installation of two Suchitha units. Demonstration using the small unit at the Dept. of Soil Science, COA Vellayani is being carried out.

#### **59. Permanent Manurial Trial**

The investigation was conducted to find out the effect of continues application of nitrogen as organic and inorganic as well as phosphorous and potassium on soil fertility and yield of rice. The result under the period of study indicated that the optimum dose of N is 80 kg ha<sup>-1</sup> and the entire dose can be given as cattle manure alone. For optimum production, at least 25% of N should be given as FYM and the remaining N, full P<sub>2</sub>O<sub>5</sub> and as K<sub>2</sub>O as fertilizers. The trail is being continued

#### **60. Integrated crop management strategies for enhancing rice productivity in Orumundakan tract**

The investigation was conducted to assess the soil fertility constrains in Orumundakan tracts and screening of suitable rice varieties for Orumundakan tracts. Enhancing rice production in Orumundakan tracts through Integrated Crop Management strategy. Soil and water samples were collected from OruMundakan areas and the analysis was done. pH ranged from 2.31-5.99 and EC from 1.1 dS/m to 17.5 dS/m. Wide spread deficiency of Ca Mg and B and Zn. Toxicity of Fe and Mn. Other operations are in progress

### **61. Developing a customized nutrient formulation for yield maximization in vegetables of upper Kuttanad**

The experiment is conducted to assess the available macro and micronutrient status in the vegetable growing areas of the Upper Kuttanad and to develop and evaluate multinutrient mixture .

Soil and water samples were collected from upper Kuttanad areas and the analysis was done. pH ranged from 4.30-5.61 and EC from 0.043 dS/m to 0.183 dS/m. Wide spread deficiency of Ca Mg and B. Work on development of customized formulation is in progress.

### **62. Strengthening and maintenance of Lead Center for Organic Farming**

The strengthening and maintenance of existing model organic farm as a permanent field study center for teaching, research and extension activities the area of organic farming and organic certification and evaluation of organically certified nano fertilizers are in progress .

### **63. All India Co-ordinated Research Project for Investigations on Soil Test Crop Response Correlation.**

#### 1. Objectives

- a. To arrive at fertilizer prescription methods based on Soil Test Crop Response studies so as to enable the farmers to increase the yield of their crops for maximum profit.
- b. To apply fertilizers and organic manures into a soil of a particular fertility level to get a desired economic yield.

### **64. Rhizosphere priming effects of conventional and non conventional organic manures on C and N dynamics**

To compare the priming effects of conventional and non conventional organic manures on rhizospheric processes with special reference to C and N dynamics

The conventional and non conventional organic manures behaved similarly in soil, however fortified TOF and MC were superior in terms of physical , chemical and nutritional properties .A significant positive priming effect was observed on total organic carbon and available nitrogen content in soil at all levels of sampling.

### **65. Long term dynamic of organic farming Practices in banana var. Nendran**

Experiment was initiated to evaluate the impact in soil nutrient, productivity, microbial population of organic farming practices in the long run and the work is in progress.

## **PG Projects**

### **Concluded Projects**

#### **1. Evaluation of mineral enriched composts for soil remineralisation and crop nutrition**

The study aimed to evaluate mineral enriched composts and mineral enriched vermicompost by monitoring nutrient release pattern under laboratory conditions and to study their effects on soil remineralization and crop nutrition using yardlong bean as test crop. Based on various physico-chemical and biological characters, fertilizing index and clean index of mineral enriched organic manures were determined and revealed that mineral enriched (rockdust as additive) organic manures were very good sources for soil remineralisation and crop nutrition. It was concluded from the study that 50% N as mineral enriched vermicompost in conjunction with PGPR Mix I helped to increase the yield as well as nutrient uptake of yardlong bean and thus played a vital role in soil remineralization and crop nutrition. It was also evident that the nutrient requirement could be reduced to half the recommended dose if mineral enriched vermicompost was used in conjunction with PGPR Mix I as nutrient source in organic cultivation of yardlong bean.

#### **2. Biological characterization of Onattukara soils under coconut based cropping system**

An inventory on the biological characteristics of the major coconut growing soils of Onattukara region in Kerala under different nutrient management practices showed that the maximum values or the most desirable values on biological properties of soils were recorded by soils of the 'very good' productivity class mostly under organic nutrition. But even soils of the 'poor' and 'average' productivity classes receiving organic nutrition recorded values of the 'very good' productivity class highlighting the importance of organic input addition as sources of nutrients in building up the biological health of the soils.

#### **3. Magnesium and boron nutrition for yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.)Verdcourt) in southern laterites of Kerala**

The study was conducted to standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yardlong bean as test crop. It was concluded that foliar application was significantly superior to soil application for yield and yield attributes. The yield was highest with foliar spray of 2% magnesium sulphate and 0.25% borax at fortnightly intervals plus soil test based package of practices recommendations. Based on B:C ratio,

economic yield was obtained when Mg and B were applied twice at first flowering and active flowering stages as foliar spray plus soil test based package of practice recommendations.

#### 4. Dynamics and interaction of zinc and boron with phosphorus in Ultisol

The study was conducted for elucidating the dynamics of zinc and boron as influenced by the phosphorus status of lateritic soil and to optimize the level of P for balanced nutrition of cowpea w.r.t. Zn & B and revealed the following. Among the 100 samples collected from Thrissur, Malappuram and Kozhikodu districts and characterized with respect to available P, 18 soil samples were selected and categorized six each from low available P (<3.5 kg ha<sup>-1</sup>), medium (17 to 20 kg ha<sup>-1</sup>) and high available P (>35 kg ha) and estimated the physico-chemical parameters. A pot culture experiment was conducted to study the optimum level of P for balanced nutrition of cowpea w.r.t. Zn and B.

The distribution of fraction of inorganic P in the three soils showed that Fe bound P was the dominant fraction contributing to more than 50% of the total inorganic P. Among the fractions of boron, readily soluble boron recorded the lowest, whereas the contribution of residual boron was the highest.

Available P status in soils with low and medium P increased due to the application of P while it decreased in soil with high P. The soil with high P soil showed that the application of phosphorous lead to the fixation of phosphorus in to insoluble forms whereas, if P was not applied there was solubilisation of Fe-P and Al-P resulting in increased availability. Application of Zn was found to reduce Al-P and Fe-P due to the formation of insoluble zinc phosphate. Application of Zn and B reduced the Ca-P, probably due to the formation of zinc phosphate and Calcium borate.

In case of zinc fractions, water soluble + exchangeable fraction and organic matter occluded zinc was directly contributing to the available pool. Application of P resulted in adsorption of zinc into specifically adsorbed zinc.

With respect to boron fraction, readily soluble boron and oxide bound boron were directly contributing to the available pool whereas binding of boron with organic matter as well as its transformation to residual boron reduced boron availability. Boron application along with P reduced the readily soluble boron.

The application of P with and without B reduced the Zn content in plants. Application of P and Zn reduced the boron content in plants and application of boron with and without phosphorus recorded the highest boron content. The highest grain yield was recorded in soil with medium P, while the high P status in soil either due to native P or due to applied P reduced the yield resulting from induced lower uptake of zinc and boron.

Thus it was essential to maintain available phosphorus level at medium status with optimizing the levels of other nutrients especially zinc and boron for optimum yield.

#### 5. Characterization of soil and water of Palakkad Eastern Plains in relation to growth and nitrogenase content of Azolla spp.

A survey of Azolla spp. in the rice growing tracts of Palakkad Eastern Plains (AEU 23) had been conducted to identify soil and water quality parameters congenial for the growth and nitrogenase content of Azolla spp. Initially three block panchayaths were taken and from each block, three gramapanchayaths were taken randomly from each panchayath 10 samples each of soil, water and Azolla were collected. In this way, 270 samples from azolla growing areas and 180 samples from non-growing areas were taken for the study.

Among the nine locations studied Nalleppillipanchayath with soil characters (pH- 7.34; EC-0.3 dSm<sup>-1</sup>; OC - 1.56 % available. NPK- 153.6, 63.3 and 191.2 kg ha<sup>-1</sup> respectively; Total Fe-1646.2 mg kg<sup>-1</sup>; Mn-234 mg kg<sup>-1</sup>; Zn - 23.3 mg kg<sup>-1</sup> and Cu - 24.8 mg kg<sup>-1</sup>) were found to favour the growth and multiplication of Azolla and the quality parameters of Azolla from the above location were C- 38.6%, N - 2.7 %, C/N ratio 12.58, crude protein 16.95 %, P - 0.174 % and K - 1.39%. A neutral pH(6.8 to 7.5) and low electrical conductivity ( 0.2 to 0.3)dSm<sup>-1</sup> was preferred by azolla for its growth.

#### 6. Nutrient dynamics and transformations in aerobic and flooded systems of rice in lateritic soils of Kerala.

A study was conducted on the nutrient dynamics, transformations, availability and absorption in aerobic and flooded systems of rice in lateritic soils of Kerala. Under both the systems, field experiments (two experiments under flooded system and one experiment on aerobic rice) were conducted to standardize the method of sampling and analysis for soil test based application of lime and fertilizers. One was based on sampling and soil testing on wet basis keeping the anaerobic environment unchanged, while the other was based on routine sampling and analysis after air drying. Under aerobic system major fraction of P was Fe-P which had contributed through Ca-P. Under flooded system major fractions contributing to available pool were Al-P, Fe-P and occluded P but through Ca-P. In the case of Boron dynamics there was

not much difference between the two systems except more solubility under flooded conditions. Higher root CEC was noticed under aerobic environment than flooded system. Yield attributes viz., number of tillers per hill, number of panicles per hill were more in aerobic system than flooded system.

The data on shoot mass, root length and root volume at active tillering stage indicated that aerobic environment enhanced root and shoot growth when compared to flooded system. This might have contributed to more uptake of nutrients and to yield under aerobic system.

The total water requirement of the crop showed almost 57% reduction under aerobic system than that under flooded system. Under both systems, the treatment combination where fertilizers applied as per soil test with lime as per "pH (F2-L2) recorded the highest net returns from the crop.

### **7. Assessment and management of micronutrient deficiencies in Onattukara**

A study on the assessment and management of micronutrient deficiencies in Onattukara soils and development of multi micronutrient mixture for balanced crop nutrition revealed the deficiency of B (77%), Zn (66%) and Cu (53%) in the Onattukara region. Micronutrient fertilizer requirement was computed based on the available micronutrient status of the region and crop requirement and developed a multi micro nutrient mixture having a composition of Zn (9.5%) + B (2.6%) + Cu (1.2%) + Mg (2.4%) + N (0.46%). From the investigation it can be confirmed that foliar application of micronutrient mixture @5 kg ha<sup>-1</sup> in two splits at 15 DAS and 35 DAS was superior to soil application (@ 20 kg ha<sup>-1</sup>) in respect of yield, quality and B:C ratio. The study revealed that micronutrient deficiency is one of the yield barriers which can be broken down by including micronutrient fertilizers in the nutrient schedule of crops.

### **8. Investigations on the efficacy of biochar from tender coconut husk for enhanced crop production**

The experiment was carried out to characterize biochar from tender coconut husk and assess its effects on soil properties, growth and yield of yardlong bean. Mixing biochar with beneficial microbial consortium like PGPR mix 1 had an additive effect on nutrient availability and plant growth. Application of biochar @20 t ha<sup>-1</sup> along with 2 per cent PGPR and NPK as per POP recorded the significantly superior yield of 20.12 t ha<sup>-1</sup> with B:C ratio of 1.56 and it can be considered as the economically viable and the best treatment.

Tender coconut husk is hard waste with high lignin content and a rich source of nutrients. There is additive effect if biochar is mixed with a consortium of beneficial microorganisms like PGPR Mix – 1 because biochar with its high surface area and pore volume helped for the better proliferation and activity of beneficial microorganisms in soil. Hence application of biochar @ 20 t ha<sup>-1</sup> with 2 per cent PGPR mix-1 and NPK as per POP resulted in the yield of 20.12 t ha<sup>-1</sup> with B:C ratio of 1.56. Biochar application can significantly reduce the CO<sub>2</sub> emission and can be used as an efficient tool for carbon sequestration. The results of the experiment revealed that all physical, chemical and electric - chemical properties of soil were significantly improved by the application of biochar.

### **9. Magnesium and boron nutrition of black pepper (*Piper nigrum* L.) in laterite soils**

The study was conducted to assess the extent of magnesium and boron deficiency in a typical laterite soil of black pepper cultivation, standardizing the dose and method of Mg and B fertilizer recommendation to black pepper and studying its effect on yield and quality of black pepper.

The study concluded that soil application of 200 MgSO<sub>4</sub> + 20 g Borax or foliar application of 1% MgSO<sub>4</sub> + 0.5 % Borax in black pepper in laterite soils resulted in highest yield, yield attributes, nutrient content in plants and highest oleoresin content and maximum piperine content.

### **10. Silicon and boron nutrition of rice (*Oryza sativa* L) in wet land soils of northern Kerala**

The investigation carried out under pot as well as field conditions in low land rice ecosystem in laterite derived paddy soils of northern Kerala had shown that the application of potassium silicate @ 0.5 % spray + borax 0.5% spray 3 rounds at 15 days interval significantly improved the available nutrient status of soil, content and uptake of nutrient by the plant and yield and yield attributes of rice. It was also effective in reducing the toxicity of Fe, Mn and Al in the soil.

### **11. Chemistry and transformations of calcium and magnesium in tropical acid soils of Kerala**

Sixty four representative soil samples from 23 agro ecological units under five agro ecological zones of the state were collected and characterized for physico-chemical properties. Among these soils, ninety two per cent were acidic in reaction, of which sixty three per cent were strongly to very strongly acidic (4.5-5.5). Lowlands of Kuttanad, Pokkali and Kaipad were extremely to ultra-acidic. Twenty seven per cent of samples were deficient (<300 mg kg<sup>-1</sup>) in available calcium, while sixty seven per cent samples were deficient in available magnesium (<120 mg kg<sup>-1</sup>). Deficiency was

negligible in soils from Attapady hills (AEU 18 and 19), Palakkad central and eastern plains (AEU 22 and 23) and the lowlands of Kuttanad, Pokkali, and Kaipad (AEU 4, 5 and 7). The availability of calcium and magnesium increased with pH, cation exchange capacity and decreased with increase in exchangeable aluminium. Forty one soil samples from different agro ecological units were subjected to sequential fractionation. The mean per cent contribution of different fractions to total calcium was in the order exchangeable > mineral > acid soluble > water soluble > organic-complexed. Exchangeable calcium and water soluble magnesium were the sole forms contributing directly to the available pool.

The quantity-intensity relationship of calcium and magnesium in twenty-three soil belonging to different AEU's of Kerala were studied at 25°C and 40 °C. Potential buffering capacity or the supplying power of soil had significant positive correlation with CEC and exchangeable cations in soil. The adsorption data of both calcium and magnesium at 25°C and 40 °C were best explained by Temp in adsorption isotherm indicating that the affinity for adsorption decreases linearly with degree of saturation. The change in free energy of adsorption for calcium and magnesium was negative in all the soils studied signifying the spontaneous nature of adsorption. The change in enthalpy ( $\Delta H^\circ$ ) was negative in most of the soils indicating the process to be exothermic. The close correlation of enthalpy change with change in entropy proved that as the enthalpy change becomes more negative, stronger is the bond and more orderly is the adsorption.

The incubation experiment conducted to study the effect of organic matter on the adsorption of calcium and magnesium revealed a positive influence of organic matter on availability of calcium and magnesium. The addition of organic matter improved the supplying power with respect to calcium and magnesium either through mineralization or formation of stable soluble complexes especially at higher pH.

Two field experiments to optimize the level of calcium and magnesium nutrition for rice in low land of north central laterites (Pattambi) revealed the clear role of calcium and magnesium in improving the yield and yield attributing characters of the crop. Application of dolomite as per  $\Delta$ pH was found to be effective in increasing the yield and maintaining optimum level of calcium as well as magnesium in soil. Application of lime was not found to influence the in situ soil pH. The response of crop to magnesium showed yield improvement to the tune of 1.18 t ha<sup>-1</sup> by application of magnesium sulphate @ 120 kg ha<sup>-1</sup>. Residual effect of dolomite had significant influence on the yield of rice whereas no residual effect of applied magnesium sulphate was evident. The correlation studies and path analysis clearly indicated that plant absorption of calcium mainly takes place from exchangeable fraction and that of magnesium from water soluble fraction.

### **12. Silicon and boron nutrition of rice (*Oryzasativa L.*) in wet land soils of northern Kerala**

The experiment aims at standardizing the dose and method of application of silicon and boron to rice crop in laterite derived paddy soils, its effect on available nutrient status of soil and yield and to study the effect of Silicon in alleviating the toxicity of Fe, Mn and Al in laterite derived paddy soils.

The sources of Silicon tried were potassium silicate and calcium silicate and the source for boron was borax. Method of application evaluated were soil application and foliar spray.

From the results of the present investigation the following conclusions were derived.

There was no significant influence of treatment on available N content of soil in both pot and field experiments. The treatments calcium silicate @ 4 g kg<sup>-1</sup> soil + borax @ 0.5 g kg<sup>-1</sup> soil and calcium silicate @ 100 kg ha<sup>-1</sup> + borax @ 10 kg ha<sup>-1</sup> produced significantly higher available P in the soil compared to other treatments in the case of pot and field experiments respectively. Application of potassium silicate @ 0.5% spray + borax 0.5% spray 3 rounds was superior to other treatments with respect to available K in soil for both pot and field experiments. Soil application of calcium silicate and borax resulted in highest available Ca in soil in both pot and field experiments. Soil application of calcium silicate was superior to foliar application of potassium silicate with respect to available Si content in soil. The investigation carried out under pot as well as field conditions in low land rice ecosystem in laterite derived paddy soils of northern Kerala has shown that the application of potassium silicate @ 0.5% spray + borax 0.5% spray 3 rounds at 15 days interval significantly improved the available nutrient status of soil, content and uptake of nutrient by the plant and yield attributes of rice. It was also effective in reducing the toxicity of Fe, Mn and Al in the soil.

### **13. Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition**

The experiments aimed to the characterization of on-farm liquid organic manures viz., cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these manures on soil health and crop nutrition using bhindi as test crop.

Physical, chemical, biochemical and biological characters of on-farm liquid organic manures indicated that these manures were potent nutrient source to improve soil health, crop productivity and quality. This can also be used as potential alternative for readily available nutrient sources for most of the crops.

Among different liquid organic manures are rich sources of beneficial micro flora which support, stimulate the plant growth and also good quality yield. On-farm liquid organic manures in conjunction with fish amino acid followed by cow urine has given the best result with respect to nutrient release.

75% N as EVC + panchagavya 3% foliar application followed by FAA 5% foliar spray and cow urine 10% foliar spray was superior to all other liquid organic manures in promoting yield and quality of bhindi. The recommended dose of inorganics can be substituted with combined application of enriched vermicompost (to get 75% N) and foliar application of 3% panchagavya or foliar spray of 10% cow urine or 5% fish amino acid at 10 days intervals. Soil health was enhanced in all the treatments compared to control.

#### **14. Technology refinement for biochar production and evaluation of its on soil health and crop productivity.**

The investigation was conducted for the refinement of technology for micro level biochar production from tender coconut husk and evaluation of its effects on soil health, yield and quality of banana (*Musa spp.*). Biochar produced by modified micro biochar kiln had ideal physical and chemical properties that qualify it to be used as a good soil amendment which is environmentally safe and contributing to the soil carbon pool. Biochar application in general, and biochar (10kg/plant) along with 75% soil test based recommendation in particular, enhanced the soil physical properties decreased the soil acidity, promoted rhizospheric microorganisms, increased soil fertility status enabling efficient nutrient use and resulted in higher growth, profitable yield and superior fruit quality of banana.

#### **15. Phytoremediation of inorganic contamination in Vellayani wetland ecosystem.**

The experiment was conducted to track the potential source of contaminants threatening the Vellayani wet land ecosystem and suggest viable phytoremediation technology

The potential sources of contaminants that threatens the Vellayani wetland ecosystems were discharge from automobile workshop and service centers, agriculture fields, domestic waste from hotels/houses/and other solid waste the pesticide residues were not detected in the system. Fe and Al responsible for the degradation of the ecosystem with minor contributions from Pb and Cd. The best phytoextractors/ phytoremediators identified *E. crassipes* for Fe, *M. vaginalis* for Al, *L. flava* for both Pb and Cd. Among the disposal methods of phyto extracted biomass, biochar production was the safest and ashing the least desirable method.

### **Continuing PG Projects**

#### **1. Nutrient management for organic rice based cropping system.**

The study aimed to develop nutrient schedule for organic rice-rice-vegetable system, to assess the residual effect of organic nutrition, to compute the energetics and economic feasibility and to evaluate the impact on soil health of organic rice based cropping system. Three crops were over and the experiment is in progress.

#### **2. “Management of Calcium, Magnesium, Sulphur and Boron in tissue cultured banana (*Musa spp.*) Var. Nendran”**

The experiments were conducted to investigate the effect of application of Calcium, Magnesium, Sulphur and Boron in potting mixture for hardening and in field condition banana var. nendran. Both the hardening studies and field experiment indicated the beneficial effect of secondary nutrients and boron on TC banana.  $T_{10}$  (150 ppm Ca, 25 ppm Mg, 25 ppm S and 0.5% B) and  $T_4$  (75 g Ca + 25 g Mg + 50 g S + 0.5% B) were found to be performing well under hardening and field conditions, respectively.

#### **3. Herbicide mixtures for weed management in direct seeded puddle rice (*Oryza sativa* L.)**

The best indicator plant selected based on the screening trial viz., maize and its shoot dry weight was used for assessing the herbicide residue of bispyribac sodium + metamifop in soil. Data on shoot dry weight of maize grown in post experiment soil treated with different doses of bispyribac sodium + metamifop viz., 60,70,80 and 90 g a.i. ha<sup>-1</sup>, bispyribac sodium @ 25 g a.i. ha<sup>-1</sup>, hand weeding twice and weedy check were statistically analyzed. Results revealed that there was no significant difference among the treatments, in shoot dry weight. Hence it can be assumed that, the residues of tested doses of bispyribac sodium + metamifop were not sufficient to cause growth inhibition in the indicator plant maize.

The best indicator plant selected based on the screening trial viz., maize and the parameter shoot fresh weight was used for assessing the herbicide residue of penoxsulam + cyhalofop butyl in soil. Data on shoot fresh weight of maize grown in post experiment soil treated with different doses of penoxsulam + cyhalofop butyl viz., 120, 125, 130 and 135 g a.i. ha<sup>-1</sup>, penoxsulam @ 22.5 g a.i. ha<sup>-1</sup>, hand weeding twice and weedy check were statistically analyzed. Results indicated that, there was no significant difference among the tested doses of penoxsulam + cyhalofop butyl and the control treatments in shoot fresh weight. Hence it can be inferred that the herbicide mixture, penoxsulam + cyhalofop butyl would not leave any phytotoxic residue in soil which can cause growth inhibition in maize crop.

#### **4. Flux and dynamics of iron and aluminium in wetlands of Kuttanad and its management for rice (*Oryzasativa L.*)**

The acid sulphate soils of Kuttanad region are having constraints of extreme acidic soil pH and pronounced toxicity of Fe and Al. This can be ameliorated using amendments and can be made more productive. The results of the investigation clearly indicate that application of phosphogypsum along with lime and foliar application of B and Si (phosphogypsum + ½ lime @ 300 kg ha<sup>-1</sup> + protassium silicate 0.25% + 0.25% boron) enhances the grain and straw yield of rice. This treatment also enhanced the available nutrient status of soil and plant nutrient content. It was very effective in alleviating toxicity of Fe and Al.

#### **5. Dynamics of iron and aluminium toxicity on rice (*Oryzasativa L.*) in saline hydromorphic soils of Kaipad**

The saline hydromorphic soils of Kaipad are having severe constraints of acidity, extreme toxicity of iron and aluminium coupled with high salinity. These problems can be ameliorated using combinations of amendments including phosphogypsum, lime and foliar application of boron and silicon (Phosphogypsum @ 500 kg ha<sup>-1</sup> + ½ lime as per KAU POP, 2011 + potassium silicate – 0.25% boron) to enhance the growth and yield of rice crop. Adoption of aforementioned management strategy could help in improving the soil health and thereby increasing the yield potential of Kaipad rice.

6. Characterization and evaluation of herbal and non herbal Kunapajalaon soil health and crop nutrition.
7. Assessment of soil health and status of heavy metals in the certified organic farms of Kerala.
8. Heavy metals stabilized sewage sludge compost as a growth medium for ornamentals.
9. Sorption and movement of flupyrad ifurone in sandy loam soils with and without organic amendment.
10. Organic manure seed pelleting for enhancing soil health and productivity of rice.
11. Effect of zinc fertilization on major plant and soil enzymes in southern laterites.
12. Development of multi nutrient fertilizer tablet and its evaluation in tomato.
13. Root phenomics and soil biological activity in response to thermochemical organic fertilizer application.
14. Soil carbon dynamics in a rice based cropping system.
15. Matrix based slow release fertilizer for increasing nutrient use efficiency in the Onattukara sandy plains.
16. Carbon pools in lateritic soil amended with coirpith-vermicompost and its effect on tomato (*Solanumlycopersicum L.*)
17. Pilot testing of fertilizer-manure blocks in Okra (*Abelmoschusesculentus L. Moench*)
18. Interaction of phosphorus and sulphur in black cotton soils of Palakkad (AEU : 23) under groundnut (*Arachishypogaea L.*) cultivation
19. Optimization of soil environment and crop response for magnesium nutrition in Ultisol
20. Salinity – nutrient interactions in salt tolerant Vyttila rice varieties
21. Organic nano NPK formulations for enhancing soil health and productivity
22. Assessment and management of micronutrients in the rubber (*Heveabrasiliensis*) growing tracts of Thiruvanthapuram
23. Taxonomy and organic carbon nutrient interactions in selected wetland soils of Kerala.
24. Spatial and temporal variations in nutrient dynamics in Pokkali soils of Kerala
25. Sulphur dynamics in major rice growing soils of Kerala
26. Calcium, magnesium and boron nutrition for grow bag cultivation of cabbage (*Brassica oleraceaL. var. capitata*)
27. Effect of soil amelioration and supplementary foliar nutrition on rice yield in Kuttanad
28. Secondary and micronutrient management forenhancing soil health and productivity in upland rice
29. Soil and nutrient management for suppression of Fusariumwilt disease of yard long bean (*Vignaunguiculatasubsp.sesquipedalis(L.)Verdcourt*)
30. Effect of phosphorus solubilisers on the availability of native P in phosphorus rich soil



# **Name of Project Coordination Group – (10) Farming Systems Research and Climate Studies**

**Compiled by:**

**Dr. Dr. Jacob John, Protect Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 4 Nos.**

**Ongoing Projects - 5 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 21 Nos.**

**Ongoing Projects - 28 Nos.**



**Concluded Projects****1. AICRP on Integrated Farming Systems (ICAR)****On-station Research****1.1: Development and validation of on-station integrated farming system models**

Dr. Jacob John  
Professor  
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Dr. Sudha B.  
Assistant Professor  
Dr. Meera A.V.  
Assistant Professor

- Gross returns of Rs.2,42,663/-, 2,34,546/-, 2,21,509/- and 2,11,046/- was obtained from coconut based, homestead based, banana based and rice based IFS models, respectively, from the maintained area of 0.20 ha each. Coconut based IFS model recorded the highest net returns (Rs.69055/-).
- Under homestead based IFS model, new aquaponics and hydroponics units were established. Quail, rabbit and goat units were included as new components in the integrated farming system. Mushroom and spawn production was started in rice based IFS model.

**1.2: Rice based cropping sequences to augment integrated farming systems in lowlands**

Dr. Jacob John  
Professor  
[jacob.john@kau.in](mailto:jacob.john@kau.in)

- The different rice based cropping sequences being evaluated are: T1 Rice-Fallow-Fallow & T2 rice-rice-fallow (existing farmers' practice/existing conventional system in lowlands); T3 rice-daincha-bush cowpea & T4 rice+daincha-rice-green gram (to improve soil health); T5 rice-cassava-amaranthus & T6 rice-cassava-bush cowpea (dual purpose) (for improving family nutrition); T7 rice-para grass-fodder cowpea & T8 rice-fodder cowpea-fodder maize (for livestock nutrition) and, T9 rice-bhindi-cucumber & T10 rice-bhindi-yard long bean (for income enhancement).
- There was no significant difference in rice grain and straw yield between treatments during first crop season. During second crop season, significantly higher rice equivalent yield (REY) was from cassava. During summer, significantly higher REY was from cucumber. The cropping sequence rice-cassava-amaranthus generated highest return (Rs.6.4 lakhs ha<sup>-1</sup>) which was nearly 200 per cent more than the conventional rice-rice-fallow, followed by rice-bhindi-cucumber (Rs.5.90 lakhs ha<sup>-1</sup>).

**2. On Farm Research Centre of AICRP on IFS, Thiruvalla**

Dr. Jacob. D.  
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**2.1. Response of nutrients in rice based cropping on farmer's field**

- Application of NPK @ 90:45:45 kg/ha along with zinc sulphate @ 20kg/ha recorded highest rice equivalent yield of 11438 kg/ha/year and the increase was 16 % and 245 % over farmers' practice and unfertilized control respectively.
- Balanced nutrition with NPK and Zn recorded the highest net income of Rs. 1.23 lakh/ha and Benefit: Cost ratio of 1.87.

**2.2. Diversification of existing farming systems under marginal household conditions**

- An average net income of Rs. 154820 was realized due to technological interventions made in integrated farming system of mean marginal farm holding size 0.43 ha and it was higher by 128 % over benchmark.
- Crop + Hort + Poultry was the predominant farming system with average net income of Rs. 116137. Paddy contributed 32 %, coconut and banana 63 % and poultry 5% of net income.

**2.3. On Farm evaluation of farming system modules to improve the profitability and livelihood of small and marginal farmers.**

- Hort + Dairy was the predominant system in marginal farm holding size of 0.82 ha and generated net income of Rs 193140 which was higher by 126 % over benchmark. Coconut and banana together contributed 67 % and dairy 33 % of net income.
- Crop + Hort + Dairy was the predominant system in small farm holding size of 1.37 ha and generated net income of Rs. 257980 which was higher by 137 % over benchmark. Paddy contributed 25 %, coconut and banana together 47 % and dairy 28 % of net income.

### 3. Network project on crop weather analysis

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#### *Crop weather relation studies in rice under the changing climate (southern region)*

- The effect of date of planting on the grain yield of rice during the *Virippu* season revealed significantly higher grain yield for 15<sup>th</sup> May planted crop (5.09 t ha<sup>-1</sup>), followed by 01<sup>st</sup> June planted one (4.80 t ha<sup>-1</sup>). Grain yield was drastically low for all the other dates of planting tested.
- The perusal of data showed no significant difference in grain yield among the different dates of planting during Rabi. The field experiment revealed that as the date of planting advanced, more assimilates were used up for producing straw rather than grain.

#### *Crop weather relation studies in rice under the changing climate (central region)*

- In *Virippu* season highest grain yield of 2620 kg ha<sup>-1</sup> was obtained in 1<sup>st</sup> June transplanting during the first year 4067 kg ha<sup>-1</sup> in 15<sup>th</sup> June during the second year. In *Virippu* season, 15<sup>th</sup> June was the best time of planting, followed by 1<sup>st</sup> June.
- In the *Mundakan* planting, the highest grain yields (4136 kg ha<sup>-1</sup> and 2860 kg ha<sup>-1</sup>) and straw yields (6327 kg ha<sup>-1</sup> and 4000 kg ha<sup>-1</sup>) were obtained with 1<sup>st</sup> October planting during both the years of experimentation.

#### *Crop weather relation studies in rice under the changing climate (northern region)*

- During *Virippu* season, in all the three years, the highest grain yield was recorded from the rice crop transplanted in the first week of June. The rice yield showed sharp decline when it was transplanted from the second week of June onwards.
- During *Mundakan* season, in all the three years, the highest grain yield was recorded from the rice crop transplanted in the first week of October. The rice yield showed sharp decline when it was transplanted from the second week of October onwards.

#### *Impact of weather factors on the flowering behavior of popular varieties of mango (southern zone)*

- Variation in the flowering behavior of selected mango varieties over different location was clearly observed. Flower initiation starts during the third week of August in many of the selected varieties. Neelam and Kalappadi showed maximum number of cycles of flowering within the season. Suvarnarekha showed an erratic pattern of flowering and poor fruit set.

#### *Impact of weather factors on the flowering behavior of popular varieties of mango (northern zone)*

- Five varieties of mango (Alphonso, Bangalora, Kalappadi, Neelam and Suvarnarekha) and three locations (RARS Pilicode, College of Agriculture, Padannakkad and District Agricultural Farm, Karimbam, Kannur) were selected for the study
- Mango flowering showed a significant positive correlation with prior week's both air and soil temperatures. Mango flowering also showed a significant positive correlation with duration of bright sunshine. Mango flowering had a negative relationship with the rainfall and relative humidity of the week prior to flowering.
- Increased day temperature and low humidity are the favourable conditions for flowering of mango.

#### *Crop weather relation and physiology in cowpea (Vigna unguiculata) at Vellayani*

- Three varieties of cow pea viz., Vellayani local, Vellayani Jyothika & Lola selected for the study. Growth performance of Vellayani Jyothika is better compared to the other two varieties.
- Weight of pods was found to be higher for Vellayani Local and Vellayani Jyothika while it was found to be less for Lola.
- Correlation studies showed that RH had significant influence on plant growth. But days to first flowering, pod maturity (harvesting time) and weight of pods were highly correlated with air temperature, soil temperature, and sunshine hours.

#### *Crop weather relation and physiology in cowpea (Vigna unguiculata)*

- The experimental trials were conducted at Coconut Research Station, Balaramapuram with three varieties of cowpea viz., Vellayani Jyothika, Vellayani Local and Lola for phenological, physiological, biochemical, flowering & yield characteristics. Maximum temperature had significant influence on weight of pods in Lola, Vellayani Local and Vellayani Jyothika. Sunshine hours, rainfall and evaporation had a positive influence on Vellayani Local, Vellayani Jyothika and Lola. Minimum temperature negatively influences Lola and Vellayani Local. Soil temperature shows negative influences on Lola. Relative humidity, wind velocity, rainfall and evaporation shows negative correlation to Vellayani Jyothika, Lola and Vellayani Local in the case of total yield. Evaporation had a negative influence on Lola and Vellayani Local.

*Crop weather relation studies in coconut*

- Five varieties of coconut viz., West Coast tall, WCT x MYD, Malayan Yellow dwarf, Chowghat Orange dwarf and Gangabondham were selected for the study at CRS, Balaramapuram.
- In West Coast Tall, wind speed and minimum temperature favoured the setting up of female flowers.
- Premature nut fall is positively correlated with the wind speed and evaporation and negatively correlated with relative humidity during day time (RH1).
- In semi-dwarf variety, Gangabondham and dwarf varieties, Malayan Yellow Dwarf and Chowghat Orange Dwarf, the percentage of female flower setting is positively correlated with relative humidity (RH1).
- There is a positive correlation between mite infestation and maximum temperature..
- The leaf rot incidents showed a positive correlation with rainfall and relative humidity along with wind speed.
- High humidity (>90%) resulted in premature nut fall in coconut.
- Leaf rot incidences and shedding of flowers were positively correlated with heavy rains.

*Crop weather relation studies in banana (nendran) under the changing climate scenario in central zone of Kerala*

- June 15<sup>th</sup> planted crop showed highest plant height compared to other plantings and early planted crops shows lower plant height
- May 1<sup>st</sup> and June 15<sup>th</sup> planted banana had highest psuedostem girth and April 15<sup>th</sup> planted crop showed lowest psuedostem girth
- Crop weather relation studies conducted with factors viz., temperature, sunshine, relative humidity, rainfall, and wind, revealed that of these five temperature had the greatest influence and wind the least.

*Crop weather relation studies in banana (nendran) under the changing climate scenario in southern zone of Kerala*

- Banana variety Nendran crop was planted during April (1<sup>st</sup> Season) and August (2<sup>nd</sup> Season) with five different dates of planting for two years and data were analyzed.
- The banana crop planted during 15<sup>th</sup> April, 1<sup>st</sup> May and 16<sup>th</sup> May showed more or less same crop period (370 days) with maximum bunch weight (9 Kg/plant).
- April-June planting season is the most suitable for banana production in the Southern zone of Kerala, ensuring more water for better growth of Nendran variety.
- April-June planting ensures higher bunch yield and higher water use efficiency and hence this season is most suitable for planting Nendran than irrigated season (August-October).

*Developing user friendly weather based calendars for various crops in different agroecological zones of Kerala*

- Crop calendar of rice was prepared for all the 23 agro-ecological units (AEU)
- During the period of assured moisture in each AEU, rainfall may cease in between, but in the soil there will be adequate moisture. Hence, cropping/date of planting in each AEU can be recommended/selected ensuring that the crop completes its life cycle within this period of assured soil moisture.

*Crop response studies using open top chambers in selected crops*

- Increase in the concentration of atmospheric CO<sub>2</sub> and the resulting modifications in the environmental conditions influenced the soil microbial types, population and interactions. This information can be made use of in soil management practices in the future.
- Elevated CO<sub>2</sub> environment had a positive influence on growth and development of pepper. Panniyur 1 was the best performing bush pepper. Pepper plants of the variety Karimunda had the best root characters, high mesophyll efficiency and low transpiration rate under elevated CO<sub>2</sub> environments which makes it suitable for water limited situations with higher water use efficiency.
- CO<sub>2</sub> enrichment improved the stress tolerance and recovery responses in tomato and amaranthus.

*Crop weather modeling in black pepper*

- Biomass partitioning of black pepper variety Panniyoor 1 has been found out
- Developed crop weather relationship of black pepper variety Panniyoor 1
- Developed crop weather model for black pepper using Universal Crop growth Simulator

**4. Network project on crop weather analysis**

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- Meteorological data base of the Southern Zone developed by incorporating 35 years weather data. 30 year period

Weather data collected from 9 stations in the zone, analyzed to find out variability in weather parameters. South West monsoon showed a decreasing trend over 20 years in the zone, rainfall increased from south to north and east to west during SW and NE monsoons. Summer rainfall showed an increasing trend in south zone. Water balance of the zone was worked out and moisture availability was found to be adequate for successful cultivation from April to Dec in the zone. Fine tuned AEU wise agro advisory generation issued through various media and mobile based dissemination of advisories to contact farmers developed.

- Development of meteorological data base of zone- data collected and analyzed. Trends in rainfall, temperature and relative humidity across the zone studied-Annual rainfall, Relative Humidity and Minimum temperature were slightly increasing and that of Maximum temperature and the Mean temperature were found to be decreasing. 20 lead farmers were selected, trained for collecting crop- weather information. Location specific advisories are prepared & disseminated
- Developed Agro Ecological Unit based meteorological data base for Northern Kerala. Studied water balance and rainfall trends of Northern Kerala. Developed AEU wise crop-weather calendar of Wayanad district and started generating location specific bulletins.
- Developed Agro Ecological Unit based meteorological data base for the entire district. Studied the water balance and rainfall trends of Wayanad district. Moisture availability index was adequate from the month of May and the periods from the June to September is considered as the periods of excessive moisture. AEU 21 shows lowest moisture availability periods of 3 months, followed by AEU 20 and AEU 15 (6 months).
- An information support centre for data collection, analysis interpretation and preparation of bulletins was established. Long term trends in climate variability across the zone were worked out. Water balance for the region was worked out. Location specific bulletins were prepared and disseminated to farmers
- The weather factors influencing incidence of important pests were identified and correlation coefficient worked out
- Correlation of Epilachna beetle (*H. vigintioctopunctata*) population in brinjal with weather parameters showed significant positive correlation with maximum temperature for egg mass, grub and adult respectively, and with minimum temperature for adult. Significant negative correlation exist with relative humidity for egg mass and grubs. Stem fly, *O. phaseoli* (Tr.) infestation in cowpea had correlation with minimum temperature, minimum humidity and wind speed whereas, negative and significant correlation observed between feeding punctures and sunshine hours. In Spotted pod borer, *M. vitrata* of cowpea a significant positive relationship between pod damage and wind speed and significant negative correlation coefficient with rainfall was noticed. The per cent pod damage by *M. vitrata* was negatively influenced by maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity.
- Established the relationship between weather variables and pest and disease incidence in rice, cowpea and banana. One week prior max. temperature, min. temperature, wind, sunshine and Rainfall showed negative correlation while RH1, RH2 and evaporation had positive correlation with pod borer in cowpea. One week prior max. temperature, min. temperature, wind, sunshine and evaporation showed negative correlation with pseudostem weevil in banana. One week prior sunshine, rainfall and evaporation showed negative correlation in which evaporation had significantly negative correlation with leaf roller attack in rice while, max. temperature, min. temperature, RH1, RH2 and wind had positive correlation. In case of sigatoka disease in banana, one week prior max. temperature, min. temperature, sunshine and evaporation showed negative correlation. In cowpea mosaic incidence, one week prior RH1, RH2, wind and rainfall showed negative correlation.
- Studied the periodical resurgence and intensity of pest and diseases of cardamom and pepper
- Correlation and regression analysis was carried out between pest/disease incidence and weather parameters. Rainfall influenced thrips population in cardamom and a unit decrease in RF increased the population. Negative correlation with morning RH and rainfall while positive correlation with sunshine hrs and thrips population was found. In case of shoot and capsule borer of cardamom positive binding of the pest with maximum temperature, minimum temperature and sunshine hours and negative correlation with morning relative humidity and rainfall was found. In case of cardamom shoot fly positive binding of the pest with rainfall and negative association with the sunshine hours was found.
- In case of mealy bug in pepper, a positive association sunshine hours whereas, negative relationship was found with

morning relative humidity. Pollu disease in pepper was positively bound with rainfall and negatively with sunshine hours

- Observation on pest & diseases noted from the surveillance plots and correlations with weather parameters was worked out. Relationship between Relative Humidity, Tmax and Tmin was worked out in case of BPH in rice, Pseudostem borer and Rhizome weevil in banana and Tea mosquito and *Colletotrichum* incidence in cashew.
- Collected pest and disease information from selected fields and analysis was done in relation to weather variables. In rice, thrips, stem borer, black bug and BPH were noticed as the major pests. The favourable weather condition was light or no rainfall with a temperature of 21 to 32<sup>o</sup> C. In case of banana the incidence of pseudo stem weevil were noticed during 150 to 300 DAP with light rainfall and a temperature between 23 to 34<sup>o</sup> C. Sigatoka disease was more prevalent during 100 to 200 DAP with a temperature of 21 to 34<sup>o</sup> C. In cow pea light rainfall and temperature between 23 – 32<sup>o</sup> C favoured the incidence of thrips, bacterial leaf blight and powdery mildew
- Identified 80 lead farmers as climate managers. 20 farmers each were selected from four districts viz. Thiruvananthapuram, Kottayam, Thrissur and Kasaragod & trained to equip them as climate managers. The information collected by them was used in agro advisory generation
- Fields survey was conducted in different parts of Thrissur, Palakkad and Ernakulam district. Many weather based ITK's were obtained from 247 farmers of Thrissur district, 225 farmers of Palakkad district and 210 farmers of Ernakulam district. Many of the ITKs were obtained on birds, animals, plants, insects, earthworms, ants, moon halos and number of stars, directions of wind, the colour of clouds etc. Three farmers awareness programme were conducted in Thrissur, Palakkad and Ernakulam districts
- A document containing Indigenous knowledge of the people in the districts of Kollam, Pathanamthitta and Thiruvanthapuram districts for forecasting weather especially rainfall prepared and published.

## Ongoing Projects

### 1. Developing an integrated farming system model at Vellayani

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### 2. Formulation of crop specific ready to use nutrient based substrates and production package for green roofs in urban agriculture

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### 3. Improving production from terrace garden in urban households through vertical farming

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### 4. Evaluation of suitable crop combination under organic farming in coconut garden

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### 5. Center of Excellence in below sea level farming

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The work of the above projects is progressing as per the approved technical programme.

## PG Projects

### Completed Projects

#### 1. Nutrient budgeting in rice based farming system

- Integrating fish in rice based farming systems resulted in higher soil residual nutrient status (P, Ca, Mg, S, Zn). The trench silt had low bulk density, high water holding capacity and was rich in N, K, S and Zn.
- Fish integration and consequent trench silt incorporation increased the rice yield by 15.56 per cent as compared to sole crop of rice.
- Fodder cowpea grown as component crop in rice based farming system resulted in positive balance for N, K and Ca. Integration of fish resulted in positive balance for K. The balance sheet of P, Mg, S and Zn was observed to be negative.

#### 2. Agrotechniques for container grown yard long bean (*Vigna unguiculata* var. *sesquipedalis*)

- The ideal growth media for container grown yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) is found to be soil, sand, coirpith, FYM in ratio 1: 0.5: 0.5: 1 by weight basis (3 kg soil, 1.5 kg sand, 1.5 kg coirpith and 3 kg FYM).
- Nutrient level and time of application : 100% recommended dose of NPK (basal application of 20 g groundnut cake + 10 g bone meal + 70 g wood ash and top dressing with fermented groundnut cake (10 g L<sup>-1</sup>) bag<sup>-1</sup> @ 30 & 45 DAS )
- Trailing method: Trellis system; Irrigation interval: Daily basis

#### 3. Crop Productivity and Weed Dynamics in Rice Based Farming Systems

- The investigations on weed dynamics revealed that the population of weeds was more in summer than in *Virippu*. During summer and *Virippu*, grasses dominated followed by sedges and broad leaved weeds, but broad leaved weeds were more in *Virippu* than in summer. In summer, weeds were more in fallow and in systems with sole crops. Among crops, weed growth was more in amaranthus. In *Virippu*, weeds were higher in the systems where rice was grown with fish.
- The productivity of summer crops and *Virippu* rice crop was more in cropping sequences integrated with fish.
- Rice+fish – rice+fish – culinary melon+fish system performed better in terms of weed control, yield and profit. This was followed by Rice+fish – rice+fish – amaranthus+fish system.

#### 4. Leaf litter recycling in homestead agroforestry systems

- Co-composting with poultry manure was the best method for rapid composting in jack and coconut leaf litter. Substituting 50 per cent recommended dose of nitrogen in amaranthus with coconut leaf litter compost (composting inoculum (liquid) + earthworm) resulted in significantly higher yield (46.7 %) and economic returns compared to 100 per cent chemical fertilizer application.

#### 5. Organic preparations and biostimulants for moisture stress mitigation in container grown okra (*Abelmoschus esculentus* (L) Moench.)

- Spraying of citric acid (0.2 %) to the container grown okra was found to be the best treatment for inducing stress tolerance, reducing the irrigation requirement, and increasing WUE (water use efficiency), water productivity and irrigation interval. It was also found to produce higher yield, net returns and benefit: cost ratio.

#### 6. Assessment of rice (*Oryza sativa* L.) production under climate change scenarios

- Grain yield decreased with delay in planting date. In Jyothi, June 20<sup>th</sup> planted crop (5782 kg ha<sup>-1</sup>) recorded highest grain yield compared other plantings and August 5<sup>th</sup> planted crop (3717 kg ha<sup>-1</sup>) recorded lowest grain yield. In case of Kanchana, June 20<sup>th</sup> planted crop (6155 kg ha<sup>-1</sup>) showed higher value of grain yield than other plantings.
- CERES-Rice model was tested and evaluated by adjusting the genetic coefficients for both the varieties with their respective planting dates. Predicted grain yield was satisfactorily agreed with observed yield in case of Jyothi and Kanchana.

#### 7. Nutrient scheduling for upland rice intercropped in coconut

- NPK @ 90:30:45 kg ha<sup>-1</sup> applied as N in two equal splits, P as basal and K in two equal splits along with foliar spray of 0.2 per cent zinc sulphate and 0.04 per cent sodium borate (n<sub>3</sub>s<sub>3</sub>) can be recommended for higher yield in upland rice intercropped in coconut.

**8. Carbon dynamics in teak planted laterite soils of Kerala**

- Cumulative CO<sub>2</sub> evolution from continuous plantation without felling didn't get affected with temperature indicating a dynamic equilibrium with atmosphere. Continuous teak rotation destabilizes carbon in soil and shows the potential to revert to a carbon source than sink if not managed sustainably.

**9. Assessment of portable biogas plants for their energy production and emission reduction potential**

- Using Portable Biogas Plants (PBP4) can result in total emission reductions of 1263.53 tonnes of CO<sub>2</sub> can be achieved per annum for 1000 households in the representative urban area of Kerala.

**10. Landslide hazard zonation of Nilambur taluk using remote sensing**

- Landslide Hazard Zonation (LHZ) map of the Nilambur Taluk was prepared using the SMCE module of ILWIS software. Study found that most of the areas fall under medium hazard zone followed by high hazard zone. The Western regions of the study area including Akampadam, Kalikavu and Karuvarakundu and areas along the Kozhikode - Nilambur - Gudallur Highway are highly unstable. Some of the reserved forest area is also coming under high hazard zone. The LHZ (landslide hazard zonation) map was validated by overlaying with previous landslide points.

**11. Mulching for soil quality, climate stress mitigation and crop productivity in okra**

- Higher soil moisture content was recorded under plots mulched with paddy straw throughout the crop period. Plots mulched with coir pith and coir chips also maintained higher moisture content at surface. Mulching with black and silver embossed sheet maintained the soil microclimate which in turn helped to improve the growth and yield of okra.

**12. Dendroclimatic analysis of teak (*Tectona grandis* L. f.) from central India to evaluate the potential for climate reconstruction**

- The various response function analyses carried out over study sites in central India clearly indicate the crucial role played by the summer climate in tree growth. The significant negative response of summer temperature associated with the positive response of summer precipitation is mainly related to the availability of moisture which is a function of both temperature and precipitation. The study highlights the importance of moisture availability during beginning of tree growth and the potential of teak for the reconstruction of summer climate.

**13. Climate change adaptation through improved water use efficiency in rice (*Oryza sativa* L.)**

- Hydrogel and irrigation had a significant impact on grain yield. Even though the higher yield (7014.63 kg ha<sup>-1</sup>) was observed for the irrigation level IW/CPE=2 without hydrogel, the mean average value of grain yield of plants treated with hydrogel is higher than plants treated without hydrogel (4455.03 kg ha<sup>-1</sup> and 3951.80 kg ha<sup>-1</sup> for with and without hydrogel). It can be concluded that hydrogel had significance only when the irrigation level was low (IW/CPE=1.5 and IW/CPE=1). However, at extreme low water level (IW/CPE=0.5) and high water level (IW/CPE=2), hydrogel failed to exhibit any beneficial role.

**14. Energy use and emission reduction in dairy farm**

- The total GHG emission from electricity usage in the farm was 87.45 kg CO<sub>2</sub> eq /cow/ year. The potential biogas production was 27.8 m<sup>3</sup> per day and only 8.6 m<sup>3</sup> was used presently. Production of electricity with the available balance biogas of 19.2 m<sup>3</sup> per day could save electrical energy. Out of the total GHG emission of 3039.7kg CO<sub>2</sub> eq / cow/year it was found that GHG emission can be reduced to 2952.2kg CO<sub>2</sub> eq / cow/ year by producing electricity from biogas.

**15. Impact of climate change variables on young coconut seedlings (*Cocos nucifera* L.)**

- Seedlings were exposed to ambient (Shade net condition), OTC control (atmospheric CO<sub>2</sub> and temperature) [ECO<sub>2</sub>] (550 and 700 ppm), [ET] (3°C above ambient) and [ECO<sub>2</sub>+ET] (550 ppm CO<sub>2</sub> + 3°C). Water deficit stress decreased plant photosynthesis, so it caused reduction in biomass and with leaf area under [ET] and no significant difference was observed in OP. [ECO<sub>2</sub>] stimulated the growth of plants under water deficit stress to certain extent and [ET] induced low growth of coconut seedlings under water deficit was compensated by [ECO<sub>2</sub>].

**16. Effect of weather on leaf blast incidence in rice and predicting potential epidemics under various climate change scenarios**

- The effects of weather and varieties on leaf blast incubation period were significant. EPRICE model was used to forecast the disease severity of leaf blast disease in rice after transplanting. The model works on daily weather parameters particularly rainfall, maximum and minimum temperature, morning and afternoon relative humidity. This shows that the predicted leaf blast severity was in good agreement with the observed values. So this model can be used for forecasting the rice blast severity under Kerala conditions.

### **17. Effect of weather on sheath blight incidence in rice and predicting potential epidemics under various climate change scenarios**

- The future carbon dioxide concentrations and climate data has been incorporated into disease simulation model- EPIRICE and predicted the future disease incidence possibility of sheath blight for the years 2030, 2050 and 2080 in all the 14 districts of Kerala. The impact of climate change on sheath blight severity in the various districts of Kerala showed an increasing trend. Southern districts are highly prone to sheath blight disease as compared to northern districts. Considering the major rice growing tracts of Kerala Alappuzha will be more prone to sheath blight than Palakkad and Thrissur.

### **18. Climate change adaptation on rice production**

- An attempt was made to quantify the impact of planting time on crop yield of variety Jyothi using DSSAT model. The observed and projected yield for the first crop season for the variety Jyothi showed more or less a continuous increase in yield starting from May 1st to August 1st. Crops planted on August 1st (6810 kg/ha) recorded the highest grain yield and the lowest was recorded during the May 15 planting (2212 kg/ha).

### **19. Impact of climate change on water resources of Kurumali river basin**

- The model predicted an increase in annual rainfall and a decrease in duration of individual storms in Kurumali river basin. An increase in the amount of SW monsoon rainfall and a decrease in the amount of NE monsoon was predicted. Evaporation losses were also found to increase and this in turn will reduce the water availability of the Kurumali sub basin. The reduced aquifer recharge consequent to high runoff and evaporation losses will disturb the demand supply balance of water within the watershed. Adoption of suitable soil and water conservation measures are recommended to overcome the water scarcity expected in future years.

### **20. Simulation of salt water intrusion into the coastal aquifers of Kadalundi river basin in Malappuram district using visual modflow**

- The study was to simulate the saline water intrusion in the coastal aquifers using Visual MODLOW and to predict the extent of saline water advancement in coastal regions of Kadalundi river basin. It was predicted that, there are chances of saline water intrusion to a lateral distance of 0.5 km to 1.9 km from the coast which extends 3.2 to 4.5 km along the coast from the northern boundary of Kadalundi river basin. Groundwater replenishment through natural and artificial recharge and sustainable development activities in the area are the main countermeasures to overcome this problem.

### **21. Impact of climate change on the temporal and spatial distribution of the Indian peafowl (*Pavo cristatus*) in Kerala**

- The study revealed the current (1950-2015) and projected distribution pattern of the Indian Peafowl for the years 2050 and 2070 under different RCP projections. The projected models explains about the increasing spatial distribution of the Indian Peafowl throughout Kerala except in Alappuzha and western slopes of Wayanad. The central part of Kerala is the hotspot of the Indian Peafowl currently and it will be the same in the future. The combined effects of precipitation and temperature variation have an indispensable role in this projected distribution of the Indian Peafowl.

### **Ongoing Projects**

1. Calibration and validation of CERES - Rice crop simulation model
2. Micrometeorological modification with different mulches to enhance the yield in tomato (*Solanum lycopersicum* L.)
3. Seed priming and foliar nutrition of upland rice in coconut garden
4. Standardization of crop establishment technique for upland rice (*Oryza sativa* L.) in coconut garden
5. Bio recycling of paddy straw for quality manure production
6. Productivity enhancement of rice based cropping system with fodder crops
7. Nutrient recycling of selected tree leaf litters in homesteads
8. Soil carbon dynamics in a rice based cropping system
9. Productivity enhancement of rice based cropping system with pulses
10. Crop-weather relations on yield and quality of Iruveli [*Plectranthus vettiveroides*]
11. Crop weather relationship of rice varieties under different growing environments.
12. Weather based irrigation scheduling in Finger millet (*Eleusine coracana* L. Gaertn) in central zone of Kerala
13. Palynological approach to screen coconut genotypes for high temperature tolerance
14. Impact of climate change on agroforestry systems of high range landscapes of Kerala
15. Measuring the climate change mitigation potential of forests and TOF (tree outside forest) systems in Thrissur
16. Influence of storage environment and packing materials on seed germination and viability of *Desmodium gangeticum* (L.) DC. and *Indigofera tinctoria* (L.)

17. Inter-annual variability of thermal and chlorophyll fronts in selected parts of eastern arabian sea and their relation to marine fishery
18. Evaluating the differences in meat characteristics between different indigenous breed goats subjected to summer heat stress
19. Microclimatic alteration on water productivity of chilli (*Capsicum annum L.*) under fertigation
20. Comparative assessment of the adaptive capacity of different indigenous breed goats to summer heat stress based on changes in phenotypic traits
21. Assessing the differences in body weight changes, rumen fermentation profile and metabolic activity between different indigenous breeds of goats subjected to summer heat stress
22. Impact of projected climate change on cropping pattern of different agro ecological units of southern Kerala
23. Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus (L.)*] under organic management”
24. Impact of projected climate change on cropping pattern of different agro ecological units of central Kerala
25. Climate variability impact on water resources in the command area of a river diversion scheme
26. Soil carbon efflux and litter decomposition in natural forests of KFRI Peechi campus
27. Vegetation dynamics of Madayipara laterite hillock in relation to weather
28. Comparative assessment of whole plant water use efficiency (WUE) of coconut seedlings (*Cocos nucifera*) to drought tolerance.



# **Name of Project Coordination Group – (11) Crop Pests and Beneficial Insects**

**Compiled by:  
Dr. Anitha. N Protect Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 9 Nos.**

**Ongoing Projects - 24 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 20 Nos.**

**Ongoing Projects - 18 Nos.**

## Concluded Projects

### 1. Consortium Research Platform (CRP) on Borers in Network Mode

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The major cerambycid borers collected during the survey were *Cerosterna scabratrix* (F.), *Olenecamptus bilobus* (F.), *Pterolophia* sp. Indet, *Apomecyna* sp. Indet, *Nupserha dubia* Gahan, *Celosterna scabrator* (F), *Aeolesthes holosericea* (F), *Macrochenus isabellinus* Aurivillius, *Epipetes uncinatus* Gahan, *Stromatium barbatus* (F), *Glenea multiguttata* Guerin – Meneville, *Nupserha* sp., *Batocera rufomaculata* (Deeger), *Batocera rubus* (Linee), *Ceresium* sp, *Acanthophorus* sp. Among these, *Nupserha dubia*, *Epipetes uncinatus* and *Glenea multiguttata*, are reported for the first time in Kerala. Study of IPM in snake gourd revealed that damage caused by the insect pest *Diaphania indica* to the crop snake gourd was reduced significantly in the plots treated with Dipel 1ml/l and chlorantraniliprole @ 0.3ml/l. Damage caused by the insect pest *Earias vitella* to the crop bhindi was reduced significantly in the plots treated with Dipel @ 1ml/l, *Metarhizium anisopliae* @ 30g/l and Malathion 50 EC @ 2ml/l. Among the biopesticides and insecticides treated against the shoot and fruit borer *Leucinodes orbonalis* of brinjal, Dipel 1ml/l and Fipronil @ 2ml/l were found effective.

### 2. Exploitation of bionematicide from potential plants of Western Ghats

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The analysis of the soil samples from the rhizosphere of ginger, pepper, turmeric and cardamom revealed the presence of root knot nematode, *Meloidogyne incognita*, burrowing nematode, *Radopholus similis*, *Reniform nematode*, *Rotylenchulus reinformis*, stunt nematode, *Tylenchorhynchus* sp. and spiral nematode, *Helicotylenchus dihystra*. *In vitro* screening studies were conducted to evaluate the larvicidal effect of aqueous extracts of weed plants viz. *maculata*, *Samadera indica*, *paniculata*, *Panicum maximum*, *Swietenia mahogany*, *Leucas aspera*, *Spilanthus paniculata*, *Samadera indica*, *Carica papaya*, *Simarouba gluoca* and *Mikania micrantha* against *M. incognita*. Aqueous extracts of *Andrographis paniculata*, *Glyricidia maculata*, *Chromolaena odorata*, *Quliqualis indica* and *Widelia trilobata* (10 % concentration) recorded 61 to 89 mortality of *M. incognita* juveniles. Maximum egg hatch inhibition was recorded by *A. paniculata* methanol extract (1% concentration). Methanol extract of *A. paniculata*, *G. maculata* and *C. odorata* at lowest concentration of 0.1% showed 68 to 78 percent mortality of *M. incognita* juveniles. Results of the pot culture studied revealed that dried powder of *A. paniculata* @ 25 and 50g/ kg soil reduced the population of *M. incognita* in soil. In pepper, the lowest mean gall number was recorded in *A. paniculata* dried powder @ 50g/kg soil. Soil application of *A. paniculata* dried powder @ 25 and 50 g/plant found to be effective in reducing the nematode population in the rhizosphere of ginger, pepper and turmeric.

### 3. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala. Sub project- 3-Development of alternative technologies for pest and disease management in Coconut and Arecanut

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Crown cleaning followed by the application of 12.5g Chlorantraniliprole 0.4GR 20g Fipronil 0.3G mixed with 200g sand in the innermost 2-3 leaf axils thrice a year is effective for the management of *Oryctes rhinoceros*. Considering the percentage reduction in infestation as well as the mean intensity score, the best treatment for Eriophyd mite management is spraying *Lecanicillium lecanii* (20g/l) thrice in a year after cleaning the crown. Among the five chemical treatments for the management of mites, Thiamethoxam 25WG (0.2g/l), Thiacloprid 21.7% SC (0.2ml/l) and Imidacloprid 17.8 SC (0.3ml/l) were equally effective when sprayed in the crown region thrice a year, avoiding the oldest and newest bunches. The best treatment for mealy bug management is spraying *Lecanicillium* 20 g/l or Imidacloprid 17.8 SC (0.3ml/l) or (20g/l) thrice a year after cleaning the crown. Leaf axil filling with Cartap hydrochloride 4%G 20g or Carbosulfan 6G 20g or Chlorantraniliprole 0.4GR 25g mixed with 200g sand were equally effective in managing Red palm weevil. Application of Imidacloprid 17.8 SC (0.3ml/L) in coconut bunches was effective in managing the coreid bug. Removal of affected tissues from the crown region followed by leaf axil pouring of Hexaconazol + Potassium phosphonate @ 3mL/L, thrice a year is the most effective treatment for management of leaf rot and bud rot

#### 4. Development of Technologies Including Alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala. Sub project-8 Development of substitutes for banned pesticides or alternative technologies for the management of nematode in cardamom

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Analysis of soil samples collected from rhizosphere of cardamom revealed the occurrence of four plant parasitic nematodes via. *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Helicotylenchus pseudorobustus*, *Radopholus similis*. Maximum reduction in nematode population was recorded by cartap hydrochloride 4% G @ 1kg a.i./ha, with a reduction of 78.8 per cent in 200 cc soil and 89.3 per cent in 5g /roots. This was followed by application of neem cake @ 2 kg/plant . Among the bio agents *B. macerans*  $1 \times 10^7$  cfu @ 30g/plant was the most effective treatment in reducing the population of nematodes followed by *P. lilacinum*  $1 \times 10^7$  cfu @ 30g/plant and *P. fluorescens*  $1 \times 10^8$  cfu @ 30g/plant.

#### 5. Development of Technologies Including alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala. Sub project-8 Development of substitutes for banned pesticides or alternative technologies for the management of nematodes in banana.

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Soil application of carbosulfan @ 16.7g/ plant found equally effective to the treatment, paring + hot water treatment + carbosulfan (8.3g/ plant)+ neem cake (1 kg/plant). In the case of root knot count, lowest number was recorded by the check treatment, P+HWT+ carbofuran + neem cake. Effect of carbosulfan @ 16.7 g/ plant was found to be statistically on par with cartaphydrochloride @ 10g/ plant giving 88 and 89 percent reduction in root knot count. Highest bunch weight was recorded in check treatment (8.62 kg) which was statistically on par with carbosulfan 16.7g/ plant (8.50Kg). Effect of carbosulfan @16.7g/ plant found equally effective to cartaphydrochloride (7.81 Kg) in increasing the fruit weight. Pooled analysis of data revealed that application of carbosulfan @16.7g /plant found to be equally effective to higher dose of chemical (33 g/plant) and check treatment (Paring + hot water treatment + carbosulfan (8.3 g/plant)+ neem cake @ 1kg/ plant) in reducing the nematode population and increasing the yield.

#### Evaluation of bio agents for the management of root-knot nematode in banana

Pooled analysis of the data revealed that the effect of Paring (P) + sucker treatment with *P. lilacinum* @ 5g/sucker+ pit application of *P. lilacinum* @ 20g/pit was statistically on par with paring + neem cake, P+ *B. macerans* @ 5g/ sucker+ pit application of *B. macerans* @ 20g/pit, P + sucker treatment with *P. fluorescens* @ 5g/ sucker+ pit application of *P. fluorescens* @ 20g/pit, P + carbosulfan pit application Highest bunch weight was obtained in *P. lilacinum* sucker treatment @ 5g/ sucker + pit application of *P. lilacinum* @ 20g/pit

#### 6. Development of Technologies Including alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala. Sub project-8 Development of substitutes for banned pesticides or alternative technologies for the management of nematodes in Vegetables.

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Cartaphydrochloride @ 0.3g.a.i/m<sup>2</sup> resulted 88 percent reduction in nematode population in soil followed by chlorantraniliprole. Lowest number of galls (4.24 per 5g root) was observed in plants treated with carbosulfan and it was statistically on par with carbofuran (7.05 galls per 5g root). Application of carbosulfan, carbofuran and cartaphydrochloride and chlorantraniliprole showed statistically significant superiority in improving the fruit yield of brinjal. Maximum number of fruits was recorded by the plants treated with carbosulfan (212.50) followed by carbofuran and cartaphydrochloride. Maximum fruit weight was recorded by carbosulfan treatment (7.46 kg) followed by carbofuran. Application of cartaphydrochloride @ 0.3g a.i/ha resulted 63 percent increase in fruit weight followed by chlorantraniliprole @ 0.03 g a.i/m<sup>2</sup>.

Nursery application of *P.lilacinum* @ 25g/m<sup>2</sup> + main field application of *P.lilacinum* @ 5g/m<sup>2</sup> and nursery application of *B.macerans* @ 25g/m<sup>2</sup> + main field application of *B.macerans* @ 5g/m<sup>2</sup> recorded 93 and 91 per cent reduction in nematode population. Regarding the number of fruits maximum number was recorded by the plants treated with chemical and the effect was statistically on par with *P. lilacinum* nursery application + main field. Highest fruit weight was recorded by

chemical treatment and it was statistically on par with *P. lilacinum* nursery application @ 25g/m<sup>2</sup> + main field application of *P. lilacinum* @ 5g/m<sup>2</sup> and nursery application of *B. macerans* @ 25g/m<sup>2</sup> + main field application of *B. macerans* @ 5g/m<sup>2</sup> giving 20.98, 19.05 and 18.58 tonnes/ha respectively. Among bioagents, nursery of application of *P. lilacinum* @ 25 g/m<sup>2</sup> + main field application @ 5g/m<sup>2</sup> and *B. macerans* nursery application @ 25 g/m<sup>2</sup> + main field application @ 5 g/m<sup>2</sup> are the best treatments for reducing the nematode population and increasing yield of brinjal.

**7. Development of Technologies Including alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala. Sub project-8 Development of substitutes for banned pesticides or alternative technologies for the management of nematodes in polyhouse grown vegetables**

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Soil application of neem cake @ 200g/m<sup>2</sup> three weeks prior to sowing +soil application of *P. lilacinum* @50g/m<sup>2</sup> at sowing significantly reduced the nematode population giving 94 per cent reduction over the untreated. Soil application of *P. lilacinum* at the time of sowing resulted 82 percent reduction in nematode population. Lowest nematode population in root was showed in plants treated with neem cake @200g/m<sup>2</sup> three weeks prior to planting + soil application of *P. lilacinum* @50g/m<sup>2</sup> at sowing. Highest fruit weight (228 Kg/plot) was observed in soil application of neem cake @200g/m<sup>2</sup> three weeks prior to sowing + soil application of *P. lilacinum* @ 50g/m<sup>2</sup> at sowing. Soil application of neem cake three weeks prior to sowing in combination with either *P. fluorescens* or *T. viride* @50g/m<sup>2</sup> at sowing and *P. lilacinum* alone found to be statistically on par with chemical carbosulfan and percentage increase in fruit yield in these treatments ranged from 60 to 62. Soil application of neemcake@200g/m<sup>2</sup> three weeks prior to sowing +soil application of *Purpureocillium lilacinum* @50g/m<sup>2</sup> at can be recommended to manage root- knot nematode in salad cucumber.

**8. Development of Technologies Including alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala. Sub project-8 Development of substitutes for banned pesticides or alternative technologies for the management pests and diseases of vegetables**

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Based of the trials conducted the following recommendatios were included in the POP

Crop	Target Pests	Recommended insecticides(With label claim)
Chilli	Sucking pests (mite and thrips)	Spiromesifen 22.9 SC @ 96 g ai/ha Fenpyroximate 5 EC @ 15 g ai/ha
Brinjal	Sucking pests (whitefly, jassids and mite)	Thiamethoxam 25 WG @ 50 g ai/ha Diafenthiuron 50 WP @ 300 g ai/ha Spiromesifen 22.9 SC @ 96 g ai/ha
Pulses(Cowpea )	Pod borers	Flubendiamide 20 WG @ 50 g ai/ha Chlorantraniliprote 18.5 SC @ 30 g ai/ha Spinosad 45 SC @ 75 g ai/ ha Indoxacarb 14.5 SC @ 60 g ai/ha Chlorantraniliprote 18.5 SC @ 30 g ai/ha
Cucurbits (Snake gourd)	Caterpillar pests (Snake gourd caterpillar, Pumpkin caterpillar)	Emamectin benzoate 5 % SG @10gai/ha Chlorantraniliprote 18.5 SC @ 30 g ai/ha
Brinjal	Shoot and fruit borer	Emamectin benzoate 5 % SG @10gai/ha Chlorantraniliprote 18.5 SC @ 30 g ai/ha
Pulses(Cowpea )	Sucking pests (aphids and pod bugs)	<i>Leccanicillium leccanii</i> 10 <sup>7</sup> spores/ml <i>Beauverria bassiana</i> 10 <sup>7</sup> spores/ml
Bhindi	Shoot and fruit borer	Emamectin benzoate 5 % SG @10gai/ha Chlorantraniliprote 18.5 SC @ 30 g ai/ha
Bhindi	Sucking pests(jassids)	Imidacloprid 17.8 % SL 20g ai/ha Thiamethoxam 25 % WG 25g ai/ha

**9. Supervised field trial sponsored by M/s Bayer Crop Science India Ltd. Bangalore and UPI limited, Mumbai**

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**Fluopyram 400 SC (Velum 400 SC) in banana**

The residues dissipated with time and reached below limit of quantification ( $<0.05 \text{ mg kg}^{-1}$ ) within 15 days in Fluopyram 400 SC @ 625 g ai/ha and 20 days in Fluopyram 400 SC @ 1250 g ai/ha at the time of sucker planting and within 15 days in Fluopyram 400 SC as basal drenching @ 250 g ai/ha and 25 days in Fluopyram 400 SC as basal drenching @ 500 g ai/ha. The mean residues of fluopyram, fluopyram benzamide in banana flower, raw banana, mature banana and soil were below limit of quantification ( $<0.05 \text{ mg/kg}$ ) in all treatments.

**Foestyl Aluminium 80 WP (Aliette 80WP)- Second Season in tomato**

The mean residues of fosetyl aluminium in soil collected at 15<sup>th</sup> day after second application were below Limit of Quantification ( $<0.05 \text{ mg/kg}$ ) in recommended and double the recommended doses ( $2.4 \text{ g a.i. L}^{-1}$  ( $3 \text{ g L}^{-1}$ ) (X), and  $4.8 \text{ g a.i. L}^{-1}$  ( $6 \text{ g L}^{-1}$ ) (2X))

**Tebuconazole 430 SC (Folicur 430 SC) in chilli**

The residues of tebuconazole in harvest time red chilli sample (20 days after spraying) is 0.40 and 0.95  $\text{mg Kg}^{-1}$  at recommended and double the recommended dose. The mean residues of tebuconazole in soil collected at harvest time were 0.68 and 0.95  $\text{mg kg}^{-1}$  in recommended and double the recommended dose respectively. The half lives of tebuconazole in chilli at recommended and double the recommended doses were 4.10 and 4.29 days respectively ( $500 \text{ g ha}^{-1}$  (X), and  $1000 \text{ g ha}^{-1}$  (2X))

**Flubendamide 240 + Thiacloprid 240-480 SC (Belt Expert 480 SC) in cardamom**

The half life values of flubendamide in green cardamom capsules at recommended and double the recommended doses ( $0.72+0.72 \text{ g a.i. } 10\text{L}^{-1}$  ( $3 \text{ ml}/10 \text{ lit. water}$ ) and  $1.44+1.44 \text{ g a.i. } 10\text{L}^{-1}$  ( $6 \text{ ml}/10 \text{ lit. water}$ ) in location I were 11.71 and 29.99 days, respectively. The half life values of thiacloprid in green cardamom capsules at recommended and double the recommended doses were 8.35 and 8.59 days, respectively. The mean residues of thiacloprid, flubendamide des-iodo in soil collected at the time of last sampling of cardamom were below limit of quantification ( $<0.05 \text{ mg/kg}$ ) in recommended and double the recommended dose, respectively. The half life values of thiacloprid in green cardamom capsules at recommended and double the recommended doses were 8.3 and 10.22 days, respectively in location II. The mean residues of thiacloprid, flubendamide des-iodo in soil collected at the time of last sampling of cardamom were below limit of quantification ( $<0.05 \text{ mg/kg}$ ) in recommended and double the recommended doses, respectively.

**Beta cyfluthrin 90 + Imidacloprid 210 OD (Solomon 300 OD) in chilli**

The half life values of Imidacloprid in chilli at recommended and double the recommended doses ( $310 \text{ g ha}^{-1}$ , and  $620 \text{ g ha}^{-1}$ ) were 12.45 and 14.80 days, respectively. The half life values of Beta- cyfluthrin in chilli at recommended and double the recommended doses were 6.98 and 10.08 days, respectively. Residues of beta-cyfluthrin in red chilli collected at the time of harvest were 0.10 and 0.21  $\text{mg kg}^{-1}$  in recommended and double the recommended dose respectively. Residues of Imidacloprid in red chilli collected at the time of harvest were 0.29 and 0.60  $\text{mg kg}^{-1}$  in recommended and double the recommended dose respectively. Residues of 6-CNA in red chilli collected at the time of harvest were 0.07 and 0.07  $\text{mg kg}^{-1}$  in recommended and double the recommended dose respectively. Residues of 6-CNA, beta –cyfluthrin were below detectable level in harvest time soil samples. Residues of imidacloprid was 0.06, 0.13 in recommended and double the recommended dose of harvest time soil samples.

**Chlorpyrifos 20 EC in French Beans**

The half life values of Chlorpyrifos in beans at recommended and double the recommended doses ( $600 \text{ g ha}^{-1}$ , and  $1200 \text{ g ha}^{-1}$ ) were 1.124 and 1.003 days, respectively. The mean residues of Chlorpyrifos in soil collected at the time of harvest were 0.17 and 0.33  $\text{mg kg}^{-1}$  in recommended and double the recommended dose respectively. Residues in seed collected at the time of harvest were 0.017 and 0.02  $\text{mg kg}^{-1}$  in recommended and double the recommended doses, respectively.

**Chlorpyrifos 20 EC in onion**

The half life values of Chlorpyrifos in onion leaves at recommended and double the recommended doses ( $5000 \text{ g ai ha}^{-1}$ , and  $10000 \text{ g ai ha}^{-1}$ ) were 1.44 and 1.76 days, respectively. The mean residues of Chlorpyrifos in onion bulb collected at the time of harvest were below detectable level in recommended and double the recommended doses, respectively. The mean residues of Chlorpyrifos in soil collected at the time of harvest were 0.34 and 0.82  $\text{mg kg}^{-1}$  in recommended and double the recommended doses, respectively.

## Standardisation of value added products of honey

Five honey based value added products viz., honey jam, honey drink, honey ladoo, honey wine and honey amla were standardized based on the sensory evaluation. In order to compensate the taste, a little quantity of the sugar is also added to the honey based value added products. Of the five products, honey wine was best in terms of the BC ratio followed by honey amla. The nutritive analysis and shelf life of the products were also conducted. In terms of the essential fatty acid content, honey jam is best followed by honey wine and honey amla. Microbial analysis revealed that the honey jam has maximum shelf life of up to two weeks while honey drink has the least shelf life. It is better to consume the honey drink soon after the preparation.

## Ongoing Projects

### 1. AICRP on Nematodes in Agriculture

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#### A.I.a. Diversity and distribution mapping of economically important nematodes in the country

Root knot nematode *Meloidogyne incognita* was the important nematode distributed in all the districts of Kerala surveyed followed by *Rotylenchulus reinformis*. In Spices maximum population in *M. incognita* was recorded in turmeric in the Pappinissery block of Kannur. In tuber crops Kodungallor in Trissur recorded *R. reinformis* population in arrowroot.

#### A.I.b. EPNs: Diversity of entomopathogenic nematodes (EPNs) gene pool of the country

EPN's isolated from Trivandrum and Kollam district showed promising pathogenicity against insect pests and EPNs were identified to be belonging to *Herorhabditis* and *Steinernema* spp.

#### A.II.a. Diversity of root-knot nematodes (*Meloidogyne* sp.) in different states of India

The nematode collected from Trivandrum district was identified as *Meloidogyne incognita* whereas, *M. javanica* was identified from Idukki based on the characters of perineal pattern, females and second stage juveniles.

#### A.II.b. Activity of phenyl alanine ammonia lyase (PAL), prooxidase and polyphenol oxidase in roots of root-knot nematode resistant and susceptible coleus cultivars

The highest PO, PPO and PAL activity was recorded in ginger variety IISR Mahima, However, variety Karthika showed lowest activity of this enzymes. Hence IISR Mahima was found to be moderately resistant to *M. incognita*. In rice highest PO and PPO activity was observed in rice variety Uma. The varieties Uma, Karthika, Pavizham and Bhadra were showed more PO activity than the susceptible check variety (TN1). The PPO activity of Bhadra, Pavizham, Karthika, Kanakom and Uma was more than that of TN1.

#### A.III. Estimation of avoidable yield losses due to economically important nematodes under nematode infested conditions

An avoidable loss of 27% and 37% were recorded in Brinjal (variety Haritha) and Okra (variety Varsha Upahar), due to *M. incognita*. The same nematode caused an avoidable yield loss of 37% in Cucumber (variety Subra and 29% in Chilli (variety Ujwala).

#### B.1. Screening, confirmation and evaluation of rice genotypes for resistance against rice root-knot nematode (*Meloidogyne graminicola*)

Among the 44 lines tested to assess their reaction rice root knot nematode *M. graminicola* AB-1792, AB-1880, GM-15-42 were found to be resistant. The lines AB-1705, AB-1794, AB-1797, AB-1798, AB-1799, AB-1802, AB-1821, GM-15-35, GM-15-39, GM-15-40 were found to be moderately resistant. The lines AB-1816, AB-1850, AB-1857 were found to be Highly Susceptible, All other lines were found to be Susceptible. Among the 51 rice cultivars screened to assess their reaction rice root knot nematode the lines tested AB 124 and AB125 were found to be moderately resistant (MR). Cen.patna, PB1121, AB112, AB105, AB102 and AB103 were found to be highly susceptible (HS). All other lines were found to be susceptible (S).

#### B. 4. Determination of host races of *Meloidogyne graminicola*

Host reaction based on Rf value revealed that rice varieties PB 1121 and Century Patent, pearl millet-bajra (HHB 67) and onion AFDR were categorized as good hosts of *M. graminicola* whereas tomato and sorghum were not found as good hosts of *M. graminicola*.

**C.1. Screening, confirmation and field evaluation of promising resistant germplasm of vegetable crops against root-knot nematode**

In brinjal among the 50 varieties tested IC-89824 and IC-144080 was found to be highly resistant. EC-136509, EC-304548, EC-315014, EC-316268, EC-136509, IC-89510, IC-136383, IC-146655, IC-146667 and IC-354624-A were found to be resistant. The line IC-89867 was found to be highly susceptible based on the number of galls and egg mass index.

**C.2. Management of root-knot nematode, *M. incognita* infesting vegetable cowpea using bioagents**

In cow pea carbofuran 3G @ 10g/m<sup>2</sup> was found to be the best treatment in increasing the yield of cowpea and reducing the population of nematodes

**C.3. Efficacy of bioagents in the management of *Meloidogyne* species in bittergourd**

Results of two trials indicated that application of *Purpureocillium lilacinum* (cfu 2x 10<sup>6</sup>) @ 2.5 kg along with 2.5 tons of FYM / ha + *Pseudomonas fluorescens* (cfu 2x 10<sup>6</sup>) @ 2.5 kg along with 2.5 tons of FYM / ha reduced nematode population and increased yield in bittergourd.

**C.4. Management of *Meloidogyne incognita*/ *M. javanica* in okra through bioagents**

Seed soaking with carbosulfan 25 EC @ 0.2% for 12 h before sowing followed by soil application of carbofuran @ 1 kg a.i./ha was found to be the best treatment in increasing the yield of okra and reducing the population of nematodes in soil (132.2) and roots (136.0)

**C.5. Management of plant parasitic nematode on okra by biofumigation**

Nematode population in soil and root showed drastic reduction at the time of harvest (4 months after sowing) in plots biofumigated with crop residues of cabbage and cauliflower. This was reflected in yield too which ranged from 18 to 20 t/ha against 11.7 t/ha in untreated.

**F.1 Management of root-knot nematode in blackpepper, *Piper nigrum* using bio-inoculants**

In pepper *Pseudomonas fluorescens* @ 20g/plant was the best treatment in increasing the yield of pepper (1.02t/ha) and was very effective in reducing the population of nematodes in soil and roots.

**F.2. Development of technology for application of bio-inoculant in banana for nematode management**

Treatment involving *Bacillus macerans* @ 5g of sucker + pit application @ 10g/plant at planting was found to be statistically superior in increasing the yield (8.8 kg/plot) of banana and reducing the population of nematodes in soil (150.3) and roots (78.3) compared to all other treatments.

**F.3. Comparative effect of mulching, biofumigation and application of organic manure for the management of nematodes in the rhizosphere of banana/grapes**

In banana Green leaf mulching with glyricidia leaves @ 5kg/plant and pit application of neem cake @ 500 g/plant reduced nematode population and increased yield in banana.

**F.6. Bio-intensive management of nematodes (specify) attacking ginger**

Rhizome treatment with *T. viride*/ *P. lilacinum* @ 3% w/w and combination of rhizome treatment with *T. viride*/*P. lilacinum*/*P. fluorescens* and green leaf mulching with glyricidia @ 1kg/m<sup>2</sup> can be recommended for the management of *M. incognita* in ginger.

**F.7 Integrated nematode management in pepper (*M. incognita*/ *R. similis*)**

Neem cake @ 200g/plant + *P. fluorescens* @ 15g/plant was the best treatment in increasing the yield (1.01 t/ha) of pepper and was very effective in reducing the population of nematodes in soil and roots.

**F.8. Evaluation of bio-agent and chemicals for the management nematodes in cardamom**

In cardamom Treatment involving carbofuran 3G @ 25g/plant was found to be statistically superior in increasing the yield (5.1 kg/plant) of cardamom and reducing the nematode population in soil (82.7) and root (30.5)

**G.6. Population build-up of nematodes associated with Cool season vegetables (Cabbage & Cauliflower) and Vegetables in poly houses/rain shelters**

In Cauliflower the population of *M. incognita* increased from 223 J2/200 cc soil and 92 nematode /5g roots during the month of August to 332 J2/200 cc soil and 95 nematodes/5g roots during the month of September and further decreased to 295 J2/200 cc soil and increased to 125 nematodes/5g roots. *Rotylenchulus reniformis* has also showed the same trend.

## 2. Isolation and identification of potential indigenous bio-control agents

Nine bacterial isolates obtained from survey. Isolate 1 at 100% concentration showed 99 percent mortality of juveniles at 72 hours after treatment

## 3. All India Network project on vertebrate pest management (AINPVPM)

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### AINP on Agricultural ornithology

#### 4.1. Community structure of birds and their diversity in relation to crop stages in different agro-ecological zones based on cropping systems

##### Avian diversity in rice-rice system

Seventy seven species of birds were recorded in the irrigated rice system of Kerala in 2017-18 periods. Cattle egret was the most dominant bird (RA 7.21%) followed by house crow (RA 5.89%) and pond heron (RA 5.48%). Depredatory birds viz., blue rock pigeon (RA 6.01%), baya weaver (RA 4.21%) and spotted munia (RA 3.89%) visited the crop field at the time of sowing, grain filling, maturity and harvest stages of the crop. In the irrigated rice crop in the observation area, baya weaver (RA 19.64%) was the most dominant bird during the period under report followed by cattle egret (RA 10.56%), blue rock pigeon (RA 6.46%) and common myna (RA 6.15%)

##### Avian diversity in vegetable fields

Community structure of birds in vegetable ecosystem showed that there were 57 species. Mean diversity index was 2.89. The bird diversity was almost uniform throughout the year. Maximum diversity index was recorded in February. The dominant bird was common babbler followed by myna. Depredatory birds viz., rose ringed parakeet, plum headed parakeet, peafowl and small green barbet, though occurred in less number compared to the beneficial birds, caused considerable damage to vegetable crops.

##### Avian diversity in banana plantations

Banana plantation had the stable avian diversity and 56 species of birds were recorded. Dominant birds in the banana ecosystem include common babbler, mynas, house crow and bee eaters. Depredatory viz., small green barbet (RA 3.92%) and rose ringed parakeet density was low compared to other birds, the damage caused by them was substantial.

##### Avian diversity in cashew plantation

In cashew plantation there were 45 different species of birds. The depredatory birds viz., peafowl was the dominant one. Except the greater coucal, annual mean rainfall did not affect birds viz., common myna, black drongo and others. The decreasing species richness of birds in the cashew plantations might be due to increased human activities and vegetation clearance from the fields.

##### Avian diversity in the orchard system

Community structure of birds in mixed orchards of Kerala showed the dominance 52 species. Being less disturbed the distribution of birds showed uniformity during the period. Almost all the dominant birds in the orchard ecosystem had positive correlation with the annual mean rainfall i.e the monsoon rains had no effect on the densities of the orchard birds.

#### 4.2. Application of information technology (IT) by using GPS & GIS for ecological evaluation of bird habitat and behaviour with reference to crops

##### a. Depredatory birds

##### Feeding ecology of key bird species

Observations on the feeding habits of common birds viz., house crow, blue rock pigeon, jungle crow, rose ringed parakeet, house sparrow and baya weaver bird were recorded. Main crops in the observation area were rice, plantain, cashew, mango, jack, guava, papaya, vegetable viz., vegetable cowpea, seed cowpea, snake gourd, bitter gourd, brinjal, moringa, tomato, pumpkin and amaranthus; tapioca, gingelly, etc.

##### b. Roost type

Small – number of birds <100, Medium - number of birds >100 but <500, Large - number of birds >500

### c. Extent of damage status in a given area

Five locations were selected to assess the depredatory bird damage to crops/ aquaculture around the roosting sites. The crop damage varied depending upon the extent of isolation of the cropped area. Main depredatory birds recorded were baya and streaked weaver, teal, rose ringed and plum headed parakeets, small green barbet, purple moorhen, blue rock pigeon, peafowl, red vented and red whiskered bulbuls, cormorants, greb, etc.

### 4.3. To identify, develop and evaluate eco-friendly bird management practices for crop protection

#### a. Screening of botanicals (non-lethal chemicals) as feeding deterrents

Botanicals viz., *Andrographis paniculata*, *Cassia auriculata* and *Lantana camara* leaves (10% aqueous leaf extract) and seeds of *Annona squamosa* (10% aqueous seed extract) were screened for feeding deterrent properties against depredatory birds like blue rock pigeon. *A. paniculata* leaf extract was on par with the methyl anthranilate (0.2%), ecodon (1.0%), copper oxychloride (0.1%) and whole egg (1.0%) in reducing the feeding of parakeet. *Annona squamosa* (10% aqueous seed extract) was the next best in reducing the food intake by the bird. Passerine bird feeding was significantly reduced by methyl anthranilate (0.2%), ecodon (1.0%), copper oxychloride (0.1%) and strontium chloride (0.1). Among the aqueous extracts, leaf of *L. camara* (10 % aqueous leaf extract) had significantly reduced the feeding in munias.

### 4.4. Exploitation of beneficial birds for the suppression of insects/rodent pest

#### a. Role of insectivorous birds in suppression of insect pests

Treatments with bird perch and *B. t.* in the open area with free access to insectivorous birds, comparatively less number of lepidoperan insects were recorded. Lowest insect population was observed in the farmer's practice, might be due to the pesticide usage. Combined use of bird perch and *B. t.* might be one of the tool in the integrated pest management of cowpea pests.

### 4.5. Food habits of birds of prey (Owlets) and barn owl using pellet analysis

Owl nesting sites had been located near the cropped and fallow lands. As the pellet analysis of the owls and other birds of prey could be one of the reliable tools in assessing the feeding guild of the birds, thirty two barn owl pellets collected from various agro ecological zones were analyzed. Results showed that the major component of the diet of barn owl was *Suncus muinus* (78.38%) followed by *Rattus rattus* (22.50%) and less quantity of bird remains and insect remnants (3.13%).

### 4.6. Evaluation of nest box design for various cavity nesting birds and their utilization

Nest box size of 12x8x8 inches with the 8 cm diameter entrance hole was found to be suitable for the birds viz., common myna and the magpie robins.

### 4.7. Evaluation of fruiting/ flowering trees to attract insectivorous/ omnivorous birds to the agricultural landscape

Efforts were made to plant mulberry and copper pod tree saplings along the roads as avenue tree in many places to attract birds viz., babblers, prinia, fly catchers, oriole, minivet, robin, etc as these trees harbor numerous insects especially the lepidopteran caterpillars.

### 4.8. Management of peafowl to minimize the conflict in agricultural landscape

#### • Evaluation of non-lethal seed treatment

For the management of peafowl in the vegetable fields methyl anthranilate based repellent, whole egg, *Andrographis*, *Ipomea*, ecodon treatments were given. Methyl anthranilate based repellent treated rice seeds were not preferred by the birds in the rice nursery for more than 20 days in RARS, Pattambi fields.

#### • Evaluation of physical barrier to prevent entry in to the field

In the rice fields wherever the peafowl frequenting, reflective ribbon and nylon rope fencing were erected to an height of 3' with two to three rows, which effectively kept off the birds from entering into rice and vegetable fields.

#### • Population details, breeding and feeding ecology

The pea fowl breeds in Kerala in the months of April and May. The mean clutch size was three. The birds fed on variety of food materials. The population of pea fowl in different cropped area was monitored over a period of time. The birds frequented more in the cashew plantation followed by vegetable fields and banana plantations.

### 4.9. Impact assessment of technologies through large scale demonstrations

#### a. Reflective ribbon – nylon rope fence against peafowl depredation

Two rows of nylon rope as tied around the vegetable field with the support of poles at 2m interval at a height of 30 cm between the ropes and single row of reflective ribbon was also tied over nylon rope as a fence around the field. Reflective ribbon was also tied over the crop at a height of 60 cm with an interval of 1.5m in NS direction to scare the peafowl from the field. From the experiment it was evident that peafowl management technique was significantly effective in reducing the bird

#### 4.10. Bird damage in aquaculture and development of prevention and control methods

There were 24 species of birds in aquaculture premises and feed on the stocking fry and developing fingerlings. In aquaculture, the most destructive birds in Kerala were the little cormorant followed by the king fishers (common, pied and the white breasted). Little grebe was the major problem during the stocking time.

#### Management of birds in aquaculture

The reflective ribbon effectively warded off the depredatory birds away from the pond allowing the fingerlings to escape from them. The effect lasted for a period of 3 months and was sufficient to cover the vulnerable stage of fingerlings from predation.

#### 4.11. Impact of weather variability on avi fauna

No appreciable impacts on the migratory birds (on their arrival and departure as well as breeding biology) were noted during the period under report.

#### 4.12. Studies and management on vertebrate pest of crops other than birds and rodents

Wild boar posed a serious threat to crops like banana, vegetables, rice, tuber crops, etc. in Kerala. Olfactory repellent with strong smell (BoRep) was taken in muslin cloth and tied on poles at a distance of 1m around the field at a height of 10 cm from the ground level. Modified nylon net fencing around the field and use of olfactory repellent were found to be superior in deterring wild boar.

#### 4.13. Bio-diversity in agricultural landscape with relevance to conservation

The study was conducted in paddy ecosystem at two different locations, State Seed Farm, Mannuthy, Thrissur and State Seed Farm, Alathur, Palakkad District.

#### II Location specific studies:

##### Bioecology of purple moorhen and control measures in kole lands

Purple Moorhen (*Porphyrio Porphyrio*) (Rallidae – Gruiforme). has silky purple-blue plumage with metallic gloss on throat and breast, contrasting with the white undertail coverts. The very large bill is triangle-shaped, with bulky and curved upper mandible, giving the bird a strange appearance. The bill extends to the head top in a bright red shield, as bill and long legs. The slender toes show fine claws, and especially the rear toe. Eyes are red too. Both sexes are similar. The egg laying occurs in April-May. Female lays the eggs in roughly done cups in communal nests. Eggs are fairly large and glossy, with pale shell which may vary in tinge and spotted purplish and brown. Incubation lasts about 25 days. The chicks leave the nests 4-5 days after hatching.

#### Studies on meta-genomics of bird fecal matter for identification of useful virus & bacteria to suppress insect pests of crops

Metagenomic analysis of cattle egret was carried out using faecal pellet. Collected specimen were preserved in 90% ethyl alcohol at -20° C. Next generation sequencing technology has been carried out to analyse the microbial community within the species by isolation and polymerized chain reaction using 16S rDNA primer. Sample was sequenced at SciGenom Labs Private Limited, Cochin (IlluminaMiSeq). A total of 12 bacterial phyla, 21 classes, 37 orders, 76 families, 119 genus and 234 species were examined by comparing sequence against the Ribosomal Database Project (RDP) via metagenomic RAST (MG RAST) server. Firmicutes were found to be most abundant and diverse phylum within the species followed by Proteobacteria and Actinobacteria. A trace amount of Bacteroidetes, Spirochaetes, Cyanobacteria, acidobacteria and Chloroflexi were also noticed in the sample.

#### 4. AICRP biocontrol

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#### Seasonal abundance of spiders in rice ecosystem

The collected spiders were sent to NBAIR for identification.

#### Surveillance for pest outbreak and alien invasive pests

The only outbreak reported was that of the giant African snail (*Achatinafulica*) in Thrissur in October 2017. Localised incidences of brown plant hopper infestation in rice was reported from Palghat district in late stages of the first crop.

**Management of rice stem borer and leaf-folder using entomopathogenic nematodes and entomopathogenic fungi**

An experiment using *Steinernema carpocapsae*, *Heterorhabditis indica*, *Bacillus thuringiensis* (NB AIR strain), *Beauveria bassiana* and *Metarrhizium anisopliae* for the management of rice stem borer and leaf folder indicated that there was no significant difference between the different treatments in terms of infestation or yield.

**Large scale bio-intensive pest management on rice.**

Adoption of IPM practices led to substantial reduction in infestation by major pests. The mean stem borer population in IPM plots was 43 per cent lower as compared to non IPM plots. Similarly, the dead heart as well as white ear head symptoms recorded 86 and 78 per cent reduction in IPM plots as compared to non IPM plots. The population of natural enemies too was higher in IPM plots. While mean spider population in BIPM plots was 7.5/m<sup>2</sup>, the same for non IPM plots was only 5/m<sup>2</sup>. The average population of *Ophionea* sp. was, however, higher in plots following conventional practices. Greater parasitoid activity was again observed in BIPM plots.

The yield obtained from IPM plots, at 8000kg/ha was approximately 20 per cent more than that obtained from non IPM plots (6800 kg/ha).

**Field evaluation of entomopathogenic fungi against banana pseudostem borer *Odoiporus longicollis***

Among the entomopathogenic fungi, *Beauveria bassiana* sprayed @ 10<sup>8</sup> spores/ml was the most effective treatment with 27.77 per cent infestation while the same applied through leaf axil resulted in 46.66 per cent infestation.

**Management of rugose whitefly in coconut with biocontrol agents**

The severity of infestation ranged from high to severe during September but decreased to medium levels by December and low levels by March, 2018. Parasitism by *Encarsia guadeloupe* ranged from 10-54 per cent in September, 2017 but increased substantially to over 90 per cent by October, 2017. Mean parasitism was 87.98 during December. Higher mean parasitism of 93.31 and 92.02 were recorded during December and January respectively. The parasitism remained high on four out of five palms during March but was very low at 7.83 per cent on one palm where the leaves had fresh infestation.

**Popularization of bio intensive integrated pest management (BIPM) in Kerala (ATMA)**

Fifteen panchayats from the three districts of Thrissur, Ernakulam and Palghat were identified in consultation with the respective Principal Agrl Officers. A total of five training programmes have been completed. A total of 92 farmers including 28 women participated in the above trainings.

**5. AICRP on Fruits**

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**Fixed plot survey:** In the reporting period, incidence of pseudostem borer and rhizome weevil along with leaf eating caterpillars viz., *Spodoptera litura* and *Pericallia ricini* were regularly present in the fixed plots. Whereas sucking pests viz., mirid bugs, lacewing bugs, whiteflies etc. were seen sporadically with higher number in rainy season. Incidence of Banana skipper butterfly (*Erionota torus*) was observed from pre-monsoon through post monsoon during 2017. Peak leaf roll formation was seen in the months of June to August coinciding with monsoon in Kerala, later subsiding during dry periods.

**Roving survey**

Nineteen different insect pests were observed infesting banana in Kerala during the survey period. Slug caterpillar (*Miresa decedens*) is emerging as a pest of concern. Similarly banana leaf thrips (*Helionothrips kadaliphilus*) and lace wing bugs (*Stephanitis typicus*) along with Rugose Spiralling Whitefly is emerging as pest of concern in summer months in Kerala.

**Integrated management of banana pseudostem weevil (*Odoiporus longicollis*)**

Among the treatments, Swabbing chlorpyrifos 0.05% at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> months after planting and Pseudostem trapping with EPF, *Beauveria bassiana* (1x 10<sup>7</sup> spores/ml) 15 g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> months after planting recorded the highest bunch weight of 8.93 kg and 8.86kg respectively, which were significantly higher than control.

**Survey of plant parasitic nematodes associated with banana**

Survey of nematode pests of banana was conducted across the state of Kerala for *Radopholus similis*, *Pratylenchus* sp., *Helicotylenchus multicinctus*, *Meloidogyne* sp. and *Heterodera oryzicola*.

### Management of nematodes in ratoon and high-density planting systems

Cartap hydrochloride @ 20 g/clump soil application followed by half dose after 3<sup>rd</sup> month was the best in reducing the nematode population. Among the bioagents, application of neem cake @ 250 g/clump followed by 250g after 3<sup>rd</sup> month and Growing *Tagetes* around the basin showed the best result in reducing the population of soil nematodes over control.

### Biorationals for the management of nematodes of banana

Application of *Paecilomyces lilacinus* @ 25g/m<sup>2</sup> (T3) effectively reduced the nematode population, increased the plant growth parameters and bunch weight which was on par with treated check application of cartaphydrochloride @ 10g/m<sup>2</sup>

### Biological control of banana stem weevil, *Odoiporus longicollis*

Entomopathogenic nematode formulation of *Heterorhabditis* sp. spray at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting and stem trap swabbed with *Beauveria bassiana* @ 20g/trap at 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> month after planting were proved to be on par with treated check in its efficacy in reducing the various stages of the pseudostem borer of banana and its management.

### Management of banana skipper butterfly-*Erionota torus*

Foliar application of Chlorantraniliprole 18.5 SC effectively reduced the banana skipper butterfly population. Among the biological control methods, foliar application of *Bt* @ 3ml/l (1x10<sup>18</sup>cfu) was better

### Evaluation of bio control agents for the management of banana nematodes

Application of *Paecilomyces lilacinus*+ *Pseudomonas fluorescens* each @ 12.5g/ plant at the time of planting and 3 MAP and EPN *Heterorhabditis* sp. @ 1 x 10<sup>9</sup> IJs/ml at the time of planting and 3 MAP showed the best result in reducing the population of soil nematodes.

### Biological management of nematodes in tissue culture banana

The lay out of the experiment will be done in the nematode sick plot which was being used for conducting banana virus experiment. Treatments will be imposed as per the technical programme in the current season.

### Survey for new and emerging insect pests of jackfruit

*Acalolepta nivos*a White (Coleoptera: Cerambycidae) was recorded as a new pest of Jackfruit. Adult stage as bark feeders and defoliators thus causing death of growing shoots and branches. Similarly *Artocarpus heterophyllus* and *Artocarpus altilis* were recorded as preferred hosts of *Epepeotes uncinatus*, as a defoliator in adult stage and wood borer in grub stage. *Glenea multiguttata*, a cerambycid beetle was observed to cause damage to Jack leaves by severing the veins leading to drying of leaves and young shoots. Incidence of *Oberea artocarp*i was recorded from Central zone mainly from trees less than 5 years old. Gregarious infestation of Leaf beetle (*Olenecamptus bilobus*) coincides with the profuse flushing especially during the monsoon period. This was closely followed by infestation of Leaf caterpillar (*Margaronia bivitalis*). The attack of Stem borer, *Batocera rufomaculata* was noticed on tress during monsoon and post monsoon period.

## 6. AINP on Pesticide Residues

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AINP on Pesticide Residues is the core laboratory in south India under the Central Sector Scheme on Monitoring of Pesticide Residue at National Level. To comply with the requirements specified in ISO/IEC 17025:2005, the method validation for the pesticides like organochlorine (OC), organophosphorous (OP), synthetic pyrethroid (SP) and new generation insecticides in salad cucumber, wheat and cardamom were carried out by PRRAL, AINP on Pesticide residues, College of Agriculture, Vellayani. Satisfactory recovery (70-120 %), precision (<20 %) and measuring range (0.01-0.5 mg/kg) was obtained in all these commodities. An amount of Rs. 634972/- has been generated through the analysis of pesticide residues in different commodities to the public.

## 7. AICRP on Honey bees and Pollinators, Vellayani Centre

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### Management of biotic stresses in pollinator

The histopathological analysis of the internal organs of diseased Indian honey bee larvae revealed significant

morphological variations in the midgut whereas the foregut and hindgut remained intact. Necrosis cell death of the internal lining of mid gut and uncleaned microvilli was observed in the diseased larvae compared to the normal ones. The cell disintegration occurred in the epithelium towards the lumen which later spread to the haemolymph leading to the leakage of the gut contents. Thus, disruption of the ventricular cells hinders the absorption of nutrients and water leads to the sudden death of the honey bee larvae.

#### Assessment of Pollinator Diversity in different Crop Ecosystems

Observation on the flower visitors of vegetables – *Moringa oleifera* indicated the presence of *Apis cerana indica*, *Apis florea*, *Xylocopa* spp., *Amegilla* spp. and three types of ants.

#### Domestication, multiplication and management of stingless bee colonies

Survey was conducted in the stingless bee colonies of Southern districts of Kerala viz., Thiruvananthapuram, Kollam and Pathanamthitta to assess the incidence of small hive beetles. Seven beetles (5 nitidulids, 1 cryptophagid and 1 tenebrionid) were collected from the hives during the survey. Among the three districts, highest incidence of small hive beetle was recorded from Kollam (19.00 %), followed by Thiruvananthapuram (16.00 %) and Pathanamthitta (3.00 %).

#### 8. Research on new molecules of plant protection chemicals Sub Project 1- Screening of new generation insecticides, bio-pesticides and other non chemical insecticides for the management of pests of cole crops.

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Twenty pest species of cole crops were recorded. Major pest in plains of Kerala – *Spodoptera litura*, pest is severe from true leaf stage onwards and persists till the curding and heading stages. Major pest in hilly areas of Kerala – *Plutella xylostella* severe during the heading and curding stages. Results of the study revealed that Spraying SI NPV 2 mL/L or Aqueous Garlic extract 2% sprayed at fortnightly intervals is effective when infestation level is mild to moderate. Under heavy infestations spraying Chlorantraniliprole 18.5 SC 0.05% @ 2mL/10L or Spinosad 45 SC 0.1% @ 2mL/10L at True leaf stage and at curd or head initiation, effectively manages the pest. For the management DBM Spraying Spinosad 45 SC 0.1% @ 2mL/10L or Chlorantraniliprole 18.5 SC 0.05% @ 2mL/10L at True leaf stage, Curd or head initiation and Heading/ curding stage is effective

#### 9. Research on New Molecules of Plant protection chemicals. Sub Project 2: To evaluation of pesticides for the management of nematodes attacking cabbage and cauliflower.

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Cartap hydrochloride 4G @ 2kg a.i/ ha was the best treatment in increasing the yield (19.0 t/ha) of cauliflower compared to all other treatments and followed by cartap hydrochloride 4G @ 1kg a.i/ ha (18.3 t/ha) and thiamethoxam 25%WG @ 200g a.i/ha (16.8 t/ha). Among the bio-control agents *Trichoderma viride* @ 2.5kg /ha was the best treatment in increasing the yield (16.0 t/ha) of cauliflower followed by T8- *Pseudomonas fluorescens* @ 2.5kg /ha (10.8t/ha). The lowest nematode population was recorded in cartap hydrochloride 4G @ 2kg a.i/ ha (116.0 J<sub>2</sub>/200cc soil) followed by cartap hydrochloride 4G @ 1kg a.i/ ha (124.0 J<sub>2</sub>/200cc soil) and thiamethoxam 25%WG @ 200g a.i/ha (138.6 J<sub>2</sub>/200cc soil).

#### 10. Research on new molecules of plant protection chemicals: Evaluation of insecticides, for the management of pests of coccinia and tomato.

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Among the four newer insecticide molecules tested against the epilachna beetle tomato Indoxacarb 14.5% SC 75g ai/ha and Chlorantraniliprole 18.5% SC 30g ai/ha were equally effective in reducing the infestation by the leaf feeder, epilachna beetle in tomato and Acetamiprid 20% SP 10g ai/ha and Thiamethoxam 25% WG 25g ai/ha were effective in reducing the infestation by the tomato leaf miner. Among the two bioinsecticides tested against the leaf feeders of tomato Fish Amino acid and Neem Seed Extract were equally effective in reducing the infestation by the leaf feeder, Epilachna beetle

### **11. Research on New Molecules of Plant protection chemicals: Newer and safer chemicals and biopesticides for the management of Pests of mango.**

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Nine trials with selected newer and safer insecticides and biopesticides for the management of hopper pest were carried out from 2014-17. Among the insecticides Imidacloprid 17.8% SL (0.005%) showed highest efficacy followed by Thiamethoxam 25%WG (0.005%) compared to control against the hopper pest of mango. Among the botanicals Oxuron 0.5% and biopesticides *Beauveria bassiana* WP 2% (ITCC 6063) were found effective for the management of hopper. Male annihilation technique (MAT) for the management of fruit flies in mango using newer molecules, Spinosad (6:4:0.2 V/V) was found effective for MAT technique. Spinosad 0.02% was found equally effective as Malathion in BAT application technique effective.

### **12. Assessment of insect biodiversity and habitat management in cowpea with special emphasis to manage cowpea stem borer in the Western Ghat tracts of Kollam district**

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The insect biodiversity analysis revealed the occurrence of an economically important new pest in the cowpea ecosystem of western ghat tract of Kollam district. The insect specimens obtained from cowpea were identified as *Nupserha* sp.nr. *vexator* (Coleoptera: Cerambycidae). The season of occurrence of pest is June to January. This pest can become a serious threat to the cowpea farmers since it cause complete destruction of the plant just like wilt disease. The management experiment showed some degree of suppression of stem borer incidence in the treatment plots with hyptis, neem oil and cashew nut shell liquid (CNSL). Laboratory trials using CNSL showed that 0.2 to 0.5 % CNSL soap emulsion is effective in controlling spodoptera, riptortus and aphids.

### **13. Identification and molecular characterisation of species and isolates of the entomopathogenic fungi *Metarhizium* and *Beauveria* and evaluation of their infectivity to crop pests**

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During 2017 -18, the bitter gourd variety Preethi was planted for the experiment in an area of 10 cents. The spacing adopted was 2 x 2 m. The experiment plot was land out in Palappuru Village near College of Agriculture, Vellayani. The most virulent isolate SP10 is being evaluated in the field. From the field experiments *Metarhizium anisopliae* SP10, was identified as the potential isolate and was found to be effective in managing Leaf feeders, bugs, beetles etc. in vegetables. The genetic study of the fungus was completed and the culture has been deposited in Indian Type Culture Collection. The culture can be exploited in future for the production of biopesticides.

### **14. KSCSTE Project Development and validation of integrated pest management for major polyhouse vegetables**

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Bio intensive and chemical modules for the management of important pests of salad cucumber (Var.KPCH) were conducted in polyhouse for the management of aphid *Aphis gossypii*, Serpentine leaf miner, *Liriomyza trifoli* and red spider mite *Tetranychus* sp. The highest per cent reduction in aphid population was observed in thiamethoxam 25WG (91.15%) followed by *Lecanicillium lecanii* 2% (90.12%). In case of American serpentine leaf miner, highest reduction was observed with Chlorantraniliprole 18.5 SC (99.00%). The chemical spiromesifen 22.7 SC recorded cent per cent reduction in red spider mite population.

**15. Development of Technologies Including Alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala: Development of substitutes for banned pesticides or alternative technologies for the management of nematode in Pepper**

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The experiment was conducted in farmers field located in Balagram area of Idukki district with an initial nematode population of 1028 J<sub>2</sub>/200 cc soil. The results of the experiment showed that the treatment with carbosulfan 6% G @16.7 kg/ha was the most effective treatment in increasing the dry weight of pepper (813.1 g/plant) followed by cartap hydrochloride 4% G @ 25kg/ha (730.8 g/plant) (Figure: 9). The next best treatments were thiamethoxam 25% WG @100g/ha (577.3 g/plant). The percentage increase in dry weight of pepper was to a tune of 59.5 and 43.4 with carbosulfan 6% G @16.7 kg/ha and cartap hydrochloride 4% G @ 25kg/ha respectively compared to untreated. Carbosulfan 6% G @16.7 kg/ha was the superior treatment in reducing the number of nematodes (595.4) in 200cc soil followed by cartap hydrochloride 4% G @ 25kg/ha (1123.4) and thiamethoxam 25% WG (1847.5). Similar trend was noticed with number of nematodes per 5g root (Table- 9). Carbosulfan 6% G @16.7 kg/ha was the superior treatment in reducing the number of galls per 5g root (38.9). However T1 (carbosulfan 6%G 16.7 kg/ha) and T2 (cartap hydrochloride 4% G @ 25kg/ha) were at par with each other.

**16. Development of Technologies Including Alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala : Evaluation of new molecules for the management of shoot and capsule borer in cardamom**

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Assistant Professor  
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Label expansion study for chlorantraniliprole 18.5 SC against shoot borer of cardamom showed that even 60 days after treatment application, residue remain in the cured sample for recommended dose (Table 1). For spinosad 45 SC, the residue level was Below Detectable Level on 15<sup>th</sup> day after treatment application

**17. Development of Technologies Including Alternatives for Banned Pesticides for the Management of Pests and Diseases of Major Crops in Kerala: Evaluation of new molecules for the management of thrips in cardamom**

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For spinosad 45 SC, the residue level was Below Detectable Level on 15<sup>th</sup> day after treatment application. Label expansion study for fipronil showed that even after 60 days, residue remain in the cured sample for recommended dose

**18. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala: Pesticide residue analysis for recommending pesticides**

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**Studies on the dissipation of fungicides in ginger samples (College of Horticulture, Vellanikkara)**

Residues of SAAF+Ekalux was below detectable Level (0.05) at the time of harvest.

**Studies on the persistence of fungicides in cardamom (CRS, Pampadumpara)**

Residues of Hexaconazole (ppm) persisted up to 45-60 days after spraying in cardamom. The residue persisted even after 60<sup>th</sup> days of spraying in double the recommended dose. Residues of cymoxanil (ppm) persisted up to 1day after spraying. Residue reached below detectable limit on 3<sup>rd</sup> day after spraying

**Studies on the harvest time residues of insecticides in Banana bunches (FSRS, Sadanandapuram)**

The results of the residue study of the presence of pesticide in the harvested produce of banana after the application of Acephate, Thiamethoxam, Chlorantraniliprole, Imidacloprid, Fipronil and Carbosulfan against pseudostem weevil revealed that the residues reached below detectable level at the time of harvest.

### **Studies on the harvest time residues of fungicides in Banana bunches (FSRS, Sadanandapuram)**

The residues reached below detectable level at the time of harvest of banana after the application of Hexaconazole, Tebuconazole, Propineb, Carbendazim, Difenoconazole Asoxystrobin in the recommended doses.

### **Studies on the harvest time residues of insecticides in Banana bunches sprayed against Pseudostem weevil and rhizome weevil (BRS, Kannara)**

The residues reached below detectable level at the time of harvest of banana after the application of Acephate Thiamethoxam Imidacloprid Fipronil Carbosulfan.

### **Studies on the harvest time residues of Fungicides against leaf spot diseases (BRS, Kannara)**

The results of pesticide residues in the harvested bunches of banana after the application of Hexaconazole Tebuconazole Propineb Carbendazim Difenoconazole Asoxystrobin revealed that the residues reached below detectable level at the time of harvest.

### **Studies on the dissipation of residues of insecticides in banana samples received from BRS, Kannara**

Residues of Fipronil 5% SC @ 3ml/L Fipronil 5% SC @ 6ml/L Carbosulfan 25EC @ 1.5ml/L Carbosulfan 25EC @ 3.0 ml/L Chlorpyrifos(0.1%) 2.5ml/L were BDL in harvested banana.

### **Studies on harvest time residues of mango (KVK, Pattambi)**

No thiamethoxam residue was observed in the harvested mango.

## **19. Strengthening the NABL Accredited Pesticide residue laboratory to the status of a state referral lab.**

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Established full-fledged ISO 17025:2005 accredited Pesticide Residue Testing Laboratory to monitor pesticide residues in food & agricultural commodities and Development of Trained personnel for establishing such laboratories throughout the state. Purchased and installed state of art equipments viz. LC MS/MS (Triple Quad), GC MS/MS and FT-IR and the laboratory recorded considerable progress during the period in terms of state of art equipments and infrastructure facilities. Laboratory is going to purchase high resolution mass spectrometry (HRMS) shortly.

## **20. Establishment of National Level Quality Control Lab for Honey**

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Objectives of the project is to establish laboratory facility for analysis of honey upto enzymatic level to assess the quality and serve as certifying laboratory for honey as per the approved national and international standards. Structural work of the building (6000 sq. ft.) completed. Tender procedures for purchase of the equipment is in progress.

## **21. All India Network Project on Agricultural Acarology**

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Studies on the diversity of spider mites associated with economically important plants recorded four species viz. *T. truncatus*, *T. macfarlanei*, *T. okinawanus* and *T. udaipurensis* and *Oligonychusbiharensis*. Pumpkin, banana, tapioca and amaranthus were new host records for *T. truncatus*; papaya, cowpea, ashgourd, banana, Gerbera, Tulsi, Amaranthus and brinjal were new host records for *T. okinawanus* and banana, okra and tapioca were new host records for *T. udaipurensis*. *Acremonium zeylanicum* at  $1 \times 10^9$  and  $1 \times 10^7$  spores  $\text{ml}^{-1}$  significantly reduced mite count. Horticulture Mineral Oil recorded 100 percent mortality of eggs at concentrations, 1.5, 2.0, 2.5 and 3.0 per cent, while neem oil recorded 93.33 per cent mortality of eggs of *T. truncates*. A farm trial was conducted to evaluate the efficacy of two novel acaricide molecules along with azadirachtin and wettable sulphur against the rice leaf mite, *Oligonychus oryzae*. Spiromesifen, fenazaquin and wettable sulphur caused significant reduction in mite population

**22. Evaluation of Insecticidal Activity of Cashew Nut Shell Liquid against Root Grubs in Coconut**

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Field studies conducted to evaluate the efficacy of cashew nut shell liquid revealed that there is no significant variation among various treatments even though there was a reduction in population among all treatments after the treatment application when compared to the pre-count

**23. Depredatory bird management in rice and vegetables**

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Damage assessment by purple moorhen (Pokkali and kole lands) and peafowl in vegetable and rice ecosystem was done during the period under report. Purple moorhen breeding season stretched from April to May and breed in warm, rounded reed/rice beds and fed on soft shoots of reeds and rice and small animals insects, frogs and snails. Roosting site clearing, use of LED light, reflective ribbon, bio-bird repellants and fire crackers to minimize the damage by purple moorhen in rice fields. Peafowl - a Omnivorous bird feed on seeds, insects, fruits, small mammals and reptiles. Among the different methods evaluated to minimize the damage of peafowl in rice and vegetable fields, physical obstruction with nylon rope and reflective ribbon fence and the TNet effectively checked the intrusion of peafowl into the cropped area

**24. Severity of mealy bug studies in Kerala**

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Altogether 34 mealybug species Nine predators and 26 parasitoid were collected and identified from 14 districts of Kerala. Morphological and biochemical basis of resistance in host plants showed that there was a positive correlation between the trichome density and the mealybug infestation on the host plant. Host plant resistance to the mealybug infestation was studied by estimating the total protein, phenol, poly phenol oxidase, peroxidase and carboxyl esterases in the host plants. To check the genetic diversity, the dominant mealybugs *Phenacoccus solenopsis*, *Ferrisia virgata* and *Paracoccus marginatus* were collected, genomic DNA isolated and amplified with 25 ISSR primers to screen the best performing one. The scored marker data matrix was analyzed using the standard procedure in NTsys Pc 2.0 package and the genetic distance or similarity was determined using the Dice coefficient. A dendrogram was constructed after cluster analysis of the similarity coefficients by the un-weighted pair-group method analysis, UPGMA. Both laboratory and field studies were carried out to screen the effective management method to combat mealybug infestation using imidacloprid 17.80 SC, thiomethoxam 25 WDG, buprofezin 25 SC, fipronil 5 SC and chlorpyrifos 20 EC

**PG Projects****Concluded Projects****1. Efficacy of *Neoseiulus longispinosus* (Evans) (Mesostigmata: Phytoseiidae) for the Management of *Tetranychus urticae* Koch (Prostigmata: Tetranychidae) on Cucumber Under Protected Cultivation**

Purposive surveys, conducted in fifteen polyhouses in four districts of Kerala viz., Thrissur, Palakkad, Wayanad and Thiruvananthapuram, revealed the occurrence of four species of tetranychid mites, namely, *Tetranychus truncatus* Ehara, *T. urticae* Koch, *T. okinawanus* Ehara, *Eutetranychus orientalis* (Klein) and one species of tarsonemid mite, *Polyphagotarsonemus latus* (Banks) on cucumber. The occurrence of *T. truncatus* and *T. okinawanus* is a new report on cucumber in polyhouse. The predatory mite fauna included *Agistemus garrulus* Chaudhari, *Amblyseius paraaerialis* (Muma), *Cunaxa* sp., *Cheyletus* sp., *Neoseiulus longispinosus* (Evans) and *Tydeus gossabaensis* Gupta. The present study has revealed the potential of the predatory mite, *N. longispinosus* as a biocontrol agent of the spider mites. The short life cycle, longer life span of adults, female biased sex ratio and preference for egg stages and above all, the density dependant nature of the prey predator relationship, brought out in the present study could provide a platform for viable biocontrol strategy based on *N. longispinosus* for management of spider mites under protected cultivation in Kerala.

## 2. Characterisation of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) for Genetic Variability, Endosymbionts and Vector – Virus Interactions in Cassava

Surveys were conducted in different agro-ecological zones of Kerala where cassava is grown and collected different life stages of white fly and these populations were subjected to both morphological and molecular level studies for their genetic variation. Polymerase chain reaction using mitochondrial cytochrome oxidase I primers indicated the presence of two biotypes, Asia I and Asia II5 in cassava plants of Kerala. Asia II5 was found to be an important biotype of *Bemisia tabaci* infesting cassava in 12 out of the 13 locations surveyed. Behavioural and life cycle variation study of *B. tabaci* using six cassava genotypes had shown that virus infection in *B. tabaci* altered the dispersal and settling.

## 3. Population dynamics and management of nematodes in banana using non chemical methods.

Important plant parasitic nematodes in banana include *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Heterodera orydicola*, *Radopholus similis*, *Helicotylenchus dihystra*, *Hoplolaimus indicus*, *Pratylenchus* sp., *Xiphinema* sp. and *Criconea* sp. Nendran was found to be the most susceptible variety and least number of nematodes obtained from Red banana. Maximum nematode population was observed during rainy season and the minimum during summer months of the year. Biofumigation using crop residues of cabbage @ 5 kg/pit was found to be the best treatment followed by mulching with green leaves of glyricidia @ 5 kg / pit for controlling plant parasitic nematodes in banana along with a considerable increase in yield. Biofumigation resulted a significant reduction in plant parasitic nematode population along with a considerable increase in the population of saprophytic nematode

## 4. Morphological variations of root-knot nematode in vegetables and banana

*M. incognita* (Kofoid & White) Chitwood, , *M. javanica* (Treub) Chitwood, *M. arenaria* (Neal,) Chitwood and *M. chitwoodi* Golden, O'Bannon, Santo & Finley were identified from brinjal, okra, tomato and banana in Thiruvananthapuram, Idukki and Thrissur districts of Kerala. The study indicated *M. incognita* as the major species of root knot nematode in Thiruvananthapuram district (91.66%) with highest percentage of occurrence in brinjal and tomato. In Idukki district, the major species of root knot nematode was *M. javanica* (66.66%). In Thrissur district, *M. arenaria* was found to be the major species (66.66%). *M. incognita* was found to be the major species in brinjal (55.55%), okra (44.44%), tomato (55.55%) and banana (44.44%) in Thiruvananthapuram, Idukki and Thrissur districts. The study recorded the first report of species having morphological and morphometrical characters similar to *M. chitwoodi* from okra in Thiruvananthapuram which opens way to molecular studies in future.

## 5. Management of American serpentine leaf miner *Liriomyza trifolii* (Burgess) Dietars in tomato

The important pests of tomato reported were American serpentine leaf miner *Liriomyza trifolii* Burgess, tomato fruit borer *Helicoverpa armigera* Hubner, tobacco caterpillar *Spodoptera litura* Fabricius, green Semilooper *Plusia signata* Fabricius, Epilachna beetle *Henosepilachna vignitocropunctata* Fabricius, Solenopsis mealybug *Phenacoccus solenopsis* Tinsley, whitefly *Aleurothrix tracheoides*, Spiralling whitefly *Aleyrodicus dispersus* Russell and minor insect pests like scales *Saiasetia* sp., Aphids *Myzus persicae* Sulzer and leaf beetle *Luperomorpha dictate*. The important predators include *Nesidocharis tenuis* , *Axinoscymnus puttardriahi* Kapur and Munshi and *Coccinella transversalis* Fabricius. Forty one host plants of *Liriomyza* sp. were reported during the study period from Vellayani area. Among the 15 cultivars, Arka Vikas, Pusa Ruby, Akshaya, Arka Meghali and Arka Abha were tolerant and also recorded higher yield. Accession LE 20 was included in tolerant group and Manulekshmi, Arka Alok and Hissar Lalith were included in moderately tolerant group. Among Kerala varieties Akshaya and Anagha were tolerant in which Akshaya produced higher yield. Green labeled chemical Chlorantraniliprole 18.5% SC can be used for the effective management of *L. trifolii* on tomato at 10 days interval followed by Chlorantraniliprole 18.5% SC at 20 days interval. The botanicals fish amino acid 0.5% and NSKE 5% at 10 days interval were the best botanicals which can be effectively incorporated as prophylactic treatments in the IPM of tomato leaf miner.

## 6. Efficacy of chitin enriched formulations of *Lecanicillium* spp against sucking pests of rice *Oryza sativa* (L.)

Indigenous isolate entomopathogenic fungi *Lecanicillium saksenae* was infective to *Leptocorisa acuta*, *Nilaparvata lugens*, *Nephotettix virescens*, and, *Nisia nervosa*, and effective dose worked out to be  $10^7$  spores  $ml^{-1}$ . *L. saksenae* caused cent percent mortality within 3 to 4 days after treatment against all test insects. *L. lecanii* was infective to *Nilaparvata lugens*, *Nephotettix virescens*, *Nisia nervosa* but non pathogenic to *L. acuta*, and effective dose worked out to be  $10^7$  spores  $ml^{-1}$ . Plots treated with chitin enriched oil formulations of *L. saksenae* recorded lowest bug count of 3.67  $plot^{-1}$ . Highest net yield of 3.16 kg  $plot^{-1}$  was obtained for plots treated with chitin enriched oil formulations of *L. saksenae*

## 7. Potential of the natural bio polymers, chitin and chitosan in pest management

Various formulations tested were, chitin (3%, 5%, 7%), chitosan (3%, 5%, 7%), chitosan gel (3%, 5%, 7%), chitin based commercial formulation, Biorakshak 2%. and chitosan based commercial formulation, Bioboost 2%. Laboratory studies

revealed that the pumpkin caterpillar, *Diaphania indica* Saunders, the leaf beetle *Henosepilachna vigintioctopunctata* F., pea aphid *Aphis craccivora* Koch, the root knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood. and the reniform nematode *Rotylenchulus reniformis* Linford and Oliveira were vulnerable to different chitin and chitosan based formulations whereas, the cut worm *Spodoptera litura* F. the leaf weevil, *Myloccerus viridanus* Schoenherr, the pod bug *Riptortus pedestris* F. and the spiral nematode *Helicotylenchus sp.* were not. Field experiment on cowpea revealed that, chitin 7% took seven days to reduce the population of *A. craccivora*, followed by chitosan 7% and chitosan gel 7%. In the field trial on tomato, population of nematodes in soil and root sample were less in plots treated with chitin 7%. The study indicated that the potential of natural biopolymers chitin and chitosan can be exploited for the holistic management of crop plants as it has capacity to regulate the population of insect and nematode pests as well as plant diseases. The growth and yield promoting attributes and safety to natural enemies makes them ideal candidates in integrated pests and disease management as well as integrated nematode management programmes.

#### 8. Seasonal incidence of predatory wasp (*Vespa* spp.) in Indian bee apiaries and evaluation of bait traps.

The incidence of honey bee pests' viz. wax moth, spiders, wasps, ants, lizard, honey buzzard and monkey, their symptoms and mode of attack were documented. The predatory wasp collected from the apiaries was identified as *Vespa tropica* Linnaeus. The predation of honey bees by the wasp recorded in the apiaries was 59.86 per cent with peak incidence during the month of November. Significantly higher wasp population was observed during the brood rearing season (September - December) of honey bees. Maximum predation of bees (18 Nos.) was observed in the 44<sup>th</sup> week.

#### 9. Management of major chewing pests, *Henosepilachna septima* (Dieke) and *Diaphania indica* (Saund) infesting bitter gourd with bacterial bioagents

Thirteen bacteria were isolated from the phylloplane of bitter gourd. Upon preliminary screening for pathogenicity, three isolates (isolate 1, 5 and 7) were found to be pathogenic to *H. septima* and four (isolate 3, 5, 7 and 12) to *D. indica*. Treatments with *S. marcescens* (Hv3) and isolate 5 were found to be significantly superior in causing mortality to *H. septima* grubs. Mortality of 90 per cent and 83.33 per cent were observed for *S. marcescens* (Hv3) and isolate 5 respectively. *S. marcescens* (Hv3) and isolate 5 were found to be effective against *D. indica* also, causing 96.67 per cent and 93.33 per cent mortality. Internal transcribed regions of DNA of 16S rRNA of isolate 5 and 7 revealed the identity of isolate 5 and 7 as *Serratia marcescens* and *Klebsiella sp.* The phylloplane isolate *S. marcescens* (pmc5) produced significantly high mortality in both *H. septima* (65.83 per cent) and *D. indica* larvae (87.78 per cent) at 7 DAT, which was on par with chemical treatment quinalphos 0.05%.

#### 10. Bioecology of small hive beetles and assessment of their damage in stingless bee colonies

Seven beetles were collected from the hives during the survey. Among these, the nitidulid beetle which caused the primary infestation is identified as *Epuraea latissima* Kirejtshuk and it is the first report from stingless bee hive. The type of hive used for maintaining the stingless bee colony is an important factor which determines the hive beetle incidence. Majority of bee keepers maintained stingless bees in wooden box followed by mud pots. The incidence was more prominent in bad quality wooden boxes. Studies on the influence of height of the stingless bee hive from the ground level with the hive beetle incidence revealed that the hives kept at 3-4 m recorded the highest incidence followed by 2-3 m. The colonies maintained at a height of > 4 m were free from hive beetle incidence. The damage symptoms recorded from infested colonies were fermentation and discolouration of honey due to the feeding and defecation by the beetle larvae and a light brown coloured undistinguished mass of hive contents. The larvae caused severe damage by tunneling and feeding the pollen pots while the adults nibbled the hive contents. .

#### 11. Entomopathogenic fungi for the management of banana rhizome weevil (*Cosmopolites sordidus* Germar)

*Metarhizium anisopliae* and *Beauveria bassiana* (NBAIR) and local isolates of *B. bassiana* and *Paecilomyces lilacinum* were found pathogenic to grubs and adults of *Cosmopolites sordidus*. In laboratory condition, *M. anisopliae* @10<sup>8</sup> spores ml<sup>-1</sup> was found to cause 100 per cent mortality of grubs. In pot-culture studies curative application by soil drenching of talc formulation of *M. anisopliae* and *B. bassiana* @10<sup>8</sup> spores ml<sup>-1</sup> @ 30 g l<sup>-1</sup> was found to be effective for the management of banana rhizome weevil *C. sordidus*

#### 12. Bioefficacy of the Acaropathogen, *Acremonium zeylanicum* (petch) Gamsand evans against the spider mite, *Tetranychus truncatus* (Acari: Tetranychidae)

The laboratory bioassay conducted to evaluate the efficacy of the fungal isolate, *Acremonium zeylanicum* against *Tetranychus truncatus* indicated that *A. zeylanicum* was more effective against adult mites compared to egg stage. At the highest concentration (1 x 10<sup>9</sup> spores ml<sup>-1</sup>), the fungus recorded maximum egg mortality of 41.33 per cent at 96 h of treatment. In the field study local isolate of *A. zeylanicum* at the higher concentration of 1x10<sup>8</sup> spores ml<sup>-1</sup> reduced the mite count by 72.71 and 74.51 per cent in first and second experiments respectively. Similarly, at a lower concentrations of 1x10<sup>7</sup> spores

ml<sup>-1</sup> *A. zeylanicum* brought about a reduction in mite count by 55.03 and 58.98 per cent in first and second experiment respectively. Assessment of sensitivity of *A. zeylanicum* to different agrochemicals revealed that the acaropathogen was highly sensitive to the fungicides Curzate (cymoxanil 8% + mancozeb 64%) and Equation Pro (famoxadone 16.6%+ cymoxanil 22.1%) recording highest per cent inhibition. Laboratory studies on the safety of *A. zeylanicum* on the predatory mite *N. longispinosus* revealed that, the fungus was found less detrimental to the predatory mite compared to the prey mite.

### **13. Response of selected okra [*Abelmoschus esculentus* (L.) Moench] cultivars to root knot nematode *Meloidogyne incognita* (Kofoid & White)**

Thirty okra cultivars comprising twenty one accessions from NBPGR Regional Station, Thrissur, eight released varieties and a highly susceptible check (Arka Anamika) were screened for their reaction to root knot nematode *M. incognita*. None of the cultivars were highly resistant or resistant whereas four cultivars viz., IC 117238, IC 117251, IC 111507 and Varsha Uphar with root knot index 3 were classified as moderately resistant. Seven cultivars viz., Manjima, IC 111536, IC 117260, IC 111500, IC 111247, IC 469689 and IC 111517 were found to be susceptible with root knot index 4. An increase in total phenol and peroxidase activity was noticed in moderately resistant cultivars than susceptible cultivars whereas total sugar and reducing sugars were higher in highly susceptible cultivars.

### **14. Biology and predatory potential of *Rhynocoris marginatus* (Fab.) (Hemiptera: Reduviidae) on insect pests of cowpea**

The eggs of *Rhynocoris marginatus* were elongate oval in shape and yellowish brown in color with an average incubation period of  $6.80 \pm 0.91$  days. It took  $32.96 \pm 1.81$  days to complete nymphal development in five instars. Adult female lived longer than male. The preoviposition period was  $14 \pm 1.30$  days and during the oviposition period of  $66.13 \pm 6.27$  days, it laid  $8.60 \pm 0.97$  batches of egg mass with mean fecundity of  $377.20 \pm 45.52$  eggs/ female. There was significant reduction in aphid population in predator released cages up to sixth week after the first release. In cages artificially infested with third instar larvae of *S. litura* the predator was able to kill all the released larvae within four days. The release of the predator in field significantly reduced the aphid population on cowpea. The infestation by pod borer *Maruca vitrata* and pod bug, *Riptortus pedestris* were negligible and the number of pod borer and pod bug were numerically less in predator released field when compared to control.

### **15. Population dynamics, biology and management of mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on okra**

The average nymphal duration of male mealybug ( $18.88 \pm 1.6$  days) was slightly longer as compared to female mealybug ( $15.3 \pm 1.74$  days) due to the presence of an additional pupal stage. The first instar crawlers were green-yellowish and with dorso-ventrally flattened body. The duration of first instar crawlers was 3 to 6.5 days. Second instar crawlers were partially covered with wax and were having yellowish flattened body. The duration of second instar crawlers were found to be 5 to 8.5 days. Third instar nymphs were yellowish and fully covered with wax over their body. Male mealy bug possessed an additional pupal instar. The duration of pupal stage ranged from 5.25 to 9 days. Adult female had a longevity of 34 to 44.5 days, whereas adult male had a longevity of only 0.75 to 3 days. Effectiveness of entomopathogenic fungi (*Lecanicillium lecanii* and *Paecilomyces lilacinus*), botanicals (NSKE@ 5% and Neem oil soap @ 2%) and chemical insecticides (buprofezin 25% EC and thiamethoxam 25 WG) was evaluated in pot culture experiment. After first spray, thiamethoxam 25 WG showed immediate effect with a population reduction of 75.94 per cent followed by buprofezin 25% EC (37.02%).

### **16. Evaluation of the effect of mineral nutrition in the management of major pests of cowpea**

On comparing the infestation caused by pests in two seasons, cowpea grown with recommended macronutrients with foliar spray of minerals exhibited lowest aphid, pod borer and pod bug incidence.

### **17. Management of pests of cowpea using red ant *Oecophylla smaragdina* (Fab.)**

Red ants are effective in controlling the pests of cowpea but they harbour red ants which is deleterious for the crop. All the selected pesticides are found to adversely affect the red ants.

### **18. Taxonomy of Rhynchophorinae (Coleoptera: Dryophthoridae) of Kerala**

Study was based on survey carried out in agro and forest ecosystems of Kerala and the samples collected from these ecosystems. Commercially available pheromone traps for the collection of red palm weevil, banana pseudostem weevil and banana rhizome weevil were installed in five agroclimatic regions. The other two weevils, i.e. *Dicalandra frumenti* and *Sitophilus oryzae* were collected from households and fields. The study also includes specimen stored in Malabar Insect Repository (MIR) and the specimens of *Rhynchophorus ferrugineus* collected from CPCRI regional station, Kayamkulam, Kerala. An annotated checklist of world Rhynchophorinae was prepared and results revealed that the subfamily

Rhynchophorinae includes 955 species under 124 genera and 6 tribes.

### 19. Taxonomic studies on Indian *Belonnotus* (Coleoptera: Curculionidae: Ceutorhynchinae)

The study constitutes five species belonging to two genera. All the species known so far under genera *Belonnotus* and *Mecysmoderes* have been taxonomically described. The descriptions of all the species studied are supplemented with taxonomic characters of genitalia and morphometric observations. An annotated checklist of the world Ceutorhynchinae had been prepared and these covered a total of 1316 species in worldwide distributed under 90 genera while the number of species reported from India is 45 distributed under 5 tribe and 13 genera. The geographic distribution of these species had been documented by taking up to date literature. The discrepancies in the description of the genera and species had been corrected and descriptions standardized to a uniform format loaded with morphometric ratios. Taxonomic keys to the species of all these two genera have been formulated and augmented with valid characters.

### 20. Eco-friendly management of major pests of Yard long bean, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt

After three consecutive sprays of Spinosad 45 SC @ 0.4 ml/l of water at fortnightly intervals there was complete reduction of pod borer larvae during kharif and rabi season. The percentage of flowers and pods infested by pod borer larvae were also reduced completely and no infestation was noticed after three consecutive sprays of Spinosad during both seasons. During kharif season, *Beauveria bassiana* was found to be the most effective treatment in reducing the nymphs and adults of pod bugs with minimum number of 0.56 bugs per plant. During rabi season, Azadirachtin 1 per cent showed no incidence of pod bugs after three sprays and Neem oil 5 per cent consistently reduced number of bugs to zero on 15 days after third spray. The aphid population on shoots and per cent of aphid infestation on shoots were found to be zero after three consecutive sprays of *Lecanicillium lecanii* at fortnightly intervals during kharif season.

## Ongoing Projects

### 1. Management of beetle pests in stored rice using botanicals

Experiment with extract of plant parts viz., tulsi leaves, neem leaves, garlic bulblets, bird chilli fruits, mint leaves and pepper seeds at two concentrations (5 and 10%) (w/v) were conducted. The highest percentage mortality was recorded in treatment with garlic bulb 10 % (53.33) which was on par with garlic bulb 5 % (38.33) and tulsi leaves 10 % (38.33). Management of beetle pest using dried plant parts viz. tulsi leaves neem leaves, clove flower buds, nutmeg mace, mint leaves and curry leaves at two concentrations (2 and 4%) (w/w) showed that mint leaves 4 % was the most effective treatment with 56.67 per cent mortality which was on par with nutmeg mace 4 % (35.00). The highest percentage repellency of weevils was recorded in rice treated with nutmeg mace 4 %, (31.67) and the lowest progeny emergence and grain damage also. However considering both mortality and repellent effect of dried plants parts, treatment with mint leaves 4 % showed the highest reduction of weevils.

### 2. The Eumolpinae (Coleoptera: Chrysomelidae) of southern India

The eumolpine leaf beetles were collected from southern India, Kerala, Tamil Nadu and Karnataka. The information on host plant is gathered in all possible cases. The specimens were identified in consultation with the relevant literature upto Genus level. Now Species level identification differentiating species complexes with the help of structure of genitalia, species description, Photography, taking measurements, further collection of additional specimens going on.

### 3. The Lamiinae (Coleoptera: Cerambycidae) of southern India

The flat faced long-horned beetles were collected from the following localities in southern India. Kerala, Tamil Nadu and Karnataka. The information on distribution, host plants, behavior etc. has been generated. The collected specimens were identified using the relevant literature and the identity was cross checked with the holotypes wherever available. Submitted a research article to the journal Zootaxa. Descriptions are being prepared. Genitalia are dissected and illustrated.

### 4. The galerucine leaf beetles ( Coleoptera: Chrysomelidae : Galerucinae : Galerucini of southern India

The collected specimens were identified using the relevant literature and the identity was cross checked with the holotypes wherever available.

### 5. Leaf footed bugs (Hemiptera : Heteroptera Coreidae) of southern India and the Andaman Islands

The collected specimens were identified using the relevant literature and the identity was cross checked with the holotypes wherever available.

### 6. Biosystematic studies on stingless bees (Apidae: Meliponini) of Kerala

A total of 225 different colonies of stingless bees were sampled from all districts of the state. Two new species (*Tetragonula* sp. nov. 1, and *Tetragonula* sp. nov. 2) of stingless bees based on adult worker specimens are described and illustrated with

the help of photographs. They are compared morphologically and molecularly with closely related species. Differences in morphology based on principal component analysis and genetic analysis based on partial sequences of the mitochondrial COI gene barcode region support the recognition of the two new species.

#### **7. Mycotoxins and enzymes of entomopathogenic fungus *Lecanicillium saksenae* (Kushwaha ) Kurihara and Sukarno and their bioefficacy on crop pests**

Cuticle degrading enzymes of *L. saksenae* viz chitinase, protease and lipase were assayed at 48 hr interval from the day of inoculation upto 15<sup>th</sup> day. Among the major cuticle degrading enzymes, Lipase recorded highest activity ranging from 0.54 to 1.86 U mL<sup>-1</sup>. The enzyme activity was highest on 4<sup>th</sup> day after inoculation. Protease activity ranged from 0.09 U mL<sup>-1</sup> to 0.84 U mL<sup>-1</sup> and the highest activity was recorded on 6<sup>th</sup> day after inoculation. Mycotoxins of the fungus were extracted and dipicolinic acid, one of the insecticidal toxins of *L. saksenae* was detected in ethyl acetate fractions of culture filtrate through LC-MS analysis. GC-MS analysis of the ethyl acetate fractions revealed the presence of dodecanoic acid and octanoic acid, which are reported to have many biological activities. Bioefficacy studies with the crude toxins of *L. Lecanii* @ 10 ppm on brinjal mealy bug *Coccidohystrix insolitus* recorded a mortality of 81.25 per cent and cent per cent at 24 and 72 hrs after treatment respectively.

#### **8. Exploitation of indigenous bacterial antagonists against root-knot nematode, *Meloidogyne incognita* (Kofoid and White)**

Two effective antagonistic bacterial culture has been sorted out from the different isolates obtained based on the mortality percentage and egg hatching inhibition. Pot culture experiment was carried out to evaluate the efficacy of selected bacterial isolates @ 50 mL/pot (10<sup>7</sup> cfu/mL) against root knot nematodes. Invitro study of Isolate 2 (white colony) and Isolate 1 showed a juvenile mortality percentage of 94% and 91% after 72 hrs of exposure respectively. Invitro study of Isolate 2 and isolate 1 showed an egg hatching inhibition of 92.87% and 92% after 8 Days of exposure respectively.

#### **9. Novel bioformulations of entomopathogenic fungi and their efficacy against banana weevils. Management of beetle pests in stored rice using botanicals**

Experiment to standardize a coating material for developing capsules revealed that Hard Gelatin Transparent (HGT), Hard Gelatin Coloured (HGC) and Hydroxy Propyl Methyl Cellulose (HPMC), were equally stable under ambient conditions of storage (26 -33°C and RH 60-80%). A trial conducted to determine the moisture content of capsules, revealed that 10 % is the ideal moisture level content of the ingredient, to maintain storage stability as well as viability of the formulation. Therefore capsules were developed with HGT coating, with chitosan / talc as carrier at 10 % moisture content. Shelf life studies revealed that chitosan is the best carrier material compared to talc in retaining viability of *Metarhizium* capsules. Shelf life studies of gel formulations indicated that both *Metarhizium* and *Beauveria* gels exhibited high viability in chitosan at room temperature and under refrigeration.

#### **10. Cashew nut shell liquid based botanical insecticides for pest management in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* ( L. Verdc).**

The bioassay using cashew nut shell liquid at different concentration has been completed using aphids and spodoptera as test insect. The maximum mortality was noticed in the 0.2% concentration. The characterization part of the CNSL was progressing. The main ingredients like cardanol and cardol was separated from the technical CNSL. The confirmation will be done using HPLC.

#### **11. Management of sucking pest complex in chilli using botanical and microbial pesticides.**

Based on the results of the laboratory evaluation of botanicals, CNSL 0.2 %, CNSL 0.075 % the lowest effective concentration with 88.67 and 92.67 % mortality at 48 hours after treatment respectively along with neem oil emulsion 2 % (58 % at 24 hours after treatment), Oxuron 5 mL L<sup>-1</sup> and chemical check, Thiamethoxam 0.03 % were selected for further evaluation in field. Among the effective microbial insecticides, *L. lecanii* the widely used myco insecticide against sucking pests was selected with 54.5, 87.5 and 100 % mortality at 24, 48 and 72 hours after treatment respectively. *L. lecanii* being compatible with CNSL 0.2 % was also included for pot culture evaluation. From the study, CNSL 0.075 % and *Lecanicillium lecanii* @ 10<sup>7</sup> spores mL<sup>-1</sup> are better choices for ecofriendly management of sucking pest complex of chilli

#### **12. Etiology of honey brood disease in Southern Kerala**

The survey conducted in the apiaries of Southern Kerala recorded highest infection of brood disease in Kollam district with 42.44 per cent followed by Thiruvananthapuram district with 4.12 per cent and least in Pathanamthitta district with 1.39 per cent. Pathogenesis of two bacteria were proven and were identified as *Bacillus pumilus* and *Achromobacter* sp. Among the botanicals used for the management, the treatments with crushed leaves of *Ocimum* sp. 0.05% and crushed garlic 0.25% were found effective to manage the disease with the percentage reduction 64.19 per cent and 62.96 per cent respectively.

### 13. Field toxicity of new generation insecticides to bee pollinators

Under laboratory condition, safest insecticides to *A. c. indica* were found to be cyantraniliprole 90 g a. i. ha<sup>-1</sup>(44.72%) and novaluron 75 g a. i. ha<sup>-1</sup> (32.50%) In *T. iridipennis* also, mortality was the lowest in cyantraniliprole 90 g a. i. ha<sup>-1</sup> (30.56%) and novaluron 75 g a. i. ha<sup>-1</sup> (30.55%) and were proved to be safer for bees. In *A. c. indica*, the foraging activities such as relative abundance, foraging rate, foraging speed and time spent on the flower were found to be unaffected by cyantraniliprole 90 g a. i. ha<sup>-1</sup>In *T. iridipennis* cyantraniliprole 90 g a. i. ha<sup>-1</sup> reduced the relative abundance, foraging rate, time spent on the flower and foraging speed by 36.17%, 15.79%, 61.26% and 34.54% respectively.

### 14. Dissipation and risk assessment of insecticides used for pest management in cabbage and cauliflower

Dissipation studies of chlorantraniliprole, flubendiamide, indoxacarb, emamectin benzoate, fipronil, quinalphos, cypermethrin, acetamidprd, thiamethoxam and dimethoate in cabbage were conducted in two agroclimatic regions of Kerala. Results of the study revealed that under plains the insecticides persisted more than hills. The insecticides persisted more in cabbage were flubendiamide (20 days) followed by acetamidprid (10 days) and quinalphos (10 days), while in hills, higher persistence was observed for chlorantraniliprole (10 days), flubendiamide(10 days), cypermethrin(10 days), quinalphos(10 days), indoxacarb (10 days), and fipronil (10 days). The lowest persistence was observed in fipronil (3 days) in cabbage under plains, however, in hills lower persistence was recorded in acetamidprid (3 days). In cauliflower higher persistence was observed for dimethoate (20 days), flubendiamide (20 days) and chlorantraniliprole (20 days) followed by thiamethoxam (10 days) and quinalphos (10 days). In hills higher persistence was recorded for quinalphos (20 days) and flubendiamide (20 days) followed by cypermethrin (15 days). Lowest persistence was observed for emamectin benzoate (3 day) in cauliflower under plains and hills.

### 15. Insecticide resistance in cowpea aphid, *Aphis craccivora* (Koch) and its management

Bioassay was carried out in CRD to assess the insecticide resistance in field population of *A. craccivora* collected from three different locations based on the intensity of insecticide application. Results revealed that population collected from Location-I (Vilavoorkal) was found to be susceptible to insecticides with resistance ratio-1. Population collected from Location- II (Instructional farm, College of Agriculture, Vellayani) was found to be moderately resistant with resistant ratios of 1.67, 2.97 and 2.81 and aphid population collected from Location- III, (Vallamcode) showed more resistance with resistant ratios of 1.71, 19.46 and 7.94 for quinalphos, fenvalerate and imidacloprid respectively. Laboratory experiments conducted to evaluate the efficacy of new generation insecticides revealed that, significantly higher mortality was observed in *A. craccivora* treated with thiamethoxam + lambda cyhalothrin 27.5 g a.i.ha<sup>-1</sup>(100 %) followed by thiachloprid 24 g a.i.ha<sup>-1</sup> (91.67 %) and thiamethoxam 25 g a.i.ha<sup>-1</sup>(90.00 %) which were on par with each other after 3 hours of treatment.

### 16. Insecticide mixtures for the management of pest complex in cowpea

The results of the study revealed that chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 0.30 mL L<sup>-1</sup> was found effective in managing the population of pod bug, *R. pedestris*, followed by thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 0.30 mL L<sup>-1</sup> and beta cyfluthrin 8.49 % + imidacloprid 19.81 % w/w @ 0.40 mL L<sup>-1</sup>. No bug was found in effective treatments against 5.67 bugs/ plant in control after 7 days of spraying. More or less similar result was obtained in the management of cowpea aphid, *A. craccivora*. No aphid was observed in the plants treated with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 0.30 mL L<sup>-1</sup>, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 0.30 mL L<sup>-1</sup>, chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (hand mixed) @ 1:1 @ 0.30 mL L<sup>-1</sup> and thiamethoxam 25 % WG @ 0.30 g L<sup>-1</sup> against 211.67 aphids/ plant in control after 15 days of spraying. Whereas, in the management of cowpea pod borer, *M. vitrata*, no larva was found in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 0.50 mL L<sup>-1</sup> and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 0.30 mL L<sup>-1</sup> treated plants after 5 days of spraying against 6.67 larvae in control. Significantly higher reduction in leaf damage by *S. litura* was recorded in plants treated with lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 0.50 mL L<sup>-1</sup> (25.03) which was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 0.30 mL L<sup>-1</sup> (26.46) and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 0.30 mL L<sup>-1</sup> (30.20) 10 days after spraying.

### 17. Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem

Fipronil 0.3G recorded the lowest damage and population of stem borer and leaf roller at the recommended and double the recommended doses. In the case of yield also all the treatments were significantly superior over control. Fipronil 0.3G and chlorantraniliprole 0.4G recorded the lowest population of natural enemies at both the doses and found to be safe to predators and parasitoids. Fipronil 0.3G was found to be highly toxic to soil fauna viz. earthworms, nematodes, snails, spiders, and soil insects.

### 18. Eco-friendly management of major pests of upland rice ecosystem

The survey conducted in six selected locations of Alapuzha district during first crop season of 2017 under upland cultivation revealed that farmers commonly depend on short duration varieties for upland rice cultivation like Bhagya and Jyothi.

Stem borer and leaf roller were found throughout the cropping period causing damage in low intensities. The damage by stem borer was high in reproductive stages and leaf roller population increased gradually from vegetative to reproductive stage. During reproductive stage, rice bugs were present in low and medium intensities and blue beetle and hispa were the minor pests observed. Natural enemies documented during the survey were parasitoids (*Goniozus nephantidis*, *Cotesia* sp. and *Tetrastichus* sp.), spiders (*Tetragnatha maxillosa*, *Argiope* sp.), and predators (dragonflies, damselflies, gryllids, *Ophionea nigrofasciata*, *Paederus* sp. and *Micraspis* sp.) Parasitoids were predominant in reproductive stage. *Paederus* sp. and gryllids were specific at vegetative stage and *Micraspis* sp. at reproductive stage of the crop.

# **Name of Project Coordination Group : – (12) Plant Pathogens and Beneficial Microbes**

**Compiled by:**

**Dr. Anita Cherian K., Protect Coordinator**

## **Plan & EAP Projects**

**Concluded Projects - 6 Nos.**

**Ongoing Projects - 26 Nos.**

## **PG Projects**

**Concluded Projects- 16 Nos.**

**Ongoing Projects - 18 Nos.**



## Concluded Projects

### 1. Development and adoption of microbial Inoculant technology for cropping systems of Kerala” Lead Centre

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All the identified sub centres were strengthened and production started to cater to the needs of the farmers of the locality.

During 2011-12 the approximate production of microbial inoculants in KAU was less than 25 tons. The organized approach to strengthen the identified production centres resulted in a steady increase in the production of microbial inoculants and revenue generation. During the years the microbial inoculant production of KAU increased significantly generating substantial revenue. During 2017-18 the total production in KAU was 253530.50kg generating revenue of Rs. 1.77 crores.

During 2017-18, the total biocontrol agents marketed from KAU for disease management was 254 tons which could avoid use of chemical fungicides to the tune of 20-50 tons. The total quantity of nitrogen fixers supplied by KAU was 24.2 tons which contributed 242 tons of biologically fixed nitrogen. Approximately 25 percent P and K fertilizers could be saved by the use of 10.7 and 10.9 tons of P and K solubilizers.

Efficient antagonistic isolates of *Bacillus sp.* & *Trichoderma sp.* could be identified. Four efficient isolates of *Azospirillum* and three isolates of *Azotobacter* and P- solubilizers obtained through screening trials. Continuous advisory service provided to the farmers visiting the centre. Regular supply of microbial inoculants to the farmers.

### 2. Soil based Nutrient Management plan for Agro Ecosystem of Kerala- Phase II – Population dynamics of microorganisms in soil samples of Kerala

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As per the programme 2400 soil samples collected by the Agricultural Officers of selected Krishi Bhavans were sent to the Dept. of Agrl. Microbiology, College of Agriculture, Vellayani for analyzing the total count of fungi, bacteria and actinomycetes. The total population of Bacteria, Fungi and Actinomycetes of 2400 soil samples could be completed. Along with this population of Nitrogen fixers such as *Azospirillum* and *Azotobacter* and population of antagonistic microorganisms like *Pseudomonas* and *Trichoderma* were also assessed. In general the population of bacteria were highest followed by fungi and actinomycetes. The population of antagonistic flora of *Trichoderma* was absent in most of the soil samples whereas the population *Pseudomonas* could be observed in certain samples even though the population is comparatively less. Hence it is presumed that the population of antagonistic microorganisms like *Pseudomonas* and *Trichoderma* are very less and hence the application of these inoculants should be advocated in such soils. The Nitrogen fixers like *Azospirillum* and *Azotobacter* as well as 'P' solubilizers were also analysed. It was found that even though the population of Nitrogen fixers such as *Azospirillum* and *Azotobacter* were very less significant number of 'P' solubilizers could be recorded in many of the soil samples.

### 3. Exploitation of native agriculturally important microorganisms (AIMS) for integrated nutrient management in various agro-ecosystems of Kerala

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Professor & Head  
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Rhizosphere soil samples were collected from two different banana plantations at Karimpuzha panchayat of Palakkad district.

The microflora such as total bacteria, total fungi, total actinomycetes, N-fixers, P-solubilizers, K-solubilizers, *Trichoderma*, *Pseudomonas fluorescens* were isolated and enumerated.

The potassium solubilizing bacteria were tested for PGP Characters.

#### 4. Microbial Inoculants Technology for cropping systems of Kerala

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A total of 212 kg *Pseudomonas fluorescens*, 138 kg *Trichoderma viride*, 111 kg *Azotobacter*, 155 kg *Azospirillum*, 87 kg *Rhizobium* were produced and distributed to farmers after checking the quality. Around 1361.5 litres of composting tonic and 290 kg of coirpith inoculum were produced.

#### 5. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala – Disease management in ginger

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The residue of plant protection chemicals in soil & rhizome decreased drastically within 15 days of drenching and also residue in ginger rhizome were found to be Below Detectable Levels (BDL). Hence, the recommended dose of combination fungicide, carbendazim + mancozeb @ 2g/l or carbendazim + mancozeb 2g/l in combination with *Trichoderma viride* / *Pseudomonas fluorescens* can be recommended for the management of rhizome rot of ginger.

#### 6. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala – Disease management in Vegetables

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Dr. Joy M.  
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##### a. Management of collar rot, web blight and *Fusarium* wilt of cow pea

Among the various treatments evaluated the best treatment for controlling collar rot is seed treatment + soil drenching with Saaf (carbendazim + mancozeb). The systemic fungicide, flusilazole as well as carbendazim left no residue in fruit after two soil drenching.

##### b. Management of powdery mildew disease of bitter gourd

The maximum reduction was observed in systemic fungicide tebuconazole followed by wettable sulphur and liquid formulation of *Trichoderma viride*. The residue of tebuconazole was not found from 3rd day onwards. Hence this compound may be recommended for management of powdery mildew of bitter gourd with a maximum waiting period of three days because the fruits were found to be completely free of the residue from 3rd day onwards.

##### c. Management of downy mildew of bitter gourd

Among the various treatments, systemic fungicide pyraclostrobin was most effective showing minimum severity which was followed by pyraclostrobin + chlorantraniliprole. Chlorantraniliprole (3 ml/10l) found effective for management of fruit borer infestation. With respect to yield, a significant difference was noticed among the treatments. Maximum yield was recorded in chlorantraniliprole. When fruits were treated with pyraclostrobin alone, the residue persisted in fruits upto 3 days after spraying. In the case of fruits treated with chlorantraniliprole alone also, the residue persisted only 2 hours after spraying. After that these compounds were found below detectable levels (BDL). Hence, the systemic fungicide pyraclostrobin @ 0.5 g/l as well as cymoxanil + mancozeb @ 2g/l alone in combination with the insecticide chlorantraniliprole (3 ml/10l) can be recommended for the management of downy mildew disease.

## Continuing Projects

## 1. Centre of Excellence in Microbial Technology

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**a. Development of Bead Formulations**

Bead formulation of PGPR MIX I was prepared and survival studies showed that the cultures of PGPR MIX I could survive upto 7 months.

**b. Pink Pigmented Facultative Methylophs**

Pink Pigmented Facultative Methylophs were isolated from different crops such as Paddy, Amaranthus, Bitter gourd, Bhindi, Cow Pea Snake gourd etc. As many as 46 isolates of PPFM were obtained from different Paddy growing locations of Kerala. They were evaluated for antagonistic efficiency, seed germination, seedling growth and yield of Paddy. IAA, Carotenoid pigment production, Proline content, Chlorophyll content, Cell membrane stability etc. Based on carotenoid pigment production, IAA production, proline content, seedling vigour index and yield of paddy, 20 isolates were selected for evaluating the efficiency for drought tolerance.

**c. Silicate Solubilizers**

Silicate solubilizing bacteria were isolated from Kerala soils. The twenty isolates obtained were screened for solubilization of silica, IAA production, antagonistic efficiency, phosphate solubilization etc.

**d. Hydrogel Technology for Microbial Inoculants**

Developed Gel formulations of *Azospirillum lipoferum* and *Azotobacter chroococcum*. The survival of the nitrogen fixers in gel formulation is being evaluated. The population of *Azospirillum* and *Azotobacter* was analysed at monthly intervals. Survival could be observed even after five months of storage.

**Training & Advisory service**

**Four hundred and fifty farmers** could be trained on microbial technology. **1205 Nos** of farmers visited the centre during the period and continuous advisory service is being provided to the farmers visiting the centre.

**Mass production of Microbial Inoculants and Revenue Generated**

A total quantity of **23,558 kg** of microbial inoculants was supplied to farmers from the centre generating a total income of **Rs. 20,11,555** during 2017-18.

**2. AINP on Soil Biodiversity- Biofertilizers- "Integration of Biofertilizer Technology with farming practices of tribal farmers of Attappady".**

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1. During 2017-18, 825 kg of PGPR Mix I and 15 kg of Composting Inoculum was distributed to the tribal farmers of Attappady.
2. Training: During the current year six trainings were conducted and 600 tribal farmers and 27 extension officers were benefited.
3. A technical leaflet in Malayalam was published covering different aspects of biofertilizers for the benefit of farmers and it was distributed to the farmers during the training.
4. In order to demonstrate the beneficial effect of the consortium of Biofertilizers (PGPR Mix I) field trials were laid out at different locations of Attappady in Tomato and Chilli. Significant increase in plant height, number of branches and yield in Tomato and Chilli was obtained due to PGPR Mix I application in two locations.

**3. Screening of Pink Pigmented Facultative Methylophs (PPFM) isolates for water stress tolerance and yield in paddy.**

*In vitro* screening of 20 isolates of PPFM for water stress tolerance by paper towel method on going.

#### 4. Centre of excellence in Microbial Technology

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An experiment was conducted to study the survival of *B. subtilis* in coconut husk and coir pith by serial dilution and plating technique and the population was noted at 15 days intervals. In case of coir pith, Initial population was found to be  $51 \times 10^6$ . Population after 90 days was found to be  $15 \times 10^6$ . In case of coconut husk, Initial population was found to be  $93 \times 10^6$ . Population after 90 days was found to be  $17 \times 10^6$ .

An experiment was conducted to study the survival of *B. subtilis* and *G. butleri* in Sache (5ml) and the population count was taken at 15 days intervals. In sachet, Initial population of *B. subtilis* was found to be  $32.55 \times 10^6$  on nutrient agar media. Population after 90 days found to be  $7 \times 10^6$ . Initial population of *Gongoronellabutleri* was found to be  $17.05 \times 10^6$ . *Gongoronella butleri* survived up to 30 days only. In case of consortium, initial population of *B. subtilis* was found to be  $25.9 \times 10^6$  and initial population of *Gongoronellabutleri* was found to be  $25.13 \times 10^6$ . *B. subtilis* survived upto 90 days ( $2 \times 10^5$ ) in consortium. But *Gongoronellabutleri* in consortium was survived upto 60 days.

#### 5. Eco friendly methods of waste management

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Objective of the project was to utilize human hair as fertilizer for crop improvement and production of composting inocula for distribution to municipalities and corporations. Fungus isolated from hair are being tested for their ability to degrade hair under *in vitro* using 10 g of hair. The work is in progress. The equipment for chemical and thermal treatment of human hair waste was designed. A total of 24 smart biobins distributed to different households.

#### 6. Native nalyz bacteria for exploitation in biosolid waste management

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The objectives of the projects were isolation and *in vitro* screening of actinomycetes degrading biosolid waste, testing the compatibility of selected actinomycetes in combination with existing microbial agents, test potential isolates for biosolid waste management in pilot scale experiment and validation through large scale experiment with Thumburmuzhi composting units. Actinobacteria were isolated from different soil samples from various locations and tested for their capacity for degrading biosolid waste. A total of 25 actino bacteria were isolated 3 isolates exhibited cellulose degradation and 8 isolates exhibited lipid degradation. Quantification of enzyme production in progress

#### 7. Utilization of human hair as fertilizer

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Human hair degradation by thermodynamical method and using microorganisms and effect of degraded hair on growth and yield of vegetable crops were the objectives. Human hair waste, treated using chemical and thermal methods was given as foliar spray on Bhindi (variety Aruna) at 5X and 10X concentrations 29.31% and 9.8% increase in plant height was observed in plots treated with 5X and 10X concentrations respectively compared to control. Increased yield in treated plots were also observed.

## 8. All India Network Project on Soil Biodiversity and Biofertilizers

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Nitrogen fixers were and K solubiizers were isolated from rhizosphere soils of Wayanad and the efficient isolates were identified. K solubilizers were also tested for their efficiency to solubilize Phosphorus and Zinc. Field experiments were conducted for black pepper and ginger with following treatments: *Microbacterium*, *Paenibacillus* and *Azospirillum lipoferum* (ref. culture of KAU). Farmer's practice (FP) served as control.

In black pepper, the no.of laterals, no.of spikes, spike length, no.of berries/spike, yield/plant, 1000 berry weight and no.of flowers and flushes were on par among the different treatments. The pedicel length was highest in plants inoculated with *Cellulosimicrobium*(1.51 cm).

Similarly in ginger, no.of tillers/plant was highest in *Azospirillum* inoculated plants (16.70). The plant height and yield (tones per hectare) were on par among the different treatments compared to control.

## 9. Evolving strategies for integrated management of diseases of salad cucumber and vegetable cowpea under poly house cultivation in terraces

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Five varieties (KPCH, Columbus, PS 4800, Sania and Noora) of salad cucumber were screened in poly house on terrace to identify the high yielding variety susceptible to important foliar diseases. The variety Sania was identified as the highest yielder, which was susceptible to powdery mildew and leaf spot diseases of salad cucumber. The trial on the management of powdery mildew and leaf spot of salad cucumber using the variety Sania has been initiated and is in progress.

## 10. Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops of Kerala

Dr. Joy M.  
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- a) **Management of Phytophthora foot rot in black pepper using new generation fungicides-** Spraying and drenching with the new generation fungicide Fenamidon + Mancozeb (Sectin)@ 0.2% was the most effective treatment in controlling the dreaded disease foot rot of black pepper. This was followed by the application of 0.2% copper hydroxide.
- b) **Management of marginal gall thrips in black pepper-** Spraying quinalphos 2ml/l was effective in managing the damage caused by marginal gall thrips. This treatment was comparable with the application of biocontrol agent *Lecanicillium lecani*.

## 11. Network project on Microbial inoculant Technology for cropping systems of Kerala – Development and adoption of microbial inoculant technology for cropping systems of Kerala.

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Dr Rini C R  
Assistant Professor  
[rini.cr@kau.in](mailto:rini.cr@kau.in)

Large scale production of biocontrol agents *Pseudomonas*, *Trichoderma* and VAM has been achieved to meet the increasing demand among the farmers.

**12 Development of IDM package with special emphasis to biorationales for the management of leaf blight diseases of amaranthus under homestead cultivation**

Dr Rini C R  
Assistant Professor  
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To formulate an integrated and healthy disease management package for the management of major diseases of cowpea and amaranthus under homestead cultivation in upper Kuttanad.

**13. Identification of Pathotypes / races in red rot pathogen.**

Dr Rini C R  
Assistant Professor  
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Cf94012-O found to be more virulent than the standard isolate CF06.

**14. Evaluation of pre-zonal/IET/zonal varieties/ genotypes for resistance to red rot.**

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Assistant Professor  
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Out of 62 genotypes evaluated for red rot resistance, 31 entries found to be resistant/ moderately resistant.

**15. Survey of sugarcane diseases naturally occurring in the area on important sugarcane varieties.**

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The diseases observed were red rot, rust, mosaic and PokkahBoeng and foliar disease viz., ring spot and sheath blight. But none of the diseases were in a severe stage to cause any drastic yield decline.

**16. MLT on leaf blight tolerant lines of small cardamom – 2018**

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The objective of the study is the evaluation of leaf blight tolerant lines of small cardamom. Nine Accessions (*viz, IC – 349650 IC – 547222, IC – 547223, IISR Vijetha, Appangala 1 and Njallani (Green Gold 1)*) are to be evaluated under the trial.

**17. Comparative accounts of some defense related bio-chemicals in resistant and susceptible black pepper var. to *Colletotrichumcapsici***

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The objective of the study is to identify the varieties/cultivars showing tolerance/resistance to *Colletotrichumgloeosporoides* and study the defence related biochemical in tolerant resistant ones.

Survey and collection of varieties/cultivars showing tolerance/resistance to *Colletotrichumgloeosporoides* and study the defence related biochemical in tolerant resistant ones.

**18. Commercial micropropagation of high value crops as per national certification system for tissue culture plants-network project**

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The objectives of the study included, to co-ordinate the virus indexing activities at different participating centers; to

assure quality of micronalyzing plants produced at various centers through clonal fidelity testing and virus indexing; and to give training on commercial micro propagation and quality assurance of micronalyzing plants.

As an experimental basis banana tissue culture samples were multiplied and virus indexed for four major banana viruses BBTV (Banana bunchy top virus), BBrMV (Banana Bract Mosaic Virus), CMV (Cucumber Mosaic Virus), BSV (Banana Streak Virus), multiplied and approximately 700 plants were sold to farmers. A demonstration of virus indexed Nendran banana plants was undertaken in the Instructional farm, Vellayani, Thiruvananthapuram.

Samples from Department of Plant Biotechnology, College of Agriculture Padannakkad and thirty seven samples from RARS Pattambi were tested for four viruses of Banana and reports were given.

One Research fellow from The Amritha school of Biotechnology, Vallikavu and One Training Assistant (Subject Matter Specialist Plant Pathology, KVK Vellanad) was trained for virus indexing of banana and other crops. Sixteen M.Sc.Ag. students and three Ph.D. students were trained on virus indexing via. Immunology and molecular detection of banana viruses with the facility developed under this project.

#### **19. Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala.**

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Objectives of the study are identification of alternative technologies for banned insecticides, fungicides nematocides and weedicides for management of pests, diseases, nematodes and weeds infesting major crops in Kerala; evaluating the safer pesticides (blue and green nalyzin) for the management of pests, diseases, nematodes and weeds infesting major crops in Kerala; evaluating the non-chemical methods (including bio-pesticides and botanicals) for the management of pests and diseases in field level to implement the organic policy of the Government of Kerala; testing the compatibility of pesticides and bio-control agents; evaluating the pesticide residues in produce and soil due to the application of the chemical pesticides; registering the potential biological control agents as per the insecticide act of CIB&RC

Seventy eight safe and eco-friendly technologies were evolved for the management of pests and diseases of major crops viz. rice, vegetable, coconut & arecanut, Black pepper, cardamom & ginger, banana and cashew and were brought in the POP KAU 2016.

Twenty five green technologies were evolved for the management of pests and diseases of major crops through organic practices including bio-pesticides were brought to the organic POP KAU 2016.

#### **20. Development of technologies including alternative for banned pesticides for the management of pests and diseases of major crops in Kerala.**

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Objectives of the study are developing eco-friendly management measures for the control of amaranth leaf blight caused by *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, the major diseases threatening the cultivation of amaranth in the State; developing eco-friendly management measures for the control of Fusarium wilt, Rhizoctonia root rot and web blight and Pythium collar rot of vegetable cowpea, serious threats in the cultivation of cowpea in the state; developing eco-friendly management measures for the control of downy mildew and powdery mildew diseases of cucurbits (bitter gourd and snake gourd) seriously affecting the cultivation of cucurbits in the state; and developing eco-friendly management measures for the control of Cercospora leaf spot of bhindi which is becoming a serious problem affecting the cultivation of bhindi in the state.

Salient findings include the following:

**Summary of recommendations approved for the package of practices of Kerala Agricultural University**

Sl.No.	Crop and disease	Recommendations in the POP of KAU	Dosage/ha	Colour code
1	Leaf blight of <b>amaranth</b> (Spray solution: 500 l/ha)	For vegetable production, * Turmeric powder – baking soda mixture(5:1 per litre water) (foliar spray and soil drenching) * Cowdung slurry supernatant 2 % + <i>Pseudomonas fluorescens</i> – 2 % (soil drenching and foliar spray) * <i>Trichoderma viride</i> – 2 % (soil drenching) + <i>Pseudomonas fluorescens</i> – 2 % (foliar spray)	2.5 kg/ha -0.5 kg/ha 10 kg/ha 10 kg/ha + 10 kg/ha	Organic  Organic Organic
2	Collar rot, root rot and web blight & <i>Fusarium</i> wilt of <b>vegetable cowpea</b>	* <i>Trichoderma viride</i> – seed treatment (2 g/kg seed) + soil drenching (2 %) * Cow dung slurry supernatant (2 %) + <i>P. fluorescens</i> 2 % - soil drenching (Drenching solution: 1500 l/ha)	30 kg/ha 30 kg/ha	Organic Organic
3	Root rot and web blight & <i>Fusarium</i> wilt of <b>vegetable cowpea</b>	* Cow dung slurry supernatant (2%) + <i>P. fluorescens</i> 2% - soil drenching * * <i>Trichoderma viride</i> – seed treatment (2g/ kg seed) + soil drenching (2%) (Drenching solution: 1500 l/ha)	30 kg/ha 30 kg/ha	Organic Organic
4	Downy mildew of <b>cucurbits(bitter gourd and snake gourd)</b>	* Cymoxanil + mancozeb @ 2g/l * <i>Pseudomonas fluorescens</i> – 2% (spray solution: 750 l/ha)	kg/ha 15 kg/ha	Blue Organic
5	Powdery mildew of <b>cucurbits (bitter gourd and snake gourd)</b>	* <i>Trichoderma viride</i> 2 % (spray solution is 750 l/ha)	15 kg/ha	Organic
6	Cercospora leaf spot of <b>bhindi</b>	<i>oderma viride</i> 2 % * <i>Trich</i> * <i>Pseudomonas fluorescens</i> 2% (spray solution: 750 l/ha)	15 kg/ha 15 kg/ha	Organic

**Ad-hoc recommendations approved for the POP of KAU**

Sl.No.	Crop and disease	Adhoc recommendations in the POP of KAU(Label claim)	Dosage/ha	Colour code
1	Leaf blight of <b>amaranth</b>	For seed purpose as well as in cases of severe incidence of the disease for vegetable purpose, Copper hydroxide 0.15% as foliar spray (Spray solution: 500 l/ha)	750 g/ha	Blue
2	<i>Fusarium</i> wilt of <b>vegetable cowpea</b>	Flusilazole– 1ml/l Hexaconazole - 2ml/l (Drenching solution: 1000 l/ha)	1.0 l/ha 2.0 l/ha	Blue Blue
3	Rhizoctonia root rot and web blight of <b>vegetable cowpea</b>	Flusilazole– 1ml/l Carbendazim + mancozeb seed treatment (2 g/kg seed) + soil -drenching (2 g/l) (Drenching solution: 1000 l/ha)	<b>d)</b> l/ha	Blue
4	Pythium collar rot of <b>vegetable cowpea</b>	Carbendazim + mancozeb– seed treatment (2 g/kg seed) + soil drenching (2 g/l) Flusilazole - 1ml/l (Drenching solution: 1000 l/ha)	2.0 kg/ha 2.0 kg/ha	Green Green
5	Downy mildew of <b>cucurbits (bitter gourd and snake gourd)</b>	* Pyraclostrobin @ 0.5 g/l (spray solution is 750 l/ha)	1.0 l/ha 375 g/ha	Blue Green
6	Powdery mildew of <b>cucurbits (bitter gourd and snake gourd)</b>	* Wettable sulphur 2 g/l * Tebuconazole 1 ml/l (spray solution is 750 l/ha)	<b>e)</b> kg/ha 750 ml/ha	Green Blue
7	Cercospora leaf spot of <b>bhindi</b>	* Tebuconazole 1ml/l (spray solution is 750 l/ha)	750 ml/ha	Blue

**Summary of recommendations approved for the organic package of practices of Kerala Agricultural University**

Sl.No.	Crop and disease	Recommendations in the POP of KAU	Dosage/ha	Colour code
1	Leaf blight of <b>amaranth</b>	(Spray solution: 500 l/ha) For vegetable production, * Turmeric powder – baking soda mixture(5:1 per litre water) (foliar spray and soil drenching) * Cowdung slurry supernatant 2 % + <i>Pseudomonas fluorescens</i> – 2 % (soil drenching and foliar spray) * <i>Trichoderma viride</i> – 2 % (soil drenching) + <i>Pseudomonas fluorescens</i> – 2 % (foliar spray)	2.5 kg/ha -0.5 kg/ha 10 kg/ha 10 kg/ha +10 kg/ha	Organic Organic Organic
2	Collar rot, root rot and web blight & <i>Fusarium</i> wilt of <b>vegetable cowpea</b>	* <i>Trichoderma viride</i> – seed treatment (2 g/kg seed) + soil drenching (2 %)* Cow dung slurry supernatant (2 %) + <i>P. fluorescens</i> 2 % - soil drenching (Drenching solution: 1500 l/ha)	30 kg/ha	Organic
3	Root rot and web blight & <i>Fusarium</i> wilt of <b>vegetable cowpea</b>	* Cow dung slurry supernatant (2%) + <i>P. fluorescens</i> 2% - soil drenching * * <i>Trichoderma viride</i> – seed treatment (2g/ kg seed) + soil drenching (2%)(Drenching solution: 1500 l/ha)	30 kg/ha 30 kg/ha	Organic Organic
4	Downy mildew of <b>cucurbits(bitter gourd and snake gourd)</b>	* <i>Pseudomonas fluorescens</i> – 2%(spray solution: 750 l/ha)	15 kg/ha	Organic
5	Powdery mildew of <b>cucurbits (bitter gourd and snake gourd)</b>	* <i>Trichoderma viride</i> 2 %(spray solution is 750 l/ha)	15 kg/ha	Organic
6	Cercospora leaf spot of <b>bhindi</b>	* <i>Trichoderma viride</i> 2 % * <i>Pseudomonas fluorescens</i> 2% (spray solution: 750 l/ha)	15 kg/ha 15 kg/ha	Organic

**21. Establishment of an Advanced Research Centre for Plant Disease Diagnosis**

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Objectives include the following-

1. Establishment of an Advanced Research Centre for Plant Disease Diagnosis
2. To establish a referral quarantine facility for the State, whenever Government need additional facilities
3. Consultancy / Advisory Services
4. Training for scientists working in this field of specialization
5. Maintain a type culture collection for reference during diagnosis
6. Production of antiserum for major plant pathogens
7. Maintain a cryptogammic herbarium

More than 60 farmers visited the lab for getting advice on plant health management measures.

In collaboration with the Karshaka Santhwanam programme field visits and advisory services through mobile phones and internet facilities were also undertaken.

Being a training centre for the extension personnels a sponsored training programme on **Plant Health Diagnosis** with the financial assistance of Kerala Centre for Pest Management (Govt. of Kerala) was conducted for 15 Agricultural Officers during Jan 16- Feb1st, 2018.

Infected cardamom and pepper samples were analyzed for the presence of virus

Facilities at the centre are being utilized for undertaking research work by Ph.D and M.Sc students of various departments of this University. Presently more than 10 research scholars have utilized this facility.

## 22. Synergism in Defense and Growth: Exploration of a root endophytic fungus *Piriformosporaindica* for the management of *Fusarium* wilt in banana with enhanced crop production.

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Objectives include the following

- 1) Standardization of the co-cultivation of *P. indica* with major banana varieties grown in the state.
- 2) Determining the best stage of seedling to prime the roots with *P. indica*.
- 3) Evaluation of the primed seedlings (TC plants) and suckers against *F. Oxysporum* f.sp. *cubense* and *R. similis* for root and foliar infection of *Fusarium* (Panama) wilt.
- 4) Evaluation of the primed banana seedling against the natural incidence yellow and black sigatoka and other foliar diseases including major viral diseases.
- 5) The compatibility study of *P. indica* with commonly used pesticides in banana cultivation.
- 6) Mass multiplication and commercial formulation of *P. indica*.

Antagonistic properties of *P. indica* against *Fusarium oxysporum* f.sp. *Cubense* causing panama wilt of banana were established through the dual culture technique. *P. indicacould* antagonize different foliar pathogens of banana through antibiosis, lysis, coiling and overgrowth.

The colonization and priming of *P. indica* in roots of TC banana seedlings were standardized in major banana varieties viz. nalyzi, red banana, robusta, quintal, monthan etc. The optimum stage of TC plants for priming of *P. indica* was also standardized.

*P. indica* root colonization in TC banana seedlings enhanced the root and shoot biomass thus promotes growth and multiple shoot formation in banana plantlets.

## 23. Integrated management of leaf spot diseases of banana var. Nendran

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The inference of the experiment was drawn by statistically nalyzing the data on PDS, YLS and DDT. In the case of disease severity, PDS at vegetative phase and at flowering were analysed. The statistical analysis of the data revealed that among the treatments, (tebuconazole + trifloxystrobin) recorded the lowest disease severity, This was followed by Tebuconazole and Hexaconazole While unsprayed control recorded the maximum disease severity. Disease Development Time (DDT) is the parameter which indicates the time or number of days taken by the leaves to produce visible symptom. DDT was maximum in the case of Hexaconazole followed by tebuconazole and (tebuconazole + trifloxystrobin). While nalyzing the yield components maximum yield in terms of bunch weight was recorded in (tebuconazole + trifloxystrobin) and followed by Tebuconazole and Hexaconazole. Control recorded the lowest bunch weight. The results revealed that the percent disease severity PDS, YLS and DDT taken at vegetative phase and at flowering were analysed. The PDS was least in the case Turmeric powder + baking soda followed by Nanma PGPR mix II and *P.fluorescens* + cowdung slurry, While control, recorded the maximum percent disease severity. Disease development time ( DDT) was maximum in case of Turmeric powder + baking soda, PGPR mix II and Nanma. While control recorded the least DDT. While comparing the yield components, maximum bunch weight was recorded in Turmeric powder oil +baking soda, followed by Nanma, PGPR mix 11, *P.fluorescens*+cowdung slurry. Control recorded the lowest bunch weight.

## 24. Management of die back disease complex in nutmeg

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Statistical analysis of the pooled data from the two locations of the field evaluation were compared with the *in vitro* evaluation of fungicides and bio agents and the following conclusions were made. Severe infection of various diseases like leaf spots/anthracnose, leaf blight and leaf fall, fruit fall and thread blight may lead to dieback disease complex, if not controlled properly. Copper based fungicide viz. Bordeaux mixture 1% and copper hydroxide 0.2% were found very effective for the management of various diseases such as leaf spot/anthracnose, leaf blight and leaf fall and fruit fall of

nutmeg The results of the *in vitro* evaluation of the selected fungicides against the major pathogens also supported this observations. Spraying with systemic fungicide, tebuconazole 0.1% was found on par with copper fungicides in its efficacy to manage various leaf spot/anthracnose diseases of nutmeg. So it can be recommended as an alternative to copper fungicides. Tebuconazole (0.1%) recorded cent per cent inhibition of all the pathogens under *in vitro* condition. Among the bio control agents tested, *Trichoderma viride* enriched with cow dung and neem cake along with aerial spraying of copper hydroxide @ 0.2% recorded > 60% reduction in various diseases of nutmeg under field condition. The *in vitro* evaluation of *Trichoderma viride* was also supported this observation. Foliar application of copper hydroxide (0.2%) or Bordeaux mixture (1%) along with soil application of *Trichoderma viride* enriched with cow dung and neem cake @ 10kg/tree can be recommended for the management of dieback disease complex in nutmeg. Tebuconazole (0.1%) can be recommended as an alternative to copper fungicide for the management of anthracnose and leaf spot diseases of nutmeg. Application of fungicides/ bio-agents should be given three times per year viz. before, in between and after south west monsoon.

## 25. Network project on strengthening production of quality planting materials and bio inputs in KAU

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The target of the project for the period of 2017-18 was the production of 1 ton of mushroom spawn and bio control agents viz, *Trichoderma viride* and *Pseudomonas fluorescens*

1. Mushroom spawn : 2250 packets – 0.675 ton
2. Bio control agents : 4 tonnes.
  - a) *T. viride*: 3 tonnes
  - b) *P. fluorescens*: 1 ton

**Total Revenue generated: Rs.4,80,000/-**

Under the sub head 420 (Equipments), a gas operated autoclave (capacity 184 L. Size 550 × 750 mm, LPG burner and regulator) with a cost of Rs.73,000/- was purchased and installed in the Mushroom production unit. The amount allotted under farm development (921) was utilized for the complete renovation work of old mushroom production unit attached to Dept. of Plant Pathology. Minor equipments like weighing machine, water purifier and microwave oven required for the conduct of the project were also purchased. Renovated mushroom production unit.

## 26. Network project on seed and nursery programme for planting material production

### Sub project: Mass production of biocontrol agents

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The objective of this project is the mass production and sale of one ton of bio control agents viz, *Trichoderma viride* and *Pseudomonas fluorescens* in the Department of Plant Pathology.

Renovated the mixing room by fixing false ceiling to make it as rat proof and also to reduce the temperature inside, for reducing the contamination of bio agents. 4. Replaced the damaged door of bio control lab with a new one.

## PG Projects

### Concluded Projects

1. Assessment of microclimatic and soil parameters on the population and functional efficiency of *Pseudomonas fluorescens* in the rhizosphere of Pokkali rice (*Oryza sativa* L.).
2. Characterization of rhizosphere and endophytic microorganisms for drought tolerance
3. Characterization and management of yellow mosaic disease of black gram (*Vigna mungo* L. Hepper.)
4. Field evaluation of abiotic stress tolerant strains of *Trichoderma harzianum* and *Pseudomonas fluorescens* for *Phytophthora* disease management in black pepper (*Piper nigrum* L.)
5. Development of alternative pest and disease management technology in spices

The objective of the study was the identification of effective bio-agents and comparatively safe chemical fungicides against Capsule rot and *Fusarium* rot of cardamom.

For capsule rot management based on disease severity, yield levels and BC ratio, drenching of fosetyl-Al @ 1 g/l was found to be most effective followed by *P.fluorescens* + *T. viride* + *G. fasciculatum*, Cymoxanil + Mancozeb and BM+COC application

For *Fusarium*rot management, BC ratio was high (>1.7) for sole application of *P. fluorescens* in cow dung slurry (2%) followed by combined application of *P. fluorescens*(2%), *Glomusfasciculatum* (100g)and *T. viride* (50g) and combination product of captan + hexaconazole @ 1.5g/l

#### **6. Establishment of Pest and disease surveillance and forewarning units in the high range zone**

The objective of the study were study on the effect of agro-meteorological factors on the incidence and spread of pest and diseases in cardamom and pepper and developing a disease and pest forecasting model for these crops based on weather parameters variability and change.

Correlation and stepwise regression was carried out to study the impact of weather parameters like Temperature (max. and min), RH (Morning and evening), Sun shine hrs and rain fall with diseases of cardamom and black pepper. Rainfall and excess relative humidity promote disease incidence in both the crops (except *Fusarium* rot of cardamom). This study gives us an indication about the impact of extreme climatic conditions on diseases and help to improve the available management tactics in these crops by re-scheduling the fungicide use pattern.

#### **7. Triazole, strobilurin and its combination fungicides for the management of anthracnose and fruit rot of chilli**

Objectives include to study the host range of *Colletotrichumcapsici*(Syd.) Butler and Bisby the incitant of anthracnose and fruit rot of chilli, in vegetable crops and to develop management strategy using new generation fungicides.

A survey was conducted in vegetable gardens of six KAU stations viz. College of Agriculture, Vellayani; RARS, Kumarakom; College of Horticulture, Vellanikkara; RARS, Pattambi; RARS, Ambalavayal and College of Agriculture, Padanakkad during 2016 – 17 to study about the prevalence and severity of anthracnose and fruit rot disease of chilli in Kerala. *C. capsici*was found to cause the disease in five locations. Maximum incidence (70 %) and severity (45 %) of the disease was recorded at Padanakkad. *C. gloeosporioides* was identified from Ambalavayal region.

Among the five isolates of *C. capsici*obtained, isolate C3 was identified as the most virulent one. Studies on growth conditions of *C. capsici* revealed thatpotato dextrose medium was the best medium for the growth and sporulation of the fungus with radial growth of 8.54 cm and dry mycelial weight of 0.491 g on 7<sup>th</sup>day of growth, followed by oat meal medium (8.2 cm and 0.42g). The optimum temperature for the growth was 30°C with radial growth of 8.53 cm and dry mycelial weight of 0.592 g on 7th day, followed by 27°C.

Host range study of *C. capsici*was performed by leaf inoculation of different vegetable crops like *C. chinense*, *C. frutescens*, cowpea, brinjal, tomato and bhindi and identified the above crops as hosts for the pathogen. Screening of eight KAU released varieties of chilli viz. VellayaniAthulya, Jwalamukhi, Jwalasakhi, Ujwala, Anugraha, Keerthi, VellayaniTejus and VellayaniSamrudhi against anthracnose and fruit rot disease was done with artificial inoculation of leaves and fruits with *C. capsici*. The study revealed that VellayaniAthulya, VellayaniSamrudhi and Anugraha were more susceptible on leaf inoculation with mean lesion size of 3.53, 2.83 and 2.4 cm respectively on 5<sup>th</sup>day of inoculation. After 7 days of inoculation ontender fruits, VellayaniAthulya was found to be more susceptible with lesion size of 2.87 cm followed by Anugraha (2.63 cm) and Jwalamukhi (2.6 cm).

New generation fungicides were tested against *C. capsici* through *in vitro* and *in vivo* evaluation. The six fungicides screened against *C. capsici*by poisoned food technique revealed that azoxystrobin + tebuconazole at 10 ppm, pyraclostrobin at 50 ppm and hexaconazole + pyraclostrobin at 100 ppm completely inhibited the mycelial growth of *C. capsici*. Triazole and strobilurin fungicides were highly effective against anthracnose and fruit rot of chilli

#### **8. Integrated management of Alternaria leaf spot of cabbage (*Brassica oleraceavar. capitata* (L)).**

The objective of the experiment is to develop management strategy to control the disease using fungicides and biocontrol agents.

As a part of study, survey was conducted in cabbage fields of three districts of Kerala viz., Trivandrum, Kollam and Idukki

and the maximum per cent disease index (57.14%) was recorded in the cabbage fields of Muthuvankudy region in Idukki district. The morphological characters & the molecular characterization confirmed the pathogen as *A. brassicicola*. A pot culture study was undertaken with cabbage variety NS-183 and evaluated the efficacy of effective fungicides, bioagents and their compatible combination and the maximum disease suppression over control was recorded with combined spraying of hexacoazole + *B. subtilis* (79.4%) followed by hexaconazole (68.3%), tebuconazole (65.1%) and propiconazole (63.6%).

### 9. Evaluation of Biochemical and Anti-cancerous activities of Mushrooms

Objectives include to undertake cultural, spawn production and cultivation aspects of five mushrooms namely, the reishi mushroom, *Ganodermalucidum*(Curtis) P.Karst., the white oyster mushroom, *Pleurotusflorida* (Mont.), the pink oyster mushroom, *Pleurotusdjamor* (Fr.) Boedjn., the blue oyster mushroom, *Hypsizygusulmarius*(Bull Fr.)Redhead. & the milky mushroom *Calocybegambosa* (Fr.) Singh and to evaluate their biochemical and anti-cancerous activities)

The present research project was aimed to analyse the nutritionally and pharmacologically active compounds present in five commercially cultivating mushroom species including *G. lucidum*, *P. florida*, *P. djamor*, *H. ulmarius* and *C. gambosa*. The spawn production study of five mushrooms was conducted on paddy grain substrate since it promoted earliness in spawn run and mycelial growth. Among the *Pleurotus spp.* *P. djamor* took least time for spawn run (12.25 days) while *C. gambosa* took a maximum of 20.00 days for spawn production in paddy grain substrate. The cultivation of *G. lucidum* was tried on a combination of rubber sawdust (80 %) amended with rice bran (20 %). The first harvesting was done in 33.50 days and a total of three harvests produced 115.00 grams of mushroom with 11.50 per cent biological efficiency. Oyster mushrooms such as *P. florida*, *P. djamor* and *H. ulmarius* and milky mushrooms were cultivated on paddy straw by polybag method.

The nutritional analysis revealed that mushrooms are potential source of proteins, carbohydrate, amino acids, vitamins and minerals with less fat content. The protein content of *G. lucidum* was estimated as 30.91 per cent which was highest among the five mushrooms followed by *C. gambosa*(26.00 %). The studies regarding medicinal properties confirmed that mushrooms were rich in bioactive immunomodulation components such as polysaccharides, terpenoids and flavonoids. *G. lucidum* recoded maximum beta-glucan content of 38.58 per cent on dry weight basis. The beta-glucan content of *H. ulmarius*, *P. florida*, *P. djamor* and *C. gambosa* were estimated as 26.62 per cent, 20.80 per cent, 32.15 per cent and 35.64 per cent respectively.

Analysis of anti-oxidant property of mushroom by DPPH assay revealed that *G. lucidum* extract exhibited 50 per cent inhibition of free radicals at 740 µg per ml concentration, whereas the extracts of oyster mushrooms (*P. florida*, *P. djamor* and *H. ulmarius*) and milky mushroom (*C. gambosa*) even at higher concentration did not reach fifty per cent inhibition of free radicals in the current study

The anti-cancerous activities of ethanolic extract of *G. lucidum*, *P. florida*, *P. djamor*, *H. ulmarius* and *C. gambosa* were assessed against cervical cancer cell lines (HeLa) *in vitro* by MTT assay. The *G. lucidum* extract at 200µg per ml concentration reduced the viability of cancer cells to 54.85 per cent which was the maximum inhibition of cancerous cells as compared with other mushrooms under study followed by *C. gambosa* (60.92 per cent).

### 10. Survival and genetic diversity of gemini virus infecting okra (*Abelmoschuseculentus*(L.)Moench) and bitter gourd (*Momordicacharantia*L.)

The study aimed at identification of genetic variability in gemini virus isolates infecting okra and bitter gourd and their dissemination in the associated weeds.

During the survey in okra and bittergourd field, nineteen weeds which expressed virus infection symptoms like mosaic, vein clearing etc., were collected from field and nearby areas and identified.. These were *Ageratum conyzoides*, *Croton sparsiflorus*, *Emilia sonchifolia*, *Sidacordifolia*, *Synedrellanodiflora*, *Acalyphaindica*, *Boerhaaviadiffusa*, *Centrosemapubescens*, *Cleome rutidosperma*, *Clitoriaternatea*, *Desmodiumgyrans*, *Hemidesmusindicus*, *Sidarhombifolia*, *Alysicarpusvaginalis*, *Richardiascabra*, *Tephrosia purpurea*, *Justiciaprostrata*, *Euphorbia geniculata* and *Phyllanthusniruri*. Among nineteen weeds tested twelve weeds viz. *A. conyzoides*, *C. sparsiflorus*, *E. sonchifolia*, *S. nodiflora*, *A. indica*, *C. pubescens*, *D. gyrans*, *H. indicus*, *R. scabra*, *T. purpurea*, *P. niruri*, *S. cordifolia*, *S. rhombifolia* and *E. geniculata* gave positive reaction with geminivirus ACMV and SLCMV.

PCR analysis and molecular characterization of geminivirus revealed that among geminivirus isolated from the nineteen weeds, only ten viz. *A. conyzoides*, *C. sparsiflorus*, *E. sonchifolia*, *S. nodiflora*, *A. indica*, *H. indicus*, *T. purpurea*, *E. geniculata*, *S.*

*cordifolia* and *S. rhombifolia*, shared more similarity with other geminivirus and thus confirmed as the collateral hosts for the geminivirus.

Phylogenetic studies indicated a clear relationship between geminivirus infecting weeds and that of okra and bittergourd. The analysis suggests that phylogenetic similarity between vein clearing symptom exhibiting weeds viz. *S. cordifolia*, *C. sparsiflorus*, *A. conyzoides*, *S. nodiflora*, *E. sonchifolia*, and two weeds exhibiting mosaic symptoms viz. *T. purpurea* and *S. rhombifolia* could be the collateral host for the geminivirus infecting okra showing yellow vein which is partially characterized in this study.

Geminivirus causing mosaic symptoms in weeds viz. *H. indicus*, *E. geniculata* and *A. indica* were closely related to geminivirus infecting bittergourd and thus these weeds can act as the collateral hosts for bittergourd mosaic disease.

### **11. Ecofriendly management of anthracnose of betelvine (*Piper betle* L.)**

Objective of the experiment was to evolve an integrated management strategy involving organic preparations, biocontrol agents and new generation fungicides for anthracnose of betel vine.

A survey was conducted in five different locations of three southern districts of Kerala viz., Thiruvananthapuram, Kollam and Alappuzha. The higher disease index (20.00) and incidence (80%) was recorded from the Cherthala region of Alappuzha. The disease symptom initiated as small necrotic spots with a yellow halo from the leaf tips which coalesced together causing leaf blight and defoliation. Lesions on vines lead to girdling of the stem ultimately resulting in drying and death of the affected vine.

The organic preparations at 10% concentration, fermented cow's urine and panchagavya recorded complete growth inhibition of the pathogen. Five *Colletorichum sp.* were isolated from affected betel leaves collected during survey. The virulent isolate was further confirmed as *C. gloeosporioides* by molecular characterization. The fungicides and bacterial isolate from phyllosphere were effective in managing the disease over the traditional management using Bordeaux mixture at 0.05% as per (KAU, 2016). The foliar spray of 0.1% propiconazole at 10 days interval can be suggested for managing the disease. If the disease is severe we have to spray the fungicide and could be followed by eco-friendly measures including antagonistic bacteria.

### **12. Etiology and management of mosaic disease in ginger (*Zingiber officinale* Roscoe)**

Objectives include to identify, characterize, clone and sequence the genes of *Ginger mosaic virus* along with the management of the disease. The symptoms of the disease appear distinguishably on the young, newly emerging leaves of ginger plant. On the leaves the symptoms are first appeared as small light green flecks. These flecks eventually increased in size and formed spindle shaped streaks. In certain plants the symptom expression initiated as appearance of light and dark green shades on the leaves, as mosaic symptom.

The infected plants showed a significant reduction in the chlorophyll content than in healthy plants due to the viral infection. The infected plants showed a significant reduction in the protein content than in healthy plants due to the viral infection.

An amplicon of size 550 bp was obtained in begomovirus degenerate primer (AV494- F and AC1048- R).

The mosaic disease of ginger is caused probably by a new strain of virus, which is related to *Tomato leaf curl virus*. The infection can be effectively managed by foliar application of Perfekt 0.5-1.0 ml L<sup>-1</sup> or 10% leaf extract of *Mirabilis jalapa*. These two sprays inhibit the viral symptom expression effectively and make the crop to withstand the disease.

### **13. Cataloguing, documentation and management of fungal diseases of strawberry (*Fragaria x ananassa* Duch.)**

Strawberry (*Fragaria x ananassa* Duch.), hybrid species of genus *Fragaria*, cherished for its characteristic flavour, colour and tantalizing aroma, is becoming an important table fruit of millions of people around the world. However, the crop is inflicted by several fungal diseases that reduce its commercial value. Purposive sampling surveys were carried out in strawberry growing tracts of Kerala viz., Wayanad, Idukki and Malappuram. Fungicides viz., carbendazim 12% + mancozeb 63%, propineb 70 WP, Bordeaux mixture, cymoxanil 8% + mancozeb 64%, difenoconazole 25EC and carbendazim 50WP were found effective against various foliage diseases. Carbendazim 12% + mancozeb 63%, cymoxanil 8% + mancozeb 64%, copper hydroxide 77WP and carbendazim 50 WP recorded cent per cent reduction in mycelial growth of *Fusarium oxysporum* (CRI-1). Similarly, carbendazim 12% + mancozeb 63%, copper hydroxide 77WP, cymoxanil 8% + mancozeb 64% recorded 93-100 per cent reduction of *Lasiodiplodia theobromae* (CRM-1). Results of dual culture studies with *Trichodermaasperellum* and *Pseudomonas fluorescens* against pathogens revealed 66.67 to 100 and 0 to 70.55 per cent

control respectively. Likewise, organic formulations like Calphomil recorded an inhibition ranging from 13.3 to 75.33 per cent, whereas neem oil, panchagavya and baking powder + vegetable oil mixture could restrict the growth of pathogen only upto 34 per cent. *In vivo* experiment was conducted to study the efficacy of fungicides and biocontrol agents under natural conditions also. Accordingly, four major selected pathogens viz., *C. gloeosporioides*, *P. longisetula*, *F. oxysporum* and *L. theobromae* were subjected to molecular characterisation prior to *in vivo* studies. The sequence homology on molecular studies revealed that the isolates showed similarity to *C. gloeosporioides*, *Neopestalotiopsis clavispora*, *F. oxysporum* and *L. theobromae*. Results of the pot culture experiment revealed that *Trichoderma asperellum* showed better control against *C. gloeosporioides* compared to other treatments followed by carbendazim 12% + mancozeb 63%. Propineb 70 WP, *T. asperellum* and carbendazim 12% + mancozeb 63% reduced the severity caused by *Neopestalotiopsis* leaf blight disease. The combination fungicide carbendazim 12% + mancozeb 63% (0.2%) was found equally efficient against *F. oxysporum* and *L. theobromae*. Thus, the study has enlightened our knowledge on the various fungal diseases inflicting strawberry as well as the role of weather in disease development and the management practices using plant protection chemicals and bioagents both under *in vitro* and *in vivo* conditions. Hence, further studies should be focused to carry out multilocal trials in strawberry growing tracts of Kerala.

#### 14. Characterization and management of fungal pathogens of cabbage (*Brassica oleracea* var. *capitata* L.) and cauliflower (*Brassica oleracea* var. *botrytis* L.)

Preliminary surveys were conducted for the occurrence of fungal diseases in cabbage and cauliflower in Kasargod, Wayanad and Idukki districts of Kerala, grown both under poly houses and open field during November- January. Diseased plant samples were collected for the isolation of associated pathogens. In the surveyed areas head rotting of cabbage, curds rotting of cauliflower and foliage diseases were observed. The incidence and severity of each disease was recorded. *Alternaria* leaf spot was the most severe and predominant disease identified in both cabbage and cauliflower. From collected samples preliminary studies of pathogen was conducted by making slides and the characters of the spores and other structures identified. Pathogens were isolated by following the standard protocol and Koch's postulates were verified by inoculating mycelial discs on head, curd and leaf. Symptomatology of the fungal diseases was studied in detail both under natural and artificial condition. Three major pathogens viz., *A. brassicicola*, *R. solani* in cabbage and *P. aphanidermatum* in cauliflower were selected for *in vivo* studies. Three biocontrol agents and fungicides which showed inhibition above 60 percent were selected for *in vivo* evaluation. Trifloxystrobin 25% + tebuconazole 50% (0.03%) and tebuconazole 5 EC (0.1%) were the best fungicides showed 50 percent disease reduction over control. *T. viride* is the effective biocontrol agent for field application for these fungal diseases.

#### 15. Management of fungal diseases of capsicum (*Capsicum annum* L.) under protected cultivation

A survey was conducted at Vellanikkara, Manuthy, Manalur, Thannlyam, Eland, Palakkad, Neuyatinkara, Plamootikara to assess incidence and severity of fungal disease of capsicum in polyhouse and rain shelter using standard score charts and procedures. The diseases noticed are powdery mildew, anthracnose, Cercospora leaf spot and wilt. Disease specimens were collected during survey. The pathogens were isolated from diseased plant parts and pathogenicity was proved and pathogen was identified. The Cercospora leaf spot caused by *Cercospora capsici*, powdery mildew by *Leveillulataurica*, anthracnose and fruit rot by *Colletotrichum capsici*, and stem and fruit rot by *Fusarium solani*. Cercospora leaf spot of capsicum caused by *Cercospora capsici* was reported for the first time in Kerala. The fungus was isolated and subjected to molecular characterization and confirmed the identity. Effective management strategies were developed against powdery mildew and Cercospora leaf spot of capsicum. It was found that tebuconazole (0.1%) and mancozeb (0.2%) were the best treatments against powdery mildew and Cercospora leaf spot respectively, foliar spray with *Pseudomonas fluorescens* also gave satisfactory control of the disease

#### 16. Molecular characterization of virus causing infectious chlorosis disease of banana

The present research was envisaged to study the symptoms, biophysical and molecular characterization and immuno-molecular diagnosis of the virus. Development of nanobiosensors for the quick and more sensitive detection of virus was also attempted.

Purposive sampling surveys were conducted in Thrissur district revealed highest disease incidence of 90 % was recorded on banana variety Robusta. The symptoms of the disease were mosaic, leaf distortion and yield reduction. The transmission studies confirmed that the virus was transmitted through aphid species viz. *Pentalonianigronevosa* and *Aphis craccivora* and also through the suckers of infected mother plants of banana. The morphological characteristics of the virus particles revealed the presence of spherical, isometric virus particles of size 28 nm. The molecular characterization of the coat protein gene of the virus was carried out through Reverse Transcription PCR. The Coat Protein (CP) gene was amplified using designed and reported primer pairs which yielded amplicons of approximate size of 750 bp and 700 bp respectively. The CP gene of eight isolates were sequenced and subjected to *in silico* analysis which revealed that the sequences of CMV exhibited significant nucleotide identity (99 to 96 per cent) with the sequences of CMV available in the data base of

genebank. The immunodetection techniques like Dot Immuno Binding Assay (DIBA) was standardised to detect CMV infection of leaf samples and showed positive reaction on nitrocellulose membrane. The field gene bank comprising about 175 accessions maintained at BRS, Kannara was screened to assess their disease reaction under natural conditions and the disease was recorded on 12 accessions with AA, AB, AAA, AAB and AAAB genome. Development of antibody based nanobiosensor were developed by fabricating gold nanorods (GNRs) through seed mediated procedure and UV-Vis spectra of GNRs solution indicated characteristic longitudinal and transverse bands at 710 and 523 nm respectively. The image under Transmission Electron microscope revealed that the solution contained rod shaped gold nanoparticles of size 54.96 nm length and 14.75 nm diameter. The outcome of this study will facilitate early detection and elimination of CMV infected plants and ensure distribution of healthy planting materials to the farmers of Kerala, thereby increasing the production as well as the productivity of banana in the state.

#### Ongoing projects

1. Characterization of *Mycosphaerella* sp. causing sigatoka leaf spot disease complex of banana in Kerala and its management.
2. Characterization and bio-intensive management of fungal fruit rots of cucurbits.
3. Characterization of *Ralstoniasolanacearum*(Smith) Yabuuchiet al. infecting solanaceous vegetables in relation to physico-chemical and biological properties of soil.
4. Microencapsulation of *Trichodermaviride* for management of major soil borne fungal pathogens
5. Molecular characterization, host range and integrated management of *Bhindi yellow vein mosaic virus* (BYVMV)
6. Characterization and evaluation of *Pseudomonas* spp. for abiotic stress tolerance
7. Development of recombinant coat protein for immune detection of *Cucumber mosaic virus*
8. Analysis of pathotypic variability of *Xanthomonasoryzae*pv. *oryzae*, the bacterial blight pathogen of rice and identification of new sources of resistance
9. Characterization and integrated management of *Fusariumoxysporum* f. sp. *cubense* (E. F. Smith) Snyder and Hansen causing fusarium wilt disease of banana.
10. Characterisation and management of powdery mildew of yard long bean (*Vignaunguiculata* subsp. *Sesquipedalis*(L.) Verdc.) under protected cultivation
11. Exploitation of abiotic stress tolerant strains of *Trichoderma* spp. for the management of soil borne fungal pathogens
12. Characterization, host range and management of *Papaya ringspot virus* (PRSV)
13. Identification and management of mycoflora associated with grain discolouration of rice (*Oryza sativa* L.)
14. Characterization of medicinal mushroom, *Cordyceps* sp. from Kasargod district
15. Characterization and management of yellow mosaic disease of black gram (*Vignamungo* (L) Hepper)
16. Development of encapsulated formulation of *Azospirillum lipoferum* and its evaluation for growth and yield in *Amaranthus tricolor* L."
17. Management of early blight disease of tomato (*Solanumlycopersicum* L.) under protected cultivation
18. Characterization and management of *Sugarcane bacilliform virus* (SCBV) causing leaf fleck disease in sugarcane

# **Name of Project Coordination Group – (13) Postharvest Technology and Value Addition**

**Compiled by:  
Dr. Mini.C., Protect Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 3 Nos.**

**Ongoing Projects - 6 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 6 Nos.**

**Ongoing Projects - 14 Nos.**

## Concluded Projects

### 1. Development of animal feed from jack fruit processing waste

Dr.Sheela.K.B  
Professor  
[sheela.kb@kau.in](mailto:sheela.kb@kau.in)

The technology standardised under the project was disseminated to the farming community through training programmes. Four training programmes on “Processing industry waste utilization” was conducted under the project. The duration of the training programmes was three days. The beneficiaries included farmers, entrepreneurs and women self help groups. Total of 61 people were benefited by the training programmes. Modernisation work of training hall of the department was undertaken. A technology hub was established for showcasing of technologies developed in the department of Post-Harvest Technology. ICAR team visited the technology hub. A council room was set up in the department under the project for conducting workshop, group discussion, panel discussion, meetings etc.

### 2. Postharvest characterisation and management of elite jackfruit types of Kerala

Dr.Saji Gomez  
Asst.Professor  
[saji.gomez@kau.in](mailto:saji.gomez@kau.in)

**Enriched jackfruit bar:** Fruit bar was prepared by blending pulp of jackfruit with fruit pulp of mango, papaya and pineapple was blended in 75: 25, 50: 50, 25: 75 and also from pulp of jackfruit alone. Blending of jackfruit pulp with mango, papaya and pineapple in the preparation of fruit bar, resulted in products with enhanced palatability, multi-nutrition and improved flavour. The product could be stored for three months under ambient conditions and over a year at low temperature.

**Dehydrated jackfruit shreds:** In order to overcome the disadvantages associated with conventional drying/ dehydration, jackfruit bulbs were diced into longitudinal shreds, followed by osmotic treatment and subsequent dehydration. Development of dehydrated jackfruit shreds resulted in a product with improved flavour and colour, besides a soft texture which makes the product a ready-to-eat snack with better shelf life. The product could be stored for three months under ambient conditions and over a year at low temperature. Non-enzymatic browning showed a gradual increase in the product stored under ambient conditions whereas it was negligibly low in the product stored at low temperature. Ascorbic acid and total carotenoids decreased during storage and the decline was rapid under ambient conditions as compared to low temperature storage. Organoleptic quality of the product remained acceptable up to three months under ambient conditions whereas at low temperature, it remained acceptable even after one year.

**Effect of storage temperature on quality of ripe jackfruit:** The experiment was aimed at finding out the optimum storage temperature for mature/ ripe jackfruit. Fruits of mature but unripe jackfruit were stored at ambient as well as low temperature (12-13°C). Observation on shelf life and qualitative attributes were recorded in the fruits. Fruits stored under ambient conditions, ripened after 4 days of storage. Fruits could be stored for 29 days in a walk-in cool chamber which was maintained at 12-13°C. Fruits ripened under ambient conditions had higher TSS (30 ° Brix), ascorbic acid (22.2 mg/100g), reducing sugars (5.7 %), carotenoids (1.08 mg/100g) whereas, low temperature storage resulted in higher titratable acidity (0.34%), non-reducing sugars (28.52 %), total sugars (33.25 %), pectin (2.34%) and phenols (1.27%). Organoleptic quality of fruits ripened under ambient conditions was better as compared to those ripened in cool chamber.

### 3. Value Addition and Post-harvest Management & Establishing a Food Pro mall

Dr.K.N.Satheesan  
Professor  
[satheeshan.kn@kau.in](mailto:satheeshan.kn@kau.in)

- i. Established a pilot plant for Virgin coconut oil Production of 500 nut/day capacity along with other equipments and machineries for processing of papaya, jackfruit, cashew etc.. Establishment of mechanized VCO Plant serve as a model for the farmer entrepreneurs as well as aid in utilizing the available nuts at the station for value addition. At least two units has been established in the district by the former trainees.
- ii. Established food pro mall to serve as a sales outlet for the innovative value added products and act as a demonstration center for technology and marketing of innovative products to entrepreneurs.
- iii. The protocols for the coconut and under exploited fruit products were standardized, commercialized and marketed through food pro mall at RARS Pilicode .Five training pogrammes of 5 days duration benefitting 38 farmers were conducted

## Ongoing Projects

### 1. Establishment of Centre of Excellence on Post-Harvest Technology-Quality control lab

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Asst.Professor  
[saji.gomez@kau.in](mailto:saji.gomez@kau.in)

The Quality Control laboratory was created with a view to provide facility for quality control aspects related to food. The Laboratory caters to the quality determination of fresh and processed food products of entrepreneurs, public and private institutions, researchers and students. Several firms, organizations and individuals have utilized the services of the Quality Control laboratory.

Analysis of quality parameters of the following products were undertaken viz .banana flour, nutrimix, Ayushmathi products, mango, jaggery, nutmeg, cheese, Nata de coco, garlic, cordyceps, dehydrated ripe banana, Mush protex, cereal flour, bitter gourd, baby food, pudding mix, soup mix, dehydrated ripe pineapple, jam and squash.

### 2. Establishment of Centre of Excellence on Post-Harvest Technology-Establishment of centre for postharvest management and value addition for underexploited fruits and vegetables of southern Kerala.

Dr. Mini.C  
Professor  
[mini.c@kau.in](mailto:mini.c@kau.in)

Production of beverages from under exploited fruits such as bilimbi, carambola, passion fruit, sapota and West Indian cherry was undertaken along with storage stability analysis of prepared products. Proven the possibility of production of fruit beverage from Gamboge, *Garcinia tinctoria*, (Yellow mangosteen). The squash produced from gamboge had 9.30 brix, 0.53% acidity with 11.4% and 9.33% total and reducing sugars respectively. The squash had 154mg/100g.vitamin C and 0.15µg/100g â- carotene with 0.12% total antioxidant activity.

### 3. Establishment of centre for formulation of convenient foods

Dr. Mini C,  
Professor  
[mini.c@kau.in](mailto:mini.c@kau.in)

### 4. Establishment of Techno-incubation centre for the commercialization of value added products from under exploited fruits and vegetables

Dr. Mini C,  
Professor  
[mini.c@kau.in](mailto:mini.c@kau.in)

### 5. Development of health proactive powder mixes and nutritive delicacies based on raw and ripe banana.

Dr.Pushpalatha.P.B  
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The following accessions in the germplasm were evaluated for its nutritional properties.

Sl. No.	Variety	Acidity (%)	Total sugar (%)	Total carbohydrate (%)	Total protein (%)	Total fat (%)
1	Kunnan	0.26	1.47	30.67	2.60	0.50
2	Njalipoovan	0.35	3.73	20.93	2.00	1.00
3	Poovan	0.49	1.33	21.60	1.40	0.50
4	Palayankodan	0.54	3.60	26.67	1.33	0.50
5	Monthan	0.22	0.80	23.07	1.33	1.50
6	Kadali	0.50	3.73	21.33	1.33	0.50
7	FHIA 3	0.42	2.00	23.46	1.87	0.50
8	Blue Torres Straight Island	0.35	4.40	32.40	2.47	1.50
9	Popoulu	0.22	1.20	23.20	2.67	1.50
10	Nendran	0.29	4.13	32.00	2.10	1.50

Among the varieties evaluated, Nendran recorded the highest carbohydrate content of 32.0%, followed by Kunnan (30.67%). Popoulu and Kunnan had the highest protein content of 2.6%. Total sugar varied from 1.20% in Popoulu to a maximum of 4.40% in Blue Torres Straight Island. Acidity among the varieties ranged between 0.22% (Popoulu) to 0.54% (Palayankodan).

## 6. Evaluation of Kunnan based proactive infant food

Dr.Pushpalatha.P.B  
Professor  
[pushpalatha.pb@kau.in](mailto:pushpalatha.pb@kau.in)

### 1. Evaluation of Kunnan powder for nutritional composition

Kunnan banana which is traditionally used as a baby food was analysed for its nutrient composition and assimilative sugar, vitamin C content and mineral composition (Table 1).

Table 1. Nutritional composition of Kunnan banana powder

Nutrient	Quantity
Total carbohydrate	30.67 %
Protein	2.20 %
Fat	0.18%
Glucose	5.00%
Fructose	7.20%
Starch	11.00%
Dietary fibre	2.40%
Vitamin C	12 mg/100g
Potassium	420 mg/100g
Calcium	28 mg/100g
Iron	0.36 mg/100g
Magnesium	32 mg/100g
Phosphorus	34 mg/100g

The present study also proved that Kunnan contains a fairly good amount of total carbohydrates (30.67%), minerals like potassium, iron, magnesium and phosphorus. Potassium and calcium are the minerals which are highly required for the growth and development of infants and hence an infant food was tried with Kunnan powder supplementing the protein with different pulses like bengal gram, ground nut, green gram and soya chunks in different combinations.

### 2. Evaluation of the powder mixes as infant food

On organoleptic evaluation, the treatment T1 was identified as the best combination for infant food involving a combination of Kunnan powder 50 g supplemented with soya chunks (5 g), Bengal gram (10 g), ground nut (5 g), green gram (10 g), sugar (10 g) and corn flour (10g).

## PG Projects

### Concluded Projects

1. Post-harvest studies in Neelamari (*Indigofera tinctoria* L.)
2. Post-harvest characterization and value addition of sweet lovi-lovi (*Flacourtia cataphracta* Roxv.ex. Willd.).
3. Post-harvest evaluation and management of cherry tomato (*Solanum lycopersicum* L. var. *cerasiforme*(Dunal) A. Gray) genotypes.
4. Optimization of methods for juice extraction and value addition of passion fruit (*Passiflora edulis* sims)
5. Development of osmodehydrated bilimbi (*Averrhoa bilimbi* L.) and assessment of bioactive compound.
6. Postharvest handling studies for extending shelf life of rambutan (*Nephelium lappaceum* L.)

### Ongoing Projects

1. Standardization of quality wine production from selected underexploited fruits
2. Feasibility of Pusa Zero Energy Cool Chamber as low cost on- farm storage structure under Kerala condition
3. Characterization and value addition of male buds of banana cultivars.

4. Process standardisation and quality evaluation of wine from banana (*Musa spp.*)
5. Postharvest treatments for delayed ripening in Nendran banana (*Musa spp.*)
6. Evaluation and utilisation of edible lichen *Parmotrema tinctorum* (Nyl.) Hale. for food preservation
7. Standardisation of packaging and storage techniques for green chillies spp. *Capsicum annum*".
8. Development of novel value added products from tender coconut (*Cocos nucifera* L).
9. Portion packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.).
10. Development of osmo dehydrated Red Banana (*Musa spp.*)
11. Development of functional jackfruit pasta
12. *Aloe vera* based edible film coating for shelf life extension in tomato (*Solanum lycopersicum*).
13. Jackfruit (*Artocarpus heterophyllus* Lam.) as a potential source of bioactive compounds
14. Assessment of bioactive compounds and product development from major *Garcinia spp.* of Kerala.



## **Name of Project Coordination Group – (14) Food Science and Nutrition**

**Compiled by:**

**Dr. Suma Divakar Protect Coordinator**

### **Plan & External Aided Projects**

**Concluded Projects - 4 Nos.**

### **Post Graduate Projects**

**Concluded Projects - 7 Nos.**

**Ongoing Projects - 10 Nos.**

## Concluded Projects

### 1. Process optimisation and quality evaluation of jackfruit (*koozha* type) based vermicelli

Dr.Sharon.C.L  
Asst.Professor  
[sharon.cl@kau.in](mailto:sharon.cl@kau.in)

Vermicelli prepared with jackfruit flour along with whole wheat flour, rice flour and jackfruit seed flour (both roasted and unroasted) were highly acceptable for sensory parameters. Roasting of flours improves the sensory attributes especially appearance, texture and taste of vermicelli and *payasam*. Jackfruit vermicelli found to be highest in nutrients like protein, fibre, minerals like calcium, iron, sodium and potassium during entire storage periods than control. The selected jackfruit based vermicelli were shelf stable without any deterioration upto four month of storage in polyethylene pouches (250 gauge). Among the different combinations, instant *payasam* mix prepared with 200g of vermicelli, 1.5 litre of milk and 150g of sugar ( $T_6$ ) was highly acceptable. The cooking time of jackfruit based instant *payasam* was found to be very low when compared to control. The jackfruit based six varieties of instant *payasam* mixes were packed in laminated pouches. Each pouch consists of 200g of roasted vermicelli, 150g of sugar, 10g of toasted cashew nuts and raisins, and 5g of crushed cardamom

### Standardisation and quality evaluation of millet based designer vermicelli

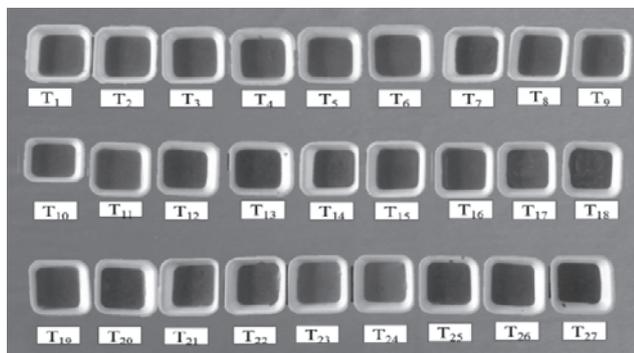
Barnyard millet based vermicelli and *uppuma* incorporated with each functional ingredient were subjected to organoleptic evaluation and showed a highest mean score in treatment  $T_{10}$  for all sensory attributes. Fenugreek, garden cress seed and *Ekanayakam* based vermicelli and *uppuma* prepared with 40 per cent germinated barnyard millet flour, 58 per cent whole wheat flour and 2 per cent functional ingredients were found to be high in overall acceptability with a mean score of 7.77 and 7.88 (fenugreek), 7.88 and 8.31 (garden cress seed) and 7.75 and 7.73 (*Ekanayakam*) respectively, whereas *Brahmi* based vermicelli formulated with (40: 59.5: 0.5) germinated barnyard millet, whole wheat flour and *Brahmi* was highly acceptable with an overall acceptability of 8.02 and 8.22 respectively.

The minerals like calcium, iron, magnesium, zinc and sodium, initially were highest in garden cress seed based barnyard vermicelli of 73.52mg 100 g<sup>-1</sup>, 15.80mg 100 g<sup>-1</sup>, 108.30 mg 100 g<sup>-1</sup>, 5.04 mg 100 g<sup>-1</sup> and 13.40 mg 100 g<sup>-1</sup> respectively. The potassium content was shown to be highest in fenugreek based barnyard vermicelli of 254.62 mg 100 g<sup>-1</sup>. There was a gradual decrease in the mineral content on storage.

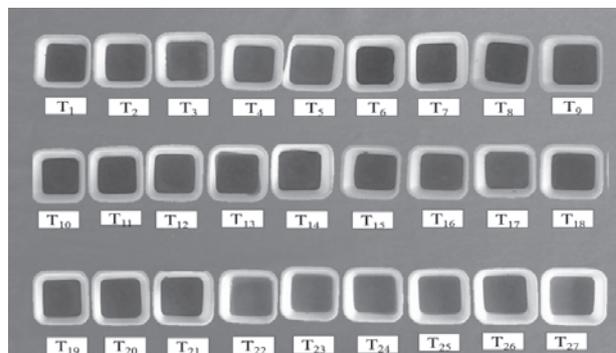
### 2. Standardisation and quality evaluation of millet based composite nutrimites for adolescents

Dr.Aneena.E.R.  
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Millet based composite nutrimites can be developed with high nutritional quality and acceptability. Functional ingredients like garden cress seeds and flax seeds can be used up to 10 per cent to develop acceptable nutrimites formulations and enhance their nutritional qualities. The prepared nutrimites were nutritionally superior with high amount of carbohydrate, protein, calcium, iron, fibre and it was highly digestible with high mineral availability. So it can be considered as a food supplement for adolescents which contain essential nutrients for the growth and development of adolescents. The product was microbiologically safe, shelf stable for minimum 4 months of storage in polyethylene laminated aluminum pouches. The developed nutrimites are suitable for food preparations



Garden cress seeds incorporated millet based composite nutrimites



Flax seeds incorporated millet based composite nutrimites

### 3. Nutritional and organoleptic qualities of value added products from banana Cv. *Musa* (AAA Group) "Grand Naine

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Grand Naine banana chips both salted and chips prepared by adding salt along with pepper were organoleptically acceptable. Chips flavoured with pepper powder and packed in laminated pouches had low peroxide value and moisture content at the end of storage. Grand Naine banana flour is a good source of starch and can be used for preparing porridge and as composite flour. Banana flour prepared by dipping banana slices in 1 per cent ascorbic acid and 0.1 per cent citric acid for 5 minutes and drying at 50°C for 48 hours attained a highest total score for organoleptic attributes. Among the different combinations the treatment T<sub>5</sub> was selected as the best for preparation of banana flour and porridge. Banana flour packed in polyethylene bags was shelf stable upto three months. *Ada* was prepared in different proportion with rice flour and banana flour at three different temperatures. Among the different combinations of *ada* T<sub>17</sub> (50 per cent rice flour incorporated with 50 per cent banana flour dried at 70°C for 2 hrs) was the best. Milk based *payasam* and jaggery based *payasam* prepared with this *ada* had acceptable organoleptic scores till the end of storage studies, which was carried out for a period of three months.



*Payasam ada*

### 4. Standardisation and quality evaluation of millet based designer vermicelli

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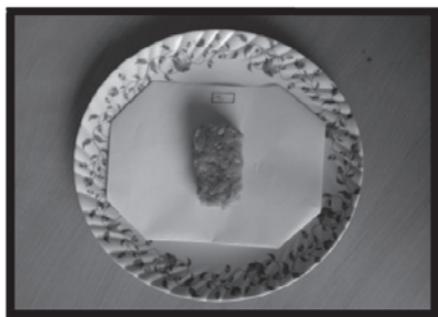
Barnyard millet is an underutilised grain which can be effectively used in development of millet based designer vermicelli incorporated with functional ingredients (2% germinated fenugreek seed / garden cress seed/*Ekanayakam* root barks and 0.5% *Brahmi* leaf powder). The selected barnyard millet based vermicelli and *uppuma* was observed to have good nutritional profile. The barnyard millet based vermicelli was considered to be low glycemic food with high antioxidant activity and mineral bioavailability. The developed products were shelf stable without any deterioration upto four month of storage in polyethylene pouches (250 gauges). The instant *uppuma* mix formulated with selected barnyard millet based vermicelli was most acceptable in T<sub>3</sub> (300ml of water) for fenugreek seed, garden cress seed and *Brahmi* whereas *Ekanayakam* based instant mix prepared, T<sub>2</sub> (250ml of water) was highly acceptable in terms of the sensory parameters.

#### PG Projects

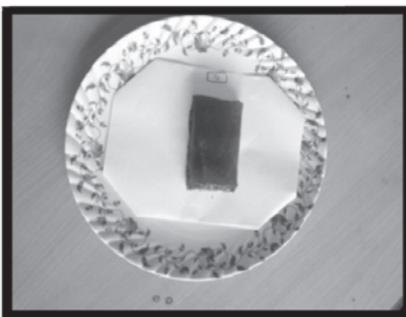
##### Concluded Projects

##### 1. Development and quality evaluation of granular fruit bars

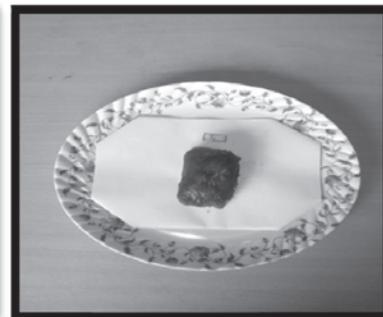
The filling for granular fruit bars were standardised using ingredients such as puffed rice, flaked rice, Bengal gram dhal, jaggery and osmotically dehydrated jackfruit. Papaya(A1), pineapple(A2) and blended coating(A3) were given to the best treatment. Microbial evaluation of GFB, revealed that, no bacterial colonies were seen in cfu 1×10<sup>-7</sup> dilution initially. Few colonies of bacteria and fungus were seen in first month and number of colonies exceeded the safe limit in second month. GFB standardized were nutrient dense, ready to eat products with fruits, grains and pulses with shelf life of one month



**Pineapple bar coated GFB**



**Papaya bar coated GFB**

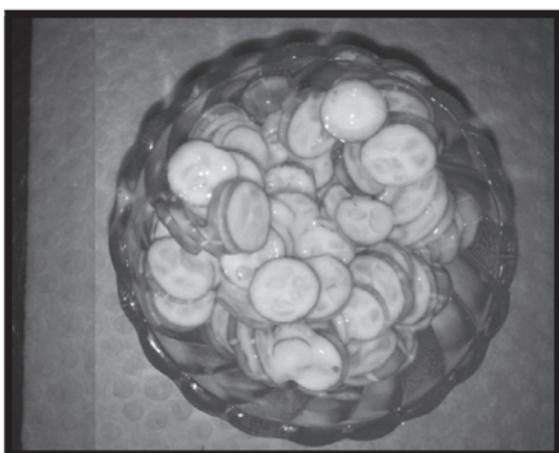


**Blended fruit bar coated GFB**

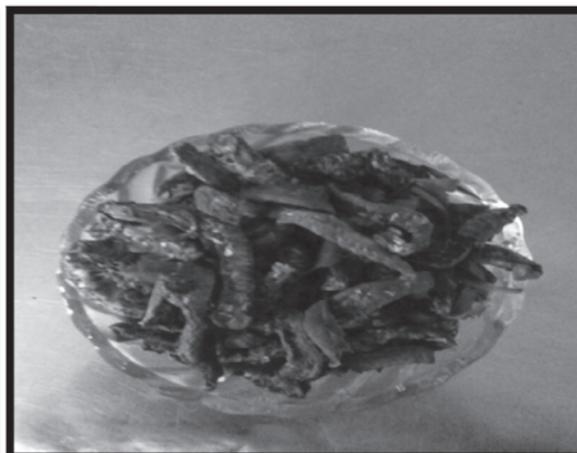
## 2. Quality analysis and development of RTE and RTC products from Ivy gourd)

Salad dressing with mayonnaise, salad dressing with pepper and lime with salad dressing were fresh after four hours and selected as the best three combinations of ivy gourd based ready to eat salads.

The standardised “olath” mix comprised of Ivy gourd, crushed red chilly, garlic, turmeric powder and curry leaves. Parameters like cooking procedure, cooking method, reconstitution time, cooking time and addition of adjuncts were also standardized. The physical characteristics like yield, dehydration ratio, bulk density and water absorption index of the developed RTC mix per 100g were assessed and the result was 38.46, 0.54, 0.18 and 4.5 respectively. Chemical compositions like pH, TSS, reducing sugar, acidity and moisture contents of RTC mix were assessed and the values were 4.84, 4.52 brix, 0.24 percent, 0.87 percent and 5.32 percent respectively.



**Standardised salad**



**Standardised RTC mix**

## 3. Quality Evaluation of Avacado (*Persea Americana*) cultivars and suitability of fruit powder for culinary preparation

Phytochemical studies of four avocado cultivars shown that total phenolic content (3.63mg/100g), total antioxidant activity (480mg/100g of ascorbic acid), total sugar (4.01g/100g), were found to be higher in Pollock whereas reducing sugar was found to be higher in Kallar round (3.82g/100g). The higher amount of vitamin C (3.25mg/100g) and peroxide value (4mEq/Kg) were observed in Fuerte.

Freeze dried powder has excellent nutritive value and extended shelf-life period, which could be exploited for making different products.

## 4. Value added products from jackfruit rind.

Among the four products developed *Koozhapad* and crispies revealed lower carbohydrate (69 g/100g), starch (3.98 g/100g) and fat content (1.02 g/100g) and were rich in crude fiber (0.9 g/100g) and dietary fiber (0.78 g/100g). Iron content in *Koozha* jackfruit rind *pad* was highest (0.117 mg/100g) followed by *koozha* crispies. Sodium content (6.28g/100g) was higher in *Varikka* crispies which could be due to the adjuncts added to it. *Koozhacrispies* were found to be high in total anti-oxidant activity.

The physical characteristics of the jackfruit rind *papads* ( $T_5P$  and  $T_{10}P$ ) has shown significant difference (at 5 % level) in the expansion percentage, thickness after frying and oil uptake and yield, diameter, diameter expansion and bulk density has no significant difference, whereas for crispies, there was significant difference in the thickness and no significant difference for yield and bulk density.

### 5. Development and quality evaluation of geriatric health mix

The best formulations of geriatric health mixes identified comprised of ragi, oats, soya, dehydrated vegetables and skimmed milk powder (their proportions being, 40g: 20g: 20g: 15g: 5g)-T4. and ragi, barley, soya, dehydrated fruit bits, skimmed milk powder (their proportions being, 40g: 20g: 20g: 15g: 5g)-T10.

Nutrient profile of the developed health mix (T4) revealed energy, protein, carbohydrate, iron, calcium, potassium, sodium and fiber level to be 310.03kcal, 18.80g, 54.07g, 5.08mg, 272.52 mg, 172.54 mg, 5.88 mg and 7.50 % respectively. In the case of T10, it was 309.72 kcal, 17.98 g, 54.21g, 4.43 mg, 270.45 mg, 174.34 mg, 6.37 mg and 7.87% respectively. The moisture, acidity and peroxide content were seen to increase with storage, but were within the prescribed limits.

### 6. Effect of cluster beans (*Cyamopsis tetragonoloba* (L.) taub.) on dietary management of life style disorders

Popular recipes such as soup, salad, bread spread, chutney powder and steamed ball were standardized and preserved products namely a minimally processed product, a ready to cook product and dehydrated powder were processed. It was observed that diet counselling played an important role in cluster bean consumption. Knowledge level and dietary practices were analysed during the pre and post counselling periods. The results revealed that knowledge level and dietary practices had improved after diet counselling.

The experimental group was supplemented with cluster bean powder for one month on a daily basis. The blood profile was assessed and it was found to improve both lipid profile and glucose levels of the respondents after supplementation.

### 7. Nutritional profile of preschool children (4-6 years) belonging to tribal families in Thrissur district

The food habits of the families are mostly deviated from the ancient tribal food habits. At present they follow a three day meal pattern. The Public distribution system provides cereals and pulses for these families. The children also participate in different supplementary feeding programmes.

The results of the present study assure the fact that there malnutrition is still prevalent among the tribal preschool children. The tribal preschool children are more malnourished compared to the non-tribal counterparts. The delayed growth could be due to low economic status and low food and nutrient intake. Hence an integrated approach is necessary to overcome these problems. Nutrition education and short term appropriately planned nutritional intervention programmes may also be beneficial for improving the nutritional status.

### Ongoing Projects

1. Garden based diet therapy for school going students with Attention Deficit Hyperactivity Disorder
2. Development and quality evaluation of fruit spreads from avocado (*Persea americana* Mill)
3. Antioxidant and anti-carcinogenic potential of jackfruit based ready to cook curries
4. Development of herbal drink mix from papaya leaves and evaluation of its anticancer potential.
5. Profiling Bioactive Compounds in Avocado (*Persea americana* Mill.) Cultivars and Freeze Dried Fruit Powder, and investigating its Potential in Cancer Cell Line.
6. Nutritional and antioxidant potential of medicinal rice variety *Rakthashali*
7. Quality evaluation of lotus rhizome and its suitability for product development.
8. Process optimisation and quality evaluation of fruit pulp based yoghurts
9. Quality evaluation of tannia corm (*Xanthosoma sagittifolium* (L.) Schott) and its suitability for product development
10. Standardisation and quality evaluation of nutri spreads



**Name of Project Coordination Group : – (15)  
Agricultural Economics, Statistics and  
Agri. Business Management**

**Compiled by:**

**Dr. Regeena.S. Protect Coordinator**

**Plan & External Aided Projects**

**Concluded Projects - 1 Nos.**

**Ongoing Projects - 1 Nos.**

**Post Graduate Projects**

**Concluded Projects - 16 Nos.**

**Ongoing Projects - 9 Nos.**



**Concluded Projects****1. Organic Farming in Kerala: Field Realities and Strategies for Future**

Dr.P.Indira Devi  
Professor  
[devi.indira@kau.in](mailto:devi.indira@kau.in)

The project was carried out to document the existing practices of organic farming in Kerala and assess the economic viability based on case studies, compare its economic and environmental viability with chemical based farming, to identify major constraints and prospects of organic farming in Kerala and to develop a guide/ road map for promotion of organic farming in Kerala. Four existing practices, viz., Spiritual Farming/ Zero Budget Farming/ Natural Farming, Biodynamic Farming, Homeo treatment in Agriculture and Organic Farming were documented. Economics of organic cultivation of different crops was also analyzed. Results are presented below:

**A. Rice**

In case of rice, the returns from Organic farms were less by 6 per cent. The price premium enjoyed by only a few growers, however resulted in higher returns. But generally, the premium which is enough to offset the production difference, is not enjoyed by many

**B. Banana**

Though, organically produced banana fetches 20 per cent more price than the conventional method, average yield per hectare from organic fields was 13 per cent lower than the other. Banana cultivation under organic system was more profitable due to better price realization.

**C. Coconut**

Yield was almost similar in both cases but there was a variation of 20 per cent in the price obtained under two situations. Organic coconut farms in the study area have access to international market. They are selling their produce directly to the exporter. Farmers enjoy 10-30 per cent higher than conventional produce.

**D. Pepper**

Cost was slightly lower due to the use of homemade plant management solutions and household labour in organic farming. Cost was high in chemical farming since the house hold labour is not used for pest management practices and the extensive use of chemicals. Yield was slightly higher in those farms which followed chemical farming practices.

**E. Price difference between organic and conventional produces paid by the consumer**

Price of both organic and conventional produces was compared, in order to evaluate the affordability of organic produce at the different income groups. For plantain and banana price variation was lower compared to the conventional produce. Vegetables like Tomato, Brinjal, Ladies Finger, Ivygourd, Cucumber and Amaranths had the highest price difference of more than 150 per cent. Chilly, Drumstick, Cabbage, Carrot, Bitter gourd, Elephant Foot Yam showed 100-150 per cent price difference, while Beans, Snake gourd, Cowpea, Ginger and Curry Leaf have a price difference of 51-100.

The major constraints and prospects of organic farming in Kerala were analysed and are given below.

**1. Farmer perceptions and production performance**

44 per cent of the respondents report there is no yield reduction. 52 per cent who report yield reduction differs with respect to the extent of decline, reporting 13 to 40 per cent yield decline. One third of them opined that the yield get stabilized by three years while 61 per cent says that it may take more time.

**2. Organic inputs-Challenges in Supply Management**

The small and marginal farmers face difficulties in getting organic manures. Only 15 per cent of the farmers were aware of the biofertiliser technology and a mere 9 per cent have ever tried it, even in organic farming methods.

**3. Influence of external factors in production**

The high gradient and undulating terrain of Kerala has created problems in following organic methods atleast in certain farm holdings.

**4. Problems in Marketing**

Low-level of information about organic production is a major challenge especially for medium and small farmers. High transaction cost, lengthy and complex certification process is also a limiting factor.

**5. Absence of appropriate institutional and policy support**

There is no subsidy oriented to organic agriculture and there is no mechanism to ensure higher price for organic produce.

**6. Lack of Financial Support**

The financial support advanced in many of the developed countries for organic farming is not seen in developing countries like India. The credit policy presently does not differentiate organic farming with conventional agriculture. There is no scale of finance for organic farming.

**7. Vested Interests**

Strong oppositions from the seed, fertilizer and pesticide industries, imparts a great threat for the development of organic farming.

### **Policy Suggestions for promotion of organic farming in Kerala.**

1. There should be policy interventions that map the prioritization of implementation of organic policy from highlands to low lands. Legal measures to popularize organic farming may be thought of.
2. KAU must take organic farming as a mandate and develop a protocol to bring maximum area under organic way of agriculture. Research should focus on developing varieties that perform high under organic management as well as soil health and management to facilitate soil biological activity. Courses like PG diploma in organic certification can be designed and offered by KAU. A scientifically designed 'Calendar of organic cultivation' for major crops of Kerala may be developed.
3. The existing protocol for different systems must be scientifically validated. Indigenous Technical Knowledge (ITKs) should also be scientifically validated. The organic farming technologies must be standardized and made amenable to commercial production.
4. Cultural, mechanical, agronomic and ecological engineering options are to be explored and scientifically tested for the management of Pest and disease in organic crops.
5. The existing subsidy systems must be extended to organic farming systems as well and appropriate compensation for the yield loss if any may be provided.
6. A scale of finance for organic farming may be developed.
7. Market support and market promotion strategies may be initiated. Uniform pricing based on cost of cultivation and value addition of organic produce can be thought of.
8. Social media can be effectively used for market promotion.

### **Ongoing Project**

#### **1. Organic Farming in Kerala: Field Level Experiences on Soil Quality and Production Performance**

Dr.P.Indira Devi  
Professor  
[devi.indira@kau.in](mailto:devi.indira@kau.in)

The major objective is to assess the biological and chemical status of the farm soils under organic farming and non organic farming management regime.

### **PG Projects**

#### **Completed Projects**

##### **1. Institutional preference for agricultural credit in Kasaragod district of Kerala**

Cooperatives are having an upper hand in the disbursement of agricultural credit for all the farmer categories followed by RRBs and public sector banks, with respect to the number of farmers financed. However, public sector banks have disbursed the highest amount of loans followed by private banks and RRBs. Co-operatives have mostly concentrated on small ticket loans targeted at marginal and small farmers.

The farmers are found to have borrowed less from micro finance institutions and private sources like money lenders. The log linear regression analysis results reveal that, area is the main predictor that has influenced the credit availed by farmers while other factors such as distance, number of visits to bank, expenses, interest rate and age failed to have any influence.

The level of awareness about various Schemes like Agricultural Gold Loan (AGL) and General Credit Card (GCC) is low among farmers. In the case of those schemes about which they are aware, viz, Crop Loans and Kisan Credit Card (KCC), the extent of utilization is also low at around 50 per cent. The level of awareness about livestock schemes is still lower with more than two – third of the farmers not aware at all.

For all the farmers - marginal, small and large - co-operative banks are the most preferred choice of institutional finance, followed by RRBs as the next best alternative. The results of factor analysis showed that institutional factors explain 36 per cent of the choice of institutional source and credit related factors are responsible for 29 per cent choice of source of finance. The farmers do not hesitate to meet and talk to any officials of a co-operative bank and the environment of the bank is much comfortable to the farmers and as they feel it as their own. But the case is not so with public sector banks where farmers are still reluctant to approach.

Proximity to the lending institution, cost of credit, adequacy and timeliness do not have any influence on the institutional preference of farmers. However, factors like procedural hassles, approachability, banker's behavior and flexibility are

found to affect the choice of source of finance.

Eighty per cent of small and marginal farmers are not satisfied with the interaction pattern of commercial bank managers. Almost 93 per cent of them are facing problems in pooling the documents required for submitting the loan application.

The marginal and small farmers remain underprivileged due to various institutional and credit related factors affecting credit delivery. Co-operatives are the most preferred source of finance which needs revival keeping in view of the present issue of demonetization.

As micro credit could not make any significant contribution for financing the agrarian activities in the study area, micro credit channels have to be improved for providing farmers with necessary finance, which can serve as bridge loans, i.e. as term loans till their term credit/working capital finances are sanctioned and disbursed from institutional sources.

## **2. Economic analysis of production, marketing and price behaviour of coconut**

The area, production and productivity of coconut in India showed an increasing trend during the period from 1980-01 to 2015-16. As compared to Indian scenario, there was no continuously increasing trend observed in case of area and production of coconut in Kerala during the same period, which exhibited growth rates of 0.4 per cent for area and 2.12 per cent for production. However, the productivity showed an increasing trend during the above period.

The analysis on the growth performance of coconut in India revealed that area, production and productivity of coconut had shown an increasing trend, with the exception of growth in area and production during Period I. During Period II, in spite of a higher growth in productivity, the growth rate was lower for production due to stagnant growth in area. However, the growth in area, production and productivity during the overall period under study was significant and positive. In case of Kerala, productivity-based growth of output was observed which means that the growth in production of coconut was mainly by the contribution of growth in productivity rather than area.

The price behavior of coconut and copra in major markets of Kerala viz., Alappuzha and Kozhikode were analyzed by decomposing the monthly price data into four components viz., secular trend, seasonal variation, cyclical variation and irregular variation assuming a multiplicative model of time series. The price of coconut and copra in these markets showed an increasing trend in the long run. While analysing the seasonal variation, it was noticed that during the Period I (1980-01 to 1995-96), price of coconut showed wide fluctuations in both the markets but it was considerably low in the Period II (1995-96 to 2015-16) whereas, the seasonal variation of copra prices in both the markets showed a similar pattern. Three to four cycles were seen in both the market prices but the length of cycles was observed to be varying. Co-integration analysis of coconut prices in the above two markets were carried out and it was revealed that both the markets were integrated. In order to provide additional evidence as to whether and in which direction, price transmission was occurred Granger Causality test was carried out and the results proved the existence of unidirectional causality between Kozhikode and Alappuzha market prices in the long run.

Since coconut is a perennial crop, its yielding phase was assumed to be 50 years, with a non-bearing phase of 7 years. The cost and returns were estimated taking into account the establishment cost and the maintenance cost. The cost of cultivation per hectare was Rs. 1,01,989 with a net return of Rs. 24,011. It was noted that human labour accounted for 50 per cent of the total cost. To evaluate resource use efficiency in coconut cultivation, Cobb-Douglas production function was fitted. Manures, fertilizers and plant protection chemicals were found to be significantly contributing towards the yield. Moreover, an increasing returns to scale in coconut production was observed in the study area which implies that there is ample scope to increase the profit of farmers by proper adoption of technology and by optimal allocation of resources.

Majority of sample farmers in the study area sold coconut in the form of copra till the last few years. But during the last 5 to 6 years, 70 per cent of the produce being marketed was in the form of raw nuts. Lack of storage facilities and fluctuating prices made the producers to sell raw nuts immediately after harvesting instead of waiting for a higher price. Majority of the wholesalers in the study area sell raw nuts in Coimbatore market, Tamil Nadu where they get a reasonable price. The most efficient marketing channel identified in the study area was channel 3 (Producer- retailer- consumers) with a high efficiency index of 5.2.

Major constraints identified in the study area were wide fluctuations in coconut prices, high labour cost, pests and diseases attack and inadequate procurement scheme. In order to tackle these problems, it is necessary to encourage coconut farmers to replant old and senile trees by providing subsidy and ensure high production by strengthening the existing procurement scheme. Strategies emphasizing implementation of comprehensive coconut rejuvenation programmes,

enhancing productivity through better technology integration and value addition through product diversification to ensure better price for farmers are suggested.

### 3. Price forecast models for coconut and coconut oil

To estimate seasonal variations in prices of coconut oil, copra and coconut, to evaluate different time series forecast models for prices of coconut oil, copra and coconut and to suggest suitable forecast models for Alappuzha, Kochi and Kozhikode markets.

Time series data on monthly average prices of coconut oil and copra for Alappuzha, Kochi and Kozhikode markets from January 1990 to December 2015 and coconut price at Alappuzha market from January 1998 to December 2015, from Coconut Development Board (CDB), Kochi formed the database.

Analysis of price pattern revealed that wide fluctuation exists in the prices of coconut oil and copra at Alappuzha, Kochi and Kozhikode markets and price of coconut at Alappuzha market. For coconut oil and copra price, the coefficient of variation was around 50 per cent indicating the instability in prices and a coefficient of variation of 37 per cent for coconut price showed that variability in price is lower than that of coconut oil and copra.

Seasonal indices for the 12 months from January to December showed that December is the peak price month for coconut oil at Alappuzha and Kozhikode markets, whereas it is January at Kochi. Lowest price is observed in May at Alappuzha and Kozhikode markets, whereas, at Kochi it is in July. In all the three markets, September– February is the buoyant phase and price depression is during March - August. For copra, peak price is in December at Alappuzha and Kochi markets, whereas, it is in November at Kozhikode. Trough price for copra is in May in all the three markets. October to February is favourable for copra price in all the three markets, whereas, depressed phase is from March to September. For coconut, peak price at Alappuzha market is in December and the buoyant phase is from November to February. April is the low price month with depressed phase from March to October. During the summer months from March to May, harvest the coconuts as tender and increase the production of neera. Also, during March- September, where the price of coconut oil and copra is low, steps are to be taken to convert coconut into other value added products like desiccated coconut powder, virgin coconut oil, activated carbon etc. and to identify regular markets in major cities of India as also outside India.

Different forecast models viz., Auto regressive Integrated Moving Average (ARIMA), Artificial Neural Network (ANN) and exponential smoothing models (single, double, Holt-Winters' additive and multiplicative seasonal) were fitted and compared for prices of coconut, coconut oil and copra in different markets. Holt-Winters' Multiplicative Seasonal (HWMS) model is the appropriate forecast model for price of coconut oil at Alappuzha and Kochi markets. At Kozhikode market, Seasonal ARIMA(1,1,1)(1,0,1)<sub>12</sub> and HWMS are equally good. HWMS model is selected as the suitable forecast model for copra at all markets. ARIMA (0,1,1) model is suitable for forecasting price of coconut at Alappuzha market.

### 4. Groundwater irrigation: Management, adaptation and economic costs under declining resource conditions

The main objectives are to analyse the extent of decline in groundwater resources and farmers' understanding of the same, to analyse the extraction practices, management and economic efficiency of groundwater irrigation and coping (short term) and adaptation (long term) strategies towards management of groundwater decline and the economic cost of adaptation strategies.

The study was conducted in three Block Panchayats (BPs) falling under three classes of groundwater development (over-exploited, critical and semi-critical) in Palakkad, one of the agriculturally prosperous districts of Kerala. Three BPs viz. Chittur, Malampuzha and Pattambi (falling under over-exploited, critical and semi-critical classes of groundwater development) were purposively selected for the study. 100 farms (50 open well irrigated and 50 bore well irrigated) from each BP were randomly selected from the GPs (GramaPanchayats) where observational wells of GWD (Ground Water Department, Palakkad) was situated. The lists of farmers available in the KrishiBhavans of these GPs served as the sampling frame. Primary data was collected from the sample farms by field visits through personal interview method using pre-tested structured interview schedule and through direct observation. Secondary data on well water levels of Groundwater Monitoring Wells (GMWs) of GWD (Ground Water Department, Palakkad) and rainfall data from meteorological observatories in the BPs were also used for the study. Statistical tools like descriptive analysis, regression analysis and stochastic frontier analysis were employed for the analysis of the data.

In most of the GMWs in the study area, the Water Level from Ground (WLG) has been declining over the years. The trend was more predominant during early summer (Dec.–Jan.) in Chittur and Malampuzha and in late summer in Pattambi BP. Regression analysis showed that WLG was significantly influenced by one year lagged rainfall in Chittur and current year

rainfall in Malampuzha and Pattambi.

The average well density was 205/km<sup>2</sup> with highest in Pattambi. Density of defunct wells was highest (45/km<sup>2</sup>) and the average functional age of bore wells was lowest (7 years) in Chittur. The depth of well was highest in Chittur where bore well depth (136 mbgl- meters below ground level) was double than that of Pattambi. Coconut based cropping system was prevalent in most of the farms except in Malampuzha where paddy was the major crop. Flood, basin and sprinkler irrigations were found to be more common in Malampuzha and Pattambi BPs, while drip irrigation was prevalent in Chittur. Cost of irrigation in Chittur was about Rs. 29,000/ha/year which accounted for 37 per cent of cost of cultivation. Annual net return per ha. of farm was lowest (Rs. 17,640/-) in Chittur due to low cropping intensity. Stochastic Frontier Analysis indicated that mean economic efficiency was high (99.9 %) in Chittur as most of the farms were functioning along the cost frontier. The variability among the farms in Chittur was low.

Respondents opined that groundwater is declining over the years irrespective of the region. Farm level adaptations to water scarcity are classified under 'supply management' (methods that facilitated increase in quantity of water available for irrigation) and 'demand management' (methods that tried to use the water effectively through minimizing the use) strategies. The supply management strategies were mainly exploitative in nature which included digging new bore well (52-58 %), improved draft technology with compressor pumps (58 %), taking pits for water conservation (7 %), coconut husk burial (12 %), coconut leaf mulching (18 %) and dependence on water markets (8 %). Digging new bore well was the most common supply management strategy in Chittur which is highly capital intensive. The average cost amounted to Rs. 8,520/ha/year. Intensive extraction was done by excessive use of subsidized electricity. Adoption of drip irrigation (60 %) was the most widely practiced demand management strategy which cost about Rs. 22,000/ha/year. Cropping pattern change from paddy and sugarcane to coconut was also observed. About 18 per cent of the land area in Chittur was kept fallow due to water scarcity.

The study brings out results that suggest policy interventions in regulating bore well digging and revisiting the power subsidy system. In Chittur area, where the rainfall is scanty, extension of the Right Bank Canal of the Chittur River irrigation project is the most feasible solution. Taking up on-farm research trials in the area to suggest efficient farming systems and practices may also be done. Simultaneously water resource conservation strategies are to be popularized through awareness creation, capacity building programmes and subsidy support.

### 5. Market access to quality paddy seed in Kerala

Rice seed production and distribution scenario in Kerala can be broadly documented as formal rice seed supply chain and informal rice seed supply chain. Informal supply include farmer saved seed and farmer exchanged seed. Formal rice seed supply is done through different agencies such as KSSDA (Kerala State Seed Development Authority), NSC (National Seeds Corporation) and KAU (Kerala Agricultural University). The major formal rice seed supply chains are:

Chain 1: KAU Research Station – Rice farmer

Chain 2: Agriculture Research Station – Participatory rice seed production unit – Participatory rice seed grower – Participatory rice seed production unit – Rice farmer

Chain 3: Agriculture research station – State Seed Farm (SSF) – KSSDA – Registered rice seed grower – KSSDA – Rice farmer

Chain 4: Agriculture research station – NSC (National Seeds Corporation) – Registered rice seed growers – NSC (National Seeds Corporation) – Rice farmer

Economics of rice seed production in farmers' field came to Rs. 68628/ha, out of which hired human labour accounted for 51 per cent followed by material cost (25%) and machine labour (18%). Average rice seed yield at farmers' field was 5331 Kg/ha with a gross income of Rs. 152089/ha. Benefit Cost Ratio was found to be 2.22 at Cost A1 and 1.66 at Cost C2.

Major constraints faced by rice seed growers were untimely seed procurement and payment followed by climate change and high labour cost. Constraints faced by rice farmers in access to quality rice seed was lack of timely availability followed by poor seed quality and unavailability of subsidized seed in required quantity. Access to Seed Index (ASI) was also worked out in order to compare different supply chains in terms of accessibility to rice farmer. KAU rice seed supply chain (chain 1&2) was having highest ASI (0.657) followed by KSSDA rice seed supply chain (0.644) and NSC rice seed supply chain (0.433).

### 6. Economic analysis of production, marketing and price of arecanut in Kasaragod district of Kerala

The area, production and productivity of arecanut in India showed an increasing trend during the period from 1980-81 to 2015-16. As compared to the Indian scenario, the increase in area, production and productivity of arecanut in Kerala was more discernible after 1990s. Export potential of arecanut was limited as bulk of the quantity was consumed within India.

The import of arecanut to India showed an increasing trend especially after 1990s, which could be attributed to the economic reforms of 1991, subsequent WTO agreement of 1995 and other proliferating Regional Trade Agreements.

The price behaviour of ripe arecanut in Nedumangad and Telicherry markets and dry arecanut in Nedumangad, Calicut and Kanhangad markets were analysed by decomposing the monthly price data into four time series components viz., secular trend, seasonal variation, cyclical variation and irregular variation, assuming a multiplicative model of the time series. The price of ripe and dry arecanut in these markets showed an increasing trend in the long run. While analysing the seasonal variation, it was noticed that arecanut prices shows considerable seasonality. Three to four cycles were seen in both the markets but the length of cycle was observed to be varying. Pair-wise cointegration analysis of arecanut price in the above said markets were carried out in the following combinations; Nedumangad ripe and Telicherry ripe, Nedumangad dry and Calicut dry, Nedumangad dry and Kanhangad dry and Calicut dry and Kanhangad dry, which revealed that all the markets prices were co-integrated. This proved that there is strong co-movement of prices between the markets of arecanut within the state.

The establishment cost of arecanut garden for the first year was worked out as Rs. 1,84,605 per hectare and land preparation accounted for the major share of the cost during the first year. The total establishment cost up to the bearing stage was estimated as Rs. 3,43,386.

The cost of maintenance for yielding categories in aggregate was worked out as Rs. 2,01,522 per hectare. The cost of maintenance per hectare worked out for yield increasing, yield stabilising and yield declining stages was Rs. 2,13,075, Rs. 2,06,925 and Rs. 1,58,608 respectively. The cost of cultivation per hectare was estimated as Rs. 2,67,164, with a net return of Rs. 1,30,085.

During the entire economic life span of arecanut palms, human labour contributed the major share in the input-wise cost. Plant protection accounted for major share of the total cost during the yielding phase of arecanut palms and was followed by expenditure on green manure.

The cost of production of arecanut was worked out as Rs. 133, Rs. 166 and Rs. 137 per kg for yield increasing, yield stabilising and yield declining stages respectively. The cost of production in aggregate was estimated as Rs. 150 per kg in Kasaragod district. To evaluate resource use efficiency in arecanut cultivation, Cobb-Douglas production function was fitted. Plant protection chemicals were found to be significantly contributing towards the yield per hectare while expenditure on human labour was found to be negatively contributing to yield per hectare.

About 45 per cent of the total sample farmers sell their produce in the form of dehusked dried nut to the village traders as they get immediate payment in cash, while 40 per cent of sample farmers sold through CAMPCO.

The four marketing channels identified were, (i) Producer-village trader-wholesaler-retailer-consumer, (ii) Producer-wholesaler-retailer-consumer (iii) Producer-CAMPCO-retailer-consumer and (iv) Producer-consumer., of which the first three were the important ones. The marketing cost was highest in channel I (Rs. 33.9), and lowest in channel III (Rs. 28.44). The marketing margin ranged from Rs. 25 per kg in channel I to Rs. 16.5 per kg in channel II and the share of marketing margin in consumer's prices ranged from 9.09 per cent and 6.15 per cent. Price spread was highest (Rs.58.90) in channel I and lowest in channel III (Rs.16.76). The producer's share in consumer's rupee was 83.02 per cent in channel III, while it was 78.54 per cent in channel I. The marketing efficiency was highest in channel III (9.42 per cent) and lowest in channel I (8.11 per cent).

Scarcity of skilled climbers for harvesting and spraying of plant protection chemicals were identified as the major constraint, followed by water scarcity. The major constraints faced by sample farmers in production were occurrence of diseases and pests, wild animal attack, high wage rate, climate change and wind and lightning. Fluctuation in prices was the foremost constraint faced by the farmers in marketing of arecanut.

Based on the above findings the following policy interventions are suggested:

1. Mechanization of operations- efficient sprayers for plant protection measures on arecanut bunches from the ground and self-operated climbing devices.
2. A workable price stabilization mechanism and regulation on the import of arecanut.
3. Farmers should be encouraged to avail the warehousing facilities to store their product and use the warehouse receipt as a negotiable instrument to avail loans.
4. Value addition and product diversification of raw arecanut to help the farmers to move up in the value chain.

5. Market intelligence and extension approaches should be strengthened to help the farmers in making decisions on timely harvesting, storage and sales.
6. Efforts must be taken to strengthen and restructure the existing water harvesting schemes initiated by NABARD and other government agencies.

### **7. Assessment and management of risk at farmer's level in rice and banana cultivation**

Paddy farmers face production constraints, financial constraints, marketing constraints and institutional constraints. Production risk was captured through their responses on realized yield levels during the past 10 years. The maximum realized yield was reported to be 5718 kg/ha with high variability at 96.8 per cent. This was realized only during two years over a span of ten years. The minimum yield was found to be 4181 kg/ha realized for three years and showed higher levels of inter-farm variability. Maximum average returns realized amounted to Rs.1.28 lakh at a unit price of Rs.22.50/kg whereas minimum return realized was Rs.41812 at Rs.10/kg.

Uncertainty in prices is one of the major factors that affect profitability in paddy cultivation. Over the past ten years, maximum realized price was Rs.22.50/kg, in the year 2017-18 and the minimum realized price was Rs.7/kg during the year 2005-06.

Own source forms the source of capital to only 32.50 per cent of the sample respondents. Of the total borrowed capital, 51.85 per cent was extended by the cooperative societies and 37.03 per cent by scheduled commercial banks and the rest of the amount was advanced by RRBs (11.11 per cent). Lack of availability of timely credit, high procedural formalities and lack of easy accessibility are the major financial constraints.

Institutional risk results from uncertainties surrounding government actions. Various institutions are functioning at national, state and local levels with various schemes to protect and preserve rice cultivation in the state. The intervention of the Kerala State Government through the paddy Procurement Scheme of SUPPLYCO is a major step for the promotion of rice farming. Farmers in the survey area agreed that they have largely benefitted from the procurement of paddy by the Supplyco. The delay in effective payment after the procurement (3-4 months) and failure to procure on time cause difficulty to farmers.

To estimate the production risk associated with rice cultivation, Modified Just and Pope production function was fitted. It was found that higher levels of investment on fertilizers and plant protection chemicals increases the risk in paddy production. Higher levels of labour involvement and larger holdings are found to be less risky.

To identify the major risks faced by paddy farmers in the study area, Henry's Garrett Ranking Technique was employed. Unexpected change in weather conditions is perceived as the most important risk factor with an average score of 70.90 followed by the severity of pests and diseases with an average score value of 70.35. Delay in receiving payment from the Civil Supplies was recognized as the next major risk factor. All the respondent paddy farmers are having labour problems such as lack of skilled labourers and high wage levels as the paddy farming is highly labor intensive. It was observed that out of the total cost of cultivation (Rs.62232), labor cost amounted to Rs.23264/ha and accounts for the highest share (37 per cent of total cost). The total cost incurred for seeds, fertilizers and plant protection chemicals are Rs.3972, Rs.12740 and Rs.9052 respectively. These together accounted for 41.35 per cent of the total cost of cultivation.

Agricultural insurance is considered to be an effective mechanism to tackle farm loss. Despite the high production and market risks in agricultural sector, the insurance coverage among the sample respondents was low. In the present study, only 47.5 per cent of the total sample respondents had insured their crops. Of the total insured farmers, 52.6 per cent depend upon Weather Based Crop Insurance Scheme (WBCIS) and 47.4 per cent depend upon State Insurance Scheme. The average cost of the insurance worked out to Rs.1000/ha. Age and years of experience of the farmer and the size of land holding had significant influence on the probability of farmer to adopt crop insurance as the risk management strategy.

The risks in banana farming was analysed by similar methods based on a sample size of 40 banana growers. The production risk in banana was captured through the realized yield levels. The maximum realized yield was reported to be 22330 kg/ha with a variability of 107 per cent. The minimum yield was 14342 kg/ha with very high variability of 128 per cent. Returns per hectare ranged from Rs 9.30 lakhs at a unit price of Rs.50/kg to Rs.2.15 lakhs at Rs.15/kg.

92.50 per cent of farmers sourced capital from external sources. Of this, 67.56 per cent was from the scheduled commercial banks and 24.32 per cent from cooperative societies and the rest by RRBs (8.10 per cent).

The marketing system of banana in the state is comparatively well organized and being a highly perishable commodity, the produce suffer losses in quality and quantity before it reaches the consumers. 85 per cent of the respondent banana farmers depend upon VFPC market to sell their produce. Farmers are getting good support from VFPC for large scale agricultural production and better price realization resulting in increased agricultural income and reduced indebtedness. To estimate the production risk associated with banana cultivation, Just and Pope Model was used with some modifications. It was observed that land holding size, human labour involvement and expenditure on manures resulted in significant positive impacts on production level. Higher levels of labour involvement (family or hired) leads to better monitoring and management. Educated farmers were found to be more efficient in risk management, often reducing the level of risk. Wide fluctuations in the market price, damage by wind, high labour cost and high cost of inputs were the major constraints to farmers. 72.5 per cent of the sample respondents had insured their crops under the State Insurance Scheme with a premium of Rs.2.50/plant. Education, years of experience and land holding size has significant influence on the banana farmers to make a choice on adoption of crop insurance as a risk management strategy.

### **8. Economic impact of microbial inoculants on vegetable production in Thiruvananthapuram District. 2017**

Average size of holding of selected farmers was 46.03 cents. Analysis of the extend of use of microbial inoculants revealed that only 27 and 17 per cent of the respondents were following the recommended rates in yard long bean and amaranthus respectively whereas 53 and 70 per cent were applying MI above the recommended rate. In the case of amaranthus as well as yard long bean, MI using farmers obtained more yield (7835kg/ha) compared to conventional farmers (7306 kg /ha) and the respective cost of production were Rs.7/kg and Rs.10/kg at cost  $A_1$ . In the case of yard long bean, the B:C ratios of conventional farmers and MI using farmers were 1.46 and 1.51 and net returns were Rs. 51,072/ha and Rs.122716/ha respectively. In the case of amaranthus the B: C ratios were 1.17 and 1.19 and net returns were Rs.21, 463/ha and Rs.48662/ha respectively for conventional and MI using farmers. Present study revealed that by using MI, cost of cultivation per ha of yard long bean and amaranthus can be reduced considerably when compared to conventional cultivation. High cost of seeds, high cost of panthal material and high pest and disease incidence were identified as major constraints in vegetable production.

### **9. Exploratory analysis of Permanent Manurial Trials in rice**

To compare the efficacy of different statistical tools for measuring the consistency of performance of rice, to optimize the fertilizer requirement, to study the transition in yield due to differential fertilizer and climate exposures and to differentiate between organic and inorganic fertilizer treatments on rice using sustainability yield index.

Exploratory Data Analysis using graphical and non-graphical methods was attempted to realize yielding behavior of treatments. Summary statistics viz., mean and median explicitly showed that treatment  $T_1$  - Cattle manure at 18000 kg ha<sup>-1</sup> was superior followed by treatment  $T_5$  - Cattle manure at 9000 kg ha<sup>-1</sup>+ ammonium sulphate to supply 45 kg N ha<sup>-1</sup>+ superphosphate to supply 45 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + 45 kg K<sub>2</sub>O ha<sup>-1</sup> as muriate of potash. Box plot of yield data remarked consistent yielding performance for the same treatments during both kharif and rabi seasons. Yield trend as assessed by regressing crop yield on time factor showed no significance in yield trend. Analysis of groups of experiments also superiority of treatment  $T_1$  followed by  $T_5$  during both seasons.

Influence of weather on grain yield was studied for three growth stages of rice viz., early tillering to panicle initiation, panicle initiation to flowering and flowering to milk stage. The results followed from correlation and regression analysis pointed to minimal role of weather in affecting grain yield. Consistency of treatments assessed through two consistency measures showed that treatments  $T_1$  and  $T_5$  had average consistency. Maximum Sustainability Yield Index (SYI) was recorded for treatments  $T_1$  followed by  $T_5$  during both seasons.

Statistically optimum fertilizer requirement was obtained by compiling the results followed from the aforementioned analyses. Treatment  $T_1$  - Cattle manure at 18000 kg ha<sup>-1</sup> to supply 90 kg N ha<sup>-1</sup> was chosen as the optimal fertilizer schedule for rice.

### **10. Time series analysis and forecasting of the prices of Indian Natural Rubber**

To decompose the prices of Natural Rubber (NR) into time series components, evaluate the growth and instability in prices of NR, study the relationship between international and domestic prices of NR, determine the factors affecting NR prices in pre WTO and post WTO periods and find appropriate model for forecasting the prices of NR.

The decomposition of domestic rubber prices into time series components was carried out under the assumption of additivity. The data were decomposed into trend, seasonal and cyclic components. The trend values proved that there was quadratic trend over the years. By trend values, it was concluded that from the year 1995, there was a great variation in domestic price. Seasonal indices revealed that the highest price was in June and lowest price in December. Cyclic

components showed three cycles over the period of time under investigation i.e., from the year 1980-1992, 1992-2002 and 2002-2016.

For evaluation of growth and instability, volatility and instability analysis were carried out for pre WTO, post WTO and overall periods in terms of rupees and dollars. Intra-annual volatility (within year dispersion) and inter annual volatility (between year dispersion) were higher in post WTO for international and domestic NR price series and crude oil prices showed higher volatility in pre-WTO period in terms of rupees as well as in dollars. GARCH (1, 1) model gave an additional evidence for persistence of volatility. It proved that the volatility persisted in the overall period in terms of rupees and dollars for domestic rubber price and for international rubber price.

Instability analysis showed that the price instability in post WTO was almost double than that of pre WTO and triple in overall period in terms of rupees and in terms of dollars, the instability in post WTO was almost triple than that of pre WTO for domestic and international NR price and crude oil prices showed double instability than pre WTO.

The relationships between domestic and international prices were analyzed through cointegration analysis and Vector Error Correction Method (VECM). Cointegration analysis showed that there was at least unidirectional relationship among the variables and Vector Error Correction Method (VECM) showed that there was long run relationship between domestic price, international price and crude oil price.

There were many factors affecting the prices of Indian NR in general like Synthetic rubber (SR) production, SR consumption, crude oil prices, International rubber prices, International demand and supply, international transactions, exchange rates, natural factors and development of automobile industries. Separate factors were sorted out affecting in pre-WTO and post-WTO using Step wise regression analysis. The analysis revealed that NR price in pre-WTO was affected by International rubber prices and in post-WTO by International rubber prices and SR consumption. Moreover, in overall period, international rubber price and high import values from other countries were the main cause for downfall of domestic rubber prices.

Domestic rubber prices were forecasted with three different models like Stepwise regression method, ARIMA and SARIMA. In stepwise regression method, annual domestic rubber price could be predicted by using annual international rubber price and annual import value of NR. Among the different forecast models tried for domestic NR price, ARIMA (4, 1, 4) and Seasonal ARIMA (4,1,4) (1,0,1)<sub>12</sub> were selected.

### **11. Economic impact of climate change and adaptation strategies in Black Pepper (*Piper nigrum* L.) cultivation in Kerala. 2017**

To quantify the impact of climate change on black pepper, to understand the adaptation practices followed by farmers to overcome climate change and to study the extent of government compensation to farmers due to weather extremes. Average temperature during Q<sub>3</sub> (July-September) and Q<sub>4</sub> (October-December) had a negative and significant impact on the production of the pepper. Rainfall had a positive effect on production but was statistically insignificant. The various adaptation practices adopted were mulching with coir pith or dry leaves, shading of young plants, spraying 1 per cent lime solution to foliage and moisture conservation tillage. Mulching was the major adaptation practice which was followed by 68.75 per cent of the respondents. While analyzing the compensation to pepper farmers in Wayanad, it was seen that compensation for flooding due to heavy rainfall and high speed wind was more than that for drought which was Rs.32, 81,192 and Rs.48, 64,984 per annum respectively. SulthanBathery block in Wayanad had the maximum beneficiaries for both type of compensations viz. compensation due to drought and compensation for flooding due to heavy rainfall and high speed wind.

### **12. Economic assessment of the use of microbial inoculants in Black Pepper (*Piper nigrum* L.) in Idukki district. 2017**

The study was undertaken with the objectives to quantify the extent of use of microbial inoculants in Pepper gardens, to assess the economics of their application and to identify the constraints of their adoption in Pepper cultivation.

Analysis of extent of use of microbial inoculants revealed that only 33 per cent were following the recommended rate of microbial inoculants whereas 46.6 per cent of farmers used it in excess. Cost C was calculated as Rs.295050.13/ha and Rs.439399.87/ha for microbial inoculants using farmers and non microbial inoculants respectively. Major share of cost A<sub>1</sub> was contributed by cost of hired labour for both categories followed by cost of manures, fertilizers and soil ameliorants. B:C ratios were 1.8 and 1.23 for MI adopters and non MI farmers respectively at cost C. Difficulty in proper identification of pests and diseases in the study area, less availability of microbial inoculants other than *Pseudomonas* and *Trichoderma*, lack of knowledge about recommended method, dose and time of application of MI and climate change were the major constraints observed. The MI using pepper farmers obtained total yield of 760 kg/ha and non MI farmers obtained a yield of 795 kg/ha. The gross returns obtained from pepper using MI was Rs.532000/ha which is less than that of non

MI farmers (Rs. 540600/ha). The net return obtained by MI using pepper farmers was more than that by non MI farmers as the price was Rs.700 and Rs.680 per kg respectively.

### **13. Optimisation techniques in long term fertiliser trials: rice - rice system**

To study the cumulative effect of weather factors and plant nutrients on the crop productivity, dynamics of soil characters in relation to the fertiliser treatment responses and to suggest appropriate statistical optimisation techniques with respect to yield and its forecast.

The data from Long Term Fertiliser Experiment (LTFE) on rice (variety: Aiswarya) with twelve treatments in four replications laid out as RCBD at RARS, Pattambi from 1997 to 2017 will be collected along with the details on weather variables.

### **14. Comparison of statistical methods for control of error in long term experiments in rice (*Oryzasativa* L.)**

The present research study entitled "Comparison of statistical methods for control of error in long term experiments in rice (*Oryza sativa* L.)" was formulated with the following objective.

To compare different parametric and non-parametric statistical approaches in the analysis of field experiments over years and seasons in long term experiments in rice and to identify the most suitable method.

The study was mainly based on the data on a field experiment on rice (var. Aiswarya) viz. 'Permanent plot experiments on integrated nutrient supply system for a cereal based crop sequence' conducted at Integrated Farming System Research Station (IFSRS), Karamana for the period from 1985-86 to 2013-14. The field experiments consisted of 12 different treatments on modified fertilizer doses based on the recommended dose including a control  $T_1$  (no fertilizers and no organic manures) and  $T_{12}$  (farmer's practice). Randomized block design (RBD) with four replications was used for kharif and rabi seasons for all these years. The main items of observations collected were grain yield, straw yield, plant height, total number of tillers, number of productive tillers, dry matter production and harvest index.

It is concluded that, the ordinary pooled analysis of data was found to be the best under the exploratory analysis. Analysis of covariance with one covariate was found to be equally good with adjusted MSE almost to that of MSE of ordinary pooled analysis.

It was found that neither the serial correlations nor partial regression coefficients were found to be significant for kharif, rabi as well as yearly data. Which means there is no any significant relationships between the season as well as yearly data.

### **15. Pre-harvest forecasting models and instability in production of cassava (*manihotesculentacrantz.*)**

The investigation entitled "Pre-harvest forecasting models and Instability in production of cassava (*Manihotesculenta* Crantz.)" was undertaken with the objective of developing early forecasting models for yield of five major short duration varieties of cassava and also to carry out trend and instability analysis on area and production of cassava in Kerala.

Growth characters such as number of functional leaves plant<sup>-1</sup>, number of primary branches plant<sup>-1</sup> and height of first branching had a significant correlation with yield at all stages of crop growth. Yield attributes such as number of tubers plant<sup>-1</sup>, average tuber weight and average tuber length had positive correlation with yield in all varieties.

In prediction models of Sree Jaya, the best linear model was obtained using inter nodal length at 3 MAP and number of primary branches plant<sup>-1</sup> at 4 MAP with  $R^2$  of 50 per cent. The best predicted variables based on non linear models were number of functional leaves plant<sup>-1</sup> at 2 MAP and number of primary branches plant<sup>-1</sup> at 4 MAP with  $R^2$  of 56 per cent.

In case of SreeVijaya, the best linear model was obtained for the pre-harvest prediction of yield, by using inter nodal length at 2 and 5 MAP and number of functional leaves plant<sup>-1</sup> at 2 MAP and plant height at 5 MAP with  $R^2$  of 58 per cent; based on non linear equations, the best model obtained was using inter nodal length at 2 and 3 MAP and number of functional leaves plant<sup>-1</sup> at 5 MAP with  $R^2$  of 59 per cent.

Multiple regression models for the variety SreeSwarna showed that the best linear model obtained for prediction of yield was using inter nodal length at 2 and 3 MAP and number of functional leaves plant<sup>-1</sup> at 5 MAP with  $R^2$  of 43 per cent; with non linear functions the best model obtained was using inter nodal length at 2 and 3 MAP and number of functional leaves plant<sup>-1</sup> at 5 MAP with  $R^2$  of 49 per cent.

The best linear model obtained for prediction of yield in the variety Vellayani Hraswa was using number of functional leaves plant<sup>-1</sup> at 2 MAP and plant height at 4 MAP with R<sup>2</sup> of 35 per cent; with non linear equations the best model obtained was using number of functional leaves plant<sup>-1</sup> at 2 MAP and plant height at 2 and 4 MAP with R<sup>2</sup> of 40 per cent.

The best linear model obtained for prediction of yield in the local variety Kantharipadarppan was using number of functional leaves plant<sup>-1</sup> at 4 MAP and plant height at 3 MAP with R<sup>2</sup> of 34 per cent; with non linear equations the best model obtained was using plant height at 4 MAP and number of functional leaves plant<sup>-1</sup> at 5 MAP with R<sup>2</sup> of 33 per cent.

The estimated trends in area, production and productivity of cassava, using semi log function revealed that there was a significant decline in area with a compound annual growth rate of 1.37 %, non significant decline in production by -0.02 % and a significant increase in productivity by 1.3 %.

#### 16. Statistical models for profit maximization homesteads in Kerala.

The present study entitled 'Statistical models for profit maximization of homesteads in Kerala' was carried out with the objectives of examining and developing statistical models for homestead farming systems in the southern and south central laterite agro-ecological units (AEU8 and AEU9) of Thiruvananthapuram district and to suggest suitable cropping/ farming system models that maximize farm income by the optimal use of available resources.

The relevant primary data from forty randomly selected homesteads of almost similar cropping systems and having area 0.1 ha to 0.3 ha from two panchayaths (Kulathoor and Karode) of AEU8 and same number of homesteads from two panchayaths (Anad and Vembayam) of AEU9 was collected using a well-structured pre-tested interview schedule. The input-output data pertains to the agriculture year 2016-17.

- Majority of the homesteads in AEU8 (82.5%) and AEU9 (92.5%) were semi-irrigated and coconut based with an average size of 0.18 ha and 0.21 ha in AEU8 and AEU9 respectively
- Perennial fruit trees like mango, jack, papaya and annual fruit trees like banana were grown in most of the homesteads.
- Tuber crops were a dominant category, and tapioca was found in almost 90 per cent of the homesteads in both agro ecological units. Majority of the homesteads in AEU8 (82.5%) and AEU9 (92.5%) were semi-irrigated.
- The commonly summer vegetables along with banana were grown mainly for household consumption.
- Black Pepper was trailed on trees in the homesteads.
- Livestock such as cow, buffalo and goat were less and poultry was more.
- The estimated total net return of the existing of the average size of 45 cents HFS S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub> was Rs.27,596/-, Rs.55,244/- and Rs.1,72,245/- in AEU8 and Rs.23,303/-, Rs.34,272/- and Rs.1,31,516/- in AEU9 of average size 52.5cents respectively.
- The optimum model developed for a homestead farmer of AEU 8 by investing an amount of 28,793/- would receive a net profit of Rs. 34577/- which indicates 25.30 per cent enhancement in net profit over the existing plan. The optimum model left a total area of 439.79 m<sup>2</sup> with an unutilized interspace area of 390.27 m<sup>2</sup> as an indication of lapse in proper farm planning.
- The optimum model AEU 9 was developed by investing an amount of Rs.23384.18/- would receive a net profit of Rs.28623.72/- indicating 22.83 per cent enhancement in net return as compared to net return from the existing plan. The model worked out for S<sub>1</sub> in AEU 9 was found to have non binding solution for enterprises like coconut, cashew, ginger, dioscorea, pineapple and banana but binding solution for all other enterprises with B: C ratio of 2.22. The optimum model for average S<sub>1</sub> homesteads in AEU 8, comprising of 23 enterprises including house and permanent structures.

#### Ongoing Projects

##### 1. Organic Farming in Kerala: Field Realities and Strategies for Future

The project was carried out to document the existing practices of organic farming in Kerala and assess the economic viability based on case studies, compare its economic and environmental viability with chemical based farming, to identify major constraints and prospects of organic farming in Kerala and to develop a guide/ road map for promotion of organic farming in Kerala.

Four existing practices, viz., Spiritual Farming/ Zero Budget Farming/ Natural Farming, Biodynamic Farming, Homeo treatment in Agriculture and Organic Farming were documented. Spiritual Farming/ Zero Budget Farming/ Natural Farming The philosophy of zero budget farming (natural farming) put forth by Mr.SubhashPalaekhar, is based on minimizing external dependence for inputs and chemical free production process. Zero budget farming is a unique method of farming

which is based on the inborn power of the healthy system to produce, without added nutrients. Under this practice, one native breed of cattle (Desi Cow) is considered sufficient to cultivate 30 acres of land. The cow dung, urine, milk and milk products of Desi Cow are the inputs for preparing the growth promoting mixtures. These mixtures promote beneficial microbial growth and facilitate the availability of plant nutrients. The system donot require farm inputs to be purchased and in zero budget farming the basic approaches include.

1. **Mixed crop and crop rotation:** including tree components helpful for keeping the soil fertile.
2. **Mulching:** Mulching with organic residues or live mulching reduces tillage and consequently labour requirements, suppresses weeds, promotes humus formation and enhances the water holding capacity of the soil.
3. **Canopy level irrigation:** The system suggest planned and scheduled irrigation management, restricting water in the active root zone alone. This can be managed at field level by observing the canopy spread of respective plant species.
4. **Nutrient management:** This system suggests the application of some formulations like Beejamrutha, Jeevamrutha which can facilitate microbial growth

#### **F. Biodynamic Farming**

The idea of Bio dynamic farming was drawn from the ideas of Rudolf Steiner during 1920s in Germany. The preparations in biodynamic farming are denoted by number starting from 500 to 508. Preparations 500 and 501 are made by packing cow dung or silica, respectively, into cow horns and burying them for a number of months before use. Steiner believed that cow horns, by virtue of their shape, functioned as antennae for receiving and focusing cosmic forces, transferring them to the materials inside. After exhumation, the contents are diluted with an unspecified amount of water to create a homeopathic solution, which when applied to soil (Preparation 500) or crops (Preparation 501), was thought to influence root or leaf growth. Six other compounds (Preparations 502–507) are extracts of various plants packed into either the skulls or organs of animals (e.g., deer bladders, cow peritonea and intestines) or peat or manure, where they are aged before being diluted and applied to compost. Steiner believed that the chemical elements contained in these preparations were carriers of terrestrial and cosmic forces and would impart these forces to crops and thus to the humans that consume them.

#### **G. Homeo treatment in Agriculture**

By principle homeopathy is a science based on experience. In 2010, a German homeopath named Christiane Maute, first published 'Homeopathy for Plants' based on a decade of personal experience applying remedies in her own garden as well as to indoors and balcony plants. Homoeopathic medicine works by producing certain chemicals that are repellent to harmful insects or by increasing the natural immunity of the plants and trees.

#### **H. Organic Farming**

The agricultural production practices based on organic inputs, with minimum of synthetic inputs can be considered as organic.

The management practices in organic farming are based on local knowledge systems or information shared among the farmers, through mass media as well as electronic media. The pest/disease incidence in organic farming is generally reported to be high, especially during early days of conversion. In paddy, the attack of rice bug is very common and the organic farmer's popular practice is to keep decayed sardine in different location of the paddy field to repel the bug. Neem oil spray is also an alternative method.

The proportion of commercial farmers, who strictly adopt organic methods are rather limited. Economics of organic cultivation of different crops is being worked out.

2. **Analysis of soil and water conservation investments in Kerala and farm level financial gains.**
3. **Institutional credit for agriculture – a study of crop loans in Kerala**
4. **Dynamics in prices and trade of Indian small cardamom and its implications on producers**
5. **Value chain analysis of black pepper in Kerala.**
6. **Economic analysis of production, marketing and price behaviour of nutmeg in Kerala.**
7. **Economic analysis of production, marketing and price behavior of tapioca.**
8. **Water crisis in coastal areas: domestic adaptation strategies and impact on agriculture sector.**
9. **Economic analysis of rice milling industry in central Kerala.**

**Name of Project Coordination Group : (16)  
Agricultural Extension and Developmental  
Studies**

**Compiled by:  
Dr. N Kishore Kumar  
Project Coordinator**

## Concluded Projects

### 1. Impact assessment study of Mahatma Gandhi National Rural Employment Guarantee Scheme in Thrissur District

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#### **MGNREGS in Thrissur: IEC strategy and unique promotional efforts**

Initiation of MGNREGS in Thrissur district is marked by a unique IEC strategy for environment building. The project administration in the district had designed laudable promotional efforts to make the administration, local leadership and the rural population aware of the features of the scheme, ways of administration and the rights and privileges of the wage earners. These efforts included massive awareness building campaigns through folk arts, pamphlets, tracts and attractive public displays.

The launching of the scheme in the district was heralded by public meetings and a few seminars on the philosophy and practice of the new approach. It was followed by a zealously crafted monkey show by eloquent ventriloquists in all the 92 GramaPanchayats in the district. All the rural households were provided with tracts containing an FAQ on the scheme in an easily comprehensible form with illustrations. Banners and posters were exhibited in prominent places declaring the initiation of the project, which helped enhance public awareness.

The job cards were designed innovatively by filling the spaces with cartoons on the provisions of the scheme. This had easily conveyed the vital messages that were important for the beneficiaries as well the project personnel. This had also turned out to be a quick reference material for streamlining the implementation of the programme. Since the programme was launched almost immediately after civic body elections, the Project Directorate saw to it that the training on MGNREGS was the first ever structured training programme received in their tenure. This is reported to have had considerable impact on the implementation of the scheme as people's representatives were keen to utilize possibilities of generating employment in their locality as much as possible. Thrissur also witnessed improvisation of some of the provisions of the scheme, which made its implementation more efficient. For instance, selected wage earners were given skill training in masonry and carpentry, which made the construction of durable assets more effective. Similarly, the district project administration also prompted wage earners to voluntarily subscribe to the JansreeBimaYojana, an insurance scheme on social security, which set an example to be emulated elsewhere. In order to make the workers aware of their entitlements under the Act, a unique programme on oath taking on entitlements were taken before start of every work in the district. Making the people more aware and responsible, handbooks on social audit for mates, elected representatives, social audit were prepared and distributed. As part of an employment guarantee literacy programme, analysis of reading and writing skills of registered workers was done, which revealed that 28 per cent of the active workers were illiterate. There used to be functional literacy classes during lunch break to address this issue.

#### **2. Biodiversity research programme (BRP) of Home garden agro ecosystem in the major riparian tributaries of Chalakudy river (in. Thrissur District).**

Such low altitude riparian forests are very rare in the rivers of Kerala and its protection is important. The remaining vegetation has to be protected as it is and degraded riparian zone should be regenerated.

Conservation of this riparian vegetation can support the livelihood means of the tribals, fisherman communities and other local people depending on the river system.

In the areas where the forests lands were given under the control of Kerala State Electricity Board and that which is leased to Plantation Corporation of Kerala etc. was observed to be transiting towards dilapidation and impairing the wildlife and forests resources found in luxury. Forest department should be given free hand to ensure the quality of this deterioration system and should be held responsible and account for loss of land under their control.

The departments of forests with the participation of local bodies should persuade and drive the development departments for initiation of programs for the conservation of the riparian lands and remaining forests under these leased areas.

Control of the tourism activities or promote the concept of conservation tourism in the riparian areas is necessary and tourism activities should be planned based on the objectives of conservation.

The activities of the private firms operating in the riparian areas should be monitored and controlled and should ensure the freedom of the local people for the healthy use of their natural resources in their day-to-day activities. The government

should ensure that the revenue land should not move to the rights of private players especially in such unique areas. Water uptake for domestic uses from the river by private firms should be controlled and monitored. Waste deposition into the river should be prevented and ensure installation and working of proper waste treatment plants by the government itself in order to make lawful enforcement.

A proper awareness about these activities and its impact on the river system should be initiated among these institutions, local people and among student groups. The externality cost should be borne by the stakeholders especially the hotel/tourism industries and such cost derived should be ascribed as compensation to be used for proper conservation activities. Its responsibility should be fixed and made accountable by the respective development department meant for the purpose. In the lower areas, the riparian vegetation acts as a gene pool for the wildlife relevant in each area. Such an ecosystem needs to be sustained by promoting agricultural activities that is inclusive of the non commodity components so that the biodiversity of the region is not adversely affected.

## PG Projects

### Completed Projects

#### 1. Technology utilisation of organic plant protection practices of KAU.

The study entitled "technology utilization of organic plant protection practices of KAU" was undertaken with the objectives of studying the adoption of standardized practices, factors affecting the rate of adoption and constraints in the process of adoption, if any with suggestions for refinement of organic plant protection practices.

From Thiruvananthapuram district three panchayats namely, Nedumangad, Kunnathukal and Chenkalpanchayats were selected from three blocks having more number of farmers practicing commercial vegetable cultivation along with organic practices for plant protection. Ninety such farmers were selected through simple random sampling procedure from the list of farmers provided by the respective agricultural officers. Two dependent variables and fourteen independent variables were studied and analyzed with the help of different scales and techniques.

On analysis of data it was found that most of the respondents (53.33%) belonged to old age group and majority of respondents (63.33%) were having high school level of education and 5.56% of farmers were identified as illiterate. Majority of farmers (84.44%) had agriculture as their primary occupation. More than half of the respondents (73.33%) were having experience in farming for more than 5 years. More than 50% of farmers (87.78%) had 1-2 acres of farm land. Most of farmers (51.11%) followed scientific practices only. Majority of farmers belonged to medium category with respect to information source utilization (54.44%), extension orientation (55.56%), economic motivation (88.89%), environmental concern (62.22%), market perception (67.78%), risk orientation (74.44%), and attitude (67.78%). The results also points to the fact that the most widely used information source was television (43.33%) followed by magazines (37.78%) and newspapers (33.33%) respectively. When 63.34% of respondents felt that television was the information source that was more useful, and 81.11% of respondents felt that information kiosk was the source that was not that useful for the farmers. Distribution of respondents based on extension contact showed that the majority of respondents (50%) visited Krishibhavan for getting information and support. In case of distribution of respondents based on extension participation 36.67% reported that they participated in seminars as and when conducted.

Majority farmers (77.78% and 64.44%) were having medium level of awareness and knowledge about organic plant protection practices. Seven out of 12 variables were significantly correlating with extent of knowledge on organic plant protection aspects at 1% significance. They were farm size, farming experience, extension orientation, information source utilization, market perception, awareness and attitude.

In case of plant protection preferences family safe food concept ranked one followed by cost effective PP practices, and sustainability. Majority (97.78% each) of farmer respondents reported that use of botanicals and cultivating crop mixtures were the two practices that were effective for them. In case of extent of perceived usefulness of the technology 91.11% opined that cultivating crop mixtures followed by use of botanicals (68.89%) was useful.

More than half of farmers belonged to medium (83.33%) level of adoption and majority (44.44%) of farmers belonged to early majority group in Rogers standard adopter category curve. The results of ANOVA revealed that there was no significant difference among the three *panchayats* of study in terms of adoption level. Extent of adoption was positively and significantly correlated with seven out of 12 independent variables at 1% significance, namely, farm size, farming experience, extension orientation, information source utilization, market perception, awareness and attitude.

Technology need assessment as perceived by organic farmers revealed that maximum need was observed for soil solarization technologies. One kg of fresh cow dung was mixed with 10 litres of water with crushed neem leaves and kept for 6 hours. The clear solution then is filtered and the supernatant liquid was sprayed at regular intervals to manage the leaf spot of amaranthus.

Lack of knowledge on organic plant protection products and its preparation cum use was perceived to be the most important reason for non adoption of organic plant protection practices followed by lack of support from extension agents and many organic plant protection practices were not effective especially in commercial growing tracts. The major constraint experienced by farmers was the ongoing drought situation during the time of data collection followed by, Lack of extension service to facilitate transfer of technology scientifically on organic plant protection, same price or even more than that of chemical produce, time consuming while resorting to organic plant protection preparation, storage and its application and organic practices that were labour intensive coupled by non availability cum high cost of labour.

The top five suggestions for refinement for tackling the constraints as perceived by farmers and refined through focus group discussions were facilitating regular and frequent farm visit, diagnostic and consultancy by krishibhavan officials on organic plant protection (90.44%) followed by making available low cost organic inputs and feasible technologies (88.33%), inclusion of more number of classes, demonstrations and seminars about organic pp practices (75.22%), Timely access to organic plant protection inputs (70.22%), construction of low cost mini dams or water storage facilities like technologies developed and popularised by RARS, Ambalavayal (65.22%).

## **2. Scenario analysis of rice cultivation in Palakkad district.**

The study entitled 'Scenario Analysis of Rice Cultivation in Palakkad district' was conducted in four blocks of Palakkad district with objectives : to assess changing trends in rice cultivation in Palakkad district, delineation of factors leading to shifting of rice cultivation, attitude of farmers towards rice cultivation, perception of farmers on governmental interventions, major constraints experienced by the farmers and finally to suggest a comprehensive strategy for revival of paddy cultivation in the district.

The study was carried out in four blocks of Palakkad district, namely Alathur, Nenmara, Pattambi and Malambuzha. Thirty farmers were selected from each of these four blocks making a sample of 120 respondents. Data was collected by interviewing the respondents personally with the help of pre – tested and well-structured interview schedule. The data collected were processed, coded and tabulated with the help of different statistical tools. The salient findings of the study are as follows:

On analysis of data it was found that the area under paddy cultivation significantly reduced in the past years. Rice was cultivated in an area of 1.45 ha in 1990 and it declined to 0.83 ha by the year 2016. At present area under rice cultivation in the district is 42 per cent (83,998 ha) of the total area in the state. The productivity of rice increased from 1845 Kg/ha in 1970 to 2728Kg/ha by the year 2016. The findings of the study indicate that majority of the respondents were old aged with sufficient farming experience, with agriculture as their primary occupation. Majority of them possessed primary to high school level of education, and none of them were illiterate. Farmers in high productive blocks had more extension agency contact and extension participation compared to the farmers in low productive block.

Analysis of the perception of farmers on various governmental interventions to revive rice cultivation shows that, most of them were useful. Production bonus for rice and operational support for Padasekharasamithi were found to be extremely useful. The farmer's attitude towards rice cultivation is an important element in sustaining rice cultivation. In this study, majority of farmers belonged to medium attitude category in both high productive block (68.33 per cent) and low productive block (85 per cent). Perception and attitude of farmers towards rice cultivation were positively and significantly correlated with extension agency contact, extension participation, economic motivation, innovation proneness, market orientation and credit orientation.

There are many reasons which force the farmers to stop rice cultivation. These are grouped into four categories namely, technological reasons, economic reasons, social/ecological reasons and political reasons. Unavailability and high cost of labour, irresponsibility of Government in Paddy procurement and lack of reasonable support price, fluctuating price and marketing problem, uneven rainfall pattern and changing climate, less access to enough irrigation water etc. were the important constraints identified in this study. The suggestions put forth by the farmers were, to increase the minimum support price of rice, facilitate better water management system, spread the idea of green army to more areas and make available timely supply of good quality seed and at reasonable prices.

The study therefore revealed that, to revive the current scenario of rice cultivation in the district a comprehensive strategy is needed focusing on area expansion, productivity enhancement, and to augment income from rice based farming, better irrigation and water management system and greater investment in research and extension in order to meet the upcoming challenges

### 3. Constraint analysis of farming on house terrace and distribution of grow bags.

The study entitled "Constraint analysis of farming on house terrace and distribution of grow bags" conducted in Thiruvananthapuram Corporation was carried out to identify the constraints in farming on house terraces and in the distribution of grow bags, to study the consumption pattern of vegetables by the urban families and to assess the knowledge and training need of respondents in farming on house terraces. The study was conducted in seven wards of Thiruvananthapuram Corporation namely Poojappura, Pettah, Manacaud, Kumarapuram, Karamana, Industrial Estate and Enchakkal. One hundred and five members of urban households involved in house terrace cultivation, fifteen extension officials and thirty office bearers of selected residents associations of the selected wards were the respondents of the study.

A well structured questionnaire and interview schedule was used to collect data regarding house terrace cultivation from the respondents. Four dependent variables and thirteen independent variables were studied and analyzed with the help of statistical tools such as average, frequency, percentage, quartile deviation and correlation.

Regarding the constraints perceived by the respondents on house terrace cultivation, crop loss due to pests and diseases attack was perceived as the major constraint and low quality grow bags and potting mixture issued by the private agencies was the major constraint in the distribution and usage of grow bags as perceived by the respondents and office bearers of residents associations of each wards. Lack of timely availability of fund was the major constraint in the house terrace cultivation and growbag distribution as perceived by the extension officials.

The consumption pattern of vegetables by the respondents revealed that majority (65.71%) of the respondents belonged to the medium category in consumption of vegetables. Majority (61.9%) of the respondents belonged to the medium category in the knowledge of respondents on vegetable cultivation (61.9%) and in the case of knowledge on house terrace cultivation, majority (74.29%) of the respondents were also belonged to the medium category. Regarding the training need of respondents on house terrace cultivation, Plant protection was the most preferred subject for training by the respondents.

It was found that majority (47.62%) of the respondents belonged to the middle aged category and 43.81% are degree holders. Majority of respondents belonged to medium category in family labour utilization (64.76%), area of house terrace (52.38%), health consciousness (83.81%), extent of micro irrigation (66.66%), leisure time availability (83.81%), availability of inputs and infrastructural facilities (53.33%), extension agency contact (52.38%), market perception (60.95%), self-reliance (53.33%) and relative advantage (61.9%). Majority of the respondents belonged to lower category in farming experience on house terrace (65.71%).

Considering the perception of extension officials towards house terrace cultivation, majority (46.67%) of the respondents had medium level of perception towards house terrace cultivation.

### 4. Gender Analysis of 'Adiya' tribal agricultural labourers of Wayanad district.

The study entitled "Gender analysis of 'Adiya' tribal agricultural labourers of Wayanad district" was conducted at the Mananthavady block of Wayanad district. In the Mananthavady block the study was conducted in the three *Gramapanchayaths* having maximum 'Adiya' tribal population, namely Mananthavady, Thirunelly and Panamaram covering 120 respondents with 40 respondents (30 women and 10 men) from each *panchayath*. The objectives of the study were to conduct gender analysis of 'Adiya' tribal agricultural labourers of Wayanad district and identification of the livelihood constraints and scale of social exclusion of 'Adiya' women agricultural labourers were also identified.

In the case of Gender analysis conducted, under the decision making analysis, major women dominated decisions were in the case of child rearing and religious decisions. Major men dominated decisions were in the cases of house hold decisions jobs to be taken, education, expenditure of income and decisions regarding elderly people in the house. In the case of benefits and incentive analysis, it was found that women were most capable of using the information obtained through extension agency contact and farmer groups. In the case of men, they were capable of using the money obtained from income, utilizing the education received for one's own empowerment, understanding and using the technological developments, enjoying the benefits of employment opportunities, utilizing the transportation facilities and utilizing the

benefits of farmer groups. In the agricultural activity analysis, women oriented activities were weeding, post harvest operations, livestock and poultry activities. Major men oriented agricultural activities were land preparation and fertilizer application.

In the case of house hold activities, women oriented activities were food preparation, child care, elderly care, cleaning activities and collection of water. In the case of men, they were mostly engaged as construction/daily wage labourers. In the case of influencing factors of development, the positively influencing factors for women were provision of equal medical facilities, permission to participate in social meetings and gatherings, no subjection to punishments if they go against the norms and to vote in elections. Denial to stay outside the home for late hours, travel distant places alone, pursue education and take up jobs, marry outside the community, take up political powers in the society and unequal wages for the same amount of work were identified as the negatively influencing factors of development. In the case of men lack of timely availability of incentives, inability to marry outside the community and inability to take up political powers in the society were the most negatively influencing factors. Results of analysis of access and control to resources shows that women had access to inputs but did not have control on any resources and in the case of men, they had access to all resources and maximum control was on land, labour, money and technology.

Social exclusion was studied under the major headings of geographic exclusion, economic exclusion, socio cultural exclusion and political legal exclusion. 43.33% of the female respondents and 40% of the male respondents in Mananthavady block experienced medium level of geographic exclusion. In the case of economic exclusion, about 49% of the female respondents and 50% of the male respondents experienced medium level of economic exclusion. In the analysis of socio cultural exclusion 62% of the females and 50% of the males experienced medium level of socio cultural exclusion. 45.56% of the female respondents and 60% of male respondents also experienced medium level of political legal exclusion. In the case of social discrimination, 57.78% of the females and 60% of the males experienced medium level of social discrimination.

The results of correlation analysis emphasis that in the case of women, for the dependent variable of social exclusion the independent variables namely annual income, size of family, educational status, extension agency contact, exposure to mass media, type of house, environmental orientation, experience in agricultural labour, indebtedness, land holding, wage structure and political orientation were found to have negative and significant relationship. In the case of men, the independent variables such as age, size of family, exposure to mass media, and type of house, land holding and political orientation were found to have negative and significant relationship with social exclusion.

In the case of correlation analysis of social discrimination with independent variables, variables such as annual income, size of family, educational status, alcoholism, extension agency contact, exposure to mass media, type of house, indebtedness, land holding, wage structure and political orientation were found to have negative and significant relationship. Whereas, in the case of men, variables namely age, size of family, exposure to mass media, type of house, and land holding, were found to have negative and significant relationship with social discrimination.

The major constraints as perceived by 'Adiya' women tribal agricultural labourers were inaccessibility of support from government, unequal wage structure, crop damage due to animal attack, domestic violence and alcoholism. In the case of men, inaccessibility of support from government, inaccessibility to incentives, depletion of agricultural lands, poor economic status, and crop damage due to animal attack.

From the findings it can be concluded that male domination still prevails among the tribal groups except in the case of household activities and social exclusion and social discrimination were found to be medium among both men and women tribal groups. The most prominent constraint experienced by both women and men was inaccessibility to support from government. Proper implementation of policies and ensuring that it reaches the stakeholders and prohibition of alcoholism, the root cause of domestic violence and indebtedness can help in the upliftment of tribal people.

##### **5. Influence of school vegetable gardens on the students and teachers of Thiruvananthapuram district: An expository analysis.**

The study entitled 'Influence of school vegetable gardens on the students and teachers of Thiruvananthapuram district: An expository analysis' with objectives: To study the influence of vegetable gardens in terms of attitudes, to assess level of knowledge on vegetable gardening, delineating the benefits, training needs, constraints and strategies as perceived by the school students and teachers.

The area of study was confined to only 130 respondents with 10 students and 3 teachers each from 10 school in Thiruvananthapuram district. The data were collected by personal interview with the school students and teachers.

In spite of the above limitations the researcher took every effort to make the research objective, systematic and reliable. The data collected were processed, coded and tabulated with the help of different statistical tools.

The salient findings of the study are as follows:

On analysis of data, it was found that majority of students involved in school gardening activities belonged to 14 and 15 age group and were studying in 7<sup>th</sup> and 8<sup>th</sup> standard. In case of teachers, majority (56.77%) of them belonged to above mean age (44 years) group and all the teachers possessed B.Ed. or M.Ed. degrees. It was heartening to notice that 40 per cent of teachers had agriculture as their secondary occupation however 53.33 per cent teachers did not have any secondary occupation indicating the need for extension service to reach schools for educating teachers to engage themselves in agriculture at home focusing on food and nutritional security and also for generating additional income through sale of surplus. Most of the students dwelling place belonged to rural area whereas teachers come from urban area and the distance from home to school was less than 3 km for students and more than 6 km for teachers.

In case of variables, viz., social orientation, social participation, attitude, factors of influence, mass media exposure and knowledge, the majority of the respondents belonged to medium category. Newspaper was their main source of information with rank one, followed by television for both teachers and students. The mean score for variables like level of volunteering, level of excitement and attitude of teachers was higher than that of students indicating the mentoring role played by the teachers for managing and maintaining the school vegetable gardening. With respect to political orientation, the students were politically sensitive to issues and 60 per cent teachers making it clear that they were not actively involved in politics but do participate in programmes like 'environment protection campaign' and 'food security programmes'. The variables namely, dwelling place, political orientation, personal and social factor, technological factors, mass media exposure and training needs were positive and significantly correlating with attitude at 5% significance and benefits at 1% significance. However, students attitude was influenced by age at 1% significance and class of study, purpose of involvement and training needs (-ve) at 5% significance. Both teachers and students reported the need for more training and 80-90 per cent fell in the category of high training needs.

The average school vegetable garden area was 18.5 cents and seven out of 10 schools were maintaining vegetable garden in an area of more than or equal to 20 cents. Majority of the school maintained mixed cropped vegetable garden (80.0%) and 7 out of 10 schools did possess protective fencing. Seventy per cent of the schools were irrigating their vegetable gardens daily and 80.0 per cent of the schools used well water for irrigation. 60.0 per cent of the schools had financial support from government and 40.0 per cent of the schools from school management or PTA funds. 14 different vegetables were grown in school vegetable gardens and the most dominant was okra (100.0%), amaranthus (60.0%), tomato (50.0%), cowpea (50.0%) and cucumber (40%).

The important suggestions for refinement of school vegetable garden perceived by student and teachers were Good quality inputs at required time and amount and Garden maintenances in summer vacations.

#### **6. Livelihood security assessment of women agripreneurs of self-help groups (SHGs) in Kerala.**

The objective of the study was to assess the livelihood security of women agripreneurs of SHGs in Kerala in terms of food, occupational, habitat, educational, social, health and environmental security and was carried out in three districts namely, Thiruvananthapuram, Palakkad, and Malappuram. Eighteen viable women SHGs involved in agripreneurship were selected from the three districts and from each of the selected SHGs, five women were randomly selected forming a sample size of 90. The perception of 30 extension officials regarding the livelihood security of members of women SHGs was also studied. The total sample size was 120.

A structured interview schedule was carried out for data collection. Livelihood security was assessed using a Livelihood Security Index (LSI) developed by Baby (2005). Statistical tools like Principal Component Analysis, ANOVA, mean, standard deviation, quartile deviation, frequency, percentage and correlation were used for analysis.

The study revealed that, majority of the respondents were in medium category of LSI in three districts i.e. 60.00% in Thiruvananthapuram, 56.67% in Malappuram and 40.00% in Palakkad and there was no significant difference between the LSI of the three districts.

Majority of respondents belonged to medium category of food security in Thiruvananthapuram (70.00%), Palakkad (80.00%) and Malappuram (70.00%). It was also found that, 96.67% and 42.22% of the respondents could avail and access balanced food respectively. Regarding occupational security, majority belonged to medium category in Thiruvananthapuram (70.00%), Palakkad (43.33%) and Malappuram (66.67%). Ninety one per cent of the respondents were having an occupation according to their qualification and 93.33% were having regular employment. In habitat security, majority of the respondents were

in high category in Thiruvananthapuram (76.67%), Palakkad (70.00%) and Malappuram (76.67%). It was found that all the respondents had toilet facilities and electric supply whereas only 81.11% had own house.

For educational security, majority of the respondents were in low category in Thiruvananthapuram (56.67%), Palakkad (76.67%) and Malappuram (70.00%). Majority of the respondents belonged to high category of social security i.e. 46.67% in Palakkad and Malappuram and 50.00% in Thiruvananthapuram. As far health security is concerned, it was found that, 42.22%, 26.67% and 7.78% had incidence of chronic diseases, specific diseases and epidemic diseases respectively in their family and 67.78% had high access to health services. Majority of the respondents were in medium category of environmental security in Thiruvananthapuram (46.67%), Palakkad (46.67%) and Malappuram (80.00%). Ninety percent, 94.44%, 67.78%, and 44.44% of respondents reported that they have negligible pollution, adequate drinking water, adequate irrigation water and negligible ground water shortage respectively.

LSI showed a positive correlation with the personal and socio-psychological characters like annual income, saving propensity, interdependence and networking, credit orientation, level of aspiration, achievement motivation, management orientation, personal initiative and responsibility, adherence to group norms, group leadership and group achievement.

Perception of officials regarding livelihood security of members of women SHGs was measured using perception index. Perception index of majority of the respondents belonged to medium category and there was no significant difference between the three districts.

It can be concluded that the LSI of respondents measured in terms of seven components belonged to the medium category in all the three districts. There was no significant difference between the perception of officials regarding livelihood security of members of women SHGs in the three districts. The major suggestions proposed for improving the livelihood security of members of women SHGs were to conduct capacity building programmes for the women to enhance entrepreneurship behaviour and to impart specific skill improvement programmes.

### **7. Women plantation labourers of tea gardens in Idukki district: A multidimensional analysis.**

The present study entitled "Women plantation labourers of tea gardens in Idukki district: A multidimensional analysis" was conducted in three *panchayaths* of Idukki district. The objectives of the study were to identify the gender roles of women plantation labourers of tea gardens in Idukki district and study the livelihood constraints and the socio-economic deprivation of women labourers.

In this study, three *Grama panchayaths* namely Munnar, Pallivasal and Devikulam were selected and from each *Grama panchayath* one ward were selected and again from each ward 30 women and 10 men plantation labourers were selected randomly. Thus, resulting in a total sample size of 120 respondents.

A well-structured interview schedule was employed for data collection from the respondents. One dependent variable namely, socio-economic deprivation and 12 independent variables namely, age, educational status, marital status, age at the time of marriage, family size, monthly income, indebtedness, food security, alcoholism, health care seeking behaviour, discrimination and political orientation were studied and analyzed with the help of different statistical tools like mean, median, frequency, percentage, coefficient of variation, correlation, z test, and Kruskal Wallis test.

The female dominated gender roles identified under productive roles were tea picking/plucking (81.67%) and food decisions (73.33%), and under reproductive roles were cooking (69.17%), childcare (65%) and elderly care (66.67%). While male dominated gender roles identified under productive roles were weeding (94.17%), pesticide application (100%), fertilizer application (100%), post-harvest techniques (89.17%), money management (54.17%), education of children (55.83%), and under reproductive roles were fetching of water (56.67%) and collection of fuel wood (58.33%). Under community roles 100 per cent of women respondents participated in *Kudumbasree* and 100 per cent men in *Seva sangam*. The overall socio-economic deprivation index was calculated as 2.165. Among the nine dimension of socio-economic deprivation income, housing, other public services, social recognition, democratic participation and credit were found to be deprived with deprivation score of 2 for income, other public services, social recognition, democratic participation and credit and for housing deprivation score calculated was 1. There was significant difference between women and men in the dimension of education and other public services. In the Devikulam panchayath, education and health (deprivation score 2 for both education and income) were also found to be deprived since this particular ward was not close to the city.

The profile characteristics of the female labourers such as family size and indebtedness showed a positive and significant correlation with the dependent variable socio-economic deprivation while political orientation showed a negative and

significant correlation. In the case of male labourers the profile characteristic, age at the time of marriage showed negative and significant correlation while indebtedness showed a positive and significant correlation with the dependent variable socio-economic deprivation.

The top five constraints faced by the women tea plantation labourers were low wages, lack of housing facilities, lack of involvement in management, inaccessibility of government financial institutions and lack of rest period. Amongst men these were low wages, inadequate employment opportunities, lack of housing facilities, lack of involvement in management and inaccessibility of government financial institutions.

From the findings it can be concluded that housing was the most deprived dimension among the nine dimensions followed by income, other public services, social recognition, democratic participation and credit. Under gender roles tea picking is dominated by women. The female dominated gender roles were tea picking/plucking, food decisions, cooking, childcare, elderly care and *Kudumbasree*. Male dominated gender roles were weeding, pesticide application, fertilizer application, post-harvest techniques, money management, education of children, fetching of water, collection of fuel wood and *Seva sangam*.

#### **8. Impact assessment of LEADS in Kollam and Palakkad district: A comparative analysis.**

The present study entitled "Impact Assessment of LEADS in Kollam and Palakkad district: A Comparative Analysis" was conducted in five panchayats of Kollam and Palakkad district. The study aims to conduct a comparative analysis of the impact of LEADS in terms of its relevance, efficiency and scale of social capital formed in Kollam and Palakkad districts and to study the perception of extension officials, lead and satellite farmers regarding the effectiveness in implementation of LEADS.

LEADS is the Lead Farmer Centered Extension Advisory and Delivery Services (LEADS). In the present study, from each of the panchayat, three lead farmers, six satellite farmers and three implementing officials were selected, constituting 30 lead farmers, 60 satellite farmers and 30 implementing officials respectively. Thus a total of 120 respondents were included for the study.

A well-structured interview schedule was employed for data collection from the respondents. Three dependent variables and ten independent variables were studied and analyzed with the help of different statistical tools like mean, quartile deviation, frequency, percentage, correlation, ANOVA, and spearman's rank order correlation.

Impact assessment of LEADS was done by assessing the impact in terms of its relevance and efficiency and scale of social capital formed. Impact created by LEADS in Kollam and Palakkad was assessed and compared by using an impact assessment tool – 'MAPP technology'. Relevance and efficiency components of LEADS was found more in Kollam district than in Palakkad district. World bank SOCAT tool was used to measure the scale of social capital formed. On analyzing the data, the social capital formed was found higher in Kollam district than that of Palakkad district. Perception of lead, satellite farmers and officials regarding the effectiveness in implementing LEADS was found higher in Kollam district than in Palakkad district.

The profile characteristics of the farmers such as age, education, information source utilization, extension agency contact, innovation proneness, social participation, decision making ability, and market orientation showed a positive and significant correlation with the scale of social capital formed in Kollam district whereas in Palakkad district, farming experience, innovation proneness, decision making capacity and market orientation showed a positive and significant correlation with the social capital formed.

Also, the profile characteristics of the farmers such as age, occupation, information source utilization, innovation proneness and market orientation showed a positive and significant association with the perception of lead farmers in Kollam district whereas in Palakkad district, innovation proneness and market orientation showed a positive and significant association with the dependent variable. The profile characteristics of farmers such as education, extension agency contact, social participation and decision making capacity showed a positive and significant association with the perception of satellite farmers in Kollam district whereas in Palakkad district, occupation, innovation proneness and decision making capacity showed a positive and significant association with the dependent variable.

The farmers of Kollam district felt that the 'lack of coordination of line departments in providing service to the farmers' as the major constraint while the farmers of the Palakkad districts opined that 'lack of usefulness of farmer oriented activities such as field visit and demonstrations' as the major constraint. The major suggestion given by farmers of both the districts was 'the scaling up of LEADS project to crops like tubers and pulses in addition to paddy, coconut, banana and vegetables'.

The major Constraint experienced by the officials in the implementation of LEADS in Kollam and Palakkad district were the lack of cooperation from the farmer groups followed by lack of active participation from the members in attending group meetings. 'Cooperation from the farmer groups' was the major suggestion given by the officials of both districts. Scaling up of LEADS project to crops other than paddy, banana, coconut and vegetables was the most important suggestion made by the farmers of both Kollam and Palakkad district.

Summing up, it can be concluded that LEADS had created an impact among the farmers in terms of its relevance, efficiency and social capital formed. Coordinated efforts of line departments especially in conducting farmer oriented activities can create a positive impact among lead farmers.

### **9. Organic farming as a strategy for climate change adaptation – an exploratory study**

An index for measuring the Integrated Adaptive Capacity (IAC) was developed. The factors of Integrative Adaptive Capacity identified are socio-economic, technological, agricultural, managerial, bio-physical and ecological factors. Each factor of the adaptive capacity index was measured by summing up the scores of sub-factors delineated through pilot study, expert opinion and judges' relevancy rating. The Integrated Adaptive Capacity (IAC) index was calculated as the composite measure of these six factors.

The IAC index based analysis revealed that majority (62%) of the organic farmers are of high adaptive capacity where as majority of the conventional farmers (56.1%) belonged to moderate adaptive capacity. The comparison of the mean scores of IAC index of organic (81.05) and conventional farmers (46.35) clearly indicated that there exist a significant difference between the two groups and the organic farmers were found to be more adaptive. The AE Unit wise comparison revealed that the farmers of South central laterites exhibited the highest IAC index (organic- 87.73, conventional- 48.74) followed by the farmers of Southern coastal plain (organic - 78.54, conventional- 43.63), Northern foothills (organic - 77.5, conventional- 43.05) and Northern laterites (organic - 77.37, conventional- 42.98). Among the six IAC factors, socio-economic factor was found to be the most contributing one followed by technological, agricultural, managerial, bio-physical and ecological factors. All these factors were found to be positively and significantly correlated with the IAC Index.

The analysis of personal, socio-economic and psychological characteristics indicated that majority of the farmers of the survey area belonged to middle aged category, medium level of annual income (between Rs. 50,000 to 1,00,000/-) and possessed an area of 1 to 5 acres of land. Majority of the farmers were studied up to high school level with high farming experience and farming commitment. Most of the respondents were having medium level of mass media exposure, closeness with agricultural support system and self confidence. Majority of the farmers had a low level of socio-political participation.

The socio economic profile of organic farmers revealed the following: Majority of the organic farmers belonged to middle aged group. A larger section of them had studied up to higher secondary followed by high school, collegiate and primary level. Most of the organic farmers were cultivating an area between 1 to 5 acres, getting an income above 1,00,000/- rupees. A great majority of them possessed high farming experience, mass media exposure and farming commitment. Most of the organic farmers were having medium level of socio- political participation, closeness with agricultural support system and self confidence.

The socio economic profile of conventional farmers revealed that, the majority belonged to old aged group. A great majority of conventional farmers were studied up to high school level followed by primary, higher secondary and collegiate level education. More than half of the conventional farmers were having an area of cultivation below 1 acre, earning less than 50,000 rupees. Most of them were having high farming experience. Majority were having medium level of mass media exposure, closeness with agrl. support system and self confidence. Majority of the conventional farmers were falling under low category of socio-political participation and farming commitment.

The results also revealed that there existed a significant difference between organic and conventional farmers with regard to the profile characteristics such as: age, education, land holding, socio-political participation, mass media exposure, closeness with agricultural support system, self confidence and farming commitment. The results also indicated a positive and significant correlation between the integrated adaptive capacity index and the profile characteristics of the farmers except age.

The major constraints as perceived by the farmers were: marketing problems (72.17%), lack of timely weather forecasts and its access to farmers (71.5%), risk due to uncertain weather parameters (69.77), inadequate storage and transportation facilities (64.54%), high cost of inputs (57.85%), inadequate labour availability (55.18%), inadequate input supply agencies/

system(48.93%), non- availability of organic inputs (48.55), inadequate institutional support (43.7%), lack of timely dissemination of appropriate technology for the needy farmers (40.77%), lack of need based training programmes (40.53%), inadequate infrastructural facilities (40.13%) and lack of farmer participatory research (34.24%).

Based on the study a workable climate change adaptation strategy is proposed for farm and farmer level. The farm level strategies were delineated for strengthening the bio-physical, agricultural and ecological factors of the farm and farmer level strategies for strengthening the socio-economic, technological and managerial factors of the farmer. The major strategies at farm level included: providing weather forecasts and early warning systems, pest and disease surveillance and forecasting, adopting locally-relevant climate-smart agricultural practices, use of precise watering technologies and water conservation techniques, diversified land use, integration of live stock component and use of climate resilient/ tolerant varieties. The major strategies at farmer level are promoting crop insurance, use of renewable energy sources, providing intense and continuous capacity building on climate change adaptation and establishing efficient transporting and marketing facilities avoiding middle men for getting reasonable income to the farmers.

A comparison of the agro ecological profile of the farmers with highest and lowest IAC index indicates that organic farmers had better adaptation capacity for coping up with climate change. Thus from the study, it is concluded that, organic farming can be considered as one of the climate change adaptation strategies, as it provides a wide variety of benefits, along with additional benefits of biodiversity and environmental services, leading to safe food production and livelihood support.

#### **10. Gender analysis of vegetable growers in the homesteads of Kollam district**

The study entitles "Gender analysis of vegetable growers in the homesteads of Kollam district" was conducted in two Agro Ecological Units of Kollam District which involved a total of 120 respondents, during the period 2016-17. The study was done to determine the gender roles of vegetable growers in Kollam district, their scale of knowledge, the arte of adoption of vegetable production practices, constraints face in vegetable production and formulate strategy to mitigate the constraints faced.

In the case of Gender analysis conducted, under the decision-making analysis, major women dominated decisions were child rearing and religious decisions. The decisions regarding the transfer and ownership of ancestral properties, various farm operations and decision related to entertainments were mainly men dominated. Both men and women were able to enjoy the benefits of basic facilities like income, education, medical facilities and transportation facilities. But in the case of political interventions, technical development, and extension agency contact, benefits were utilized more by men than women. The benefits of government policies and incentives, employment opportunities and farmers group were enjoyed more by women. In the agricultural activity analysis, major women oriented activities were post-harvest operations, livestock and poultry activities. Major men oriented agricultural activities were land preparation, collection and arrangements of inputs, fertilizer application and plant protection activities.

In the case of house hold activity analysis, all the house hold activities were women oriented. In the case of influencing factors of development, the positively influencing factors for women were provision of equal medical facilities, freedom to pursue education and take up jobs, inherit properties of their parents and freedom to vote in elections. In the case of men, when most of the factors were positively influencing. Results of analysis of access to resources showed that mostly male dominated.

Vegetable growers according to their knowledge about vegetable cultivation practices indicated that the majority of respondents had medium level of knowledge about vegetable cultivation and only few of them (39 per cent) had high knowledge. Only 12 per cent of respondents were in the group of low knowledge level. Majority of the respondents were having high knowledge about the KAU varieties, sowing methods, spacing, pest and diseases attack of the particular crops, and harvesting of the produce.

Correlation analysis of scale of knowledge with independent variables, education and economic motivation were positively and significantly correlated to scale of knowledge at 5 per cent level of significance. Whereas the variables, such as experience in vegetable cultivation, extension agency contact, information seeking behaviour, social participation and training were positively and significantly correlated to scale of knowledge at 1 per cent level of significance.

In the case of adoption, 72 per cent of respondents belonged to the category of medium level adoption. 20 per cent of the respondents were found having high level of adoption and 8 percentage of the respondents belonged to low level of adoption category. Majority of the farmers adopted KAU varieties and they followed almost all the cultural practices like seed treatments, seed rate, land preparation, weeding and application of manures as per the recommendation of Package

of Practices. A partial adoption was noticed in the case of application of NPK fertilizers and similar trend was observed in case of plant protection measures. On distributing the respondents into various adopter categories, only 2% of them were innovative in nature, which was almost on par with the normal Rogers curve (2.5%), whereas majority of the respondents fell into the category of early majority (33%) followed by late majority (31%). This is indication of fairly good level of adoption of KAU cultivation practices by homestead vegetable growers.

Independent variable such as occupational status, economic motivation and family labour utilization were positively and significantly correlated to extent of adoption at 5 percent level of significance. Whereas the variable such as experience in vegetable cultivation, extension agency contact, information seeking behaviour, social participation and training were significantly correlated to extent of adoption at 1 percent level of significance. A negatively significant correlation was noticed between extent of adoption and experience in vegetable cultivation.

The major constraints faced by the respondents were scarcity of water resources, prevalence of pest and diseases, price fluctuation, high labour charges, high cost of cultivation, labour scarcity, non availability of quality planting materials and non assurance of premium price for organic products.

To solve the acute water shortage especially during the summer season, rain water harvesting systems in the homesteads should be encouraged. In case of labour shortage, necessary amendments, be made to bring the NREGS workers to the agricultural sector. Integrated pest and disease management approaches can reduce the problem of prevalence to pest and diseases. Homestead farming has to be made more remunerative to attract more farmers, for which measures like popularization of organic vegetable production, timely availability of inputs, fixation of minimum support price for organic produce and proper post harvest management will enable the farmer to commercially utilize the produce in an effective manner and thereby increasing overall output.

From this study, it can be concluded that even though there are some men and women dominated operations in homestead cultivation, both the gender had a significant participation in most of the activities. There was no single homestead where the agriculture is done by male partner alone which implied that the women had a significant contribution in agricultural activities. Hence the overall extent of knowledge about vegetable production technology was found to be medium, there is a need of special attention by providing training about vegetable production to the farmers, so that their knowledge could be increased and the adoption of technology would be enhanced. Therefore, more educational efforts are, required to be undertaken by extension agencies by organizing training and demonstrations to enhance the knowledge and adoption level of farmers.

#### **11. Techno-Socio economic analysis of house terrace cultivation in Thiruvananthapuram Corporation**

Homegardens forms the predominant type of agricultural production system in the state of Kerala presenting a traditional agroforestry system designed to meet the food, fodder, fuel wood and timber requirement of the farm households and to generate supplementary income through the sale of surplus for meeting secondary needs of the households.

This study was undertaken in Thiruvananthapuram district wherein the total number of homegardens selected was limited to 20 so that each homegardens were subjected for a comprehensive study. The base crop dominance established in terms of structural, numerical and economic dominance was the criteria for selecting homegardens. The study examined the biodiversity of crops, diversity of soil nutrients, fungal diversity in soil, water quality in terms of e-coli build up, measure of dominance, characterization of homegardens based on technical, economical and socio cultural dimensions and influences, extent of adoption of technology/scientific practices and constraints experienced by homegarden farmers. The structural configuration, cropping patterns and type of homegardens were identified using the measure of Shannon and Wiener diversity index. The study revealed that irrespective of the size of holdings the gardens tends to preserve the maximum taxonomically distinct variance within the region and the highest diversity index was observed in the mid region and was found to be on par with courtyard. Dominance was measured in terms of structural, numerical and economic dominance. The mean of ranked scores revealed that coconut, banana, tapioca, pepper, vegetables, yam and colocasia and arecanut were the most dominant crops.

The soil nutrient diversity of the selected homegardens were done for both surface soil and sub surface soils from both cropped and uncropped area in homegardens. The results illustrates that Organic Carbon, K, Cu, Zn and Mn show highest diversity during wet season, while P and Fe exhibits highest diversity during dry season. pH shows highest diversity in wet season while EC exhibits highest diversity during dry season. The study on nutrient diversity in homegarden soils indicated that there exist good soil nutrient diversity between surface, sub surface, cropped area and uncropped area. Data from results on water quality revealed that Coliform build up in well water was more pronounced during dry season, 13 out of 20 wells had coliform buildup during dry season of which one sample was excessively contaminated

which needed immediate intervention like de-watering and then recharging along with chlorination of well water.

Characterization of homegardens was done in terms of technical, socio-cultural and economic dimensions. Profitability was ranked the most important dimension followed by initial cost of the technology, regularity of returns, simplicity of technology, continuing cost, observability of the results, environmental sustainability, local resource utilization, availability of raw materials, supplies and services, rapidity of returns, resource recycling capacity, social approval and cultural compatibility in the decreasing order of importance. On the aspect of cropping intensity of homegardens, all the homegardens of study showed >100% agricultural cropping intensity, which could be attributed to the fact that homegardens selected were purposive in nature with the criteria of homegardens being functional in nature. Agrobiodiversity of homegarden crop components were documented and the same was categorized as commodity and non commodity crops. Analysing the interventions made in homegardens, it can be concluded that homegardens of Kerala are mostly inclining to organic practices or more precisely integrated practices thereby taking care of the ecology of homegardens by reducing the use of chemicals practices. Results of technology needs assessment the highest technology need of homegarden farmers was for value addition technologies indicating the economic motives of farmers which is of genuine nature as the continuance of any farming is linked to profitability. The distribution of respondents based on the extent of adoption of scientific production practices in homegardens revealed that majority of farmers falls under medium category (60 %) followed by high category and low category with 26.67 per cent and 13.33 per cent respectively. The results on the number of ITK practices with reference to the different crops/livestock components indicated the adoption of 21 ITK practices that was distributed among 6 homegarden components. Six each of indigenous practices were recorded for vegetables and banana followed by coconut with four practices, tubers (2), livestock and poultry (2) and spices (1).

Perceived usefulness and effectiveness of selected KAU production technologies was studied. 46.67 per cent of total homegarden farmers opined that KAU practices were 'useful', 30 per cent of respondents considered the practices to be 'very useful' whereas 23.33 per cent of farmers considered the same to be 'not useful'. The effectiveness of KAU practices as perceived by the homegarden respondent showed that 43.33 per cent of farmers considered KAU practices 'very effective', 36.67 per cent said KAU practices were 'effective' but 20 per cent of homegarden farmers said that the practices were 'not effective'. An attempt was also made to draw out and document the various ecosystem services including the aesthetic and recreational services provided by the homegardens with the help of the qualitative observations made during the study.

The results of classification of homegardens based on net annual income as perceived by homegarden respondent showed that majority of the homegardens (60% and 65%) belonged to low category of net annual income with both median and mean value as the check. The study also implied that the net income derived from homegardens with less area is positive and it can be enumerated that as area decreases the cropping intensity would be more thus enabling homegarden farmers to derive more income from less area. The results of role of middleman obscured that 70 percent of the total homegarden respondents felt that middleman were useful and essential in the marketing of homegarden produce, but about 80 per cent of the total respondents opposed the need for middleman in marketing their specialized components.

The most important constraints faced by the homegarden farmer was "high labour cost" which is on par with low price of produce, lack of markets for products of homegarden, lack of extension service and assistance, surplus but insufficient for marketing, inadequacy of capital and poor economic status of homegarden farmers, prohibitive cost of inputs, lack of knowledge about technology and non-availability of supply and services considering mean value as the check. One of the most important suggestions put forth the homegarden farmers was for the need for a POP recommendation specific for homegardens situation in vernacular language. Also, policy prescriptions that are a sine-quo-non to realize the full potential of Kerala with reference to promoting homegardens were also documented with a suggestion for a *Homestead Act* to be introduced for preventing further fragmentation of agriculture holdings, to prevent suspension of agricultural activity owing to mushrooming of real estate business and encompassing it for sale, provision of special incentive schemes for promoting agriculture through home garden farming and its biodiversity and participatory value addition and marketing. To conclude, primarily a system with dominance has been developed which is again derived from diversity index and measure dominance. Variability in homegarden crop biodiversity, surface-sub surface soil nutrient diversity, fungal diversity exists within different regions of homegardens. Above all the characteristics of homegardens, cropping intensity, constraints, technology requirement and delineated dimensions of technology was worked out based actual homegarden situation, thus providing a holistic approach to the entire homegarden scenario of the state with special reference to Thiruvananthapuram district.

## 12. Sustainability of commercial vegetable cultivation in Thiruvananthapuram district: A multidimensional analysis

- Fifty percent of the respondents belonged to medium category in respect to sustainability of commercial vegetable cultivation.
- Among the five dimension of sustainability, economic dimension of sustainability contributed 72% of the total sustainability followed by socio-psychological dimension (36%), environmental dimension (7%), technological dimension (5%) and temporal dimension (4%).
- In the case of total sustainability 55% of the respondents belonged to the medium category followed by 23% in high category and 22 % in low category.
- With respect to knowledge about the KAU practices in amaranthus, cowpea and bitter gourd 60% of the respondents were having higher level of knowledge whereas only 40 % respondents belonged to low knowledge category.
- In the case of adoption of KAU practices in amaranthus, cowpea and bittergourd 54% respondents belonged to medium category whereas only 27% had high rate of adoption.
- Only 19% respondents had higher level of perception about the feasibility of commercial organic vegetable cultivation, whereas 58% of them belonged to medium category.
- Forty eight percentage of the respondents belonged to medium age category
- Forty four percent of the respondents had high school level of education
- Forty seven percent of the respondents had annual income above 1 lakh
- Fifty one percent of the respondents had 10-25 years of experience.
- Majority of them had a medium level of credit orientation (69%), economic motivation (52%), market orientation (55%), entrepreneurial behaviour (64%) and risk orientation (57%)
- Most of the respondents had regular contact with Agricultural Officers (62%), Asistants (51%) and VFPCCK (49%).
- Most of them use newspapers (72%), mobiles (61%), and TV (56%) regularly for getting information regarding commercial vegetable cultivation.
- As to the trainings undergone 46% of the respondents had undergone at least one training regarding commercial vegetable cultivation and the major topic majority (69%), of them attended was 'Organic vegetable production – safe to eat vegetables'.
- The trainings was mainly conducted by Krishi Bhavan (70%) and VFPCCK (58%).
- Sixty three percentage of then had received inputs as incentives for commercial vegetable cultivation mainly from Government (KB, Dept.) (72%) and from private input agencies (62%).
- Sustainability of commercial vegetable cultivation was positively and significantly correlated with annual income, knowledge about KAU practices, adoption of KAU practices, farming experience, economic motivation, market orientation, exposure to mass media, entrepreneurial behaviour, training undergone and incentives received for commercial vegetable cultivation.
- Sustainability of commercial vegetable cultivation was negatively and significantly correlated with perception about the feasibility of commercial organic vegetable cultivation.
- Scarce water resources, extremity in weather conditions, non-assurance of premium price for organic products, incidence of pest and diseases, were the important constraints faced by the commercial vegetable growers.
- The suggestions put forward by the farmers were inclusion of accessible and low cost technologies, ensuring of premium price for the product especially for organic vegetables, improve the marketing and transport facilities without intermediaries, promotion of value addition technologies, providing training programmes to youth and support from the extension agents for the adoption of improved practices.

### Ongoing Project

1. **Entrepreneurial behaviour of lease land vegetable growers in Thiruvananthapuram district (Date of Completion: 21-07-2018)**
2. **Scenario analysis of cardamom growers in cardamom hill reserves of Kerala district (Date of Completion: 22-07-2018)**

The study was carried out in three blocks of Idduki district namely Kattappana, Nedumkandam and Adimali, which comes under Cardamom Hills Reserve (CHR) zone. Twenty growers and ten agricultural labourers were randomly selected from each of these blocks making a sample of ninety respondents. Data was collected using a of pre- tested and well- structured interview schedule. The data's were analysed using different statistical tools.

On the analysis of data, it was found that the area under cardamom cultivation has significantly reduced in the past years. Cardamom was cultivated in an area of 40,867 ha in 1997 and it declined to 39,080 ha by the year 2017. The productivity of cardamom had increased tremendously from 130 Kg/ha to 400 Kg/ha over a decade. The major findings of the study was that majority of the farmer respondents were middle aged with sufficient farming experience, with

agriculture as their primary occupation and none of them were illiterate.

Majority (65.00 %) of the respondent farmers had an annual income of more than four lakh and 56 per cent of agricultural labourers had an annual income less than one lakh. Majority (66.66%) of the growers were in medium category of economic motivation, risk orientation, scientific orientation. Nearly three fourth of the growers had medium level of innovative proneness and decision making ability. As high as (81.66 %) of the growers had medium level of credit orientation and market orientation (83.33%).

Less than half (48 %) and 11.67 per cent of the growers had low and high level of adoption respectively. The data subjected to correlation analysis between good agricultural practices and fifteen independent variables revealed that two variables viz., age and farming experience had negative and significant correlation and education status and credit orientation had positive and significant correlation.

The major constraints faced by cardamom growers are: not getting the cardamom registration card was a great concern among the growers, non-availability and high cost of labour, price fluctuation and marketing problem, lack of cardamom grading facilities, lack of support price based on the cardamom production, uneven rainfall pattern and changing climate, lack of irrigation facilities, man- animal conflicts, high production cost, inadequate extension services at village level. The suggestion to improve the cardamom cultivation were, establishment of cooperative societies for the procurement of cardamom will increase the direct selling of the produce through auction centers, minimum support price based on the production of cardamom as like of other food crops, then the cultivation of cardamom will increase and the farmer get the premium price, crop demonstration about improved variety and improved technologies, which will increase the adoption of new technologies and reduce the cost of cultivation of cardamom, subsidies on inputs like bio- fertilizers and pest control agent and to promote microbial products that are much cheaper and more sustainable and give best products and protect environment and the health of labourers and the local public, establishment of cardamom dryers and grading machines, introduction of the oil extraction facilities or factories, eco-tourism/ Farm tourism.

3. **Emotional intelligence and job stress of Agricultural Officers of Kerala State Department of Agriculture: A psycho-personal analysis. (July 2018)**
4. **Livelihood security assessment of women agripreneurs of self help groups (SHGs) in Kerala(Date of Completion:20-07-2018)**
5. **Work Life Quality and job satisfaction of agricultural professionals in commercial banks of Kerala: A critical analysis (Date of Completion: 04 -05-2018)**



# **Name of Project Coordination Group – (17) Sugar crops and Tuber crops**

**Compiled by:**

**Dr. Sheeba Rebecca Issac, Project Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 7 Nos.**

**Ongoing Projects - 18 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 2 Nos.**

**Ongoing Projects - 7 Nos.**

## Concluded Projects

### 1. Performance of improved short duration tapioca cultures/ varieties under different population densities in flood prone Upper Kuttanad area

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Varietal cum spacing trial was conducted at ARS, Thiruvalla and farm trials in 13 different locations coming under Pathanamthitta and Alappuzha districts. The results of the trials conducted at the station over the years revealed that the growth and yield/plant<sup>-1</sup> were maximum when wider spacing of 90cm x90cm was followed. But the yield ha<sup>-1</sup> was under closer spacing (75 cm x75cm) solely because of the difference in plant population per unit area under different spacings. In the case of varieties, Vettikkavala Local out yielded all the varieties tested (59.50 t ha<sup>-1</sup>). Its cooking quality was also excellent compared to all the other varieties included in the trial. A similar trend was noticed in the case of farm trial results also where Vettikkavala Local has recorded the highest yield (55.60tha<sup>-1</sup>) compared to the check Vellayani Hraswa (34.64 t ha<sup>-1</sup>).

It can be concluded that for getting maximum yield/ha<sup>-1</sup>, closer spacing (75x75 cm) is better than wider spacing (90x90cm) even though growth and per plant yield will be more in the latter since the total yield depends upon plant population per unit area. Vettikkavala Local is the best variety suited for the flood prone Upper Kuttanad area since its yield was maximum as well as tuber quality was excellent among the different varieties tested.

The promising culture Vettikkavala Local has been released as a variety with the name KAU Uthama for cultivation in the flood prone Upper Kuttanad area.

### 2. Zonal varietal trial for identifying early maturing varieties

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The experiment was laid out in RBD with 3 replications at ARS, Thiruvalla and five entries tried were Co 11001, Co 11004, CoM 11081, CoM 11082 and CoM 11084 and the standards Co 85004, Co 94008 and CoC 671 during 2016-2018. The pooled analysis results are briefed as follows-

CCS (t/ha): No significant difference was observed between the entries

Cane yield (t/ha): No significant difference was observed between the entries

Brix %: No significant difference was observed between the entries

Extraction %: No significant difference was observed between the entries

NMC ('000/ha): No significant difference was observed between the entries

Stalk Length (cm): All the entries except CoM 11081 performed on par with best standard

Stalk Diameter (cm): No significant difference was observed between the entries

Single cane weight (kg): No significant difference was observed between the entries

### 3. Varietal trial for identifying Midlate maturing varieties

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The Comparative yield trial was taken up at ARS Thiruvalla during 2016-2018 with six entries viz., Co 11005, Co 11007, Co 11012, Co 11019, CoM 11085 and CoM 11086 and two standards, Co 86032 and Co 99004 in Randomized Block Design with 3 replications. After pooled analysis it was concluded that for the attributes

CCS (t/ha): No significant difference was observed between the entries

Cane yield (t/ha): No significant difference was observed between the entries

Brix %: Best standard performed significantly superior to all the entries

Extraction %: No significant difference was observed between the entries

NMC ('000/ha): No significant difference was observed between the entries

Stalk Length (cm): No significant difference was observed between the entries

Stalk Diameter (cm): No significant difference was observed between the entries

Single cane weight (kg): No significant difference was observed between the entries

**4. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2004 series**

Dr. Shajan V. R  
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The objective was to evolve red rot resistant flood tolerant high yielding high sugared varieties of sugarcane suited to different agro climatic tracts of Kerala. Maximum cane yield (t/ha) was recorded by standard Madhuri (87.25) which was on par with Cul. 17/14 (76.89) and Cul.68/04 (71.14) and significantly superior to other entries. Number of millable cane count ('000/ha) recorded by Madhuri (91.73) and on par with Cul. 17/14 (74.85) and Cul. 68/04 (74.62) and significantly superior to other entries

**5. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2005 & 2007 series**

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Seventeen zonal crosses and 31 general collections were made and the seedlings obtained are to be evaluated for high yield, better quality parameters and reaction to red rot. Similarly the following 16 station crosses, 15 zonal crosses and 36 polycrosses and general collections were made and the seedlings obtained are to be evaluated for high yield, better quality parameters and reaction to red rot. Entries from these were also evaluated in CYT along the entries from 2005 series. The results are as follows: Cane yield (t/ha): Maximum cane yield (t/ha) was recorded by the standard Madhuri (90.42) and significantly superior to all the entries. None of the entries found promising

**6. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2008 series**

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The objective of the programme was to evolve red rot resistant flood tolerant high yielding high sugared varieties of sugarcane suited to different agro climatic tracts of Kerala. Nearly 17 station cross, 14 zonal crosses, 10 poly cross and 20 general collections were made and the seedlings obtained are to be evaluated for high yield, better quality parameters and reaction to red rot. The standard Madhuri reported significantly superior cane yield compared to all the entries and performance of the entries were inferior compared to standard

**7. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2009 series**

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The trials were laid out to evolve red rot resistant flood tolerant high yielding high sugared varieties of sugarcane suited to different agro climatic tracts of Kerala. Ten station crosses, 14 zonal crosses, 12 poly crosses and 31 general collections were made and the seedlings obtained are to be evaluated for high yield, better quality parameters and reaction to red rot. Standard Madhuri outperformed all the entries for cane yield and NMC ('000/ha). No entry was found promising compared to standard

**Continuing Projects**

**1. Agronomic performance of elite sugarcane genotypes**

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The experiment to evaluate the performance of elite sugarcane genotypes was planted on 27.01.2017 and was harvested on 20.01.2018

In the case of early varieties, the germination % and tiller count were influenced significantly by the various genotypes and the highest values for the said parameters were recorded by CoM 11082 followed by Co 94008 under both the spacings (120 and 150 cm)

The treatment variation due to various genotypes were significant for cane length, cane diameter, single cane weight, MCC, cane yield and sugar yield and CoM 11082 recorded the highest value for the said parameters (232.65 and 240.28 cm, 2.99 and 3.07cm, 1.31 and 1.35 kg, 69360 and 74430 nos./ha, 63.90 and 70.72 t/ha, 7.10 and 7.82 t/ha respectively) followed by Co 94008 (228.00 and 235.34 cm, 2.96 and 3.03 cm, 1.29 and 1.32kg, 60210 and 65650 nos./ha, 55.70 and 62.41t/ha, 5.88 and 6.28 t/ha respectively).

With regard to midlate varieties, both the growth and yield parameters were influenced significantly by the genotypes and the highest values for cane length, cane diameter, single cane weight, MCC, cane yield and sugar yield were recorded by Co11007 (255.33 and 262.74 cm, 3.03 and 3.10 cm, 1.52 and 1.57 kg, 72120 and 77770 nos./ha, 69.30 and 75.17 t/ha, 7.60 and 8.25 t/ha) followed by Co 86032(252.33 and 257.14cm, 2.91 and 2.96 cm, 1.49 and 1.53 kg, 60180 and 65250 nos./ha, 55.17 and 60.08 t/ha respectively).

## **2. Impact of integrated application of organics and inorganics in improving soil health and sugarcane productivity**

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The experiment to study the impact of integrated application of organics and inorganics in improving soil health and sugarcane productivity was planted earlier as specified in the technical programme. The ratooncrops(1st and 2nd) were also harvested subsequently.

The germination and tiller count remained unaffected due to various treatments tried. The variation due to different treatments were significant for growth and yield parameters. In both ratoon crops, among the various treatments, T<sub>8</sub> (FYM/compost @ 10 t/ha + biofertilizer(Azotobacter/Acetobacter+PSB) +100 RDF) recorded significantly higher values for cane length(265.07 and 255.83 cm respectively), MCC(73240 and 71320 nos./ha respectively) etc and resulted in maximum yield(81.10 and 74.48t/ha respectively). Brix % and sugar yield also followed the same trend with significantly higher values for sugar yield (8.55 and 7.98t/ha respectively) for the very same treatment. It was followed by T<sub>6</sub>(FYM/Compost @ 20 t/ha + inorganic nutrient application based on soil test (rating chart).

Slight variation in the soil fertility parameters were noticed before and after the conduct of the trial especially regarding the status of major nutrients where higher values were recorded in the soil after the conduct of the experiment. The nutrient composition of the farm yard manure used was 1.0:0.5:1.0 % N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O. The treatment T<sub>8</sub> recorded the highest BC ratio(1.38).

## **3. Use of plant growth regulators (PGRs) for enhanced yield and quality of sugarcane**

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The experiment was conducted to study the effect of plant growth regulators on germination, growth, yield and juice quality of sugarcane. The crop was planted on 15.01.2017 and was harvested on 11.01.2018.

The results revealed that the different treatments have significantly influenced the germination percentage and tiller count.

The highest germination percentage and tiller population were recorded by T<sub>8</sub> (T<sub>4</sub>+ GA<sub>3</sub> spray (35ppm) at 90,120 and 150 DAP) and the lowest value for the above parameters were recorded by T<sub>2</sub> (planting of setts after overnight soaking in water).

Maximum cane length (260.33 cm), MCC (83180 nos./ha), cane yield (111.23t/ha) etc. were recorded T<sub>8</sub>. Sugar yield also showed same trend and recorded significantly higher value (11.60t/ha) for the very same treatment (T<sub>8</sub>). There was some variation in the soil fertility parameters prior to and after the conduct of the trial. The highest BC ratio of 1.40 was also recorded by T<sub>8</sub>.

#### 4. Scheduling irrigation with mulch under different sugarcane planting methods

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The experiment with the objective of enhancing crop and water productivity in sugarcane was planted on 20.01.2017 and harvested on 15.01.2018.

There were no effect on germination % and tiller count due to various planting methods and irrigation schedule.

The treatment variation due to planting methods, green manure and mulch practices as well as irrigation schedule were significant for growth and yield parameters.

The growth and yield attributes recorded in P<sub>4</sub> (furrow planting at 120 cm spacing with alternate skip furrow irrigation after earthing up + green manure/brown mulching) was significantly superior to other planting methods and mulch practices tried. The maximum cane length (262.56 cm), cane diameter (3.18 cm), single cane weight (1.56 kg), MCC (82000 nos/ha), cane yield (101.00 t/ha), and sugar yield (9.47 t/ha) were recorded by P<sub>4</sub>. With regard to irrigation schedule, the highest value for cane length (259.92 cm), cane diameter (3.10 cm), MCC (77020 nos/ha), cane yield (81.55 t/ha), and sugar yield (7.994 t/ha) were recorded by I<sub>3</sub> (IW/CPE ratio -1.00).

The interaction effect was significant for cane length, MCC, cane yield and sugar yield and the maximum values were recorded by the treatment combination P<sub>4</sub>I<sub>3</sub> (260.94 cm, 88250 nos, 111.27 t/ha and 10.90 t/ha respectively).

There was slight variation in the fertility status of the soil before and after the conduct of the trial. Among the treatment combinations, the highest BC ratio of 1.41 was recorded by the treatment combination P<sub>4</sub>I<sub>3</sub>.

#### 5. Carbon sequestration assessment in sugarcane based cropping system

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Asst.Professor  
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The plant crop has been taken up during 2016-17 and subsequently treatment schedule for the ratoon crop as specified in the technical programme has been undertaken during 2017-18. There were no effect on germination % and tiller count due to various treatments. The variation due to different treatments were significant for growth and yield parameters. Among them, T<sub>5</sub> - Sugarcane-Ratoon (trash mulching with Trichoderma)-cowpea recorded the maximum cane length (260.68 cm), cane diameter (2.47 cm), single cane weight (1.70 kg) etc. and resulted in significantly higher cane and sugar yield (77.17 and 8.23 t/ha respectively) followed by T<sub>6</sub> - Sugarcane-ratoon-cowpea (trash incorporation through rotavator and Trichoderma incorporation before sowing of cowpea) which recorded the values of 254.33 cm, 2.41 cm, 1.65 kg and 69.65 and 6.81 t/ha respectively for the said parameters.

There was considerable variation in the fertility status of the soil before and after the conduct of the trial where the nutrient status was improved after imposing the various treatments.

#### 6. Identification of pathotypes of red rot pathogen

Dr. Rini C.R  
Assistant Professor  
[rini.cr@kau.in](mailto:rini.cr@kau.in)

The disease development on different differentials indicated that, among the isolates, Cf94012-O behaved differently from the reference pathotype CF06 and was found to be the most virulent one during the current year.

#### 7. Evaluation of zonal varieties for resistance to red rot

Dr. Rini C.R  
Assistant Professor  
[rini.cr@kau.in](mailto:rini.cr@kau.in)

Varieties which showed either Resistant (R) or Moderately Resistant (MR) red rot reactions in Initial Varietal Trial (IVT): Co 14002, Co 14003, Co 14004, Co 14006, Co 14008, Co 14009, Co 14012, Co 14016, Co 14023, Co 14026, Co 14027, Co 14030,

Co 14031, Co 14032, Co 13021, Co 13022, CoN 14071, CoN 14072, CoN 14073, CoN 14074, CoSnk 14102, CoSnk 14103, CoT 14366, CoT 14367, CoTl 14111, MS 14081, MS 14082, CoVC 14062, VSI 14122, and CoSnk 05103  
Advanced Varietal Trial (1<sup>st</sup> Plant):Co 12008, Co 12019 and CoSnk 05103  
Advanced Varietal Trial (II<sup>nd</sup> Plant Early): Co 11004, CoM 11084, Co 85004 and Co 94008  
Advanced Varietal TRIAL (II<sup>nd</sup> PlantMidlate): Co 11007, Co 11012, CoM 11086 and Co 99004

#### **8. Survey of sugarcane diseases naturally occurring in the area on important sugarcane varieties**

Dr. Rini C.R  
Assistant Professor  
[rini.cr@kau.in](mailto:rini.cr@kau.in)

During 2017–18, the most predominant diseases were PokkahBoeng and the foliar diseases viz., ring spot and sheath blight. But they were not found in such a severe form to cause any drastic yield loss.

#### **9. Zonal varietal trial for identifying early maturing varieties**

Dr. Rini C.R  
Assistant Professor  
[rini.cr@kau.in](mailto:rini.cr@kau.in)

Comparative yield trial (First plant, second plant and ratoon) crop of the selected genotypes are being carried out

#### **10. Standardisation of nutrient requirements for the sugarcane tracts of Marayoor and Kanthalloor in Idukki district.**

Dr.Jayakumar.G.  
Asst.Professor  
[jayakumar.g@kau.in](mailto:jayakumar.g@kau.in)

Even though the trial is of 2015-16 plan project,due to technical reasons,it could be implemented only during 17-18.The experiment has been laid out and the crop was planted as per the technical programme and is progressing accordingly.Results of the trial will be available only after the harvest of the crop and hence such data pertaining to juice quality and yield are awaited.

#### **11. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2010 series- CC 06-00 07/TLA 9 10KAU**

Dr. Shajan V. R  
Professor  
[shajanvr@kau.in](mailto:shajanvr@kau.in)

The experiment was repeated

#### **12. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2011 series- CC 06-00 07/TLA 9 11KAU**

Dr. Shajan V. R  
Professor  
[shajanvr@kau.in](mailto:shajanvr@kau.in)

Entries were ratooned

#### **13. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2012 series- CC 06-00 07/TLA 9 12KAU**

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Professor  
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Entries were ratooned

#### **14. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme**

2013 series- CC 06-00 07/TLA 9 13 KAU

Dr. Shajan V. R  
Professor  
[shajanvr@kau.in](mailto:shajanvr@kau.in)

Entries were ratooned

**15. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2014 series- CC 06-00 07/TLA 9 14 KAU**

Dr. Shajan V. R  
Professor  
[shajanvr@kau.in](mailto:shajanvr@kau.in)

Entries were ratooned

**16. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2015 series- CC 06-00 07/TLA 9 15 KAU**

Dr. Shajan V. R  
Professor  
[shajanvr@kau.in](mailto:shajanvr@kau.in)

Seedlings ratooned

**17. Evolution of sugarcane varieties for the different agro climatic tracts of Kerala and fluff exchange programme 2016 series- CC 06-00 07/TLA 9 16 KAU**

Dr. Shajan V. R  
Professor  
[shajanvr@kau.in](mailto:shajanvr@kau.in)

Seedlings ratooned

**18. Exploitation of under-utilized root and tuber crops for food and nutritional security**

Dr. Kumari.OSwadija  
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The field trial demonstrating the influence of INM and organic nutrition on west Indian arrowroot in farmer's field revealed organic nutrition (FYM@15 t ha<sup>-1</sup> + biofertiliser) to be superior to application of FYM @ 15 t ha<sup>-1</sup> without biofertiliser, FYM @10t ha<sup>-1</sup> +50:25:75 kg NPK ha<sup>-1</sup> with and without biofertiliser and control(no input). In order to popularise cultivation and utilisation of arrowroot for food and nutritional security, a one day training programme on "Arrowroot as intercrop in coconut- cultivation and processing" was conducted on 24/03/18 at Coconut Research Station Balaramapuram for 37 farmers. Planting material was also distributed. Two field trials in arrowroot have also been laid out in farmer fields in Thiruvananthapuram.

**PG Projects**

**Concluded Projects**

**1. Weed management in elephant foot yam [*Amorphophallus paeoniifolius*(Dennst.) Nicolson]**

The experiment was envisaged to investigate the effect of frequency of weeding through various means on growth and yield of elephant foot yam was completed in December 2016. Based on the results it was concluded that mulching with black polythene, pre emergence application of oxyfluorfen and post emergence application of glyphosate are effective weed management options in elephant foot yam.

**2. Agronomic package for container grown elephant foot yam**

The experiment to standardize the growth medium and nutrient + irrigation schedule for elephant foot yam at CoA, Vellayani revealed that the best medium was soil, coir pith and FYM in 1 :1:1 ratio by volume (9 kg soil + 3kg coir pith and 3 kg FYM). The recommended dose of 100:50:150 kg NPK ha<sup>-1</sup> can be supplied through groundnut cake, bone meal and

wood ash in which bone meal is given as basal dose and groundnut cake and wood ash in six splits at monthly intervals. Irrigation was standardized as once in three days during non rainy months.

### Ongoing PG Projects

**1. Standardisation of nursery techniques through field validation in minisett cassava (*Manihotesculenta*Crantz).**

Field experiment has been completed Data tabulation and statistical analysis are in progress

**2. Nutrient management for productivity enhancement of cassava var. Vellayani Hraswa in lowlands**

Field crop was harvested and chemical analyses are being done

**3. Growth and yield of tannia (*Xanthomasagittifolium*(L.) Schott) under different shade levels and planting materials**

The field experiment has been completed, data analysis and compilation of results are under progress

**4. Crop-weather-nutrient relations in cassava under moisture stress**

The field experiment has been completed; dataanalysis and compilation of results are under progress

**5. Genetic variability in chinese potato (*Solenostemenrotundifolius*Poir) for yield and nematode tolerance**

**6. High density planting and seed tuber size on productivity of lesser yam (*Dioscoreaesculenta*)**

**7. Integrated nutrient management in minisett cultivation of elephant foot yam [*Amorphohalluspaeniifolius* (Dennst.) Nicolson]**

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## **Faculty – AGRICULTURAL ENGINEERING**

**Dr. Santhi Mary Mathew  
Professor (RC)**



# **Name of Project Coordination Group – (01) Farm Power Machinery and Energy**

**Compiled by:**

**Dr. V. R. Ramachandran, Project Coordinator**

## **AICRP on FIM**

**Concluded Projects: 1 Nos.**

## **Post Graduate Projects**

**Concluded Projects: 3 Nos.**



**Concluded Projects****Year: 2017 - 2018****1. Title: Computer aided analysis of sit and stand type coconut climbers for mechanical stability****FRC No:** FPME/01-04-01-16/TNR(1)/KAU/PG

Testing the mechanical stability and strength of coconut palm climbers (KAU and Farmer's model) using ANSYS 15.0 software was done. The KAU and farmer's model were safe to use up to a load of 1000 N. A draft test code with Minimum Performance Standard (MPS) was also prepared under the study

**2. Title: Design analysis of KAU pokkali paddy harvester towards the development of its scale down prototype****FRC No:** FPME/01-04-02-16/TNR(01)/KAU/PG

The newly designed scale down prototype had an overall size of 6.2 x 1.7 x 1.7 m with a total weight of about 1700 kg. The new design was done in such a way to suit the fragmented pokkali areas. The vertical centre of gravity of the new design was 0.58 m, longitudinal centre of gravity 2.67 m and transverse centre of gravity zero. As the transverse centre of gravity was zero, scale down harvester was stable to float and longitudinal centre of gravity was near to the centre.

**3. Title: Investigations on design parameters for the development of a pineapple harvester****FRC No:** FPME/01-04-03-16/TNR(1)/KAU/PG

The cutting energy requirement of pineapple stem and leaves were determined using an impact test rig apparatus. For the mechanical harvesting of pineapple, three fruit holders were designed and fabricated. The maximum cutting energy and force of pineapple stem was obtained as 18.10 J and 842.70 N respectively, during the first harvest. In case of pineapple leaves, older leaves require maximum cutting energy of 9.60 J. The field evaluation of fruit holders was conducted and it was found that the holder with 150 mm diameter blade required minimum time for harvesting with a capacity 132 fruits/ h. The minimum damages of leaves and more comfort in handling and operation was also observed with this model.

**4. ALL INDIA COORDINATED RESEARCH PROJECT ONFARM IMPLEMENTS AND MACHINERY**

Dr. Shaji James. P  
Professor (FPME), KCAET, Tavanur  
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**Year: 2015-18****1. Title: Design fine tuning and testing of pineapple harvesting attachment to brush cutter****FRC No:** FPME/01-06-01-15/TNR(01)/KAU/ICAR**Co – PI:** Er. Shivaji K. P., Assistant Professor, Dept. of FPME, KCAET, Tavanur

A pineapple harvesting attachment to brush cutter was developed. The model had a fixed fruit holder and was found working satisfactory when operated for the first year crop. The holder was then modified so as to move it using a cable arrangement. Then it was tested in the field for second year crop and the average time taken for harvesting one fruit was observed as 25 seconds. Although the performance was satisfactory, difficulty in positioning the cutter head and holder due to thickly grown leaves was a drawback. Then two refined models of the fruit holders were developed as attachment to back pack engine operated brush cutter. The first design consisted of a holder which can be moved with respect to cutting edge by a operating lever. The second design consisted of a finger like holder which can grip the fruit tightly while harvesting. The fixed holder with the movable base plate required less time for harvesting and was found more comfortable in handling.



## **Name of Project Coordination Group – (02) Soil and Water Engineering (SWE).**

**Compiled by:**

**Dr. Rema. K.P., Project Coordinator**

### **Plan & External Aided Projects**

**Concluded Projects - 2 Nos.**

**Ongoing Projects - 3 Nos.**

### **Post Graduate Projects**

**Concluded Projects- 3 Nos.**

**Ongoing Projects - 18 Nos.**



## Concluded Projects

### 1. Network Project on Enhancing Water Productivity in Coconut Farming through Precision Irrigation

#### Lead Centre - Department of Agricultural Engineering, College of Horticulture, Kerala Agriculture University, Vellanikkara.

The effect of point of application of drip irrigation was showing significant impact on coconut yield in all treatments of subsurface application compared to surface application. Water application at 75% PE and fertigation @ 50% POP recommendation is sufficient for better water productivity and yield in coconut.

A "Farmer Service Support Group" namely "*Karshika Jala Sankethika Sena*" capable of design, installation and maintenance of drip irrigation, installation of different site specific water harvesting and conservation works, operation of mini tractor, brush cutter etc was formed by conducting 21 days advanced training for a selected group of 28 farmers. Training programmes were conducted to create awareness on water harvesting and judicious use of irrigation water to different stake holders Altogether 26 no. of trainings were conducted for 1017 stakeholders.

Totally 8 nos. of research papers were published including National and International journal papers, popular article and booklets. A demonstration model of drip fertigation unit was installed at Nodal Water Technology Centre. A Software for drip irrigation design namely e-DID (electronic device for Drip Irrigation Design) was designed, developed, tested, popularised and launched in KAU web site.

#### Participating Centre- Regional Agricultural Research Station, Pilicode.

The studies conducted by the centre indicated that subsurface drip fertigation is more productive compared to application of water through surface drip system and fertilizer through conventional methods. Treatments with irrigation at 100% Pan Evaporation (quantity of water applied varied from 34lit/day in November to 49 lit/day in April) using subsurface drip & 75% of recommended dose of fertilizer produced highest yield of coconut. The study indicated that there is saving of 62% of water when compared to basin irrigation in coconut and 25% saving of fertilizer by adopting drip fertigation when compared to conventional method of fertilizer application. The study also indicated that irrigation at 100% Pan Evaporation & 75% of recommended dose of fertilizer is sufficient to achieve better water productivity in coconut farming with high yielding varieties (highest water productivity in the year 2016 is 13nuts/palm/cum of water). As a result of this study, drip fertigation schedule for high yielding variety of coconut could be developed.

Several training programmes were conducted to create awareness on water saving irrigation technologies, fertigation, rainwater harvesting etc. Altogether 599 stake holders were trained. This will immensely motivate the farmers in adopting drip fertigation system in their field for various crops, and also for better management of drip system once it is installed.

A Farmer Service Support Group - *Karishika Jala Sankethika Sena* was formed by giving advanced training of 15 days on Design, installation, repair and maintenance of drip fertigation system. The team consists of 28 persons including educated youth and farmers. The group is now engaged in the installation of drip irrigation to farmers. They are also undertaking repair and maintenance work of already installed drip system in the farmers' fields. The service rendered by this group will helping in addressing one of the major constraints pointed out by the farmers during survey i.e. lack of repair and maintenance facilities of drip system installed in their field.

#### Participating Centre - Coconut Research Station, Balaramapuram, Thiruvananthapuram,

Research works carried out for enhancement of water productivity in coconut by applying water and nutrients at the root zone through sub surface drip irrigation revealed that all the treatments with subsurface application of fertilizer and water through drip were significantly superior to surface application through drip. The treatments with 75% PE (Pan Evaporation) irrigation level and 75% (POP - KAU) fertilizer level and 125%PE irrigation level and 75%(POP) fertilizer level gave higher yields even though they were on par with other levels of irrigation and fertigation through sub surface application. The effect of irrigation on yield increase under both surface and subsurface application was pronounced from third year of experiment onwards. The study on water productivity revealed that subsurface drip irrigation at 75% PE and fertilizer @ of 50% POP recommendation through fertigation is sufficient for better water productivity and fertilizer use efficiency in coconut. The soil nutrient status of the treatment plots showed that the fertilizer use efficiency is higher in subsurface fertigation treatments compared to conventional method of application. The highest soil moisture for surface drip is about 12 % while in sub surface irrigation it is 24.1% at 45cm depth, which revealed that about 12% soil moisture is more conserved in subsurface treatments due to reduction in the evaporation losses from the surface.

## **2. Development and testing of Organic Fertigation unit with power operated agitator**

Organic fertigation unit with hand operated agitator was developed and tested for its performance. Fabricated a power operated agitator. Nutrient analysis of agitated manure solution, filtrate, residue etc. was done. Hand operated agitator was found effective in agitating the organic manures. A hand operated agitator was developed and tested. The nutrient content of manure solution, filtrate and residue were analyzed and found good for fertigation. A power operated agitator was fabricated and tested for its performance. Vermicompost solution for fertigation can be prepared by mixing vermicompost and water in a ratio of 1:5 followed by agitation for 10 minutes and settling for 6 hours. In the case of cowdung when settling time increases nutrient content in filtrate decreases. Agitation time does not have any effect on nutrient content in the cow dung solution. The power operated agitator developed and tested was found effective in agitating organic manure and could be incorporated in organic fertigation unit.

## **Ongoing Projects**

### **1. Study on structural design and management for Hi-Tech Horticulture in Kerala**

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In this project, detailed studies are going on at hi-tech research station, IF, Vellanikkara; with various crops in different combination of sheet different color of shade net, different types of structures etc. Screening/ evaluation of vegetables suited for Kerala under protected structures by noting growth and yield characteristics and economic viability are also going on. In each greenhouse studies are going on for comparing the soil and soilless media. Studies are progressing in six number of hydroponics units (NFT) and two number of dutch bucket system to select suitable crops, optimum water quality parameters to be maintained in NFT while cultivating vegetable crops and to evaluate the balanced nutrient mix developed at HTR&TU. Studies were also conducted to find suitable variety of lettuce, yard long bean, amaranthus salad cucumber, Gherkins, chilly etc in aquaponics and also to find crops suitable for media bed and deep water culture. Studies were also conducted to reduce the energy consumption in Aquaponics by utilizing the timer, new generation pumps and ventury in the system. Study revealed that more than 75% energy consumption can be reduced by introducing these facilities in the system. An automatic fish feeder has also developed which will function with the help of this timer. Studies were conducted by regulating circulation of water by controlling the operation by utilizing a timer in 2 family Aquaponics system and one commercial Aquaponics system.

Studies are progressing to combine the poly kitchen garden, Aquaponics system and poultry unit. All multitier grow bags are attached to this system. This study aims to provide fish, egg, meat and vegetables in a single system.

A final model of polykitchen garden has been developed and more and more improvements were introduced on this aspect. This system was recommended for popularization among public and centre has constructed about 10 number of units in the farmer field and Govt. farms. Now studies are progressing to combine the poly kitchen garden, Aquaponics system and poultry unit so as to make available fish, vegetable, egg and meat from one unit for a family. A nutrient solution suitable for hydroponics system was developed and found that it is giving better performance compared to other commercially available nutrient solutions for hydroponics. Study revealed that by utilizing the service of a timer for controlling circulation of water, new generation pump for circulating water and new generation pump and ventury for aeration in Aquaponics system, we can reduce the power consumption more than 75%. If the media is 20mm metal, we have to pump the water in a media bed only during 7am to 7pm with 1 hr off and 10 to 20 mts on depending on the size of the bed (it is the time required to fill the bed upto the required level plus additional 5 to 10 min time to flow water through bed upto wet and dry zone, ie; 3 to 5 cm below the top of bed). This will not only help to reduce power consumption, but also help to improve the growth and yield of crop. The final specification of polyhouse and polykitchen garden based on the studies conducted has been approved by ZREAC and is given to funding agency for popularization among the public. Full package of polykitchen garden details have been given to funding agency and training has been given for agro service centres of various districts of Kerala. Recommendations to farmers based on the study conducted at the centre has also been given to funding agency on nutritional aspects, bed preparation, variety selection, soilless cultivation, Aquaponics and hydroponics etc.

### **2. Development of a Suitable Filtering Techniques For Reusing Household Waste water for Irrigation**

As a preliminary study, 30 samples of each were collected and analysed for physico-chemical parameters like pH, EC, Chloride, Carbonates, Bicarbonates and Potassium. The laboratory analysis for other parameters such as sodium, potassium, boron, calcium, magnesium, SAR, RSC and presence of heavy metals were also done. Nutrient content and biochemical oxygen demand of kitchen waste water and normal water were also analysed.

Observations showed that EC, SAR and boron were low, but RSC ranged from low to medium level. Presence of heavy metals such as lead, chromium and nickel was found to be negligible and/or within the permissible limits in kitchen waste water. Biochemical oxygen demand of kitchen waste water is 32.10 mg L<sup>-1</sup> which is safe for irrigation purpose. Mineral elements viz. calcium, magnesium, sodium and potassium present in the kitchen waste water is higher than normal fresh water but it is within the permissible limit. It was found that all the parameters tested were within the safe limits and water is moderately suitable/suitable for irrigation.

A field trial in vegetable crop, okra (*Arka anamika*) was conducted using kitchen waste water during the summer season in the year 2016-17. Performance of the crop was compared with that of normal fresh water. Observations on growth and yield of the crop were noted. Observations on growth of the crop showed that height and number of leaves in the two treatments were on par even though the growth of the crop irrigated with kitchen waste water was higher than well water. Phenotypic observations showed no toxic symptoms on plants. Observation on yield characters such as fruit weight and number of fruits showed that yield of the crop irrigated using kitchen waste water was 6.20 kg/plot(6 plants) while it was only 4.10 kg/plot(6 plants) with well water. Higher yield in kitchen waste water irrigated crops may be due to the presence of more nutrient minerals.

Ponds of size 6m x 3m x 2m were made for fish farming using kitchen waste water. Fish fingerlings of tilapia of 45 days old were grown and compared with the growth of the fish in the fresh water. Fish farming using kitchen waste water showed that tilapia variety grows well and gained an average weight of 200 g in 6 months. Average biological oxygen demand of the water was 32.1 mg/l which is suited for aquatic life while the normal fresh water was only 2.5 mg/l. Quality analysis of kitchen waste water for irrigation purpose showed that all chemical characteristics including heavy metal content were within the permissible limit and it is moderately suitable/ suitable for irrigation. Field tests in vegetable crop, okra showed better performance of the crop compared to well water. Results of the study showed that kitchen waste water can be used for irrigation purpose in okra and also for fish farming without undergoing any treatment

### 3. Studies on augmenting vegetable production by Poly house cultivation using water and energy efficient ecofriendly technologies.

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Professor  
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The study aims at installing a solar powered irrigation system for the existing poly house in the research plot of the Department of Irrigation & Drainage Engineering. The work is in progress and the procedures for tendering and procuring solar panel is completed.

#### PG Projects

#### Concluded Projects

##### 1. Comparative evaluation of evapotranspiration parameters in a naturally ventilated poly house and open field.

A study was conducted for the comparative evaluation of evapotranspiration parameters in a naturally ventilated poly house and open field in the research plot of KCAET, Tavanur. The proportion of diffuse radiation inside polyhouse is different from that outdoors. Chance of variation in the values of crop coefficients, between inside and outside the polyhouse is higher. Non-weighing Mini-Lysimeters were used to determine evapotranspiration parameters and to develop crop-coefficient curves for Okra. Indirect methods were also used for comparison. ET<sub>0</sub> estimated using FAO-56 Penman – Monteith provides good agreement with evapotranspiration obtained by lysimeteric data with a high correlation coefficient of 0.88 and 0.87 for polyhouse and open field conditions respectively. Seasonal average ET<sub>0</sub> for polyhouse and open field were 4.74 and 5.02 mm/day. It was observed that polyhouse K<sub>c</sub> values were lower than the open field. The variations in micro climate inside polyhouses with reduced solar radiation and wind velocity combined with higher humidity and temperature were observed as the reason for lesser ET inside poly houses.

##### 2. Regional groundwater resource modelling using modflow – a case study

In this work, Visual MODFLOW was used to develop a groundwater flow model for the West Godavari district of Andhra Pradesh. Model was calibrated using groundwater level data from 2003 to 2007 in steady state and is validated using 2008 to 2016 data in transient state condition. After validation, model was used for prediction in transient condition. The sensitivity of the model to input parameters was tested by varying only the parameters of interest over a range of values, and monitoring the response of the model by determining the root mean square error of the simulated heads compared to the measured heads. The developed model was also used to study the effect of Pattiseema Lift Irrigation Project on

groundwater scenario in the West Godavari district. Developed model was also used to predict the groundwater heads for next 15 years with increase in use of 5 % for every five years and decrease in recharge of 5 % for every five years.

### **3. Evaluation and refinement of low cost automation system for naturally ventilated greenhouse**

The refinement of the existing greenhouse automation system was done at Agricultural Research Station Anakkayam during July 2015 to October 2015. Evaluation of the refined low cost automation system was conducted at Agricultural Research Station, Anakkayam from December 2015 to February 2017. This field evaluation was done by installing the automation system in a greenhouse at ARS Anakkayam. Then field data were collected with salad cucumber crop inside the greenhouse for three crop seasons. Data includes microclimate data as well as biometric observations and yield data of crop. For the comparison of the data with a manually controlled greenhouse, salad cucumber crop was cultivated in another greenhouse without any automation. Microclimatic as well as crop data were collected from that greenhouse also. The results of the study proved that automatic microclimate control inside the greenhouse is better than manual control of greenhouse. Maximum yield was obtained from automated greenhouse.

### **Ongoing Projects**

1. Study on structural design and management for Hi-Tech Horticulture in Kerala
2. Development of a Suitable Filtering Techniques For Reusing Household Waste water for Irrigation
3. Conjunctive water management model for a multi crop irrigation command.
4. Assessment of lateral flow and base flow for effective interventions in water conservation.
5. Water availability and climatic water balance for a selected cropped area
6. Regional ground water resource modelling using MODFLOW-a case study
7. Study of geomorphological influence on the runoff characteristics of a catchment.
8. Soil erosion risk assessment in Kunthipuzha sub-watershed using RS&GIS
9. Evaluation of SWAT model for a tropical watershed with changing parameters
10. Irrigation planning and management of a canal irrigated command using geospatial tools
11. Modelling Ground water pollution using VISUAL MODFLOW-A case study.
12. Studies on augmenting vegetable production by Poly house cultivation using water and energy efficient eco friendly technologies.
13. Determination of subsurface storm flow using tracer method.
14. Estimation of soil moisture indices using diffuse reflectance spectroscopy
15. Determination of subsurface storm flow using tracer method
16. Runoff estimation of KCAET campus by curve number method adopting RS and GIS techniques
17. Development and evaluation of an automated pulse irrigation system
18. Development of automated drip fertigation system using GSM based controller

# **Name of Project Coordination Group – (03) Food & Agricultural Process Engineering**

**Compiled by:**

**Dr. K. P. Sudheer, Project Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 6 Nos.**

**Ongoing Projects - 10 Nos.**

## **Post Graduate Projects**

**Concluded Projects- Nos.**

**Ongoing Projects - Nos.**



## Concluded Projects

### 1. Centre of Excellence in Postharvest Technology-Development and optimization of microwave assisted process for extraction of nutmeg mace essential oil

Dr. Prince M.V  
Professor,  
[prince.mv@kau.in](mailto:prince.mv@kau.in)

Essential oils which are the volatile components distilled from the aromatic plant materials, have gained importance in cosmetic, therapeutic, aromatic, fragrant and spiritual uses. But the conventional methods of distillation carry the disadvantages mainly concerned with the quality of final product such as loss of some volatile notes, low extraction efficiency and degradation of unsaturated ester compounds through thermal or hydrolytic effects. These processes also requires high extraction times and energy consumption. However, in order to reduce these difficulties microwave energy could be effectively used to mediate extraction of essential oil in place of steam or water heating in order to introduce its inherent advantages. As in the case of microwave heating of food materials, the internal heating of the in-situ water within the plant material by the microwaves leads to the rupture of the glands and oleiferous receptacles freeing the essential oil which is then evaporated by the in-situ water of the plant material. The water then evaporated could then be passed through a condenser outside the microwave cavity where it is condensed. This study envisages development of a microwave assisted extraction system for extracting nutmeg mace essential oil. The developed extraction system consists of a microwave cavity, extraction unit, supporting stand and energy meter. In order to evaluate the developed system towards extraction of nutmeg mace essential oil, the process parameters like solid: water ratios of 1: 14, 1: 10 and 1:6, power densities of 9.6, 14.4 and 19.2 W/g and soaking times of 2, 3 and 4 h which would influence the essential oil yield, extraction time and energy consumption were chosen as independent variables. The physical quality characteristics like refractive index, specific gravity, solubility and colour of essential oil were selected as dependent variables. The optimized conditions of solid: water ratio, power density and soaking time for extracting nutmeg mace essential oil in microwave assisted process was found to be 1: 14, 14.4 W/g and 4 h respectively. Therefore, microwave assisted extraction could be considered as an extraction technique that results in the production of high quality oil in higher quantity in less time with minimum energy consumption.

### 2. Establishment of Agri- Business Incubator Facility at KCAET Tavanur

Dr. Rajesh G.K,  
Asst. Professor,  
[rajesh.gk@kau.in](mailto:rajesh.gk@kau.in)

The Agri-business Incubator (ABI) facility at KCAET Tavanur encompassing agri-market-oriented development plan that seeks to improve farmers' livelihoods through agri-business incubation. ABI provide facilities for enterprise support services component and other agribusiness information resources. The centre has provided entrepreneur support to eight processing industries (two rice mills, banana based ethnic mix, dehydrated vegetables, spice powders, thermal processed tender jack fruit, Intermediate moisture ripe banana and jack fruit, passion fruit processing. These processing industries provides a regular income to the rural youth specially women group. The ABI also conducted nearly 14 training for the potential food processing entrepreneurs.

### 3. Studies on microwave steam distillation process for extraction of lemongrass essential oil

Dr. Prince M.V,  
Professor,  
[prince.mv@kau.in](mailto:prince.mv@kau.in)

Microwave steam distillation is based on the interaction between water in the plant material and microwaves generated by the energy source. In this process, the steam generated outside accelerates evaporating and carrying of the essential oil, from the plant material, towards the condenser. In this study a microwave steam distillation system for extracting lemongrass essential oil was developed which composed of a microwave reactor, steam generator, cartridge, unit, supporting stand, energy meter and temperature sensor and controller.

In order to evaluate the developed system towards extraction of lemongrass essential oil, the effect of process parameters which would influence the essential oil yield, energy consumption and temperature of extraction such as bulk densities, microwave powers and soaking times were studied. The physical quality characteristics such as specific gravity, refractive index, solubility and colour of essential oil were analysed. The optimised operating conditions of bulk density, microwave power and time of extraction for lemongrass essential oil in microwave steam distillation were found to be of 0.375 g

cm<sup>-3</sup>, 420 W and 30 min respectively. Scanning Electron Micrographs of lemongrass provided evidences to sudden rupture of essential oil glands with microwave steam distillation process. Gas Chromatographs of essential oil extracted through microwave steam distillation process showed higher percentage of Citral than that of steam distillation process. From the study it was concluded that microwave steam distillation could be considered as an extraction technique that results in the rapid production of high quality essential oil at shorter extraction period with minimum energy consumption.

#### 4. Development and quality evaluation of spray dried probiotic flavoured yoghurt containing *Lactobacillus bulgaricus*.

Dr. Rajesh G.K,  
Asst. Professor,  
[rajesh.gk@kau.in](mailto:rajesh.gk@kau.in)

Commercial production of yoghurt has not been able to prove its supremacy in market due to its shorter shelf life. The shelf life of yoghurt can be improved by reducing its water content by drying. The dried products obtained are in shelf stable powder form which can be stored at ambient temperature. Spray drying technique has showed to be highly successful in prolonging the shelf life of food products. Considering these facts, a study was undertaken to develop a process protocol for flavoured yoghurt powder. The spray drying of yoghurt was carried out in lab scale spray dryer with twin fluid atomizer. The spray drying experiments were conducted with different process parameters viz., carrier blend ratio, inlet air temperatures and feed rates. Maltodextrin, corn starch and their combinations were used as wall material to produce yoghurt powder. Physicochemical properties of spray dried yoghurt powder were evaluated by standard procedures. The reconstituted yoghurt samples prepared from spray dried yoghurt powder were evaluated in terms of solubility and wettability. The process parameters were optimized based on the physico-chemical and microbiological properties of the developed yoghurt powder. By considering all the physico-chemical and microbiological analyses done on the spray dried yoghurt powder at different processing conditions, powder sample processed at 170°C inlet temperature with carrier blend 3:1 at feed rate of 10 rpm was selected as optimized sample. Flavoured yoghurt powder (with 2.5% white pepper extract and 3% ginger extract) was packed in laminated aluminium pouches and sealed using a hand sealing machine and subjected to storage studies. Sealed pouches were stored at ambient and refrigerated storage (4°C) for a period of three months and the effect of physical, chemical and microbiological characteristics during storage was studied. The product stored at ambient condition is acceptable only up to 50-75 days. But the product stored at refrigerated condition found safe up to 3 months.

#### 5. Development of A Multi - Fruit Slicer- Cum- Dicer

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

Importance of minimally processed fruits has already attained a very stable position in the market. Fresh-cut products are preferred over processed one because consumers are now aware of the commonly nutritional losses, desired sensory attributes such as colour and flavour and increased demand for 'Naturallike' attributes. The cut fruits are also used in preparation of chips, dry products salads and a wide variety of products. But the cutting of fruits and other vegetables were done manually which was found to be a difficult job at the same time affected the quality of the products. Thus, the need of the hour was to develop a multi-fruit slicer cum dicer (Fig.1) which could minimise all the mentioned problems. Main parts of the developed model consist of a 1 hp electric motor which was used to supply power to the transmission box, a conveying mechanism to feed the raw material to cutting blade assembly, and two blade drums made of stainless steel. Two types of cutting drums are provided in the machine, which helps in slicing and dicing of fruits and vegetables. The fabricated machine was evaluated for its overall capacity, slicing efficiency, and percentage damage. The fruits to be sliced or diced are fed into the machine using a belt conveyor towards the blade drums. The conveying drums properly guide the fruits into the blade. Later, the slices and dices can be collected from the tray. The capacity of the machine was 25 kg/hr. The developed machine helps in making the work much easier than manual method. Hence the machine could be widely used for small and medium industrial purposes.



Fig 1. Multi - fruit slicer- cum- dicer

## 6. Development and quality evaluation of hot extruded RTE product from speciality rice

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

As the eating patterns are changing day by day, snack foods play very important role in the diet of the modern consumer. Consumer appeal for ready to eat (RTE) products is forecast to grow rapidly as consumers demand convenient snacks with exciting sensory and textural properties. Extrusion technology has been used extensively in the production of cereal RTE snacks due to its ease of operation and ability to produce a variety of textures and shapes which appeal to consumers. So the present study was undertaken to develop ready to eat (RTE) expanded products from rice varieties (Rakthashali and Kumkumashali) and corn. The blends of six different combinations were extruded at temperature of 100, 110 and 120°C at a screw speed of 350 rpm and 17.5% feed moisture content. From these seven extruded product was evaluated for physical, colour and textural properties. The extruded products were stored in aluminium pouches and with nitrogen flushing. The quality parameters (expansion ratio, water activity, colour and textural properties) of stored RTE products were analysed upto three months. Based on sensory evaluation, RTE product produced from 50% Corn and 50% Kumkumashali was selected as the best combination.

### Ongoing Research Projects

#### 1. Establishment of Technology Refinement and Marketing Programme

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

The project '**Technology Refinement and Marketing Programme** -(TREMAP)' facility, at College of Horticulture Vellanikkara encompassing agri-market-oriented development plan that seeks to improve farmers' livelihoods through business incubation and commercial facilitation. TREMAP provide facilities for technology transfer, enterprise support services component and other agribusiness information resources. TREMAP work towards pushing the innovative technologies, up the commercialisation cycle, towards market through a network of technology commercialisation facilitators and establishing an enabling ecosystem for the same. The objective of the TREMAP programme is to facilitate linkages of the innovative technologies and developed products with market.

#### 2. ICAR National Fellow project "Effect of High Hydrostatic Pressure Processing on Textural and Nutritional Behaviour of Minimally Processed fruits and vegetables"

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

Preliminary trails on minimal processing of pineapple and jackfruit were carried out with various treatment combinations at ambient and refrigerated storage temperature. Minimally processed pineapple retained good quality attributes beyond 9 days under refrigerated storage. However, at ambient storage condition almost all samples were spoiled after 5<sup>th</sup> day of storage. By considering the quality parameters and decay score, the best treatment optimized for pineapple was a combination of NaCl, Citric acid and Sodium benzoate (SB), followed by a combination of CaCl<sub>2</sub> and SB. In case of tender and matured jackfruit, standardized pre-treatment was a combination of NaCl and SB. However a treatment combination of CaCl<sub>2</sub> and SB, was found ideal for ripe jackfruit bulbs. Further experiment will be carried out at the optimum storage condition (temperatures) using different packaging materials.

#### 3. Development and Quality Evaluation of Nutritionally Enriched RTE flakes from Speciality Rice

Dr. K.P Sudheer,  
Professor,  
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Consumption of brown rice is increasing due to the health benefits of germinated grains. Germinated rice contains abundant starch and high quality protein which are commonly used in food and beverage industry. It is reported that germination activates all the enzymes and increases the availability nutrients. Brown rice extract with enhanced levels of <sup>3</sup>-amino butyric acid (GABA) was reported to be having an inhibitory action on leukemia cell proliferation and had a stimulatory action on the cancer cell apoptosis. Hence efforts were taken to develop a RTE product enriched with GABA content in flakes from specialty rice to ensure a food which is nutritious without consuming much time for preparation.

It was found that rate of germination increases with increase in germination period in all the three paddy varieties. The highest germination rate was observed at 36 h germination period and the lowest at 12 h. Kumkumasali has lower rate of germination compared to other two varieties. Quantification of GABA content in germinated rice flakes and its quality evaluation is in progress.

#### **4. Development and performance evaluation of Coconut scraper**

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

Scraped coconut is an inevitable ingredient in south Indian dishes like chutneys, *puttu*, confectionaries, and sweet items. This is also used for the production of coconut milk, which is a common ingredient in various food items and used for the preparation of virgin coconut oil and other products. Scraping with mechanical scrapers/ traditional method is tedious and less comfortable. Keeping this in mind, this study was aimed to develop scrapers which can be used in large scale production as well as for household purposes. The current coconut scraping machines include traditional manual scrapers, mechanical scrapers, and electronic scrapers. Coconut scrapers of two different models were developed to meet the consumer requirement. Performance evaluation of developed scrapers are in progress.

#### **5. Establishment of Agri-Food Entrepreneurship Development Centre**

Dr. Geethakutty P.S  
Professor  
[geethakutty.ps@kau.in](mailto:geethakutty.ps@kau.in)

An Agri-Food Entrepreneurship Development Centre (AfedC) was established at CGSAFED to promote expanded opportunities for agri-food enterprises of major crops in the state through facilitation and capacity building of agribusiness operators, local government and development agencies. A database of crop produce surplus and status of the agri-food supply chains of the major food crops in Kerala (In two districts - Thrissur and Palakkad) were developed with respect to technology in harvest and post harvest management loss, and skill gaps. The centre would promote facilitation and capacity building for increased opportunities of agribusiness enterprises with stakeholder agencies. The field survey on crop produce surplus and value addition efforts of farmers engaged in commercial cultivation of selected crops in the two districts of Central Zone of Kerala – Palakkad and Thrissur was carried out during 2016-18. Relevant details of Ten crops - four major crops (common) (paddy, coconut, banana, vegetables) and six minor crops (optional) - (ginger, turmeric, jack, mango, tapioca, and nutmeg) were collected. 120 farmers and 60 farmers each were selected for common major crops and optional major crops (respectively). Thus a total number of 840 farmers (387 female and 453 male) selected from the districts of Thrissur and Palakkad in the Central Zone of Kerala has formed respondents for the study. The data collected is tabulated and data analysis is in progress.

#### **6. Development and evaluation of process protocol for Vacuum fried bitter gourd chips**

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

Nowadays with a growing demand of snacks around the world, products like chips, French fries and other fried food products are becoming more marketable. The fried bitter gourd snack is one of the most important nutritional snack in the market. The fried products are favoured by all age group of people, but it effects on human body like heart diseases, cancer, obesity etc. The atmospheric frying leads to higher oil absorption, degradation of oil quality that results in high production of acrylamide content. To overcome these problems, an alternative method of frying, i.e., vacuum frying was tried for the preparation of bitter gourd chips. The vacuum fried snacks retain good quality due to the less oxidation and lower frying temperature. The vacuum fried oil could be reused for more than 50 times/frying cycles. In this experiment is aimed to optimize the time, temperature, pressure and pre-treatment combination to retain the quality of frying oil and bitter guard chips. The experiment is in progress.

#### **7. Development of specialty rice based nutritionally enriched cold extruded pasta**

Dr. K.P Sudheer,  
Professor,  
[kp.sudheer@kau.in](mailto:kp.sudheer@kau.in)

Consumers are increasingly interested in foods containing healthy ingredients. Pasta has an excellent nutritional profile,

being a good source of complex carbohydrates and a moderate source of protein and vitamins. Besides being easy to prepare and a very versatile food, pasta has a relatively long shelf life when it is stored appropriately. Pasta is generally made from wheat flour. Instead of this, pastas were produced using Raktasali rice flour along with wheat and corn flour. Based on the cooking properties, treatment combination containing Rice flour of 59%, Wheat flour of 39% and Guar gum of 2% seems to be better treatment combination with lower cooking time and solid loss. Evaluation of physical properties and sensory characteristics are in progress.

#### **8. Development of a user friendly tool for pulp/ seed separation from toddy palm fruit**

Dr. Santhi Mary Mathew  
Professor  
[santhi.mathew@kau.in](mailto:santhi.mathew@kau.in)

The work was under taken to develop a user friendly tool to separate pulp from toddy palm. The engineering properties of toddy palm fruit were done prior to the fabrication work. Physical properties of toddy palm fruit viz., diameter of fruit, average spacing between the three seeds, thickness of husk, thickness of seed, length of seed and width of seed were studied. Mechanical properties viz., compression strength and firmness of the fruit were also determined. Based on the study of engineering properties, cutting blade of toddy palm fruit was designed and developed. Further refinement and development of the toddy palm fruit separation machine is going on.

#### **9. Value chain of jackfruit- Microwave assisted extraction of pectin from jackfruit (*Artocarpus heterophyllus*.L) waste (rind and core)**

Mrs. Sreeja R  
Asst. Professor,  
[sreeja.r@kau.in](mailto:sreeja.r@kau.in)

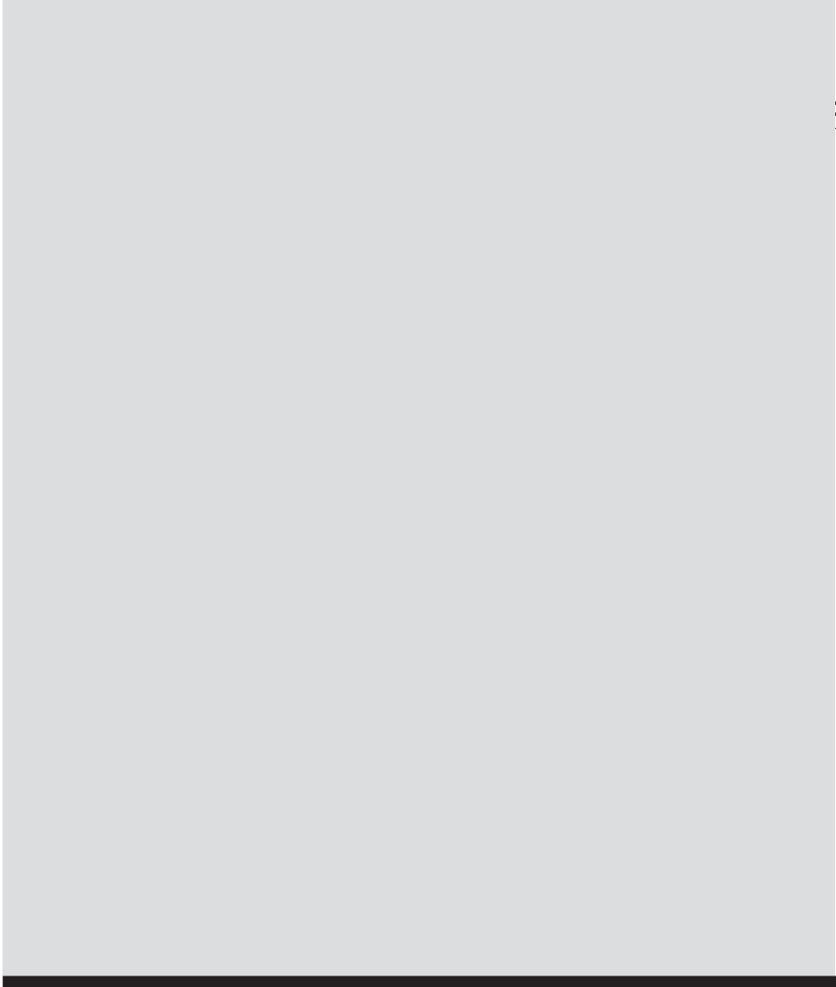
Jackfruit waste (rind and core) of different maturity stages were collected and dried at 60°C. Preparation of jack fruit waste powder and determination of pectin content in jackfruit waste using standard procedure are to be done. Proximate analysis (moisture content, ash content, crude lipid content, crude protein content and crude fiber content) for jackfruit rind and core will also be conducted.

#### **10. Development and evaluation of a batch type rotary cocoa dryer**

Dr. Rajesh G.K,  
Asst. Professor,  
[rajesh.gk@kau.in](mailto:rajesh.gk@kau.in)

Very high and very low temperature drying of cocoa beans results in low quality products. Stickiness nature of the fermented cocoa beans is also a major challenge at this field. Considering the above facts, an attempt was made to develop batch-type rotary cocoa bean dryer. It consists of drying chamber, blower, flow control valve, heating coil, rotating paddle type agitator and motor. Drying temperatures of 40, 45 and 50°C were tried at constant air flow rate of 2 m/s. The time required to achieve the constant moisture content in the case of sun drying at a temperature 30-36°C was 4 days with rest period at night from 5 pm to 9 am whereas the maximum time taken for the developed dryer at 40, 45 and 50°C were 10, 7 and 5.5 hrs, respectively. The determination of quality parameters of dried beans are in progress.





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## **Faculty - Forestry**

**Dr. P.O. Nameer**  
**Professor (RC)**



# **Name of Project Coordination Group – (01) Natural Forests and Biodiversity (NFB)**

**Compiled by:  
Dr. A.V. Santhoshkumar, Project Coordinator**

## **Plan & External Aided Projects**

**Concluded Projects - 3 Nos.**

**Ongoing Projects - 14 Nos.**

## **Post Graduate Projects**

**Concluded Projects- 19 Nos.**

**Ongoing Projects - 4 Nos.**



## Concluded Projects

### 1. Establishment of A GIS – RS Unit At The College of Forestry, KAU – To Serve as Central Facility for the University for Spatial Databases and Cartography

Dr. E.V. Anoop  
Professor  
anoop.ev@kau.in

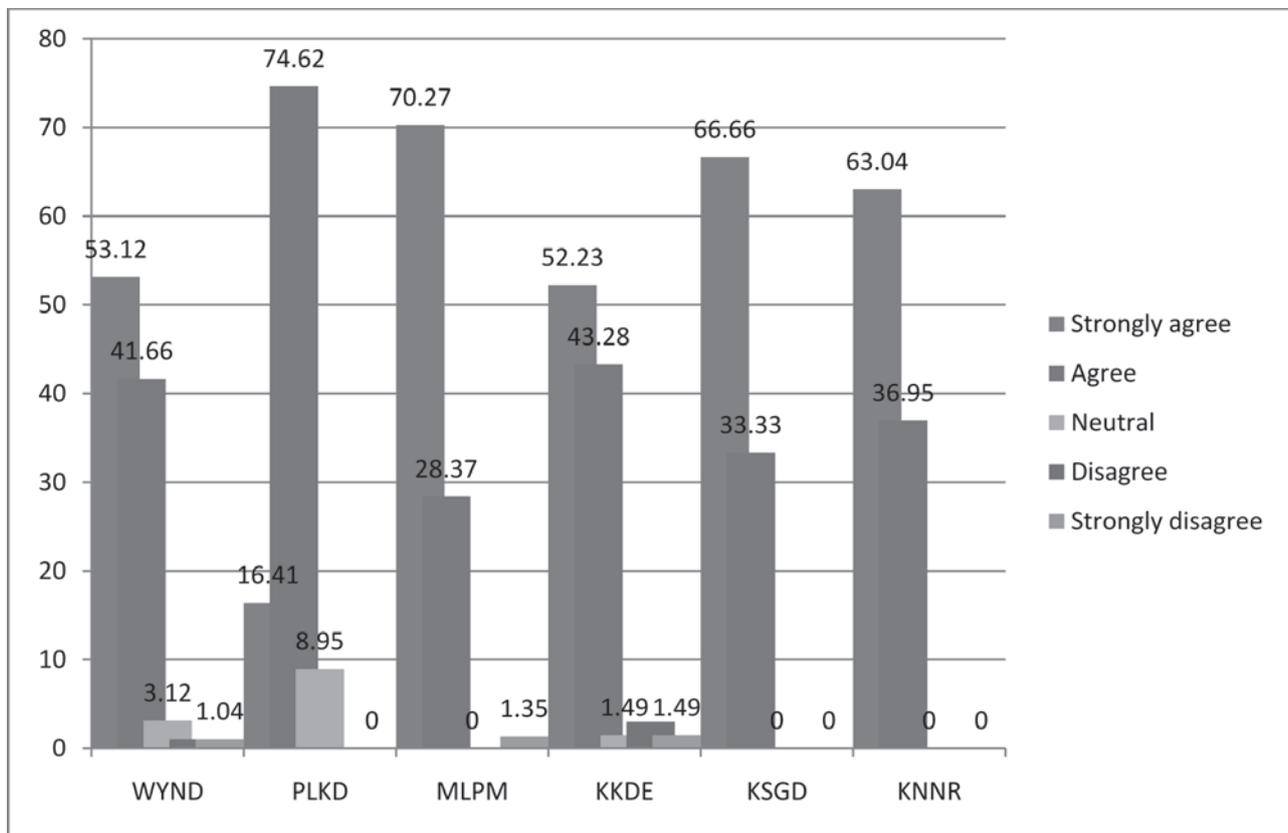
Duration of the project was from 26.09.2016 to 31.03.2018. The objectives included Introduction of GIS and image processing software and essential hardware for the establishment of Remote sensing-GIS centre at college of forestry, Vellanikkara and to organize orientation training to the scientists and students of Kerala Agricultural university and officers of line departments as well as research staff from other research organizations in remote sensing and GIS. The unit will serve as RS-GIS unit for the mapping and spatial database needs of the Kerala Agricultural University fraternity. The facility also serves as a training centre for equipping under graduate and post graduate students of the colleges of Kerala Agricultural University. As a part of the project work, several digital toposheets were collected having the scale of 1:20000 and 1:50000. And shape files of Thrissur district with boundary, Taluks, Panchayaths, Blocks, were digitized. Assisted to cater mapping, cartographic and RS-GIS needs of the entire teaching, research community of KAU, including scientists and students. The facility functioned as a training centre for BSc and M.Sc students of all the Colleges in the University in various aspects of RS, GIS and GPS applications. Analyzed the change detection of Kadalundi - Vallikkunnu Community Reserve (KVCR). Created the map of "Area of production of Marayoorjaggery.

### 2. Explorative study and capacity development on human-wildlife conflict management in selected forest tracts of Kerala

Dr.S. Gopakumar  
Professor  
gopan.s@kau.in

The study was to assess the extent and nature of human-wildlife conflicts that occur in the selected forest tracts of Kerala with focus on selected wild animals. The aim also was to identify and document best practices and methods adopted by forest department and local communities to avoid and overcome infringement of wild animals into human habitats. It was also envisaged to analyse cause-consequence factors of human-wildlife conflicts in relation to patterns of land use and land cover change. Attempt was also done to understand awareness and attitude about the laws and rules of protection and conservation of forest, biodiversity and wild life among victims of human-wildlife conflicts. Organizing capacity development programmes for human-wildlife conflict mitigation among stake holders through awareness campaigns was also one of the objectives. The project commenced on 28.03.2015 and ended on 30.09.2017. The wildlife involved in the conflicts as well as the preferred mitigation options against such conflicts were identified for each conflict locations in the six districts. Based on these onformation location specific action plans can be designed. A 22 minute documentary "Athijeevanam" in Malayalam and English featuring human-wildlife conflicts was shot and screened in the select schools and community halls in the six districts as a part of capacity building efforts of this project. Concurrently eleven (11) leaflets describing the different wild animals like elephant, wildboar, tiger, leopard, peacock etc which are involved in the conflicts and two leaflets featuring WPA 1972 and its schedules were drafted in Malayalam and was printed and distributed among the public in the project area spanning the six northern districts, viz., Palakkad, Malappuram, Kozhikode, Wayanad, Kannur and Kasargode. As a pilot attempt, College of Forestry, Kerala Agricultural University, Govt. Model

Engineering College, Kochi and Integrated Rural Technology Centre (IRTC), Palakkad had jointly developed an ELEPHANT INTRUSION DETECTION AND EARLY WARNING SYSTEM (beta version) as a part of this project, which is being field tested.



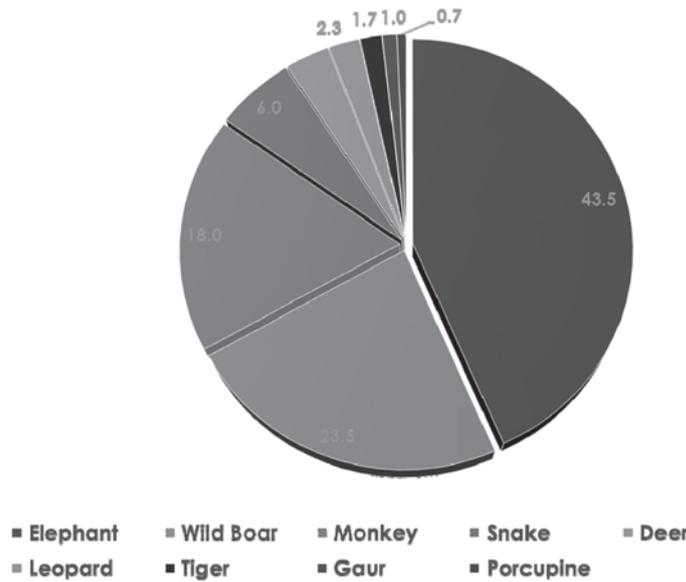
**Responses to the statement “Dearth of accurate data on the carrying capacity of forests is escalating the conflict”**

### 3. Study on Human-Wildlife Conflict in Kerala

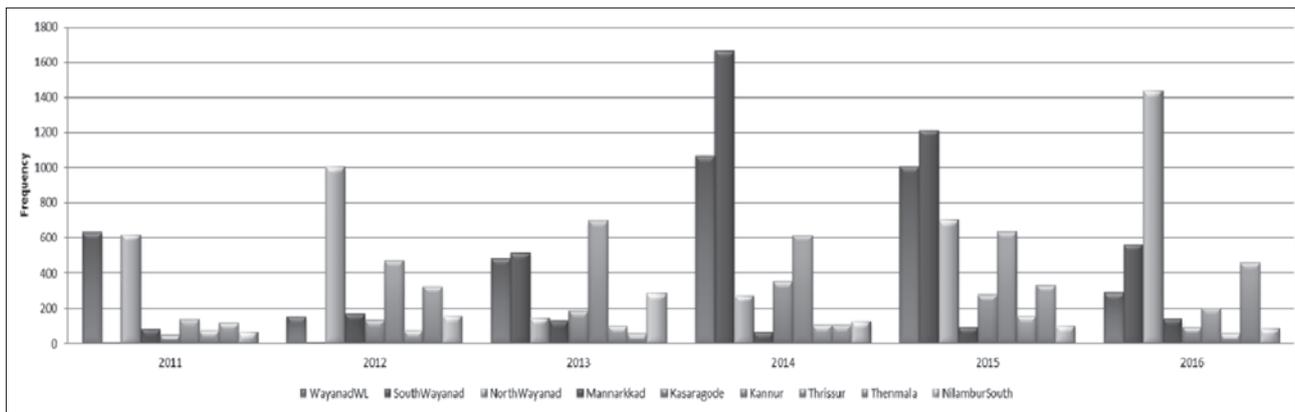
Dr. P.O Nameer  
Professor  
nameer.po@kau.in

The objectives of the study were to find out the nature, extend seasonality and causes of human – wildlife conflict (HWC) and to prepare geo-referenced maps of the conflict areas using modern tools like Geographical Information System. Study also aims to suggest location –specific measures to overcome human –wildlife conflict. Study was started in May 2017 and ended in August 2018. Data on human wildlife conflict for the last ten years (2006 to 2016) was collected from Forest Division Offices of Kerala Forest Department. Location details of each conflict incident was also collected. Maps were prepared in GIS platform using the location data. Spatial and temporal pattern of conflicts were studied by analyzing these maps. More than 60 per cent of the conflict incidences are reported from the three Forest Divisions in Wayanad District. Identified the conflict causing animals and magnitude of conflict by each animal species. Identified the extent of occurrence of conflict incidences in Kerala. Elephant is the most conflict causing animal leading to maximum damage to crops due to conflicts, wild boar being the second. About 50 per cent of the conflicts are due to elephants, 22 per cent due to wild boar and 16 per cent due to monkeys. Studies reveal that most of the conflicts occur

during rainy season. Identified the most conflict affected villages in Mannarkkad and Thrissur Forest Divisions. Changes in land use pattern during the last two decades in the conflict affected villages in Mannarkkad and Thrissur Forest Divisions was analysed using GIS software. Socio-economic studies were carried out in the two Forest Divisions. Baseline data on the HWC for the various Forest Divisions of Kerala have been prepared.



The major wild animals that cause Human Wildlife Conflict in Kerala



The most conflict prone Forest Divisions in Kerala

## Ongoing Projects

### 1. Harvesting, processing and value addition of natural dammars of Kerala

Dr. K. Vidyasagan  
 Professor  
 vidyasagan.k@kau.in

The objective of the study is to survey the distribution and resource base of selected natural dammars of Kerala viz. *Canarium strictum* and *Vateria indica* and to standardize methods of extraction and production characteristics of selected natural dammars. Study aims to develop scientific method of

processing, value addition, and product diversification in selected natural dammars and find out the influence of habitat and tree characteristics on production of natural dammars, the project also envisages to train members of the tribal societies on scientific collection, preservation and value addition. The project was started in September, 2014. A detailed survey was conducted on major dammar producing trees of Kerala. Sustainable harvesting method was developed for the extraction of black dammar and white dammar. As part of the project, tapping knives for developed for sustainable extraction of black dammar from the tree. Training programmes were conducted to tribals on sustainable harvesting and value addition of black dammar. During 2017-2018, value addition of black dammar and developed Incense sticks which are having mosquito repellent properties were developed. Training was imparted to tribes on sustainable harvesting and value addition of black dammar at various forest divisions of Kerala. Work plan for ensuing year includes standardization of gum-oleo resin extraction techniques in *Ailanthus triphysa* (Dennst.) Alston and survey, documentation and digital herbarium preparation of gum and resin yielding trees of Kerala Forests

## **2. Assessing and developing farm tourism models in Kerala**

Dr. P.O Nameer  
Professor  
nameer.po@kau.in

The objectives of the study are to promote public awareness and learning experiences, provide diversity of experience to visitors through farm based activities promote family farming, organic farming and sustainable and integrated agricultural, livestock, fishery and forestry practices. Study also aims to promote farm tourism for ensuring the physical and psychological health in conjunction with ecotourism and also to revitalize the agriculture sector of Kerala and supplementing the farmers. The project was started in February, 2018 and the project is in progress

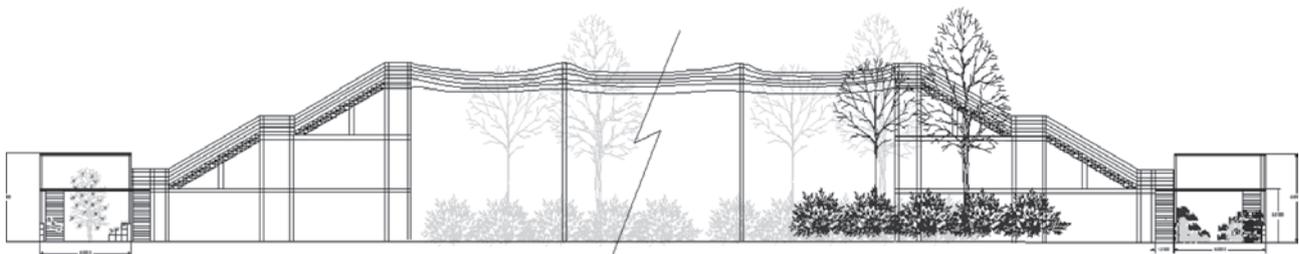
## **3. Development of KAU Botanical Garden (Itty Achuthan Memorial Botanical Garden) into Learning Resource Centre and Biodiversity Conservation repository**

Dr. P.O Nameer  
Professor  
nameer.po@kau.in

The objectives of the project are to develop the themes such as Arboretum, Orchidarium, Fernarium, Palmatum, Bambbostum, Gymnodperm collection, Cacti and xerophytic plants, ornamental plants Medicinal plants, Wetland plant collections, water bodies, canopy walk-ways etc. and also to develop the KAU Botanical Garden into a learning centre for the students and the general public. A Master Plan of the Botanic Garden has been prepared. The whole area of Botanical garden is surveyed using Total Station (Leica Geosystems). Using data logger, the survey data has been processed digitally to generate contour lines in the format of AUTOCAD Version 13.0. For planning the different themes according to the elevation, a 3D model of the contour data is developed using Arc GIS 10.1. The location of different thematic areas, the local movement plan and locations of different structure are also planned based on the 3D DEM. Master Plan of the Botanic Garden has been prepared. Water harvesting ponds have been constructed. The trees in the Botanic Garden have been labelled. 200 plus wildlings have been planted in the Botanic Garden during last monsoon season and all the plants have been protected using tree guard and the success have been 100%. A Botanical Garden of International standards is in the making.



Master Plan on KAU Botanic Garden



Plan of Canopy walk-way in the KAU Botanic Garden

## PG Projects

### Ongoing

1. Comparison of feeding ecology of two endemic species of langurs, Tufted Grey Langur (*Semnopithecus priam*) and Himalayan Grey Langur (*Semnopithecus ajax*)

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To study the food and feeding habits and habitat preference of *S. priam* and *S. ajax*. The project is in progress

## **2. Efficiency of intervention measures against crop raiding wild animals, in Wayanad Wildlife Sanctuary**

Dr. P.O Nameer

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Efficiency of intervention measures against crop raiding wild animals, in Wayanad Wildlife Sanctuary. The project is in progress.

## **3. Utilisation of the waterholes by wild animals in Wayanad Wildlife Sanctuary**

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The objective of the study is to document and map all the natural and artificial waterholes in Wayanad Wildlife Sanctuary. It is also proposed to assess the utilisation pattern of the waterholes by the wild animals. The project is in progress.

## **4. Drought response among plus trees of teak (*Tectonagrandis* Linn. f.) provenances in Kerala**

Dr. A.V Santhoshkumar  
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To evaluate the variability in drought stress on morphological, physiological and biochemical responses among plus trees of teak from different provenances of Kerala. The project is in progress.

## **5. Morphological and biochemical diversity assessment of *Garcinia indica* Choisy (Thouars) germplasm**

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This work aims to explore the morphological and biochemical variability in the trees of *Garcinia indica* germplasm collection maintained at NBPGR, Vellanikkara. The project is in progress.

## **6. Floristic diversity and regeneration status of moist deciduous forest in Thrissur district, Kerala: Reassessment after three decades**

Dr. T.K. Kunhamu  
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The primary objective of the study is to assess the floristic diversity, structure and regeneration status of moist deciduous forests in the selected locations in Thrissur forest, Kerala. The study also aims to investigating the vegetation changes and the drivers of change compared to a similar study carried out in the same locations three decades before. The project is in progress.

## **7. Impact of invasive alien plants on understorey vegetation in Tholpetty Forest Range of Wayanad Wildlife Sanctuary**

Dr. S. Gopakumar  
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The major objective of this study is to assess the distribution characteristics of selected invasive alien species viz. *Lantana camara* L., *Sennaspectabilis* (DC.) H.S. Irwin and R.C. Barneby and *Chromolaena odorata* (L.) R.M. King & H. Rob. in the selected ecosystems inside Tholpetty Forest Range of Wayanad Wildlife Sanctuary. This study also aims to investigate the effect of these invasive alien plant species on the regeneration of other plant communities. The project is in progress.

## **8. Small carnivores of selected protected areas of Kerala**

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The objective is to study the status of small carnivores such as felids (lesser cats), herpestids (mongooses), viverrids (civets) and mustelids (otters and martens) in selected protected areas. It is also intended to study habitat preferences of small carnivores and their distribution in selected protected areas. It is proposed to study the temporal segregation between sympatric small carnivores. Feeding ecology of otters will also be studied. It is also proposed to study the feeding ecology of viverrids. In addition to the above, conservation challenges faced by the small carnivores in these selected study areas will also be studied. The project is in progress.

## **9. Phytosociological and edaphic attributes of forest ecosystems of Shendurney Wildlife Sanctuary, Kerala**

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The main objectives of the study are to investigate the floristic diversity, structure and soil physico-chemical properties of various ecosystems in the Shendurney wildlife Sanctuary and also to map the vegetation using geographical information system. The project is in progress.

## **10. Genetic diversity and domestication of *Pyrenacanthavolubilis* Wight., an anti-cancer drug yielding plant**

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To explore the genetic diversity in fragmented natural populations of *Pyrenacanthavolubilis*, to virtually screen camptothecin and its major derivatives isolated from *P. volubilis* for druggability against major cancer proteins and to identify elite lianas through a progeny trial. The project is in progress.

## 11. Modelling the impact of climate change on Net Primary Productivity (NPP) of selected forest ecosystems in Nilgiri Biosphere Reserve, India.

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The main objective of the study is to assess the impact of present as well as projected climate change of the RCP scenarios on the Net Primary Productivity of forested ecosystems in the Nilgiri Biosphere Reserve. The project is in progress.

### PG Projects

#### Concluded Projects

##### 1. "Phylogeny and systematics of the genus *Cynopterus* (Chiroptera: Pteropodidae) in Kerala

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The objectives of the study were to resolve the taxonomic ambiguity of the genus *Cynopterus* (Chiroptera: Pteropodidae) in Kerala through morphometric and molecular analysis, to barcode the genus *Cynopterus* of Kerala and to infer the phylogenetic relationship between the members of the genus *Cynopterus*. Twenty-four sequences of *C. sphinx* and 7 sequences of *C. brachyotis* were used for molecular analysis. The phylogenetic tree constructed and the pairwise genetic distance calculated using the molecular data has proved that the *C. sphinx* from Kerala constitutes the 'true' *C. sphinx*, since they are genetically more identical to *C. sphinx* from its type locality. The *C. sphinx* from the other parts of its geographical distribution could be different lineages.

##### 2. Status, distribution and habitat preferences of small carnivores in Eravikulam National Park, Kerala

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The study was conducted to assess the status, distribution and habitat preferences of small carnivores such as felids (lesser cats), herpestids (mongooses), viverrids (civets) and mustelids (otters and martens) of Eravikulam National Park (henceforth NP), Kerala. One hundred and seventy-one trap stations were established in the Eravikulam National Park. A total of 84 photographs of 17 mammal species and two bird species were obtained. Out of these, the carnivores accounted for 30 (35.7%) photographs, among that 60% were small carnivores in seven species. The most common species recorded was Jungle Cat *Felis chaus* (27.8%) followed by Leopard Cat *Prionailurus bengalensis* (22.2%), Stripe-necked Mongoose *Herpestes vitticollis* (22.2%) and Asian small-clawed Otter *Aonyx cinerea* (11.1%). The Nilgiri Marten *Martes gwatkinsii*, Common Palm Civet *Paradoxurus hermaphrodites* and Small Indian Civet *Viverricula indica* were captured only once (5.5%) in the camera traps during the study period.

The small cats were abundant in all the grasslands than in the *shola* forests. The least abundant group was the Nilgiri Marten. Abundance of civet is almost four times greater in the *shola* forests than the grasslands. Similarly, the abundance of mongoose is greater in the grassland when compared to the *shola* forests. The difference in abundance of otter between the two habitats are negligible. All the small carnivore groups except small cats and mongooses showed a greater preference to the

*shola* forests, followed by grasslands. Otters were found to prefer both *shola* forests and grasslands nearer to water bodies.

### **3. Diversity and distribution of polypores in the wet evergreen and shola forests of Silent Valley National Park, Kerala.**

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The objective of the study was to find out the diversity, spatial and seasonal distribution of polypore fungi in the wet evergreen and shola forests of Silent Valley National Park. A total of fifty seven species were recorded from the national park and among this *Inonotuspachyphloeus*, *Phylloporiapectinata*, *Trametesmenziesii*, *Trametesochracea*, and *Trametespubescens* were the first report from Kerala. Three species (*Inonotus sp. nov.*, *Microporus sp. nov.* and *Polypores sp. nov.*) were found to be new to the science and these species have been described based on the macro and micro-morphology.

### **4. Cause- consequence analysis of human – wildlife conflicts in Nemmara Forest Division, Kerala**

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Objectives of the study were to portray the nature and distribution of human-wildlife conflicts in Nemmara Forest Division, Palakkad and to analyze its cause–consequence factors with focus on land use and land cover change pattern and also to assess the awareness and attitude of the forest fringe people, including the victims of human-wildlife conflicts about the forest and related biodiversity laws and rules. The increased animal number was highlighted as one of the prime reasons for crop raiding in the entire division. The most problematic animal at Alathur range was sambar deer and at Kollengode range it is wild boar. In Nelliampathy range, bonnet macaques posed the maximum threat. Generally, agriculture practices moved from food crops to cash crops. At Alathur and Nelliampathy, cropping patterns shifted from food crops to cash crops such as rubber. In all the three ranges the respondents had a positive regard to conservation of wildlife and nature. The respondents selected local communities as the second best choice to mitigate conflicts. Mitigation strategies should be not only location specific it should also be both people and as well as animal specific. At Alathur, people favoured mitigation strategies which were cheap both initially as well as in the long run. At Kollengode, they preferred strategies that have a low start-up cost, low maintenance, proven effectiveness and low labour effort. On the other hand, at Nelliampathy the preferred mitigation strategy must be a combination of low maintenance, low labour effort and low start-up cost.

### **5. Functional diversity of a moist deciduous forest ecosystem in Vazhachal Forest Division, Kerala**

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## 6. Functional diversity of an evergreen forest ecosystem in Vazhachal Forest Division, Kerala

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The study was undertaken with the principal objective to enumerate the species and functional diversity of selected aboveground and belowground biological components. The study also aimed at understanding the links between diversity, soil aspects and functioning of this forest ecosystem. Eighty-four tree species were recorded from the 0.5 ha area with basal area of 85.43m<sup>2</sup>. *Aglaia barberi*, *Cullenia exarillata*, *Mesua ferrea* and *Palaquium ellipticum* are dominant trees in the top canopy. *Euphorbiaceae*, *Dipterocarpaceae* and *Meliaceae* were the dominant tree families. The diameter frequency as well as height frequency distribution showed an inverse J shaped curve which reflects a healthy plant population structure. Rényi's diversity profiling and Principal Component Analysis returned only minor variation vis-à-vis vegetation characteristics across the five sampled sites. The dominating plant functional traits like evergreen plant (70.2%), simple leaf (72.6%), glabrous textured leaf (78.57%), smooth textured bark (47.2%), medium thick bark (53.5%), capsule fruit (32.1%) and zoochorous dispersal (55.95%) are the typical plant functional traits expected in a tropical evergreen forest ecosystem. The functional diversity indices are FRic (17.11), FEve (0.76), FDiv (0.84) and FDis (2.27). There were 28 different orders of soil invertebrates in the 0.5 ha area. *Isoptera*, *Hymenoptera* and *Coleoptera* are the dominant orders. The species diversity index of the soil invertebrates were Shannon-Wiener Index (2.40), Simpson Index of diversity (0.14) and Pielou's evenness Index (0.51). The resident soil microbial population includes Bacteria (44.4 x 10<sup>6</sup>cfu g<sup>-1</sup>), Fungi (26.3 x 10<sup>3</sup>cfu g<sup>-1</sup>), Fluorescent pseudomonads (18.3 x 10<sup>4</sup>cfu g<sup>-1</sup>), Nitrogen fixers (14.4 x 10<sup>4</sup>cfu g<sup>-1</sup>), Actinomycetes (16.4 x 10<sup>4</sup>cfu g<sup>-1</sup>) and Phosphate solubilizers (20 x 10<sup>3</sup>cfu g<sup>-1</sup>). The various edaphic properties observed were also typical of an evergreen forest [Soil temperature (19.82<sup>o</sup>C), Bulk density (1.28g cm<sup>-3</sup>), moisture content (29.06%), organic carbon (4.19%), soil acidity (5.25), Soil electrical conductivity (0.07dSm<sup>-1</sup>) and Sandy loam soil (Sand- 78.15%, Silt- 16.04%, and Clay- 5.82%)]. The study could also observe several linkages between functional traits and ecosystem functioning.

## 7. Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala.

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The objective of the study was to assess the species diversity, distribution pattern, and habitat preferences of bats in Silent Valley National Park. Bats of eight species belong to five genera and three families were recorded from Silent Valley National Park. In these eight species three species such as *Latidenssalimalii*, *Myotis montivagus* and *Cynopterus sphinx* are new reports from Silent Valley. The Salimalii's fruit bat (*Latidenssalimalii*) is the first report from Kerala. Four frugivorous bats from the family Pteropodidae were recorded which includes *Latidenssalimalii*, *Cynopterus sphinx*, *C. brachyotis* and *Rousettus leschenaulti*. Two species from family Rhinolophidae were recorded and it includes *Rhinolophus lepidus* and *Rhinolophus rouxi*. Two species from family Vespertilionidae were also recorded and it includes *Myotis montivagus* and *Myotis horsfieldi*.

## 8. Status, distribution and habitat preferences of small carnivores in Silent Valley National Park, Kerala

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To study the status of small carnivores such as felids (lesser cats), herpestids (mongooses), viverrids (civets) and mustelids (otters and martens) of the Silent Valley National Park. Also proposed to study the distribution pattern and habitat preferences of small carnivores. In addition to the above, the conservation challenges faced by the small carnivores of Silent Valley National Park also would be studied. A total of seven species of small carnivores in four families were recorded from the SVNP during the present study. This comprise of two species each of herpestids, viverrids, mustelids, and one species from felidae. The most common species recorded was Small Indian Civet *Viverriculaindica* (45.57%) followed by Brown Palm Civet *Paradoxurusjerdoni*(20.89%), Stripe-necked Mongoose *Herpestesvitticollis* (17.09%), Brown Mongoose *Herpestesfuscus*(6.33%), Leopard Cat *Prionailurusbengalensis*(6.33%) and Asian Small Clawed Otter *Aonyxcinereus* (3.16%). The Nilgiri Marten *Martesgwatkinsii* was captured only once (5.5%) in the camera traps during the study period. The overall small carnivore success rate has been generally high at SVNP (10.90%). The analysis of activity pattern of small carnivores of SVNP showed a significant difference in activity distribution of sympatric species. The Stripe-necked Mongoose have diurnal activity pattern where Brown Mongoose have a nocturnal activity pattern. Even though two species of viverrids, Small Indian Civet and Brown palm civet are nocturnal they have varying peak activity periods. Logistic regression analysis was done for predicting the presence of Brown Mongoose, Stripe-necked Mongoose, Brown Palm Civet, Small Indian Civet, and Leopard Cat.

## 9. Taxonomic inventory and ecology of the rodents and insectivores of Silent Valley National Park, Kerala

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To study the status and distribution of the rodents and insectivores of the Silent Valley National Park. It was also proposed to study the distribution pattern and habitat preferences of rodents and insectivores. Six species of rodents and one species of insectivore were recorded from Silent Valley National Park. The rodents recorded were members of Muridae, Sciuridae and Hystricidae families. These includes *Rattuswroughtoni*, *Golundaelliotti*, *Ratufaindica*, *Funambulustristriatus*, *Funambulussublineatus* and *Hystrixindica*. The insectivore observed at SVNP was *Suncusmurinus* of the family Soricidae. Though the rodent and insectivore abundance were more during the monsoon season, there was no significant difference. Similarly, though the rodent abundance was more at the evergreen forests, this was also insignificant. Among the microhabitat parameters studied, the climber density has found to be significantly influencing the rodents at Silent Valley. *Rattuswroughtoni* was the most abundant species of rodent at Silent Valley. Among the rodents of Silent Valley, *Ratufaindica* is endemic to peninsular India while *Funambulustristriatus*, *Funambulussublineatus* are endemic to Western Ghats. The *Funambulussublineatus* is a threatened species of squirrel seen at Silent Valley and the IUCN Redlist category of this is Vulnerable.

## 10. Efficacy of arbuscularmycorrhizal fungi for drought tolerance in *Swieteniamacrophylla* King. Seedlings

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Study was carried out to analyze the influence of four different levels of water stress (IW/ET=1, 0.8, 0.6 and 0.4 per cent of cumulative evapotranspiration) and three different species of arbuscularmycorrhizal fungi (AMF), viz; Funneliformismossae, Glomusetunicatum, and Rhizophagusintraradices on the growth and development of *Swieteniamacrophylla* seedlings in nursery. Drought stress was found to affect the growth and physiology of mahogany seedlings significantly. Colonization with AMF, especially with *G. etunicatum* significantly improved the biometric as well as the physiological attributes of the seedlings. Inoculated seedlings were found to perform better compared to non-inoculated seedlings under higher levels of water stress. Among the various species of AMF used, *F. mosseae* was found to have the lower suitability with the host plants. From the experiment, it was apparent that the performance of inoculated seedlings was better than the non-inoculated ones. The application of AMF was found to influence the production of quality planting stock of mahogany positively. Inoculation with AMF was also observed to impart drought tolerance to the seedlings. Among the three different AMF species used, *G. etunicatum* was found to be the most beneficial and suitable one for the mahogany seedlings.

## 11. Geographical Indications status for Nilambur Teak (*Tectonagrandis*L.f.).

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The study was carried out in teak plantations of Nilambur and in Central Kerala (Thrissur, Palakkad and Ernakulam) during 2014-2016. The investigation focused on analyzing the potential of securing Geographical indications status for Nilambur teak by exploring the historical importance of Nilambur teak with the help of PRA tool timeline, comparing its wood quality with other National and International provenances and analysing the soil properties and climatic factors that are responsible for the uniqueness of Nilambur teak and to assess the popularity of Nilambur teak among the timber traders. It was found that Nilambur teak has a long history that helped it to secure a place in the international timber market. Unique characteristics of Nilambur teak includes its colour (Golden brown colour), higher heartwood – sapwood ratio, moderate values for density and higher values for dynamic MOE. The climate and soil also act as contributing factors that influence the uniqueness of Nilambur teak. The presence of site quality I and II in the area contribute to the superior quality of Nilambur teak. The study also found that Nilambur teak has a good reputation among the timber merchants. The factors like historical importance, reputation in the timber market and its unique characteristics as a result of genotype, climate and soil make Nilambur teak a potential candidate for obtaining GI status.

## 12. Feasibility of forest certification in Marayoor Sandal Division, Kerala

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The study has acknowledged the feasibility of forest certification in Marayoor Sandal Division, by

assessing the socio-economic characters such as age, education, annual income, source of income and occupational status of the stakeholders. The study also enquired the feasibility of Marayoor Sandal Division to the P&C of FSC. The socio-economic parameters such as education, monthly income and source of income were the important factors which greatly influenced the participation of respondents, because the sandal division directly and indirectly enhanced the socio-economic variables of the stakeholders, especially Forest Dwellers, Local Community, Casual Labourers and Forest Officials. Similarly, the sandal division comply with most of the FSC principles, which means that the division had the potential of implementing forest certification.

### 13. Cause-consequence analysis of human-wildlife conflict in Wayanad district, Kerala

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The main objective is to describe the nature, frequency, distribution and intensity of human wildlife conflicts in Wayanad and to understand the causative factors involved in the conflicts by identifying and mapping hotspots of conflicts using vulnerability mapping and GIS methods. This study also intends to suggest mitigatory measures and enhance human-wildlife co-existence in Wayanad District. The study noticed a definite shift in the farming practices in Wayanad. The respondents believed that the shortage of resources in their natural habitats is pushing the wild animals to the farmlands. Proper habitat enrichment programs, they believe, can reduce the conflicts. According to them, the forest department and the local people are working hand-in-hand to reduce the conflicts. There was no significant difference between any of the social demographic variables such as age, educational status to attitude towards human-wildlife conflicts and wildlife conservation in Wayanad district which indicates that the attitude of the population is not affected by any of these factors. The major conflict causing animals reported by the respondents in all the study areas are elephant (*Elephas maximus*), wild boar (*Sus scrofa*), bonnet macaque (*Macaca radiata*), leopard (*Panthera pardus*), giant squirrel (*Ratufa indica*), spotted deer (*Axis axis*), tiger (*Panthera tigris*), peafowl (*Pavo cristatus*) and porcupine (*Hystrix indica*). The five best mitigation measures suggested by the respondents (in decreasing order of priority) were improving the food resources inside the forests, facilitating access to water for wild animals, fencing of farmlands, providing insurance coverage for crops and livestock and adequate and immediate compensation.

### 14. Dendro-remediation of heavy metal pollutants from the contaminated soil

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### 15. Species diversity and community structure of reptiles of selected agroecosystems in Thrissur, Kerala

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To study the species diversity and the reptilian community structure of various agroecosystems in Thrissur, Kerala. It is also proposed to assess the spatial variation of reptile distribution using Geographic

Information System (GIS) tools. A total of 594 individuals of reptiles, belonging to 18 species were observed during the study. This includes six species from Family Gekkonidae, four species from Family Scincidae, one species from Family Agamidae, one species from Family Elapidae, five species from Family Colubridae and one species from Family Natricidae. The species richness was the highest in the two habitats such as Coconut plantation and Cashew plantation, with each supporting 11 species each, while the species richness was the lowest in the Wetland habitat, with just two species. The abundance of the reptiles was greatest in the Botanical Garden (159 individuals) and lowest in the Wetland habitat with five individuals. More reptiles were recorded during the night hours. Habitats variables were found to be influencing only certain species. Occurrence of Russell's Kukri Snake *Oligodontaeniolatus* was found to be influenced by variables such as litter cover, litter depth, canopy height, canopy cover, shrub cover and herb cover. Occurrence of Oriental Garden Lizard *Calotesversicolor*, Beddome's Cat Snake *Boigabeddomei*, Termite Hill Gecko *Hemidactylustriedrus*, Spotted House Gecko *Hemidactylusbrookii*, Common Wolf Snake *Lycodonaulicus*, Common Trinket Snake *Coelognathusesche* and Checkered Keelback *Xenochrophispiscator* was found to be influenced by relative humidity. Occurrence of Common Krait *Bungaruscaeruleus*, Dussumier's Litter Skink *Sphenomorphusdussumieri* and Bark Gecko *Hemidactyluseschenaulti* was found to be influenced by maximum temperature. 31 reptiles reported from Kerala Agricultural University Main campus

#### **16. Status, distribution and habitat preference of small carnivores in Wayanad Wildlife Sanctuary, Kerala**

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The objectives of the study were to understand diversity, status, distribution and habitat preference of the small carnivores of Wayanad WLS. Nine species of small carnivores were recorded from the Wayanad WLS. This comprise three species from both Family Viverridae and Family Herpestidae, two species from Family Felidae and one species from Family Mustelidae. All members available in the Western Ghats of Family Viverridae were recorded from Wayanad WLS. That includes Small Indian Civet, Brown Palm Civet and Common Palm Civet. Small Indian Civet *Viverriculaindica* found as most common species followed by Stripe-necked Mongoose *Herpestesvitticollis*, Common Palm Civet *Paradoxurushermaphroditus*, Brown Palm Civet *Paradoxurusjerdoni*, Ruddy Mongoose *Herpestessmithii*, Indian Grey Mongoose *Herpestesedwardsi*, Leopard Cat *Prionailurus bengalensis*, Asian Small-clawed Otter *Aonyxcinereus* and Jungle Cat *Felischaus*. Logistic regression analysis was done for predicting the presence of Small Indian Civet, Common Palm Civet and Stripe-necked Mongoose. All micro habitat parameters have significant influence in the presence all three species.

#### **17. Species diversity and community structure of amphibians of selected agroecosystems in Thrissur, Kerala**

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The objective of the study was to assess the species diversity and community structure of amphibians of selected agroecosystems in Thrissur and its association with various habitat parameters. The study also assessed the spatial variation of amphibian distribution using Geographic Information System (GIS) tools. A total of 14 anurans were recorded from the selected agro ecosystems such as Botanical Garden, Cashew Plantation, Coconut Plantation, Homegarden, Rubber Plantation and Wetlands of

Thrissur dt., Kerala. Besides 14 species, one additional species was also recorded from the Kerala Agricultural University campus. Amphibian species richness was found to be higher in Rubber Plantation with eight species followed by Botanical Garden with five species. The amphibian abundance was higher in the Wetlands followed by Rubber Plantation. Most common of amphibian species was *Pseudo philautuswynaadensis*. *Pseudo philautuswynaadensis* was found to be cosmopolitan in the present study with its detection from all the five habitats. Amphibian diversity was found to be significantly different between Home garden and Botanical Garden, Home garden and Coconut Plantation, Home garden and Rubber Plantation, Home garden and Wetlands, Wetlands and Rubber Plantation and Wetlands and Botanical Garden at 1% significance and between Cashew Plantation and Botanical Garden, Rubber Plantation and Botanical Garden and Wetland and Coconut Plantation at 5% significance. Among the various methods used, we found that visual encounter survey and the opportunistic sampling, were found to be efficient. The micro-habitat variables that influenced the presence or absence of *Pseudo philautuswynaadensis* were soil moisture, soil pH, litter depth, maximum air temperature, minimum air temperature, shrub density, soil temperature at 5 cm depth and evaporation.

### **18. Status and habitat preferences of White-rumped Vulture (*Gyps bengalensis*) population of Wayanad Wildlife Sanctuary, Kerala**

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The objective of the study was to understand the status, distribution and population of *Gyps bengalensis* of Wayanad Wildlife Sanctuary. It also proposed to study the breeding success of *Gyps bengalensis*. An estimated population of about 130-150 species of Vultures are present in the sanctuary. As their foraging range is very high, seasonal variation and availability of food are some of the factors that affect their population. 3 species of vultures were identified; *Gyps bengalensis*, *Gyps indicus*, and *Sarcogyps calvus*. Nests of vulture in Wayanad WLS is in a decreasing trend yearly. Only four active nests were identified in 2017-2018 nesting season of which three nests belongs to *Gyps bengalensis* and one nest is of *Sarcogyps calvus*. 30 species of trees were identified belonging to 17 different families from the 44 circular plots surveyed in the nesting colony of Wayanad Wildlife Sanctuary. *Terminalialalata* has the highest density of 23.29%, followed by *Tectonagrandis* (10.85%), *Anogeissuslatifolia* (10.84%), *Haldinacordifolia* (8.21%) etc. The most common five species in the study area were *Terminalialalata*, *Tectonagrandis*, *Haldinacordifolia*, *Cassia fistula* and *Lagerstroemia lanceolata*. Active and old nests were found in 6 tree species in the nesting colony. Out of the six, only *Haldinacordifolia* have active nests and the other tree species are; *Tectonagrandis*, *Stereospermumchelonioides*, *Dalbergialatifolia*, *Lagerstroemia lanceolata* and *Terminalialalata*. 4 out of 4 nestings were found in 2 different locations in Kurichiyad range. Kazukankolli is an important nesting area of *Gyps bengalensis*. 3 out of 4 active nests in this year is present in this area.

### **19. Habitat Characterisation of Asian Elephants (*Elephas maximus*) in Wayanad Wildlife Sanctuary, Kerala**

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The objective of the study was to understand the habitat preference of Asian Elephants in Wayanad Wildlife Sanctuary. The study also proposes to find out the correlation, if any, between habitat

preferences of Elephant with the human-Elephant conflict. A total of 667 dung piles were recorded from 60 km of transect in season 1 (wet season) at an encounter rate of 11.12 per km. A total of 997 dung piles were recorded in season 2 (dry season) at an encounter rate of 24.75 per km. The population density also showed variation between vegetation types across the two seasons. The density of elephants in dry deciduous habitat was higher in both seasons, although it remained the same across seasons. The density of elephants in moist deciduous forests and plantations showed marked increase in the second season but they were still less than density in dry deciduous habitat. It was also observed that elephants prefer natural forests over plantations from the high elephant density in dry and moist deciduous habitats over low density in plantations. The population density also varied considerably among the four ranges across the seasons. The highest population density was recorded at SulthanBathery in the first season, which decreased in the second season. In the second season, density in all three ranges other than SulthanBathery increased and highest was recorded in Muthanga.

## Ongoing Projects

### 1. Impact of invasive alien plants on understorey vegetation in Wayanad Wildlife Sanctuary

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The main objective of the study was to evaluate the distribution characteristics of selected invasive alien species viz. *Lantana camara* L., *Sennaspectabilis* (DC.) H.S. Irwin and R.C. Barne by and *Chromolaenaodorata* (L.)R.M. King & H. Rob. In the selected ecosystems inside the Wayanad Wildlife Sanctuary. The study also aims to understand the impact of these invasive alien species on there generation of other plant communities. The project is in progress.

### 2. Impact of Participatory Forest Management on the livelihood of indigenous communities in Central Forest Circle, Kerala

Dr. S. Gopakumar  
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The main objective of the study was to understand the impact of PFM activities on the livelihood of indigenous people of the Central Forest Circle, Thrissur. The study also attempt a perception analysis to know the pre and post PFM changes in livelihood due to PFM as perceived by the community. The project is in progress.

### 3. Diversity, distributional status and ecology of polypores in forest ecosystems of Kerala

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The objective of the study is to find out the diversity and distribution of polypore fungi in different forest ecosystems of Kerala and also to study their relationship with substrate type, diameter, and decay stage. The project is in progress.

#### **4. Spatio-temporal patterns in human-wildlife conflict in Kerala**

Dr. P.O Nameer

Professor

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The major objective of the study is to assess the spatial and temporal pattern of occurrence of human-wildlife conflict in Kerala. The evaluation of the present preventive measures adopted against human-wildlife conflict will be done at Mannarkkad Forest Division and Thrissur Forest Division (FD). It is also proposed to study of the attitude, expectations and perceptions of the affected individuals/ community towards human-wildlife conflict, in Mannarkkad and Thrissur FD. The study aims to suggest suitable location specific measures to reduce the incidence of human-wildlife conflict in Mannarkkad and Thrissur FD. The project is in progress.



## **Name of Project Coordination Group – (02) Planted Forests and Utilization**

**Compiled by:**

**Dr. E. V. Anoop, Project Coordinator**

### **Plan & External Aided Projects**

**Concluded Projects - 4 Nos.**

**Ongoing Projects - 14 Nos.**

### **Post Graduate Projects**

**Concluded Projects- 23 Nos.**

**Ongoing Projects - 8 Nos.**



## Concluded Projects

### 1. Standardization of methodologies for improving wood quality of coconut (*Cocosnucifera*, L.) for structural uses and pulping – wood property profiling of coconut palms

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The objective is to study the anatomical, physical and mechanical properties of coconut wood and to analyze variation in these properties in coconut palms of different age classes and varieties grown in different agro-climatic zones of Thrissur district. Wood anatomical, physical and mechanical properties of samples collected from 51 coconut palms belonging to three age groups viz., 15-25 years (young), 35-45 years (mature) and 55-65 years (over mature), grown in three agro-climatic zones (Malayoram, Central midland and Coastal sandy) of Thrissur district, Kerala were profiled in this study.

Dermal, sub-dermal and core wood from each sample were used for assessing physical and anatomical properties and samples of density above  $650 \text{ kg m}^{-3}$  were selected for profiling mechanical properties. Nested analysis of variance was carried out to analyse the variation in coconut palm wood properties due to location, age and radial position. Most of the physical, anatomical and mechanical properties did not vary significantly across agro-climatic zones and age groups. However, across age groups, basic density, vascular bundle percentage, fibre lumen diameter, fibre wall thickness and compression parallel to grain (maximum load and compressive stress at maximum load) were found to vary significantly. Along the radial positions there was significant difference in physical and anatomical properties. Basic density, being highly positively correlated with mechanical and anatomical properties, estimation of density can be used as a key to determine end use under field conditions for potential utilization at the industrial level.

### 2. Understorey productivity of selected medicinal herbs in major land management systems in Kerala

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The objective of the study was to study and compare the performance of shade tolerant herbaceous medicinal crops viz. *Curcuma longa* (Turmeric), *Zingiberofficinale* (Ginger), *Alpiniacalcarata* (Chittaratha) and *Kamperia galangal* L.(Lesser galangale) when grown in combination with major tree based cropping systems in Kerala viz homegardens, pure coconut, rubber and cashew, to study the biochemical changes affecting product quality of the medicinal crops from various tree-based land management systems and to explore the biophysical interactions between the crop components and the soil variables. Understorey productivity of the herbaceous medicinal crops in general was highest under cashew followed by rubber, coconut and home garden. Among the intercrops the average performance was higher for turmeric followed by ginger and galangal while chittaratha showed the lowest growth among the intercrops. Yield reduction compared to open control was lowest under turmeric while there was substantial reduction in intercrop yield in the home garden. Based on the economic analysis the best tree-crop combination was found to be cashew + turmeric among the land use systems and intercrops investigated. This combination showed a B:C ratio of 2.55. Other prominent systems emerged from the study are turmeric-rubber (BCR 1.64), cashew-galangal (BCR 1.34) and rubber-galangal (BCR: 1.15). Invariably all the home garden based intercropping systems were non-remunerative with BCR

less than one. Increased yields from the tree products (coconut, cashew nut and rubber latex) suggest complementary interaction between the tree-crop components.

Integration of herbaceous medicinal plants such as turmeric, ginger and galangal following the recommended practices improves the soil organic matter content and nutrient status thus benefiting the enhancement in the productivity of the main tree crops. The tree-based systems sequestered substantial amount of carbon and nutrients in the deep soil assuring long term productivity of the tree-based systems.

### **3. Development of model Forestry Instructional farm for KAU**

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Profesoor  
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The study aimed to develop master plan and arrange basic facilities for the establishment of model instructional farm for the promotion of forestry as a promising land use option for economic and environmental benefits. Development of master plan for the Forestry Instructional Farm in the campus of College of Forestry. Basic lay out, land allotment and layout, land clearing, levelling, , procurement of planting materials, potting media, planting containers, irrigation facility, construction of temporary sheds were achieved during the project period.

### **4. Silvopasture strategies for fodder self- sufficiency through homestead cultivation**

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The objective of the study was the development of a 3-tier silvopasture model with fodder grass, legume and tree (Hybrid napier + desmanthus+ calliandra) for fodder self- sufficiency and profitable milk production for small scale dairy farmers and to develop standardized management practices for optimizing fodder yield and quality from tree fodders like mulberry, subabul and calliandra. Developed a 3-tier intensive silvopasture model with fodder grasses, legumes and trees for providing year round quality fodder for single cow in homesteads, thereby ensuring profitable milk production. Standardized management practices for maximizing fodder yield and quality from hedge row grown fodder trees like calliandra, mulberry and subabul. Achievement of fodder self-sufficiency in Kerala through above interventions is the major outcome of the project.

## **Ongoing Projects**

### **1. Short and long-term strategies for income generation from teak, matti and silver oak plantation areas at Panchavadi hills in KAU main campus**

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The objective of the study is to establish profitable short term and long term plantation forestry models at KAU campus and establishing demonstration facility for the promotion of tree farming for small and medium farmers of Kerala. The procurement of approved equipment and other infrastructure

has been completed under the project. As part of the project, *Ailanthus triphysa* was established in 1.5 acre of the land at Panchavadi hills. This involves a tree improvement trial on *A. triphysa*. Promising ten phenotypically superior collections of *A. triphysa* were collected and planted in compact family blocks during June 2016. Project in progress.

## 2. Development of model Forestry Instructional farm for KAU

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The objective of the study is development of model integrated multi-storeyed agroforestry production system, establishment of farm forestry/agroforestry interpretation centre, establishment of animal rescue and rehabilitation facility and development of wood processing yard. Results obtained during the period includes development of multipurpose tree gardens of economic importance, development of model farm forestry production system, State of the art interpretation centre with focus on farm forestry and agroforestry and development of a water pond to facilitate water conservation through natural drainage. The project is in progress.

## 3. Establishing bamboosetum for KAU

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Establishment of bamboosetum of commercially and ecologically important tropical bamboos species. Development of interpretation centre on the prospects of profitable cultivation of bamboo for small and medium farmers of Kerala. The bamboosetum was established in August 2017 at the 3.0 acre area allotted to College of Forestry in the KAU Instructional Farm, Vellanikkara. The bamboo plants were collected from the KFRI, Peechi and from IWST, Bangalore during July 2017. All the plants are growing satisfactorily. The project is in progress.

## 4. Training and Technology Demonstration Project for Making Value Added Products from Coconut Wood

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Set up a modern Coconut Wood Technology Demonstration Centre (CWTDC), installing advanced machineries for sawing, seasoning and preservation and manufacture of utility items such as furniture, interior decorative items, building materials, handicraft items etc. based on coconut wood so as to popularize the use of cocowood for additional income to farmers. To develop a value chain model of cocowood extraction, conversion, design, manufacture and sale of cocowood furniture and other value added products in collaboration with Furniture Consortium Private Ltd. and the Kodungallur Coconut Producer Company Ltd. (KCPL). Two training programmes on "Processing, Value Addition and Product Manufacture from Coconut Wood" were organized at the Coconut Wood Technology Demonstration Centre (CWTDC), at the College of Forestry, Vellanikkara where machineries for making furnitures and fixtures from coconut wood including a Portable Saw Mill were installed. As part of the training. The

trainees mainly from KCPCL were given training in the manufacture of furniture items out of coconut wood by the Master Trainer. The project is in progress.

## **5. All India Coordinated Research project on Agroforestry**

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### **A. Provenance evaluation of *Acacia mangium* Willd**

A field trial with 10 provenances of *Acacia mangium* collected from Australia and Papua New Guinea were conducted to get information on genetically superior planting material for farmers.

### **B. Provenance evaluation of teak (*Tectona grandis* Linn f.)**

Teak accessions were collected from established teak growing regions in South India. Prominent collections from Kerala include Arienkavu, Konni, Malayattur, Nilambur, Parambikulam, Waynad and Thiruvazhamkunnu (local). In addition, seeds from teak provenances supplied by the IFGTB, Coimbatore were also included as part of the study.

### **C. Standardization of pruning and thinning regimes for *Acacia mangium* stands**

The primary objective of the study was to optimize the planting density and pruning regimes of *Acacia mangium* for various end uses including agroforestry.

### **D. Diagnosis and Design survey in the urban home gardens of Kerala**

A survey was initiated in the Arimpoor Panchayath (ward 11 and 12) of Anthikkad block in Thrissur during 2016-17 to assess the current status and to suggest the most suitable interventions for the revitalization of these homegardens in vertical and horizontal dimensions and on a well described time scale with strong willingness and participation of the stake holders / households. The sample homesteads were divided to small (<0.4 acre), medium (0.4 to 0.8 acre) and large (>0.8 acre) based on the extent of area. Study included the enumeration of tree species and assessment of different crops and livestock components; their quantitative assessment in terms of number per homegardens.

### **E. Multitier silvopastoral systems suitable for tropical homegardens**

This experiment was initiated during 2012 to address the fodder scarcity and associated decline in dairy farming in Kerala. The primary objective of the trial is to secure fodder self sufficiency by developing a multi-tier fodder production system involving fodder trees, fodder legumes and fodder grasses arranged in definite design within the homestead. Management techniques will be also standardized for maximizing fodder yield from fodder trees. This trial was initiated under AICRP but later on received additional funding from KSCSTE. The trial involves two parts.

*Part I: Development of silvopastoral system for integrating with homegardens*

*Part II. To optimize hedge row fodder tree management practices*

### **F. Development of an integrated, multitier agro-silvo-pastoral system suitable for the humid tropics**

This project has been initiated during 2011 at KAU main campus, Vellanikkara with a view to develop a model multitier integrated farming system suitable for humid tropics. Such live models will be helpful to demonstrate the successful integration of compatible tree-crop-animal combinations and their comparative advantage with other land use systems in the economic, ecological and social dimensions. The project is in progress.

**6. Wood property variation in jack (*Artocarpusheterophyllus* Lam.) grown in Thrissur district, Kerala.**

The objective is to study the variation in wood properties of jack (*Artocarpusheterophyllus* Lam.) grown in different regions of Thrissur district to understand the effect of different girth classes on wood physical, anatomical, chemical and mechanical properties. It is also intended to understand the effect of growing locations *i.e.* lowland, midland and highland on the wood properties of jack wood. The project is in progress

**7. Standardisation of planting stock production techniques for teak (*Tectonagrandis*Linn.f.)**

The study is in progress

**8. Standardization of kiln seasoning schedule for coconut (*Cocosnucifera*L.) wood**

The study aims to standardize kiln seasoning schedule for coconut wood. The project is in progress.

**9. Screening of jack trees (*Artocarpusheterophyllus*Lam.) for quality timber production.**

This study is aimed at selection of plus trees of jack (*Artocarpusheterophyllus*Lam.) from different regions of Thrissur district through seed collection, raising, and their evaluation in the nursery. It is also aimed at assessing the farmers' perceptions towards growing jack as a timber species in homesteads of Thrissur district. The project is in progress.

**10. Standardization of tree injection procedures of azadirachtin in coconut (*Cocosnucifera*L.), mango (*Mangiferaindica*L.), and neem (*Azadiractaindica*A Juss.).**

This study is aimed at selection of plus trees of jack (*Artocarpusheterophyllus*Lam.) from different regions of Thrissur district through seed collection, raising, and their evaluation in the nursery. It is also aimed at assessing the farmers' perceptions towards growing jack as a timber species in homesteads of Thrissur district. The project is in progress.

**11. Impact of seed priming techniques on germination and seedling performance in sandal (*Santalum album*, L.)**

The study is envisaged to evaluate the effect of different seed priming techniques on the germination and seedling growth of *Santalum album*. It focuses on the influence of biopriming, chemical priming, hydropriming and osmopriming on seed germination and seedling growth attributes. The project is in progress.

**12. Development and characterization of a natural resin basednanocomposite**

The objective of this study is to develop and characterize a natural resin based nanocomposite and also to ascertain its selected mechanical and thermal properties. The project is in progress.

**13. Productivity of tree fodder banks in selected homegardens of Central Kerala.**

To assess the forage yield and nutritive value of selected fodder tree species under hedgerow planting in selected home gardens of Central Kerala. The study will also probe short term changes in soil nutrient status of selected homegardens with tree fodder integration. The project is in progress

**14. Physico-chemical characterization of gum oleoresin from *Ailanthus triphysa* (Dennst) Alston and effect of ethephon on gum oleoresin yield**

The main objective is to assess the effect of ethephon on gum-oleoresin production from matti trees of different diameter classes and Study will also attempt to know the physico-chemical characteristics of gum-oleoresin. The project is in progress.

## PG Projects

### Concluded Projects

#### **1. Anatomical characterization and development of anatomical key of selected mangrove species of West Coast of India**

The objective of the study was to analyze vessel morphological properties such as vessel length, vessel diameter and vessel frequency of selected mangrove species of the West Coast of India. The study also aims at finding out the vessel mesomorphy and vulnerability of the selected mangrove species. Further, the study aims to prepare an IAWA (International Association of Wood Anatomists) based wood anatomical key of the selected mangrove species.

The present investigation focused on the ecoanatomical characterisation of the wood of 17 selected true mangroves collected from 10 locations in the Western Coast of India. A total of 221 characters listed in the IAWA (International Association of Wood Anatomists) list of card key features were studied for each species as there is a felt need for creating databases of mangrove wood anatomy which allows quantifying the relative amount of intra- and interspecific variation, as well as variation within and between the mangrove genera. Mangrove wood from West Coast of India is characterised by diffuse-porosity, scalariform to opposite vessel wall pitting, scalariform perforations with few bars or large number of bars. Most mangrove family members were found to have simple perforations, septate or non septate fibres with distinctly to minutely bordered pits, bordered, half bordered to simple pits, paratracheal parenchyma, apotracheal and banded parenchyma. Hetero cellular to homocellular rays with mostly procumbant cells with one or several marginal row of square/upright cells was also observed in these mangrove genera. Short numerous vessels with small dimension and vessel grouping were also common. The most advanced characters like vestured pit, helical thickening, crystals and vessel occlusions were present in majority of the samples. A perforated card key based on the IAWA list of microscopic card features for mangrove identification was also prepared. The development of an IAWA based anatomical key will be helpful for the identification of mangrove species based on wood anatomy. The eco anatomical characters such as vessel diameter, vessel frequency, vessel grouping, type of vessel plate, lateral wall pitting, type of pits of true mangrove species were studied and compared with data from their nearest upland relative. The eco anatomical features of wood of mangrove species are correlated with xeromorphic nature of their upland relatives. Because of the highly variable and stressful environmental condition, the mangroves developed certain strategies and adaptations during their evolution. These special morphological and physiological adaptations made it for the mangrove species to survive in these conditions in contrast to their upland relatives. A safe hydraulic architecture is only one of the alternative ways for a plant to be able to survive in water stress situations. The modification of xylem hydrological structure of mangrove wood helps to balance safety versus efficiency of water transport system. These modifications of wood structure due to ecological conditions are the driving force to evolution of wood anatomy. Thus the evolution of mangrove genera has been shown to be likely driven by environmental condition and not by phylogeny. The general pattern of wood anatomy of mangrove genera of different families indicates convergent evolution. These trends of wood anatomy in mangrove species provide new examples of phenotypic plasticity in angiosperms. To ensure safety, certain primitive structures such as bordered pits, scalariform vessel plate, scalariform, transitional, opposite lateral wall pitting and vessel bars still persist in the true mangrove genera of the present investigation. Thus the development of wood anatomical characters in mangrove genera were an example of heterobaty. The presence of mostly primitive wood character states suggest an unbroken occupancy of stressful habitat by its ancestral genera. Mangrove occurs in different families in which the gamut

of wood specialization ranges from advanced to highly advanced features. Rhizophoraceae members were found to be the most primitive ones with less specialization whereas the other mangrove species were found to have highly advanced wood anatomical characters.

## **2. Optimisation of fertiliser regime and understorey productivity in four-year-old *Swieteniamacrophylla* King. Stands**

Major objectives of the study include standardization of fertilizer regimes and optimization of understorey productivity by growing three shade tolerant herbaceous medicinal crops viz. turmeric (*Curcuma longa* L.), ginger (*Zingiber officinale* Roscoe) and wild turmeric (*Curcuma aromatica*) as intercrops in 4-year-old *Swieteniamacrophylla* stands. Also, the root distribution pattern of young mahogany trees will be studied following partial excavation method. The carbon sequestration potential of 4-year-old *Swieteniamacrophylla* stands will be assessed as a function of tree nutritional interventions. The study revealed that the applied fertilizer had profound influence on all the growth attributes of 4-year-old mahogany. There existed a direct relationship in tree growth with increase in fertilizer dose. The range in diameter and height growth increased substantially with increase in fertilized dosage. Tree growth in general showed complementary interaction with intercrop for all growth attributes. The increase in basal area in the heavily fertilized plot compared to unfertilized control where 75.92% at the end of 24 months after the fertilizer application. Both the mean tree biomass and stand level biomass increased with increase in fertilizer dosage (60 per cent increase). Among the components stem wood represented almost 50% of the total biomass production for all fertilizer regimes followed by roots which accounted almost 18% of total biomass production. Biomass accrual by the various components in the decreasing order was: stemwood > roots > branchwood > leaves > twigs. Higher carbon storage in the stem wood and roots give positive indication of possible long-term storage of carbon in biomass especially for mahogany which is used for structural timber purpose. High carbon in the roots adds to better carbon turnover in the soil carbon pools. Root distribution studies using logarithmic spiral trench technique suggested increase in rooting intensity with fertilizer application for total roots and root class < 2.5 mm. Hence the increase in fine root count in high fertilized plots suggest higher nutrient uptake and thereby higher tree growth for mahogany. The maximum foraging zone for 6-year-old mahogany has been observed to be at 2.17m lateral distance and 40 cm soil depth. At the present stocking this leads to considerable overlapping of the rhizosphere of mahogany and intercrops and thereby limits the prospects of intercropping. Hence the possible optimal spacing for 6-year-old mahogany would be 5.5m x 5.5m for effective intercropping. Performance of all the three intercrops showed better growth in fertilized plots as compared to unfertilized control. Ginger, wild turmeric and turmeric showed increase in all biometric variables and rhizome yield in the treeless open control plots as compared to mahogany intercropped plots. However the growth differences compared to open control were lower in the heavily fertilized plots.

## **3. Performance of calliandra (*Callinandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system**

The study aimed to assess the influence of planting density, pruning height and pruning frequency on initial forage yield and nutritional qualities of calliandra intercropped in coconut gardens. The study will also explore the initial soil fertility changes associated with intercropping calliandra in coconut plantations. Forage yield and quality of young stands of calliandra underneath coconut garden could be optimized at the cheapest level by adopting a tree density of 27,777 plants ha<sup>-1</sup>, pruning height of 1m and pruning interval of 12 weeks. Moreover, based on the growth and yield performance and quality aspects, it is found that calliandra is a promising fodder tree, which can be successfully integrated with the existing coconut gardens of Kerala. Establishment and proper management of calliandra in

coconut garden at appropriate management levels thus offers a cheap source of quality forage to Kerala farmers against the highly expensive concentrate feeds.

#### **4. Harnessing Arbuscular Mycorrhiza (AM) for quality seedling stock production of *Tectonagrandis* Linn. and *Swieteniamacrophylla* Linn.:**

The objectives of the study were to assess the impact of inoculation potential of selected AM on growth and quality of *Tectonagrandis* and *Swieteniamacrophylla* seedlings. The study assessed the impact of inoculation of selected AMF on growth and quality of seedlings. The native AMF species (*Funelliformis mosseae*, *Glomus intradices*, *Glomus proliferum*) at different levels (10, 20 and 50 g inoculum per seedling) were applied on the seedlings raised in polythene bags. The experiment was laid out in a factorial RBD with control. Seedlings raised in the presence of AMF showed a significant difference in plant growth and quality over those grown in the absence of AMF. The extent of growth and quality enhancement differed among AMF species and levels of inoculation. In general, mycorrhizal symbiosis significantly improved plant growth performance, such as plant height, stem diameter, shoot, root or total dry weight. Mycorrhizal colonization of seedlings ranged from 17.3 per cent to 56.3 per cent in *S. macrophylla* and 15.0 per cent to 36.0 per cent in *T. grandis*.

By looking at overall parameters studied, it can be concluded that *F. mosseae* at 50 g of inoculum at the time of transplanting @ 10 spores /g confers maximum growth and seedling quality benefits in nursery as compared to all other fungi used in for *S. macrophylla*. Seedlings of *T. grandis* with *G. proliferum* at 50 g inoculum performed better in nursery. This technology has the potential to reduce the nursery period and increase in quality of seedlings produced resulting in considerable economic gains.

#### **5. Influence of planting density and pruning on thermal radiative and moisture regimes in *Acacia mangium* Wild.**

The objectives were to study the thermal, radiative and moisture regimes under different planting densities and pruning regimes in *Acacia mangium* stand. The study also attempts to estimate water use efficiency of *Acacia mangium* as influenced by plant density and pruning. Diameter at breast height, tree height and individual tree biomass increased with decreasing density, while aboveground standing biomass on stand level and LAI followed a reverse trend. The unpruned stand had significantly higher DBH and biomass as compared to that of the pruned stand. Biometric characters had positive correlations with the AT, PAR at 5 and 10 m above the ground level, RWC, ST (5, 10 and 20 cm) and SMC (20 and 30 cm depth), while it was negatively correlated with the evapotranspiration and SMC (5 and 10 cm depth). No significant correlation was found between CATD and RH (5 and 10 m above ground). Air temperature (5 and 10 m above ground) and ST (at depths of 5, 10 and 20 cm) were negatively correlated to planting density and LAI. It was found that the largest differences with open area for these parameters were recorded at a density of 5000 trees/ha, throughout all seasons. It was found that there is an average difference of 2.62° C and 2.52° C between AT in the *Acacia mangium* stand compared to the open area at 5 m and 10 m above the ground level respectively. Soil temperature (5, 10 and 20 cm depth) was negatively correlated with the SMC (5, 10, 20 and 30 cm depth). An average ST difference of 2.6° C, 2.6° C and 2.5° C was found between the *Acacia mangium* stand and open area at depth of 5, 10, 20 and 30 cm depth respectively. Pruning did not affect both the AT and ST except, ST at 5 cm depth during the post-monsoon season. CATD was positive and higher in high density treatments during the summer and pre-monsoon, while it remained negative and unaffected by density during the other seasons. CATD was negatively correlated to evapotranspiration, RWC, and SMC at various depths. Influence of planting density on RH was evident only during the summer season. It was found that there is an average difference of 7.51 % and 5.76 % in RH between the

*Acacia mangium* stand and open area at 5 m and 10 m above the ground level respectively. The RWC, evapotranspiration and SMC (20 and 30 cm depth) were significantly higher in the low planting density, while reverse trend was noticed for SMC (5 cm and 10 cm depth). An average SMC difference of 4.50 %, 3.70 %, 3.32 % and 3.11 % was found between the *Acacia mangium* stand and open area at depth of 5, 10, 20 and 30 cm depth respectively. The RWC was significantly higher in the pruned stands during the pre-monsoon and post-monsoon season, while no differences were observed during the summer and monsoon season. Water use efficiency (WUE) of *Acacia mangium* stand was not significantly affected by the planting density and pruning treatments.

Radiation below the canopy was found negatively correlated to planting density and LAI, while it was not influenced by pruning. It was found that there is an average difference of 450 W/m<sup>2</sup> and 466 W/m<sup>2</sup> between the *Acacia mangium* stand and open area at 5 m and 10 m above the ground level respectively. The average mid-day PAR transmittance from the unpruned stand (5000 trees/ha) to the pruned stand (625 trees/ha) ranged from 24.27 % to 54.72 % of incident PAR above the canopy. There was strong relationship between the PAR and LAI. The light extinction coefficient (K) for *Acacia mangium* stand was estimated to be 0.328.

## 6. Provenance evaluation of *Acacia mangium* Wild

A provenance evaluation of *A. mangium* was conducted in 14 year old plantation at Livestock Research Station, Thiruvazhamkunnu, to understand the variation in growth and wood traits among the provenances. Ten provenances and one local seed source was used for the trial.

The provenances had high survival percentage (77.44%), but did not differ significantly between provenances. Significant differences between provenances were found in tree height, while they were on par for DBH, volume, tree form and branching habit. The provenances of Kuranda, Arufi Village, Upper Aramia, Oriomo, Balimo and Binaturi were taller than the rest. Heritability of growth attributes was highest for height (63%). Morphometric traits of seeds were found to be significantly different between the provenances. Arufi Village provenance was found to be better than the other provenances for the traits. Lake Murray provenances showed the best performance in most of the parameters studied for germination. No significant differences between provenances were observed for germination capacity. Germination parameters are under moderate to high genetic control. The provenances differed significantly in physical properties of wood, but not in mechanical properties. The provenances differed significantly for heartwood only at the base, while basic density was significantly different at all the height levels. Wood properties of the provenances were under strong genetic control. Based on the study, Tully-Mission Beach, Arufi Village, Kuranda, Upper Aramia, Lake Murray and Binaturi provenances can be recommended for growing under Kerala condition.

## 7. Quality evaluation and value addition of fruits of *Elaeocarpus serratus* L. (Ceylon olive tree)

The objective of the study was to ascertain the physico-chemical and sensory characters of *Elaeocarpus serratus* fruits, to develop value added products such as Ceylon olive pickle and candy and to study the organoleptic and chemical qualities of the product developed.

The physical characteristics of the fruits revealed that the mean fruit weight, volume, length, diameter for the fruit were 3.55 g, 5.97 cm<sup>3</sup>, 23.07 mm and 15.58 mm respectively. Correlation matrix revealed a significant and positive relation among all the studied physical parameters. The nutritional composition of the fruits was found to be in par with other tropical fruits like tamarind, passion fruit, jack fruit etc. Organoleptic evaluation of the fruit showed the mean scores for appearance, colour, flavor, texture, odour and taste. The organoleptic scores for the pickle and candy show high values

for all the parameters with the overall acceptability mean score of 8.4 and 7.7 respectively.

### **8. Screening of *Ailanthus triphysa*(Dennst.) Alston. for preferred match wood qualities**

The objective of the study was to assess the variation in growth and wood traits of *Ailanthus triphysa* grown in homegardens of Thrissur and Palakkad for match manufacture. Selection of plus trees of *Ailanthus triphysa* for seed collection and their evaluation and selection of superior planting materials will be aimed at. Growth performance of planted seedlings of *Ailanthus triphysa* will be assessed in farmers' fields for superior match wood quality. It is also aimed at assessing the farmers' perceptions towards growing raw material species for matchwood industries in selected panchayaths of Palakkad and Thrissur districts. The morphological parameters like height, collar diameter, root length, leaf area, number of leaves etc. were found to vary significantly at nursery but not throughout the study period. Relative Growth Rate, Absolute Growth Rate and Net Assimilation Rate did not show significant variation among the seed sources. Field performance of the progenies was evaluated at Aaramkal, Vellanikkara, Thrissur, Kerala in RBD. Height and collar diameter varied significantly initially but the differences were not significant for collar diameter from 90 days after planting. However, survival percentage did not show any significant difference between the progenies. FCV AT 1 showed the maximum height growth at 150 days after planting. A questionnaire survey was conducted to assess farmers' perception towards growing raw materials for match manufacture. The respondents had an overall positive approach toward tree farming. The majority of the respondents were confident that scientific guidance will help them in increasing the yield.

### **9. Performance of selected medicinal herbs under prominent land management system in Kerala viz. homegarden and coconut garden**

The study intended to assess the relative performance of selected herbaceous medicinal crops viz. ginger (*Zingiber officinale* Roscoe), turmeric (*Curcuma longa* L.) and kacholam (*Kaempferia galanga* L.) when grown under two major tree based cropping systems in Kerala viz. homegarden and pure coconut garden. Further, the study will probe into the biophysical and biochemical changes affecting productivity and product quality of the medicinal crops when grown under two systems. Result converges to the generalisation that despite better soil physico-chemical attributes, understory productivity in the homegarden is by and large decided by the PAR availability. Hence there is need to develop stand structure that optimize the productivity in homegarden through judicious stand density regulation and tree management practices

### **10. Performance of selected medicinal herbs under rubber and cashew plantations**

The objective of the study was to assess the understory productivity of two prominent land management systems in Kerala viz Para rubber and cashew through intercropping with shade tolerant herbaceous medicinal crops. To study the biochemical changes in these medicinal crops and the bio-physical attributes influencing the productivity of both of these land management systems. Also, to assess the soil carbon sequestration in these two land management systems. The biophysical attributes influencing the productivity of the land management systems and the biochemical changes in the products of understory crops were studied. Additionally, soil carbon sequestration in both the given land use systems and the treeless open plot was estimated. In terms of yield attributes, the selected understory crops have better prospects in wooded land use system in general and the specific advantage of cashew over rubber was also obvious. This may be attributed to relatively better PAR transmission, higher nutrient accumulation and lesser root competition in cashew. Further, the better quality of rhizomes under comparably higher shade levels suggests their performance in tree-based land use systems.

### 11. Diversity, structure and standing stock of timber in the home gardens of Thrissur district, Kerala

The main objective of the study is to assess the diversity, structure and standing stock of timber trees in the home gardens of Thrissur District, Kerala. The study will also assess the wood qualities of the selected commercially important timber species from the home gardens of Thrissur. Further, it would probe into the socio-economic drivers of home garden change in the Thrissur district. There was a great variability in diversity, abundance and standing stock of different tree species belongs to different use categories among three home garden size classes and across different eco regions. There were 163 total species present in the entire Thrissur district that included 122 trees species and 41 agricultural crop species. Contrary to earlier studies, consistent decline in diversity was observed with decrease in home garden size. Economically important functional groups such as timber, fodder, fuel, green manure and other MPTs were abundant in large homesteads. Eco-region wise comparison of tree diversity suggested high diversity in the midland and highland regions while lower in coastal land and peri-urban areas. Vertical diversity of the studied home gardens suggested high species richness associated with middle storey. Also all three strata of large home gardens were more diverse than medium and small home gardens irrespective of eco-region. In total there were 41 species of agricultural crops and medicinal plants identified from selected home gardens. *Musa* sps., *Areca catechu* and *Cocosnucifera* were the predominant species of all size holds. Simpson Index and Shannon Diversity Indices of agricultural crops of all size holds showed no large difference. The most frequent constraints of home gardens included high wage of the labourers involved in home garden maintenance, less labour availability, large expense/less profit, pest and disease, etc. Wood quality assessment of *Tectonagrandis*, *Artocarpusheterophyllus* and *Swieteniamacrophylla* using NDT showed that oven dry specific gravity (SPGo.d) has no influence on eco-regions and tree size classes. The dynamic modulus of elasticity (MOEdyn) showed significant differences for *Artocarpusheterophyllus* and *Swieteniamacrophylla* across eco-regions. However, this was not prominent for *Tectonagrandis*.

### 12. Autoallelopathy of selected multipurpose tree species and the effect of their leachates on agricultural test crop

The study aimed to identify the allelochemicals present in the leachates of five selected MPTs and also to understand the possible effects of leachates of these MPTs on germination, seedling growth and dry matter production of seedlings of the same tree species and the agricultural test crop. The autoallelopathic effect of leachates from tree species on its own germination noted the lowest germination for seeds irrigated with leaf leachate of all the five selected tree species and maximum for the seeds irrigated with tap water. The allelopathic effect of leachates from tree species on germination of agricultural test crop showed a decrease in germination percent with the seeds irrigated with leaf leachate of *A. auriculiformis*, *A. mangium*, *A. triphysa* and *G. robusta* against cent percent germination for control. The germination percent of *S. macrophylla* seeds irrigated with leaf leachate showed cent percent germination showing least inhibition of germination by the biochemical present in leaf leachate. The seedlings of the agricultural test crop irrigated with tap water as control showed increased shoot length, root length and higher dry matter production compared to the seedlings irrigated with different tree part leachate.

### 13. Comparative performance of mulberry (*Morus alba* Linn) and subabul (*Leucanealeucocephala* Lam) under diverse management regimes in a coconut based fodder production system

The study aims to assess the influence of planting density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens. The study will also explore the soil fertility changes associated with intercropping these fodder trees in coconut plantations. Management of mulberry and subabul fodder banks for optimizing forage yield and nutritive value in coconut garden has been standardized. The technology provides an alternate protein

source to livestock against costly concentrate feeds.

#### **14. Standardisation of propagation through branch cuttings in selected bamboo species of Kerala**

The study aimed to standardize the vegetative propagation through branch cuttings of in selected bamboo species of Kerala. The study focuses on influence of season, type and concentration of growth regulating substances and media on rooting of branch cuttings. Rooting trial of *B. balcoo* branch cuttings in response to season, rooting media and growth regulator and its concentrations indicated that root induction was not possible in this species with the present frame work of study. The sprouting percentage was good in this species and it ranged from 1.67 to 48.33% and sprouting attributes varied due to treatment combinations. In further trials with higher concentrations (0, 1000, 2000 and 3000 mg l<sup>-1</sup>) of growth regulators (NAA and IBA) by soaking and quick dip method of IBA and NAA treatments at concentrations used were 0, 1000, 1500 and 2500 mg l<sup>-1</sup> also failed to initiate rooting. Studies on adventitious root induction in *Dendrocalamus giganteus* branch cuttings in response to season, rooting media and growth regulator and its concentrations also indicated that rooting was absent in this species with the treatments given. Sprouting in the branch cuttings in different treatments ranged from 5.00 to 43.3%. The experiment to initiate rooting in *Thyrsostachys oliveri* cuttings in different seasons, rooting media and growth regulator concentrations also was a failure. The maximum sprouting was observed in cuttings treated with IBA 100 mg l<sup>-1</sup> third season (41.67%) kept in the sand and the least was in those treated with NAA 250 mg l<sup>-1</sup> (0.00%). From the study it can be concluded that the present set of treatments are not effective in initiating the rooting in branch cuttings of the three bamboo species studied.

#### **15. Genetic diversity and population structure of two distinct natural populations of *Syzygium travancoricum* Gamble**

The objective of the study is to compare the genetic variation between two populations of *Syzygium travancoricum* Gamble growing in geographical isolation at two different natural habitats. The study further will investigate the population structure and variation in reproductive biology occurring within the species, to determine if constraints to seed production may explain the rarity of the species. The study revealed that, flowering occurred in *S. travancoricum* after a dry period and the fruiting occurred just before the onset of rain. The inflorescence of the species was axillary cymose with white, calyptrate flowers. Mass flowering was observed in *S. travancoricum*, but, when compared to other syzygium species, number of flowers produced per tree was less. The species associated with *S. travancoricum* was different in Kalasamala and Kattilappara. The relative density of the species was different in the two populations. The two populations showed significant variations in the case of wood anatomical characters. The seed banks too differed significantly between the two sites. The study concluded that the constraints such as, lesser flower production, poor fruit set, lower seed germination, poor seed viability could be the main causes of the rarity of *S. travancoricum*. The study further showed that the two populations have considerable differences between them, either environmental or genetic.

#### **16. Morpho-physiological diversity assessment of *Garcinia gummi-gutta* (L.) Robs. germplasm collection**

The objective of the study is to explore the variability, physiological and biochemical characters in the trees of *Garcinia gummi-gutta* collection maintained at NBPGR, Vellanikara. The present investigation related to variation in morphological and biochemical parameters in *G. gummi-gutta* indicated considerable variation among the accessions. Trees could be grouped into five clusters based on these characters using cluster analysis. Thus, there is a possibility of taking up hybridisation work using the present germplasm for improving the yield and nutritional value of this important tree crop of Kerala.

### **17. Wood property profiling of coconut palms grown in different agro-climatic zones of Thrissur district, Kerala**

Objective of the study is to look into the anatomy, physical, mechanical, and chemical properties of coconut timber and to find out wood property variation in relation to variation in farming regions and within tree variations of coconut palm. The study also aims to establish an improved treatment (seasoning and preservation) schedule for coconut timber.

Wood anatomical, physical and mechanical properties of samples collected from 51 coconut palms belonging to three age groups viz., 15-25 years (young), 35-45 years (mature) and 55-65 years (over mature), grown in three agro-climatic zones (Malayoram, Central midland and Coastal sandy) of Thrissur district, Kerala were profiled in this study. Dermal, sub-dermal and core wood from each sample were used for assessing physical and anatomical properties and samples of density above 650 kg m<sup>-3</sup> were selected for profiling mechanical properties. Nested analysis of variance was carried out to analyse the variation in coconut palm wood properties due to location, age and radial position. Most of the physical, anatomical and mechanical properties did not vary significantly across agro-climatic zones and age groups. However, across age groups, basic density, vascular bundle percentage, fibre lumen diameter, fibre wall thickness and compression parallel to grain (maximum load and compressive stress at maximum load) were found to vary significantly. Along the radial positions there was significant difference in physical and anatomical properties. Basic density, being highly positively correlated with mechanical and anatomical properties, estimation of density can be used as a key to determine end use under field conditions for potential utilization at the industrial level.

### **18. Forage yield, soil fertility and carbon dynamics of calliandra (*Calliandracalothyrsus* Meissn.) in coconut plantation**

The study aimed to assess the influence of tree density and pruning interval on forage yield and carbon storage potential of three-year old calliandra intercropped in coconut gardens. The study also explored the variation in coconut productivity and soil fertility changes associated with intercropping calliandra in coconut plantations. Three-year old calliandra fodder banks with tree density of 27,777 plants ha<sup>-1</sup> and harvested at 12 weeks interval yielded the maximum forage and sequestered 90 Mg ha<sup>-1</sup> additional carbon than coconut monoculture systems.

### **19. Characterisation of phytopathogenic fungi in nursery seedlings of *Tectonagrandis* L.f. *Swieteniamacrophylla* King and *Cassia fistula* L. in central Kerala**

The main objective of the study was to detect and diagnose the fungal diseases affecting Teak (*Tectonagrandis* L.f.), Mahogany (*Swieteniamacrophylla* King) and Indian Laburnum (*Cassia fistula* L.) at the nursery stage. The study will attempt an *in vitro* evaluation of selected fungicides and biocontrol agents against these diseases. 13 isolates of fungal pathogens were identified from the tree crop nurseries surveyed in Thrissur and Palakkad districts (Teak-8; Mahogany-2; Indian laburnum- 3). This study also identified screened and standardized fungicides and biocontrol agents combinations that are effective against these diseases.

### **20. Standardisation of preservation techniques of coconut (*Cocosnucifera*) palm wood**

The study aimed to develop appropriate preservative methods for sawn and round form coconut palm wood and to find out the variation in retention and penetration in different parts of coconut palm wood. It is also proposed to evaluate the effectiveness of preservative treatments applied through graveyard test and the effect of various factors on the treatability of coconut wood.

Wood samples were treated with inorganic (Copper Chromium Boron - CCB and Borax Boric Acid - BBA) and organic preservatives (Cashew Nut Shell (CNS) oil, neem oil and turpentine). Diffusion and

pressure treatment were deployed for inorganic preservation and organic preservatives were investigated only through diffusion treatment. The study found that sawn coconut wood samples could be effectively treated with preservatives complying with the prescribed retention and penetration percentages as per the different standards and therefore, can be used as a potential substitute for conventional timbers.

### **21. Selection and evaluation of superior planting materials of *Ailanthus triphysa* (Dennst.) in Thrissur**

### **22. Long term effect of thinning on productivity and wood properties for 20 year-old *Acacia mangium* wild. Stands**

The major objective of the study is to assess the long-term effect of thinning on growth, biomass production, carbon storage potential and soil properties in 20-year-old *Acacia mangium*. The study also attempts to understand the effect of stand thinning on wood properties of 20-year-old *Acacia mangium*.

### **23. Variation in wood physical and anatomical properties of anjily (*Artocarpushirsutus* Lam.) grown in different agro climatic zones of Thrissur district, Kerala**

The study aimed to assess the variation in wood anatomical and physical properties of anjily (*Artocarpushirsutus* Lam.) grown in different agro climatic zones of Thrissur district, Kerala and to compare anatomical and physical property of wood between plantations and homesteads.

Different analysis revealed that basic density and moisture content didn't show any significant variation across three agroclimatic zones as well as between girth classes. Ecoanatomical characters like vulnerability index and vessel mesomorphy were also analysed and vulnerability index was found to be highest in central midland. The result of the present study can be used as a baseline data for future tree improvement programme of this species for different end uses. As information on wood properties of *Artocarpushirsutus* is very scarce, this study can provide more details regarding wood properties of this species.

## **Ongoing Projects**

### **1. Genetic variability and plus tree selection in natural populations of malaveppu (*Meliadubia* Cav.)**

The study will assess the genetic diversity in *Meliadubia* and select plus trees in natural populations of this species. This study will also analyze the clonal and seed progeny of plus trees for early growth and vigor. Further, commercially viable clonal propagation protocol for the species will also be attempted. The project is in progress.

### **2. Wood quality of plantation grown teak (*Tectonagrandis*Linn.f) raised under different sites within and outside India**

The objective is to analyse the variation in the physical and anatomical properties of plantation teak wood grown in different sites with special reference to the samples collected from important teak growing regions within and outside India. It is also intended to assess the extent and nature of juvenile wood in these plantation grown sources through the analysis of wood properties. The study is in progress

### **3. Miniclonal propagation of matti (*Ailanthus triphysa* (Dennst.) Alston) and kanala (*Melicopelunu-ankenda*. (Gaertn.) Hartley).**

Standardisation of mini clonal propagation techniques in *Ailanthus triphysa* and *Melicopelunu-ankenda* for production of quality plantlets. The study is in progress.

#### **4. Productivity, carbon and nutrient stocks in mulberry (*Morusindica* L.) and subabul (*Leucaenaleucocephala*Lam.) based high density fodder production system in coconut.**

To evaluate the effect of tree density and harvest interval on forage yield and carbon storage potential of three-year old mulberry and subabul fodder banks underneath coconut garden. To study the variation in coconut productivity and soil fertility changes associated with intercropping these fodder trees with coconut. The project is in progress.

#### **5. Field evaluation of stump and root trainer grown teak (*Tectonagrandis*L.f.) plantations**

The primary objective of the study is to evaluate and compare the field growth performance of teak plantations established by stump and root trainer technique. The study also attempts to examine the differences in root distribution patterns of teak as a function of planting technique. Further, the study compares the effect of variable spacing on the performance of root trainer grown teak plantations. The project is in progress.

#### **6. Understorey productivity of selected fodder grasses in mature coconut and rubber plantations**

The objective of the study is to assess the productivity of selected fodder grasses viz., *Brachiaria ruziziensis* (Congo signal), Guinea grass (*Panicum maximum*) and hybrid napier cultivars CO-3, CO-5 in mature coconut and rubber plantations. Project in progress.

#### **7. Screening of superior genotypes of *Ailanthus triphysa*(Dennst.) Alston, for matchwood quality**

To assess the variation in growth and wood traits of *Ailanthus triphysa* grown in the main campus of Kerala Agriculture University, Vellanikkara under a tree improvement trial. It is also aimed at screening the superior genotypes of this species through an assessment of the genetic worth of their parents. Among the five best performing progenies, FCV AT 11 and FCV AT 20

were found to perform well in terms of height and collar diameter. The progenies of FCV AT 11 also showed also highest mean stem volume of 0.006 m<sup>3</sup>. Bioassay using *Bacillus thuringiensis* (Bt) was found to be effective against both the lepidopteran defoliators, *Eligma narcissus* (carm.) and *Atteva fabriciella* Swederus.

#### **8. Standardisation of gum-oleoresin extraction technique in Matti (*Ailanthus triphysa* (Dennst.) Alston.)**

The main objective is to develop an appropriate technique for extraction of gum-oleoresin and also to study the correlation between tree dimension and anatomical features with gum-oleoresin production in Matti (*Ailanthus triphysa* (Dennst.) Alston.). The project is in progress.

## Appendix: The list of research publications of KAU during 2017-18

Authors	Title of Paper
1. Abdul Niyas, P.A., Sejian, V., Bagath, M., Parthipan, S., Selvaraju, S., Manjunathareddy, G., Kurien, E.K., Varma, G and Bhatta, R (2017).	Effect of heat and nutritional stress on growth and testicular HSP70 expression in goats. <i>Journal of Agrometeorology</i> , 19(3): 189-194. IF: 0.563
2. Abhirami M Jayakumar and PO Nameer (2018)	Species composition and abundance estimates of reptiles in selected agroecosystems in southern Western Ghats, India. <i>Journal of Threatened Taxa</i> . NAAS 5.1
3. Adarsh, C. K., Ganesh, P. N. and Vidyasagaran, K. (2017).	Distribution of polypores along the altitudinal gradients in Silent Valley National Park, Southern Western Ghats, Kerala, India. <i>Current Research in Environmental &amp; Applied Mycology</i> . 8 (3)
4. Adarsh, C. K., Vidyasagaran, K. and Ganesh, P. N. (2018).	A checklist of polypores of Kerala state, India. <i>Studies in Fungi</i> . 3(1): 202–226
5. Afsal, A. and Sejian, V (2018).	Somatotropic Axis Associated Growth Governance in Livestock. <i>Journal of Veterinary Science and Research</i> , 3(1): 000150.
6. Afsal, A. Sejian, V, Bagath, M, Krishnan, G, Devaraj, C, Bhatta, R (2018).	Heat Stress and Livestock Adaptation: Neuro-endocrine Regulation. <i>International Journal of Veterinary Animal Medicine</i> , 1(2):108.
7. Afthab Faisal, Amal US and PO Nameer (2018)	Preliminary checklist of anurans of Nelliampathy Hills, southern Western Ghats, Kerala, India. <i>Zoos' Print Journal</i>
8. Airina, C.K., T. Pradeepkumar and S. Krishnan. (2017).	Combining ability studies exploiting gynocy in cucumber ( <i>Cucumis sativus</i> L.). <i>Electronic J Plant Breed</i> . 8(2): 724-731
9. Aiswarya, C.S. and Sreelathakumary, I. (2017)	Evaluation of chilli ( <i>Capsicum annum</i> L.) hybrids for biochemical constituents. <i>Trends in Biosciences</i> 10 (46): 9384-9386
10. Aiswarya.L and Suma Divakar. (2018)	Impact of cluster bean consumption on hyperlipidemia and hyper glycemia". <i>International Journal of Food Science and Nutrition</i> Vol.3 (2) March. P. 35-35
11. Ajay Bhardwaj, T. Pradeepkumar and C. Varun Roch. (2017).	<i>In Vitro</i> Regeneration of Parthenocarpic Cucumber ( <i>Cucumis sativus</i> L.) <i>Int.J.Curr.Microbiol.App.Sci</i> 6(7): 1711-1720
12. Ajeesh, R., Santhoshkumar, A.V., Gopal, S. and Binu, N.K. 2017.	Screening of selected native arbuscular mycorrhizal fungi at different levels for their symbiotic efficiency with <i>Tectonagrandis</i> seedlings. <i>Journal of Tropical Forest Science</i> 29(4): 395–403.
13. Alex, S., Saira, A., Nair, Deepa, S., Soni, K.B., Sreekantan, L., Rajmohan, K. and Reghunath, B. R. 2017.	Bioethanol production from watermelon rind by fermentation using <i>Saccharaum cerevisiae</i> and <i>Zymomonas mobilis</i> . <i>Indian Journal of Biotechnology</i> (16): 1-4. IF: 0.368
14. Amida Saparya, K.M. Sreekumar, T Santhoshkumar and P.R. Suresh (2018)	Red ant <i>Oecophylla smaragdina</i> (Hymenoptera: Formicidae) in the management of cow pea pests. <i>Entomon</i> 43(1) March 2018 -
15. Anamika Menon, Akhil Das and PO Nameer (2018)	A new record of <i>Miniopterus fuliginosus</i> (Hodgson, 1835) from Wayanad Wildlife Sanctuary, Western Ghats, India. <i>Zoos' Print Journal</i>
16. Angel, S.P., Amitha, J.P., Rashamol, V.P., Vandana, G.D., Savitha, S.T., Afsal, A, Bagath, M, Krishnan, G and Sejian, V (2018).	Climate Change and Cattle Production: Impact and Adaptation. <i>Journal of Veterinary Medicine and Research</i> . 5(4): 1134.
17. Angel, S.P., Bagath, M., Sejian, V (2018).	Climate change and hypothalamic–pituitary–adrenal axis in livestock: what we know and what needs to be explored? <i>Advanced Journal of Environmental Science and Technology</i> , 5(4):245-246.
18. Anil G, N Kishore, N Gafoor, N Ommer and PO Nameer (2018).	Observations on the Nilgiri Marten <i>Martes gwatkinsii</i> (Mammalia: Carnivora: Mustelidae) from Pampadum Shola National Park, the Southern Western Ghats, India. <i>Journal of Threatened Taxa</i> . NAAS 5.1

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19. Anith, K.N. S. Aswinia, Shilpa Varkey, N.V. Radhakrishnan, Deepa S. Nair. (2018)	Root colonization by the endophytic fungus <i>Piriformosporaindica</i> improves growth, yield and piperine content in black pepper ( <i>Piper nigrum</i> L.). <i>Biocatalysis and Agricultural Biotechnology</i> . 14(2018): 215-220
20. Anjali, K., M. Ameena and Nimmy Jose. 2018.	Morphological characterization of weedy rice morphotypes in Kerala. <i>Indian Journal of Weed Science</i> 50(1):
21. Anooob, P., Santhoshkumar, A.V. and Paul C. Roby 2017.	Impact of particulate pollution on photosynthesis, transpiration and plant water potential of teak ( <i>Tectonagrandis</i> L.). <i>Current Science</i> . 112(6): 1272-1276. IF: 0.883
22. Anu, S. K., Raj, A.K., Kunhamu, T. K., Thomas, C.G. and Santhosh Kumar, A. V. (2018).	Management of calliandra ( <i>Calliandracalothyrsus</i> Meissn.) in coconut plantation for boosting forage yield and nutritive value. <i>Range Management and Agroforestry Journal</i> Vol.39 No.1.
23. Anupama BM, Sudheer K P, Sankalpa K B and Ranasalva N. (2017).	Development and Performance Evaluation of a Blancher cum Dryer, <i>Trends in Biosciences</i> 10(31).
24. Aparna, K. K., Menon, M. V., and Prameela, P. (2017).	Efficacy of pre and post emergence herbicides on <i>Echinochloa</i> spp. <i>Journal of Tropical Agriculture</i> . 55 (1): 91-95.
25. Archana, P.R., Sejian, V., Ruban, W., Bagath, M., Krishnan, G, Aleena, J., Manjunathareddy, G.B., Beena, V and Bhatta, R (2018).	Comparative assessment of heat stress induced changes in carcass traits, plasma leptin profile and skeletal muscle myostatin and HSP70 gene expression patterns between indigenous Osmanabadi and Salem Black goat breeds. <i>Meat Science</i> , 141: 66-80 <a href="https://doi.org/10.1016/j.meatsci.2018.03.015">https://doi.org/10.1016/j.meatsci.2018.03.015</a> IF: 2.821
26. Arun Kumar Singh and Ramesha Barrikkad.(2017).	Taxonomic redescription of the coconut bark weevil ( <i>Diocalandrafrumenti</i> ). <i>Journal of Pharmacognosy and Phytochemistry</i> SP1: 1049-1053.
27. Arya. S. R. and Ameena. M. (2017)	Efficacy of new generation herbicides for weed management in dry direct seeded system of rice. <i>Annals of Agrl. Research</i> . 38(2): 149-154.
28. Asna, A.C. Jiji Joseph, P. Sainamole Kurian and K. Joseph John (2018)	Identification of bitter gourd genotypes with field tolerance to viral diseases. <i>Journal of Tropical Agriculture</i> 56 (1) : 9-16
29. Aswathy, T. S. and Jessykutty, P. C.(2017).	Rapid multiplication of Kasthuri turmeric ( <i>Curcuma aromatica</i> Salisb.) through miniset technique and nursery management. <i>Journal of Spices and Aromatic crops</i> : 26(1): 47-50
30. Atheena, A., Prameela, P., and Menon, M. V. (2017).	Tank mix application of cyhalofop-butyl with selected herbicides for weed control in wet-seeded rice. <i>Indian Journal Weed Science</i> 49(3): 283-286.
31. Bagath, M., Sejian, V., Krishnan, G., Vidya, M.K., Pragna, P., Archana, P.R and Aleena, J (2017).	Nutrition and Immune System in Livestock: Mini Review. <i>Journal of Dairy and Veterinary Sciences</i> , 2(2): 555-582.
32. Beena C., Kanakamany M.T. and Sindhu P.V. (2018).	Quality evaluation of important ayurvedic raw drug Brahmi ( <i>Bacopamonnieri</i> ). <i>International Journal Of Tropical Agriculture</i> 36(3): 649-652.
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34. Beena, R., Praveenkumar, V. P, Vighneswaran, V, Sindhumole, P, and Narayanankutty, M.C. (2017).	Phenotyping for root traits and carbon isotope discrimination in rice genotypes of Kerala <i>Oryza</i> 54(3)
35. Beena, R., Praveenkumar, V.P., Veena V., Sindhumole, P. and Kutty, M.C.N. (2017).	Phenotyping for root traits and carbon isotope discrimination in rice genotypes of Kerala. <i>Oryza</i> 54(3): 282-289.
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37. Brinda, G. B., Susha. S., Thara, C. M., and Suma Divakar. (2017)	Nutritional analysis and organoleptic evaluation of paddy straw mushroom ( <i>Volvariellasp</i> ). <i>Food Science Research Journal</i> . 8 (2): 230-234

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