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Response of upland irrigated rice (*Oryza sativa* L.) varieties to irrigations

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Abstract
A field investigation entitled "Response of upland irrigated rice varieties to irrigations" was conducted at Plot No. 66, Research Farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Kharif* season of 2016-2017. The main plot treatments were: I_1- Irrigation at 0.6 IW/CPE, I_2- Irrigation at 0.8 IW/CPE, I_3-Irrigation at 1.0 IW/CPE and I_4-Irrigation at 1.2 IW/CPE and in the subplots, varietal trial was carried out, which consisted of four varieties: V_1- Variety Avishkar V_2- Variety Parag, V_3- Variety Sindewahi-1 and V_4- Variety PBNR-03-02. The experimental results revealed that the rice varieties performed best at 1.2 IW/CPE, in which irrigation water was provided when cumulative pan evaporimeter reading reached 50 mm. The yield attributes, grain yield, straw yield and the biological yield were observed to be the highest with 1.2 IW/CPE. Among the varieties, the variety Avishkar, was found to perform the best in terms of yield attributes like number of panicles, weight of panicle, number of filled spikelets and test weight which resulted in highest grain yield in the variety. All the varieties responded well to irrigations and the maximum yield and other characteristics were observed at higher irrigation levels. The variety Avishkar was found to perform the best under the upland irrigated conditions with 50 cumulative pan evaporation.

Keywords: upland rice, irrigation, cumulative pan evaporation, varieties

Introduction
Rice (*Oryza sativa*) being the staple food of almost two thirds of the population plays a pivotal role in Indian economy. India ranks first in the world in area of rice cultivation with 43.97 million ha and second in production with 104.32 million tons. In Asia, more than 75% of the annual rice supply comes from 79 million ha of irrigated paddy land. Thus, the present and future food security of Asia depends largely on the irrigated rice production system. However, rice is a profligate user of water. It takes 3,000 to 5,000 L to produce 1 kg of rice, which is about 2 to 3 times more than the amount needed to produce 1 kg of other cereals such as wheat or maize (Bouman *et al*., 2001) [2]. Irrigation water is an important production factor in rice systems but water is no longer available in unlimited rice-growing areas.

The productivity of the upland rice is very low because of a host of problems among which soil moisture stress is the most important. Kato *et al.* (2006) [4] studied on the growth of three rice cultivars under upland conditions with different levels of water supply found that the total water supply greatly affected the total dry matter in uplands. Another limitation with the cultivation of upland rice is that the yield potential of upland rice cultivars is far less as compared to that of the wetland rice cultivars, which limits its cultivation in most of the dryland tracts. The quality rice cultivars are also rare in the upland conditions. And also, the quality and trust of upland cultivars are been preferred by illite group in market. The yield of rice under upland conditions can be increased by judicious management of production inputs. Sokoto *et al.* (2013) [12] conducted a pot experiment to study the responses of rice varieties to water stress (FARO 44, NERICA 2 and FARO 15). The results indicated that there are significant differences among the genotypes. FARO 44 differed significantly from others in plant height, number of leaves per plant and total biomass.

Materials and Methods
The field experiment was carried out in Agronomy farm, Dr. Panjabro Deshmukh Vidyapeeth, Akola during kharif season of 2016-2017. The field was clayey in texture and was slightly alkaline in nature (pH 7.2), moderate in organic carbon (0.67%), low in available Nitrogen (218 Kg/ha), low in Phosphorous (18.4 Kg/ha) and high in available Potassium (337 Kg/ha). Rainfall received during the cropping season was 832.3 mm in 43 rainy days. During the crop growing season, the maximum temperature ranged between 30.2^{0}C in the 32nd meteorological week to 34.1^{0}C in 26th meteorological week.

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Morphological characterisation of weedy rice morphotypes of Kerala

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ABSTRACT

Weedy rice (*Oryza sativa* f. *spontanea*) has emerged as a major threat to global rice production and has already established in the major rice growing tracts of Kerala, *viz*. Palakkad, Kuttanad and Kole lands. The main objective of the study was to compare the morphological characteristics of weedy rice morphotypes across the state so as to chalk out morphometric relationship between the weedy and cultivated rice at different stages of plant growth. Different morphotypes of weedy rice were collected from the major rice tracts of the state and characterization was done, both for qualitative and quantitative (morphometric) traits. The study revealed similarity in most of the qualitative traits observed for weedy and cultivated rice. The morphometric characters that varied significantly between weedy and cultivated rice during the initial stages of growth included thickness of culm and length of ligule. Most striking difference observed was in the number of tillers/plant with 87 per cent of weedy rice morphotypes recording higher tiller number (ranged from 11 to 20) compared to cultivated rice (10 and 9 for '*Jyothi* (Ptb-39) and '*Uma-MO-16*, respectively). Studies also revealed that weedy rice plants were lanky, taller (105 to 115.67 cm) with more round culm, with or without anthocyanin pigmentation at the nodal region, short ligule, early flowering compared to cultivated rice, more number of tillers per plant and mostly with awned grains. Similarities between weedy and cultivated rice were found to increase after every cultivating season due to the repeated back crossing and gene flow between the two plant types as evident from compact panicles and awnless grains observed among the morphotypes. As weedy rice invasion reduces crop yield substantially (40-70 percent), its management is an urgent need of the hour. Some of the morphological adaptations exhibited by the morphotypes in response to the prevailing ecological situations clearly indicated the possibility of weedy rice becoming a persistent threat to rice cultivation. Morphological characterization could help in identifying the competitive traits of weedy rice morphotypes which can be used in advanced breeding programmes for developing ecofriendly weedy rice management strategies.

INTRODUCTION

The introgressed product of wild and cultivated rice widely known as weedy rice (*Oryza sativa* f. *spontanea*), was first documented in North Carolina, USA as early as in 1846 (Smith 1981). However, reports of weedy rice emerging as a major weed in the direct-seeded rice tracts of South East Asia appeared after more than a century.In direct seeded rice, this noxious weed emerged as a major threat with its huge seed bank in cropped fields favouring persistent invasion. In Asia, weedy rice infestation was first reported from Malaysia in 1988, Philippines in 1990, and Vietnam in 1994 (Saha *et al*. 2014). In India, the first attempt of identifying and characterizing different types of weedy rice in farmer's field was done in Madhya Pradesh (Varshney and Tiwari 2008). In South India, especially Kerala weedy rice infestation and spread has reached an alarming proportion in major rice tracts during 2007-08. The weed then evolved as a major problem in the rice fields reducing the yield from 30 to 60 per cent at an infestation rate ranging from 3 to 10 mature plants per square metre (Abraham *et al*. 2012). Of late, it has infested large rice growing areas across the major rice belts of Kerala, *viz*. Palakkad, Kuttanad and Kole lands with

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Growth and productivity of selected fodder grasses intercropped under mature coconut and rubber plantations at Vellanikkara, Thrissur

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ABSTRACT : A field experiment was conducted at Vellanikkara, Thrissur, Kerala to assess understory productivity of four fodder grasses *viz.*, *Brachiaria ruziziensis* (congo signal), *Panicum maximum* (guinea), hybrid napier cultivar CO-3 and CO-5 under mature coconut (*Cocos nucifera*) and rubber (*Hevea brasiliensis*) plantations, which are the two prominent land-use systems in Kerala, from May 2017 to February 2018. The selected fodder grasses were planted in beds (10 m × 1 m × 0.3 m) in the understory of mature coconut and rubber plantations. Coconut grown fodder grasses showed maximum plant height with a per cent increase of 3.73, 8.97 and 5.28%, respectively over control for first three harvests. Tiller production also varied significantly. At fourth harvest, with maximum number of tillers clump^{-1}, the coconut grown fodder grasses exhibited only 36.35% decrease in tillers whereas it was 78.29% in rubber as compared with open. The mean number of leaves clump^{-1} observed in open grown fodder grasses was 127.25, whereas it was only 66.71 and 16.04 in coconut and rubber plots, respectively at the second harvest, which recorded the maximum leaf production. Understory photosynthetically active radiation (PAR) transmittance ranged from 39.84-56.08% in rubber and coconut, respectively. Coconut grown fodder grasses showed an equally good performance in growth and yield attributes with the open whereas a substantial reduction in the yield was observed in fodder grasses grown in the understory of rubber.

Key words: *Brachiaria ruziziensis*, *Cocos nucifera*, *Hevea brasiliensis*, integrated farming and *Panicum maximum*.

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1. INTRODUCTION

The fodder resources of our country are hardly sufficient for feeding even half of the existing cattle population and the shortage of green fodder is well recognized. An expected deficit of 65% of green fodder and 25% of dry fodder is expected for Indian livestock by 2025 (Singh *et al.*, 2013). Among milk producing states in the country, Kerala ranks 14th with a share of just 1.5% of the total milk production in the country (GOK, 2017). Non-availability of land stands as a major hindrance for fodder cultivation. Due to marginal holdings coupled with increasing demand for food crops due to demographic pressure and shift in the land-use patterns followed in the state, exclusive fodder cultivation is not feasible. The cost of concentrate feeds is increasing, making it almost impossible for the dairy farmers in the state, especially those with limited financial resources to maintain cattle. The projected gap between demand and supply of green and dry fodder invites an attention to frame perspective planning, time bound strategies and concerted efforts to meet this challenge.

In this context, the vast area of interspaces available under commercial plantations dominated in Kerala offers excellent opportunity for integrating compatible fodder grasses with these plantations. Among these, mature coconut (>25 years) plantations are excellent option for intercropping on account of their wider spacing and ample light availability in the understory. Rubber is another plantation crop of importance for fodder grass integration, primarily on account of the vast stretches of land under rubber plantation and the deep rooted nature of the rubber trees (Sreenivasan *et al.*, 2004). Improved varieties like hybrid napier (*Pennisetum purpureum* × *Pennisetum americanum*) are recommended for intensively managed small-holder crop- livestock farming systems and are well suited for the "cut and carry" feeding system. Guinea grass (*Panicum maximum* Jacq.) and congo-signal grass (*Brachiaria ruziziensis* Germain & Everard) are also known for their strong persistence, palatability and suitability for intercropping. Intercropping in the tree-based system is primarily a function of the light demand, tree-root distributions and tree-crop interactions. A reliable information about influence of biophysical interactions on growth and productivity of fodder grasses under mature coconut and rubber plantations can be beneficial for small-holder dairy farmers. Keeping in view of these aspects, study on growth and productivity of selected fodder grasses intercropped under mature coconut and rubber plantations at Vellanikkara, Thrissur was undertaken.

2. MATERIALS AND METHODS

The two land-use systems studied *viz.*, coconut and rubber plantations and control plot were located in the KAU main campus, Vellanikkara, Thrissur, Kerala (10° 13' N latitude and 76° 13' E longitude and at an elevation of 40 m above mean sea level). The rubber and coconut consisted of mature trees aged 30 and 26 years and planted at spacing of 4.5 m × 4.5 m and 8 m

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Forage yield and nutritive quality of three-years-old calliandra (*Calliandra calothyrsus* Meissn.) under different management options in coconut plantations of Kerala, India

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ABSTRACT : Integrating protein rich fodder tree calliandra under existing coconut gardens is a promising option for addressing crude protein deficit in smallholder livestock farms in Kerala, but needs standardization of effective stand management practices for optimizing forage yield and nutritive value from limited land area. Hence, the present study was conducted to determine the optimum tree density and pruning interval to maximize production of quality forage from calliandra hedgerows underneath coconut garden, by comparing three levels of tree density (27,777; 22,222 and 17,777 plants ha^{-1}) and three levels of pruning intervals (8, 12 and 16 weeks), laid out in 3 × 3 factorial randomized block design, replicated thrice. The study indicated that the annual fresh fodder yield of intercropped calliandra per hectare of coconut garden increased from 43.44 to 55.40 Mg from lower to higher density classes. The edible forage fraction (12.64 Mg ha^{-1} yr^{-1}), with leaf and green stem, was also higher for the highest density. Highest fresh edible forage yield (40.16 Mg ha^{-1} yr^{-1}) was obtained for the medium pruning interval of 12 weeks. Annual crude protein yield from total fodder (3.06 Mg ha^{-1} yr^{-1}) was highest in the highest density. Maximum annual crude protein yield in leaf (2.17 Mg ha^{-1} yr^{-1}) and total fodder (2.76 Mg ha^{-1} yr^{-1}) was reported in 12 weeks pruning interval rather than the shortest or longest cutting intervals. Hence, establishment of calliandra hedgerows underneath coconut plantation with a tree density of 27,777 plants ha^{-1} and scheduling harvests at interval of 12 weeks can enhance quality forage production and reduce expenses on costly concentrate feeds for profitable dairy farming in Kerala.

Key words: Crude protein yield, fodder yield, pruning interval and tree density.

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1. INTRODUCTION

A major constraint to dairy farming in the tropics is the seasonal fluctuation in forage yield and poor nutrient quality of fodder grasses especially during dry season. Fodder grasses contain less crude protein compared to fodder trees. Since livestock farming is a major means of subsidiary income for small farmers and agricultural labourers in Kerala, the state also faces the problem of scarcity of nutrient rich fodder. It is estimated that the state produces only 60 per cent of the fodder requirement for livestock (Kerala State Planning Board, 2011). Further, the heavy dependence of livestock farmers on costly concentrates reduce their profit to a considerable extent. Hence, cultivation of nutrient rich fodder on farm itself is highly warranted for profitable dairy farming. Fodder trees with their nutrient rich foliage serve as a potential source of quality green fodder to livestock especially during lean periods.

Calliandra (*Calliandra calothyrsus* Meissn.), a native of Central America, is a fast-growing multipurpose leguminous tree grown primarily for forage. The suitability of calliandra, as a promising fodder tree by virtue of its nutritive foliage and ability to withstand severe pruning has already been reported. Since the agro-climatic requirements of calliandra suit well to that of humid tropical Kerala, there is a good scope for utilizing calliandra as a source of quality fodder in the state. However, due to land constraints in Kerala, the possibility of growing calliandra as a monocrop in open lands is rather limited. Only alternative is to integrate with the existing cropping systems in the state. Coconut, being the most prominent plantation crop in Kerala stretching over an area of 0.82 M ha (Kerala State Planning Board, 2015), any attempt to integrate forage trees like calliandra with coconut would be a desirable strategy for profitable animal rearing.

Usually, low density planting patterns are followed for fodder trees in semi-arid and arid regions due to the constraints in soil nutrients and moisture. But, species like calliandra permit high density intensive cultivation in close hedgerows in humid high rainfall tropical condition like Kerala which is well evident from the various studies conducted earlier. Savory and Breen (1979) reported the highest forage yield from the high density stands of 60,000 plants ha^{-1} compared to lower densities (10,000 and 30,000 plants ha^{-1}). Density trials of mulberry and subabul fodder banks in coconut gardens of Kerala also reveal the significant improvement in fodder yield from lower planting ear of

Research Paper

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Liquid Formulation of *Azospirillum* sp. and Phosphate Solubilizing Bacteria (PSB) Performed Better than Carrier based Formulations on the Growth of *Amaranthus* sp. under Field Conditions

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ABSTRACT

A study was conducted to evaluate the liquid formulations of *Azospirillum* sp. and PSB using amaranth as a test crop under field conditions. Based on the plant height, number of leaves, number of days taken for flowering and total biomass of the plant, the PSB (liquid formulation) was the most promising biofertilizer for enhancing the growth of amaranth. While comparing the performance of liquid and carrier based formulations of *Azospirillum* sp. and PSB, the liquid formulations of the two biofertilizers performed better than carrier based formulations. Results of the present studies indicated that liquid biofertilizers are better than carrier based formulations as the liquid formulations have better shelf-life and higher population of the bacterial isolate.

Key words: Liquid formulations, *Azospirillum* sp., Phosphate solubilizing bacteria, *Amaranthus spp.*

Biofertilizer are the preparations containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulolytic microorganisms used for application to seeds, soil or composting areas which will augment the availability of nutrients that can be easily assimilated by plants. Biofertilizers are low cost, effective and renewable source of plant nutrients to supplement chemical fertilizers. However, the success of any biofertilizer depends on the quality of bioformulations. At present, most of the biofertilizers produced are of inferior quality and the survival of microorganisms up to field application is another major problem. The carrier-based formulations (solid substrates) which are currently available in the market have certain limitations like short-shelf life, unavailability of good quality carrier material in the local area, labour intensive, sensitivity to temperature, contamination etc. To overcome the problems of carrier based formulations, a new approach of developing formulations such as liquid formulations are being approached due to its advantages like no contamination, better survival on seeds, longer shelf-life, less dosage than carrier based formulations and easy touse.

Liquid biofertilizers (LB) contain a desired organism and their nutrients with special cell protectants or substances that encourage longer shelf life and tolerance to adverse conditions. The liquid formulations of *Azospirillum* and phosphate solubilizing bacteria (PSB) have been standardized with a shelf-life of 9 months at room temperature (Surendra-Gopal and Akhila 2016). Amaranth belonging to the family Amaranthaceae, is the most popular leafy vegetable of Kerala. It can be grown throughout the year. The leaves and succulent stems are good sources of iron, calcium, vitamin A and vitamin C. The crop is adapted to a wide range of soil conditions. Since, the amaranth leaves are directly consumed; it is highly amenable to the organic/ microbial sources of nutrients. Literature on the liquid formulations of biofertilizers is scanty and no information is available on the effect of liquid microbial fertilizers on *Amaranthus* crop in Kerala. Therefore, this study was undertaken with an objective to evaluate the efficiency of liquid biofertilizers using *Amaranthus* crop (Arun -Red Variety) under field conditions.

MATERIALS AND METHODS

Liquid formulations of *Azospirillum* and PSB were carried out using amaranth as the test crop. The details of the experiment are presented below:

Preparation of land: The field experiment in randomized block design with eight treatments and three replications was conducted at department of Agronomy, College of Horticulture, Vellanikkara from October, 2016 to January, 2017. The soil of the experimental site was of lateritic origin (Oxisol), belonging to Vellanikkara series, having 75.26

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Trend Analysis of Rainfall of Pattambi Region, Kerala, India

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Keywords

Mann-Kendall test, Sen's slope, Trend analysis

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A B S T R A C T

The study of rainfall trends is very important for any place whose food security and economy are dependent on the timely availability of water. In this work monthly, seasonal and annual trends of rainfall have been studied over Pattambi region using rainfall data of 35 years (1983-2017). Mann-Kendall analysis and Sen's slope estimator are used for the trend analysis. The results of the study indicated that the rising trend was observed in the months of February, March, April, May, September, October and December months whereas the falling trend was seen in January, June, July, August and November months. There was no significant trend observed in any of the months at 5% level of significance. There was a significant trend observed in the summer season and no significant trend was seen in the remaining seasons. The results of the trend analysis using Sen's slope estimator revealed that the annual rainfall was observed as falling trend. There was a falling trend observed in South-West monsoon and North-East monsoon seasons and rising trend in summer season. The winter season does not showed any trend as the estimated Sen's slope was zero.

Introduction

Water is the most important and limiting natural resource in the world. The economic development of any country depends on many factors in which water is one of the most important factors. It is the main requirement for the survival of any living organism and also plays an important role in agriculture and industry. Rainfall is the main source available for water in the design of water catchment structures, river basin management strategies and crop planning. In particular, the nature and state of agriculture in a region depend strongly on the total annual rainfall, its intensity and distribution. The distribution of rain varies greatly in time and space. The magnitude, frequency and intensity are the three main characteristics of rain that vary from place to place, day to day, month to month and also from year to year. The detailed knowledge of these characteristics is crucial for the planning of crops in a region and the full use of rainwater.

Intergovernmental Panel on Climate Change (IPCC, 2007) has reported that future climate change is likely to affect agriculture, increase of risk of hunger and water scarcity and may lead to rapid melting of glaciers. Kumar and Jain (2010) reported that a higher or lower or changes in rainfall distribution would

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SEX PHEROMONE BLENDS FOR RICE CASEWORM *PARAPONYX STAGNALIS* ZELLER

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ABSTRACT

Studies on sex pheromone of rice caseworm, *Paraponyx stagnalis* (Zeller) using EAG and GC-MS indicated the presence of four pheromone compounds *viz.*, Z-13-octadecenyl acetate, Z-9-hexadecenal, Z-11-hexadecenal and Z-11-hexadecenyl acetate in the ovipositor extract. Five different blends prepared from the tentatively identified compounds were evaluated for their field efficacy in rice fields at Pattambi, Kerala. Pheromone blends with Z-13-Octadecenyl acetate alone and with Z-11- Hexadecenal as a two component blend in the ratio of 1:1 were found promising in attracting more number male moths of rice caseworm in the field study.

Key words: *Paraponyx stagnalis*, sex pheromones, Z-13-octadecenyl acetate, Z-11- hexadecenal, Z-11-hexadecenyl acetate, Z-9-hexadecenal,moth catches

Rice caseworm (*Paraponyx stagnalis*) is assuming major pest status and posing major threat in all rice growing tracts of India viz., Assam (Gogai and Bora, 2013), Madhya Pradesh (Patel and Khatri, 2001), north western Uttar Pradesh (Singh and Singh, 2014), and Bihar, Odisha and West Bengal (http://www.rkmp.co.in// research themes/changing pest scenario). Management of this pest is difficult with chemical insecticides due to survival of insects in stagnant water. Using semiochemical/pheromone based methodologies is one of the promising alternative for an effective, potential and ecologically safe pest management for such pests inhabiting cryptic living habitat.

However, lack of an effective pheromone lure for caseworm is hampering its control. In collaboration with Indian Institute of Chemical Technology (CSIR-IICT), Hyderabad, the existence of female based pheromone system with electrophysiological behavioural bioassays has been brought out now. Isolation and identification of the four probable pheromone compounds from females under this collaborative programme (unpublished) has been achieved. Herein, the evaluation of the field efficacy and confirmation of the sex pheromone blends in the rice fields of Regional Research Station of Kerala Agricultural University (KAU) at Pattambi, Kerala is presented.

MATERIALS AND METHODS

The experiments were conducted at the Regional Agricultural Research Station, Kerala Agricultural University, Pattambi in collaboration with Indian Institute of Chemical Technology, Hyderabad during 2014-15 and 2015-16. Studies on characterization of pheromonally active chemical components from ovipositor extracts (from females collected at Pattambi) using Electroantennography (EAG), Gas chromatography linked EAG (GC-EAD), High Pressure Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) etc. were conducted at CSIR-IICT. All field evaluations were conducted in the experimental rice fields of Kerala Agricultural University, Pattambi, with the pheromone blend components provided by CSIR-IICT.

Field collected larvae were maintained individually in 10 ml test tubes until females emerged in the insectary at 28 ± 2p C and 70% RH. Ovipositor clipping of two days old virgin females was done during early hours of scotophase period as most females exhibited calling posture during this period, for collection of pheromonally active constituents. Excision was done with micro scissors by gently pressing the abdominal tips. The excised ovipositors were then soaked in HPLC grade hexane for 10 min and the supernatant transferred to a glass vial after subjecting it to microfiltration and stored at -30°C until used.

Electroantennogram Recording Technique (EAG): For electrophysiological recordings, Syntech EAG (Syntech, Hilversum, The Netherlands) was employed

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Research Article

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Antagonistic Potential of Bioagents against *Alternaria brassicicola*, the Incitant of Alternaria Leaf Spot of Cabbage

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ABSTRACT

Cabbage (Brassica oleracea var capitata (L.)) is widely grown cool season vegetable crop all over the world belongs to the family cruciferae. Economic part of cabbage is leaves forming the compact head. Now this cool season vegetable crop is cultivated under roof top conditions all over the Kerala. In recent years, losses has been observed at large scale due to Alternaria leaf spot of cabbage caused by Alternaria brassicicola as the severity of the damage was too high right from seedling stage to harvest stage. Application of chemical fungicides against this disease creates residue problems as economic part is leaf portion. Hence the present study was conducted to provide an effective biological management strategy against this disease. For this, fungi have been isolated from the phyllosphere of healthy cabbage plant in Alternaria disease affected field and the efficacy of fungi was evaluated against Alternaria leaf spot of cabbage by dual culture technique. The results revealed that the fungi Myrothecium inundatum isolated from the phyllosphere of cabbage were found to be an effective bioagent against the leaf spot pathogen Alternaria brassicicola. Along with this the antagonistic potential of two fungal bioagents Trichoderma viride, Trichoderma harzianum and two bacterial bioagents Bacillus subtilis, Pseudomonas fluorescens were evaluated against Alternaria leaf spot of cabbage by dual culture technique. In this method, the highest mycelial growth inhibition was recorded with Trichoderma viride (83.3%) followed by Trichoderma harzianum (80%), Bacillus subtilis (63.3%) and Myrothecium inundatum (55.5%).

Key words: *Cabbage, Alternaria leaf spot, Phyllosphere isolation, Molecular identification, Dual culture technique.*

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) is a profitable vegetable crop in Kerala grown for its compact head formed by the leaves. Cabbage is defenceless to a variety of pathogens which can bring about generous misfortune in yield. Among the fungal diseases of cabbage, Alternaria leaf spot caused by *A. brassicicola* is a noteworthy concern.

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Phenotypic plasticity of roots in mixed tree species agroforestry systems: review with examples from peninsular India

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Abstract Agroforestry entails different life forms including mixtures of trees that occupy different soil strata and exhibit a certain degree of spatial complementarity in resource use. However, rigorous experimental studies characterising root interactions in tree–tree systems are notoriously few. We present here the available empirical evidence to support the hypothesis that occurrence of two or more tree species close to one another may favour diminished lateral spread and/or deeper root penetration of the woody components and closer the tree components are located greater will be the subsoil root activity. These evidences are based on either root excavation studies in coconut-based multistorey production systems, or ^{32}P soil injection experiments involving binary mixtures of coconut+interplanted dicot multipurpose trees (*Vateria indica*, *Ailanthus triphysa* or *Grevillea robusta*), and bamboo (*Bambusa bambos*)+teak (*Tectona grandis*) or Malabar white pine (*V. indica*). The excavation study denotes a spatially segregated root distribution pattern of the component species. Furthermore, in the coconut + dicot tree system, interplanted dicot trees absorbed considerable quantities of the radio-label applied to the palm, which declined log-linearly with distance from the palms, signifying a substantial potential for "capturing" the lower leaching nutrients, at proximal distances. Likewise, lower teak/*Vateria* root activity in the surface horizons and higher activity in the deeper layers, when bamboo clumps were nearby and vice versa when they were farther apart, implied that proximity of species/individuals favoured competitive downward displacement of roots. Nutrient pumping and/or current transfer of nutrients between the rhizospheres of the two associated crops are also possible. In designing sustainable agroforestry systems, it is, therefore, advantageous to mix trees with divergent root growth habits.

Keywords Belowground architecture · Nutrient pumping · Root system plasticity · Safety net role of trees · Tree+tree systems

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Introduction

The central hypothesis of agroforestry and other multistrata systems is resource complementarity. Cannell et al. (1996) postulated that the tree components included in the multi-species systems endeavour to access nutrients from the lower layers of the soil profile, and horizontally from non-cropped areas, or

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Root distribution pattern of young *Swietenia macrophylla* King. stands in Central Kerala, India

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ABSTRACT: The major constraints to intercropping in woody ecosystems are belowground competitions for water and nutrients which are in short supply. The spatial spread of roots of the trees play major role in this context. The root distribution pattern was examined in a seven-years-old mahogany (*Swietenia macrophylla* King.) plantation established at 2.5 m × 2.5 m spacing by following logarithmic spiral trench technique. The root intensity steadily declined with increase in root diameter classes. The small roots (<2.5 mm size class) represented the major share of the total root intensity (7566 number m^{-2}), followed by medium sized roots (4713 number m^{-2}; size class >2.5 to<5.00 mm) and lowest for the coarse roots (406 number m^{-2}; size class>5.0 mm). Significant variation in root intensity was observed for different soil depths and lateral distances sampled. The roots generally followed decline in intensity with increasing lateral distance from the tree as well as with increasing soil depth. The small root count at the proximal end of the trench (closest to the tree base; 0.39 m) was 2266 while the corresponding count at farthest lateral distance (2.99 m) was only 133. The shallow soil depth of 0-20 cm represented almost 41% of the total small root count. The soil zone lying within 2.17 m lateral distance from the base of the tree and at 50 cm soil depth accounted for almost 84% of the total roots for the *S. macrophylla* tree studied. This forms the zone of root activity for most of the field intercrops hence could lead to intensive competition with field crops. The observed root distribution for *S. macrophylla* at seven year age indicates that the probable safer spacing for effective intercropping would be nearest to 5.34 m between trees.

Key words: Foraging zone, logarithmic spiral trench and root intensity.

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1. INTRODUCTION

Swietenia macrophylla (big leaf mahogany) belonging to family Meliaceae is one of the valuable timber species due to its attractive colour and dimensional stability (Lamb, 1966). It has a widespread geographical range in the Neotropics, from Mexico through central America and across the southern Amazon of Bolivia and Brazil (Rodan *et al.*, 1992). Mahogany was introduced to India from West Indies first to Royal Botanical Garden, Culcutta (India) in 1795 which was later introduced to Edacode, North Forest Division, Kerala in 1893 (Troup, 1921). In the recent times, mahogany has received wide acceptance among tree growers in Kerala due to its fast growth, remarkable wood qualities, durability, workability, better form and higher sawn out turn. It is cultivated in diverse fashion such as small wood lots, along farm boundaries and intimate multi-storey combination as in homegardens of Kerala.

Belowground competition with the component crops for nutrients and water is the cardinal factor that limits productivity of agroforestry systems. Root production and its spatial distribution patterns among the component crops play major role in deciding the resource acquisition for their optimal productivity. Superficial root systems may reduce loss of nutrients by leaching and soil erosion while improving porosity, infiltration and aeration. However, competition with associated food crops for the available nutrients and water in the topsoil is undesirable (Ball, 1985). Deep roots intercept leached nutrients and recycle them to the surface and may not cause competition or cultivation difficulties in tree-based cropping system. Hence, maintenance of differential zone of water and mineral absorption help to reduce interspecific competition especially when the resources are in short supply. However, our understanding on the belowground mechanisms of resource sharing especially in polyculture systems involving trees is very much limited. The methodological difficulties in assessing the root production and distribution often limit our search for such vital information. Such awareness may help to minimize the tree-crop interactions and thereby help attain optimal combined productivity.

Most of the direct methods of root studies are destructive and laborious in nature. To tackle such obstacles, different methods have been developed for characterising the spatial distribution of root systems in soil (van Noordwijk *et al.*, 2000).The logarithmic spiral trenching method is one such strategy which can give detailed information on overall spatial pattern of root distribution (Tomlinson *et al.*, 1998). This non-destructive method involves partial excavation of the soil around the tree and counting the roots at various lateral distances from the tree at various soil depths. The present study aims to understand the root

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Biomass production, carbon sequestration and nutrient characteristics of 22-year-old support trees in black pepper (*Piper nigrum*. L) production systems in Kerala, India

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Abstract Diverse kinds of fast growing multipurpose trees are traditionally grown as support trees (standards) for trailing black pepper vines in the humid tropics of India. Apart from differential black pepper yields, such trees exhibit considerable variability to accumulate biomass, carbon and nutrients. An attempt was made to assess the biomass production, carbon sequestration potential (tree + soil) and nutrient stocks of six multipurpose tree species (age: 22 years) used for trailing black pepper vines (*Acacia auriculiformis, Artocarpus heterophyllus, Grevillea robusta, Macaranga peltata, Ailanthus triphysa* and *Casuarina equisetifolia*). Results indicate that *G. robusta* showed the highest total biomass production (365.72 Mg ha^{-1}), with *A. triphysa* having the least value (155.13 Mg ha^{-1}). Biomass allocation among tissue types followed the order stemwood > roots > branchwood > twigs > leaves. Total C stocks were also highest for *G. robusta* (169 Mg C ha^{-1}), followed by *A. auriculiformis* (155 Mg C ha^{-1}). Mean annual carbon increment also followed a similar trend. Among the various tissue fractions, stemwood accounted for the highest N, P and K stocks, implying the potential for nutrient export from the site through wood harvest. All the support trees showed significantly higher soil carbon content compared to the treeless control. Soil N, P and K contents were higher under *A. auriculiformis* than other species. Nitrogen fixation potential, successional stage of the species, stand age and tree management practices such as lopping may modify the biomass allocation patterns and system productivity.

Keywords Pepper standards · Site fertility · Carbon sequestration · Nutrient export · Tree allometry · Biomass partitioning

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Introduction

Black pepper (*Piper nigrum* L.), the king of spice, is an important foreign-exchange earning commercial crop of India. The crop is grown extensively in peninsular India, especially in the state of Kerala, which accounts for 69% of Indian area of 1,17,760 ha. Production is about 37,000 tonnes, which is 54% of the gross Indian production (Spices Board India 2015). Other pepper growing regions in the country include Tamil Nadu, Karnataka and the north-eastern states. The cultural

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Understorey productivity of selected medicinal herbs in major land management systems in humid tropical Kerala

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ABSTRACT: A field study was conducted in the humid tropical Kerala, India to evaluate the performance of understorey herbaceous medicinal crops viz. *Zingiber officinale*, *Curcuma longa* and *Kaempferia galangal* when intercropped with major land management systems in the humid peninsular India such as mature plantations of coconut, cashew, rubber and homegarden. These landuse systems by virtue of spatial and temporal advantages offer good scope for integrating shade tolerant crops and thereby offer supplementary returns to the farmer. The intercrop growth considerably varied among the land use systems both in vegetative growth and rhizome yields. Except turmeric yields under cashew all other crops showed reduction in yield under various systems as compared to treeless open. Ginger biometric growth was better under homegarden during early growth phase while the dry rhizome yield was considerably lower compared to coconut, cashew and rubber. Understorey productivity for ginger in terms of rhizome yield at final harvest followed the order treeless open (3.45 Mg ha^{-1}), coconut (2.86 Mg ha^{-1}), cashew (2.63 Mg ha^{-1}), rubber (2.60 Mg ha^{-1}) and homegarden (1.49 Mg ha^{-1}). Turmeric rhizome production showed considerable variation with highest rhizome yield from mature cashew plantation (7.63 Mg ha^{-1}) followed by open area (7.01 Mg ha^{-1}) and the lowest from homegarden (1.77 Mg ha^{-1}). Highest Galangal yields were reported from the treeless open (3.05 Mg ha^{-1}) while homegarden recorded the lowest production (2.04 Mg ha^{-1}). Intercrop yield for galangal was highest under cashew (2.95 Mg ha^{-1}) followed by rubber (2.91 Mg ha^{-1}) and coconut (2.15 Mg ha^{-1}). Understorey photosynthetically active radiation (PAR) transmittance presumed to have a cardinal influence on intercrop growth which was highest under cashew (75%), followed by rubber (58%), coconut (17%) and lowest under homegarden (7%). Turmeric and galangal showed strong positive correlation with understorey PAR. Regression equation relating PAR with rhizome yields showed statistical soundness with high coefficient of determination (R^2) values (0.80 to 0.92). Linear, quadratic and logarithmic models were the best predictors of understorey productivity for the selected intercrops. Results suggest the vast opportunity for successful integration of shade tolerant, commercially important intercrops under mature agricultural land management systems prevalent in the tropics.

Key words: Intercropping, Rhizome yield, PAR and Prediction models

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1. INTRODUCTION

Land use practices in humid tropics are undergoing unprecedented transformation in the recent times on account of demographic pressure and socioeconomic reasons (Kumar, 2011). The congenial agroclimatic conditions of humid tropical Kerala permit the cultivation of an array of agricultural crops along with perennial trees. However, the per capita land availability and the fragmentation of available land put limits to the intensive land management with multiple crop components (Kumar and Nair, 2004; Peyre *et al.*, 2006; Guillerme *et al.*, 2011). The demand for perennial cash crops such as rubber, cashew, coconut and spices are on the increase in view of their cost effectiveness and economic returns (Kumar and Nair, 2004). The traditional homegardens of Kerala, once known for rich biodiversity and self reliance, are under the clutches of transformation towards less intensive monoculture practices. For instance there has been 3 fold increases in the area under rubber in Kerala during the last decade (Guillerme *et al.*, 2011). This shift from traditional farming practices owes primarily to the high cost of cultivation and the high opportunity cost of land.

Despite the limitation in crop intensification in the highly fragmented marginal lands, there exists better scope for integration of diverse crops components with the traditional plantation trees crops of Kerala such as rubber, coconut, cashew etc. Intercropping in tree based systems is primarily a function of light availability, tree root distribution and tree-crop interactions (Nair, 1993). Generally, intercropping is possible during the early growth phase of the trees when the system will be at suboptimal levels of resource acquisition. However at the young stage, vigorous growth of the tree stand may exert heavy competition with the intercrop leading to poor crop performance. But in the later phase of

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Short Communication

Influence of seed storage conditions and germination media on the germination of a priority bamboo species, *Dendrocalamus brandisii* (Munro) Kurz

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Abstract

The present investigation was formulated to determine the optimum storage condition and suitable germination media for enhancing the germination of *Dendrocalamus brandisii* seeds. Seed samples were stored at 4°C, 16°C and room temperature. The influence of four media on germination of the seeds was also estimated. Of the four media used, higher germination rates were observed in the vermiculite (60%), followed by quartz sand (55%), germination paper (55%) and soil (36%). Seeds with initial germination of 60 %, when stored for 36 months at 4°C and 45% relative humidity (RH) maintained their viability throughout the storage period. Whereas, in room temperature and 16°C, the seeds were viable only up to five and ten months respectively. The results indicated that seed viability of *D. brandisii* could be extended by reducing moisture content up to a critical level (8%) prior to storage, and fluctuations in moisture content play a significant role in seed deterioration and decrease in seed germination. It was also found that speed of germination was higher in vermiculite and germination paper (0.62) and lower in soil (0.22). Peak value was highest in germination paper (4.62), followed by vermiculite (3.76). Higher germination value was for vermiculite (0.27), followed by quartz sand and germination paper (0.16). The findings will contribute for successful storage of seeds, whenever flowering and seed set occurs and will help to establish plantations using seedlings.

Key words: *Dendrocalamus brandisii*, Germination paper, Quartz sand, Seed viability, Vermiculite

Propagation through seeds is the cheapest method of propagation in bamboo; however, seed propagation faces serious setbacks. Most of the bamboo species are monocarpic and most of the commercially exploited bamboo species belong to the gregarious flowering group, where the flowering starts synchronously in all the daughter clumps originating from one parent clump leading to the death of entire population after seed setting (Janzen, 1976). The major limitation of propagation of bamboos by seed is their short shelf life. So the development of appropriate storage methods and use of suitable germination medium will assure the use the large quantity of quality seeds produced during gregarious flowering to raise seedling nurseries in subsequent years.

Dendrocalamus brandisii (Munro) Kurz is a very large clump forming evergreen edible bamboo, commonly used for house building, basketry, handicrafts and furniture. It is mostly distributed in South and North-Eastern India and Myanmar, and was introduced to South East Asia. Its natural population in India is limited to tropical forests up to an altitude of 1300 m in Manipur and Andamans, but it is widely cultivated in Karnataka and Kerala.

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Short Communication

Induction of multiple shoots through *in vitro* male bud culture in banana *Musa* (AA) cv. 'Kadali'

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Abstract

Male buds of banana (*Musa* (AA) cv. 'Kadali') collected 20-25 days after the emergence of bunches were used for *in vitro* shoot regeneration, during 2016-2018. Sterilized male buds were inoculated on Murashige and Skoog basal medium with different combinations of naphthalene acetic acid (NAA) and benzyl adenine (BA). The earliest and highest percentage of culture establishment and multiple shoot induction (15.99) were observed on full strength MS medium with NAA 1.0 mgL^{-1} and BA 4.0 mgL^{-1}.

Key words: Direct organogenesis, 'Kadali', Male bud, Micropropagation, MS medium, *Musa*, Tissue culture.

'Kadali' is one of the banana varieties with great demand in the state of Kerala, India, as it is used for offering in temples, and the fruits are bestowed with a special flavour besides possessing medicinal properties. Major problem faced by the 'Kadali' growers is the non-availability of good quality planting material. Normally suckers and tissue culture plants (raised through shoot tip culture) are used for planting, but their availability is limited (Sapheera, 2005). Further, contamination is a problem in shoot tip culture. In addition to suckers, male buds can be used as a potential explant for raising tissue culture plants as this part goes unutilized during the harvesting of banana bunches. Therefore, *in vitro* male bud culture forms a good alternative since the male buds are less contaminated and male inflorescences of different sizes from different bract positions can be taken as explants (Darvari et al., 2010; Mahadev et al., 2011). With this in view, the present study was undertaken to explore the potential of male buds for mass multiplication of the diploid banana *Musa* (AA) cv. 'Kadali' under *in vitro* conditions. The work was carried out in the Plant Tissue Culture Laboratory at Banana Research Station, Kannara during 2016-2018.

Male flower buds from field grown healthy plants were collected 20-25 days after the emergence of bunches. According to the size of male bud, up to 35-45 bracts covering the hands of male bud were removed in a stepwise manner, without causing any injury until it became too small to be separated. Male buds (4-5cm in length) were washed four times thoroughly in tap water. The explants were first surface sterilized with 0.1 per cent (w/v) mercuric chloride for four minutes and then rinsed thrice with autoclaved double distilled water in the laminar air flow cabinet. About 45-50 protective bracts covering the male flowers were removed under sterile conditions using sterilized blade and forceps, and then male flowers having a size of 0.5-1.0 cm (Fig. 1. A) were taken out and inoculated in full MS/ half MS (Murashige and Skoog) medium

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Short Communication

Performance of Kiriyath (*Andrographis paniculata* (Burm.f.) Wall. ex. Nees.) under different shade levels, dates of planting and mulching

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Abstract

A field experiment was taken under to study the effect of variations in shade levels, time of planting and mulching on yield and quality of Kiriyath (*Andrographis paniculata).* The treatments consisted of two shade levels (open and 50 per cent shade), four dates of planting (15th May, 15th June, 15th July and 15th August), and three mulching practices (no mulching, paddy straw mulching and black polythene mulching). Higher biomass yield was obtained when planted on 15th May under shade with black polythene mulching (15.67 t ha^{-1}). However, it was on par with June planting with black polythene mulch under shaded condition (14.33 t ha^{-1}). Andrographolide, the major secondary metabolite responsible for the medicinal property, was higher when planting was in July under shade with paddy straw mulching (1.17%) and was on par with August planting with paddy straw mulching under shade (1.14%).

Key words: *Andrographis paniculata*, Black polythene mulch, Dates of planting, Kiriyath, Paddy straw mulch.

Kiriyath (*Andrographis paniculata* (Burm.f.)) Wall. ex. Nees., an important medicinal plant belonging to the family Acanthaceae, is known as "King of Bitters" and is traded in high volume and prioritized by State Medicinal Plant Board, Kerala. It is best suited to hot and humid climatic conditions but during monsoon season it can also be cultivated in subtropical regions. It is one of the foremost broadly utilized plants in ayurvedic medicines and was prescribed in Charaka Samhita dating to 175 BC for treatment of jaundice, besides other plants (Sharma, 1983). It is also used for the treatment of snake bite, diabetes, dysentery, fever and malaria. Variations in environmental conditions have great influence on production of active principles, and it is necessary to identify optimum growing conditions to grow cultivars with high yield potential. However no information is available about the effect of variations in shade levels, time of planting and mulching on yield and quality of Kiriyath (*Andrographis paniculata*).The present experiment was conducted during May - January 2017 at Agronomy farm, Department of Agronomy, College of Horticulture, Vellanikkara. The experimental site was situated at 13° 32'N latitude and 76° 26'E longitude, at an altitude of 40 m above mean sea level. The soil of the experimental site was low in pH (4.65), high in organic carbon (1.13%), low in available N (189 kg ha^{-1}) and available P (10.08 kg ha^{-1}) and medium in available K (259.84 kg ha^{-1}).The experiment was laid out in RBD (factorial), with three replications. The plot size was 3 m x 3 m with a plant spacing of 30 cm x 15 cm. The treatments comprised two shade levels (open and 50 per cent shade), four dates of planting (15th May, 15th June, 15th July and 15th August) and three mulching practices (no mulching, paddy straw mulching and black polythene mulching). Seeds were pre soaked and sown in pro trays filled with coirpith compost and watered. FYM was applied

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Short Communication

Weed dynamics in crop+fish farming systems in summer fallow of double cropped lowland rice fields

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Abstract

A field study was conducted in double cropped lowland rice fields during summer of 2016 to assess the crop performance and changes in weed species and weed population in different crop (amaranth, culinary melon, fodder cowpea) + fish (catla, rohu) farming systems *vis-à-vis* sole cropping. Productivity of culinary melon and amaranth was higher when integrated with fish compared to the sole crop. Culinary melon+fish system recorded the highest rice equivalent yield (REY). Among the weeds, grasses dominated followed by sedges and broad leaved weeds. Among grasses, population of *Echinochloa colona* was the highest followed by *Isachne miliacea*, *Digitaria ciliaris* and *Eragrostis tenella*. Among broad leaved weeds, *Lindernia grandiflora* ranked first followed by *Phyllanthus niruri*, *Oldenlandia umbellata* and *Cleome rutidospermum*. Among sedges, *Fimbristylis miliacea* outnumbered others. Lower weed dry matter production and higher weed control efficiency were observed when crops were integrated with fish. Culinary melon+fish system performed better in terms of weed control and productivity.

Keywords: Amaranth, Culinary melon, Farming system, Fish, Fodder cowpea, Lowland, Rice, Weed.

In Kerala, paddy fields are part of wetland ecosystems with several noteworthy ecological and economic functions. Rice-rice-fallow is identified as a major rice based cropping system in Kerala (John et al., 2014). Diversification of crops along with a livestock component in the cropping system reduces the risk besides increasing and stabilizing the farm income.

Weeds are the major impediment to rice production. A major approach to reduce the predominance of any given weed species is to increase the diversity of crops within the cropping system. Changes in the weed species and population is also influenced by crop, cropping system, variety, type of soil, tillage, method of sowing, water, nutrient and weed management methods (Koocheki et al., 2009; Murphy and Lemerle, 2006). Hence, the inclusion of crops with different growth habits and requiring change in land configuration during summer in rice based sequences can bring about changes in the weed species diversity and their population. In this context, a study was undertaken to assess the weed dynamics (changes in weed flora and population) in different crop+fish farming systems *vis-à-vis* sole cropping during summer in the lowland double cropped rice fallows.

The field study was undertaken in the double cropped lowland rice fields of Integrated Farming System Research Station, Karamana, Thiruvananthapuram during summer 2016 (February to May 2016). Rice (var. Uma) was raised in the field selected for the study during first (*Virippu*/Kharif) and second (*Mundakan*/Rabi) crop season either as sole crop or integrated simultaneously with fish as per treatments. The

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