Journal of Tropical Agriculture 56 (1): 27-33, 2018



# Utilization of water hyacinth as mulch in turmeric

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Received 31 May 2018; received in revised form 4 June 2018; accepted 24 June 2018

**Abstract**

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms), considered as the world's worst aquatic weed, was evaluated for its mulch value as a part of its control strategies. A field experiment comprising of three mulch materials viz., jack fruit leaves, green water hyacinth, and coconut leaves, were compared with no mulching in turmeric. The study was carried out at the Department of Agronomy, College of Horticulture, Vellanikkara during 2014-15 and 2015-16. All the mulch materials including water hyacinth had positive effects on most morphological and physiological parameters like plant height, number of leaves, leaf area index, leaf area ratio, and dry matter production of turmeric. In 2014-15, rhizome yield was higher in plots mulched with jack leaves (22.45t/ha), but it was on par with mulching by water hyacinth (20.52 t/ha) and mulching by coconut leaves (20.12 t/ha) compared to non-mulch control (15.91 t/ha). In 2015-16 too, the same trend in rhizome yield was observed. Nutrient uptake by the crop was also higher with mulching compared to non-mulched control. All the mulch materials substantially reduced weed density, weed dry weight, and turmeric-weed competition for different growth factors.

**Keywords**: Aquatic weeds, Mulching, Turmeric, Utilization, Water hyacinth.

## Introduction

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is considered as the world's worst aquatic weed. It is estimated that 20-25 per cent of the total utilizable water in India is infested with water hyacinth alone (Varshney *et al.*, 2008). It adversely affects water sources by blocking canals and water ways, providing convenient breeding sites for mosquito, and interfering with fishing and fish culture. In the past, several chemical, biological, and mechanical methods were tried to prevent its proliferation and spread, but all these have not been very successful because of the weed's survival strategies. The initial clearance of the weed followed by regular, periodic removal of the regrown weeds, coupled with proper utilization of the harvested weeds as fibre, animal feed, manure, and mulch seem to be viable solutions to this weed menace. Utilizing the high productivity in better ways can be a part of integrated management of water hyacinth.

An experiment was planned to utilize water hyacinth as a mulch material taking turmeric, which requires heavy mulching, as a test crop. In turmeric, mulching is an important cultural practice, and mulching immediately after planting with green leaves and subsequently, after 50 days is recommended (KAU, 2011). Initial growth of turmeric is slow, and if weeds are not controlled properly, it may cause considerable yield reduction. The commonly used mulch materials in turmeric are jack leaves and coconut leaves but during the planting time of turmeric, shortage of mulch materials is common. It is hoped that using water hyacinth as a mulch will be a blessing for the farmers as well as the public because of the conversion of a menace for a good cause.

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*Indian Journal of Weed Science* **51**(1): 67–71, 2019

Print ISSN 0253-8040 Online ISSN 0974-8164

# Utilization of water hyacinth as livestock feed by ensiling with additives

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**Article information**

**DOI:** 10.5958/0974-8164.2019.00014.5

**Type of article:** Research article

**Received** : 14 December 2018
**Revised** : 9 February 2019
**Accepted** : 17 February 2019

**Key words**
Aquatic weeds
Water hyacinth
Utilization
Silage
Additives
Cassava powder

**ABSTRACT**

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is one of the most productive plants on earth, but it is also considered as the world's worst aquatic weed. An experiment was carried out with the objective of utilizing it by converting to silage for its usage as animal feed. The quality and palatability of water hyacinth silage prepared with additives such as molasses, cassava powder, and rice bran were assessed. The completely randomized design (CRD) with 12 treatment combinations and 3 replications, was used. The treatments included: combination of wilted and fresh water hyacinth with or without rice straw or guinea grass and using any of the additives such as molasses, cassava flour and rice bran. Wilted water hyacinth plus cassava powder (10%), wilted water hyacinth plus rice straw (10%) plus cassava powder (10%), and wilted water hyacinth plus guinea grass (10%) plus cassava powder (10%) had good fodder quality due to low pH. The odour of these combinations was rated as either 'good' or 'very good'. The quality of rice bran added silages was low in terms of pH, odour and palatability; although its nutritional quality was high. Rice bran enhanced crude protein, crude fat and ash content of silages. Molasses ensured the quality of silage by lowering pH and enhancing intake. Cassava powder addition in general reduced the pH of the silage and enhanced the palatability of silage.

Most aquatic weeds interfere with the normal functioning of water bodies, besides causing several harms to the environment. Among the aquatic weeds, *Eichhornia crassipes* (Mart.) Solms, commonly known as water hyacinth is considered as the world's worst aquatic weed. It is estimated that 20-25 per cent of the total utilizable water in India is infested with water hyacinth alone (Varshney *et al.* 2008). Recognized by its lavender flowers and shinning bright leaves, water hyacinth is prolific in growth and is one of the most productive plants on earth. The plant can tolerate both fresh and saline water (AERF 2005); hence, its spread knows no boundaries. The plant is also a serious threat to biodiversity as it prevents the growth of other aquatic plants. It adversely affect water sources by blocking canals and motor pumps in irrigation projects (Jayan and Sathyanathan 2012), providing convenient breeding sites for mosquito, and interfering with fishing and fish culture.

In the past, several methods were tried to prevent its proliferation and spread (Bindu and Ramasamy 2005), but all these have not proved much because of its survival strategies. An alternate option is to utilize water hyacinth for various purposes such as fibre, animal feed, and manure (Jafari 2010). Silage for feeding animals is such an option. Livestocks are reluctant to eat water hyacinth in fresh form. Tham (2012) reported that improved silage could be made from water hyacinth by the use of additives such as molasses and rice bran. Molasses is a universal additive to silage but not easily available to common people. Lowilai *et al.* (1993) reported the use of cassava flour instead of molasses. Little bag silage in polythene bags is a viable option for small holders as traditional silos such as bunker, trench or tower silos are not feasible for them (Lane 2000). Having considered all the possible options, an experiment was designed and conducted to explore the possibility to utilize water hyacinth as a feed for ensiling, especially suited to small holders.

## MATERIALS AND METHODS

The experiment was carried out at the College of Horticulture, Vellanikkara, Thrissur and University Livestock Farm and Fodder Research Station,

Journal of Tropical Agriculture 56 (2): 201-205, 2018



Short Communication

# Biological efficiency of chilli + amaranth intercropping system under fertigation

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Received 18 June 2018; received in revised form 11 September 2018; accepted 01 December 2018

**Abstract**

An experiment was conducted at Water Management Research Unit, Vellanikara during January to July 2017 to study the biological efficiency of chilli+ amaranth intercropping system under different nutrient and water regimes. The treatments consisted of chilli + amaranth intercropping system planted at two different planting geometries *viz*., normal row planting and paired row planting, three nutrient levels *viz*., 100, 75 and 50 per cent NPK recommendation of both crops as fertigation and two irrigation levels *viz*., 100 per cent Epan and 75 per cent Epan along with two controls *viz*., chilli pure crop and amaranth pure crop. Biological efficiency of intercropping system was assessed by calculating LER, LEC, ATER, RCC and CEY. Chilli + amaranth intercropping under normal row planting produced significantly higher LER (2.84) compared to paired row planting. The intercropping system fertilized at 100 per cent of the recommended NPK dose to both crops showed the highest LER (2.81) compared to lower doses. Irrigation at 100 per cent Epan recorded significantly higher values of LEC (1.54) and ATER (2.56). Chilli equivalent yield was higher in chilli+ amaranth intercropping system (16553 kg/ha) compared to pure crop. The higher values of LER (>1.0), LEC (> 0.25), ATER and CEY revealed the biological efficiency of chilli + amaranth intercropping system compared to pure crop system.

**Keywords:** ATER, CEY, Intercropping, LEC, LER, RCC.

India ranks second in vegetable production, next only to China, and contributes about 12 percent of the world's production. The estimated production of vegetables in Kerala is 8.25 lakh MT as against the requirement of 36.7 lakh MT with practically little scope for horizontal expansion of the area under cultivation. Hence technology needs to be generated to include vegetables in the intercropping systems. Intercropping will help to increase total production per unit land per unit time. Productivity of intercropping systems can be enhanced by curtailing inter and intra species competition for various resources. This is possible by selecting compatible crops, adopting suitable planting geometry and proper water and nutrient practices. Fertigation is widely popularized as an efficient and economically viable method for water and nutrient management, on account of its highly localized application and flexibility in scheduling water and fertilizer applications. Research works on optimal schedules for micro-irrigation, fertigation and planting geometry in intercropping systems are very limited. The present study was done against this back drop and to assess the biological efficiency of chilli + amaranth intercropping system under different nutrient and water regimes.

The experiment was conducted at Water Management Research Unit, Vellanikara from January to July 2017 in randomized block design with three replications. Chilli variety (Ujwala) with longer duration (150 days) and wider spacing was taken as the base crop, and amaranth (Arun) with shorter duration (75 days) and closely spaced was

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Short Communication
Range Mgmt. & Agroforestry 39 (2) : 307-312, 2018
ISSN 0971-2070

# Effect of cutting intervals and additives on quality silage production from hybrid napier

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Received: 11th September, 2017 Accepted: 4th August, 2018

**Abstract**
An experiment was conducted to study the effect of cutting intervals and additives on quality silage production from hybrid napier. The experiment was laid out in factorial CRD with two factors *i.e.*, ensiling materials from different cutting intervals ($E_1$: 45 days, $E_2$: 60 days and $E_3$: 75 days) and additives ($A_1$: urea- 2%, $A_2$: jiggery- 2%, $A_3$: urea- 1% + jiggery- 1%, $A_4$: molasses- 2% and $A_5$: no additives) using hybrid napier (variety, Suguna) fodder. It was observed that quality silage can be prepared by ensiling the fodder harvested at 45 days interval with 2% urea or 1% urea and 1% jiggery as additives.

**Keywords:** Additives, Cutting interval, Hybrid napier grass, Quality silage

**Abbreviations: ADF:** Acid detergent fibre; **AIA:** Acid insoluble ash; **CF:** Crude fibre; **CP:** Crude protein; **EE:** Ether extract; **NDF:** Neutral detergent fibre; **NFE:** Nitrogen free extract; **NS:** Non-significant; **RP:** Recovery percentage; **TA:** Total ash

India is the leading country in milk production and livestock population. India accommodates nearly 20 per cent of the world's livestock. Although India has a very large population of livestock, the productivity of milk and other livestock products per animal is very low compared to developed countries in the world. Lack of availability of good quality green fodder throughout the year is the major constraint for high productivity of animals. Future development and growth of livestock are highly associated with the scope of availability of fodder from cultivable land, forest, pastures and grazing lands and also preservation of green fodder for lean season to ensure the year round availability (Shah *et al.,* 2011).

Kerala state has the highest percentage of crossbred animals with higher genetic potential for milk production, but the productivity is very low. Here also non-availability of good quality fodder is prominent. Although the per capita land availability is very less in Kerala, but high yielding varieties are expected to tackle the problem of fodder shortage. Among the fodder crops hybrid napier is the most popular fodder crop in Kerala, especially under rainfed conditions (Savitha and George, 2014). Compared to other fodder grasses it has good nutritional quality as well as high yield potential. However, appropriate cutting management is essential for high yield as well as quality of napier grass.

In south India the fodder shortage is severe during summer months due to high temperature. So ensiling is an alternative method to tackle this fodder shortage. Silage preserves the green fodder for a long time and also it is more nutritious than hay. For improving the nutrient content as well as quality, additives can be used. But use of inexpensive available materials as additives is expected to be very helpful for the rural farmers. Since this will reduce the loss of fodder during ensiling and also help to improve the quality and shelf life of silage. Keeping this in view, the present experiment was undertaken to study the effect of cutting intervals and additives for production of quality silage from hybrid napier grass.

The study was conducted during 2015-2016 at Kerala Livestock Development Board (KLDB) Farm, Dhoni, Palakkad. The hybrid napier variety Suguna released from Kerala Agricultural University was used for the study. The crop was raised as per the package of practices recommended by Kerala Agricultural University (KAU, 2011). The crop was harvested at different cutting intervals (45, 60 and 75 days). The harvested fodder was immediately chopped using chaff cutter. Then it was wilted under sun for 2-3 hours to reduce the moisture content to an optimum limit. The additives were prepared by mixing with water, and applied @ 30 ml/kg green fodder and thoroughly mixed with the wilted fodder. After thorough mixing, the silo bags were filled compactly and tied tightly. The experiment was laid out in factorial CRD, with 15 treatment combinations and 3 replications. It had two factors *i.e.* ensiling materials from different cutting

*International Journal of Farm Sciences* **8(4):** 81-87, 2018; doi: 10.5958/2250-0499.2018.00111.8

# Structural diversity, leaf litter recycling and allelopathic influences of leaf litter in an agroforestry homegarden of southern Kerala

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*Received: 9.7.2018/Accepted: 26.8.2018*



## ABSTRACT

Agroforestry systems offer immense potential for sustainable agriculture as the tree-based systems are rich in biodiversity and organic matter production that can be suitably recycled in the systems. The present study explored the diversity of a selected tropical agroforestry homegarden in southern Kerala. It assessed the organic additions via litter fall from the perennial components, recycling through vermicomposting and allelopathic influence of litter on sprouting and early growth of tannia (*Xanthosoma sagittifolium*). The homegarden represented a multispecies cropping system with diversity index of 2.03 and annual litter additions of 1782.89 kg from the 28 perennial tree components. The amount of litter added by the different trees varied with the species, number and age. Recycling of the litter using earthworms was attempted and vermicomposting of litter could accrue nutrients to the tune of 10.67 kg N, 3.82 kg P and 1.71 kg K per year in the homegarden emphasizing the importance litter has on sustaining soil productivity. The allelopathic influence of selected eight species litter revealed that litter leachates at 2 per cent did not exert any significant allelopathic effects but when applied as mulch, mango, nutmeg and *Ailanthus* litter exhibited significant allelopathy on sprouting and seedling growth of tannia.

**Keyword:** Agroforestry; allelopathy; homegarden; litter; recycling

## INTRODUCTION

Agroforestry, the practice of growing trees in combination with agricultural crops with or without livestock is an integral component of the agriculture systems in Kerala. The state with many woody perennial-based land use practices is often regarded as the 'Mecca of agroforestry' (Kumar 2011). Agroforestry practiced in and around the farmer dwelling is characterized by the disparate and intricate species mix which is responsible for its uniqueness and ecological importance. The multiple functions performed by the system include the potential to provide food, fuel, green manure and timber resources, conservation of biodiversity, carbon sequestration, regulation of physical and chemical fluxes in ecosystems and mitigation of environmental pollution (Nair 2008). Analysis of the structure of the systems and the recycling potentials are important for further sustainable and eco-friendly interventions. In this background an investigation was undertaken in an agroforestry homegarden in Kollam, southern Kerala to assess the diversity, biomass additions from the different components, possible recycling of litter through vermicomposting and use as nutrient source in tuber crops and also to examine the allelopathic influences of selected species litter on sprouting and early growth of tannia (*Xanthosoma sagittifolium*), a popularly grown tuber inter-crop in homegardens.

## MATERIAL and METHODS

The field experiment on the structural analysis and organic recycling was carried out in a selected agroforestry homegarden in the western Ghat tract of Ummanur Panchayat, Kollam district, southern Kerala during 2013-14. The garden falls in the agro-ecological unit, 12 southcentral foothills of Kerala, (latitude 9°16'N, longitude 76°37'E, altitude 91.44 m amsl) and enjoys a warm humid tropical climate with mean maximum temperature of 35.13°C and minimum of 23.13°C. Data on tree-crop-livestock components in

*The Indian Forester* (*founded in 1875*)
*Oldest International Peer Reviewed Forestry Journal*

ISSN No. 0019-4816 R.N.I No. 4839/57





**SL NO 93**

# Screening of Superior Genotypes of *Ailanthus triphysa* (Dennst.) Alston. (Matti) for Matchwood Quality

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## Abstract

Growth parameters viz., height, collar girth, stem volume, survival percentage and bole straightness of the progenies of twenty different Candidate Plus Trees (CPTs) was studied. The experimental trial was located at the Kerala Agricultural University (KAU) main campus near Aramkal, Thrissur, Kerala, India. The field observations were carried out after 16 months of field planting. The variation in bole straightness was found to be significant among the progenies whereas height, collar girth, stem volume did not show any significant variation. Survival

Journal of Tropical Agriculture 56 (1): 56-62, 2018



Short communication

# Variability studies for quality characters in *neikumbalam* accessions

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Received 09 October 2017; received in revised form 07 December 2017; accepted 24 June 2018

**Abstract**

*Vaidyakumbalam/medicinal ashgourd* or *neikumbalam* is a specific ecotype of ashgourd in Kerala which is highly valued for its medicinal properties. *Neikumbalam* 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. In the present study, *neikumbalam* accessions were collected from different locations in Kerala and laid out in field experiment along with vegetable ash gourd variety "Indu". Fully mature fruits were harvested and used for phytochemical screening and biochemical estimation. Phytochemical screening of the fruit extracts revealed the presence of sugars, starch, proteins, amino acids, tannins, phenols, glycosides and flavanoids in both type of ash gourds. The biochemical analysis of mature fruits of *neikumbalam* revealed higher content of total minerals and total free amino acids. The *neikumbalam* type BH 4 recorded significantly highest total free amino acid content and total mineral content than other accessions.

**Keywords**: Antioxidant property, *Benincasa hispida,* Medicinal ashgourd, *Neikumbalam*, Total free amino acids, Total minerals.

*Benincasa hispida* is a commonly used cucurbitaceous vegetable which has been used as a food and medicine for thousands of years in the Orient (Mathad et al., 2005). Its fruits contain various minerals and vitamins, having a relatively high level of K and Na, low calorific value and no fat. The fruit also contains 11-70 mg of calcium per100 g and 0.3-0.45 per cent of other minerals (Pandey et al., 2015).

Ash gourd (*Kushmanda*) has been mentioned in 'Charaka Samhita' for its medicinal properties. It has been used in India to treat disorders of the gastrointestinal tract, respiratory tract, urinary tract and *diabetes mellitus* (Asolkar et al., 1992; Sivarajan, 1992). According to Sanskrit texts, *Benincasa hispida* fruit is useful in insanity, epilepsy, constipation, piles, dyspepsia, and other nervous disorders. The fruit of *B. hispida* is used as a diuretic and the seeds have been reported to possess antiangiogenic effects in prostate cells (Nandecha, 2010). Ash gourd, being low in calories, is particularly useful for diabetic and obese people. It is cooling and laxative and thus increases the secretion and discharge of urine. Ash gourd acts as a blood coagulant (Pandey et al., 2015). Fresh juice is given either with sugar or as an adjunct to other medicines for these diseases (Patricha, 1997). A decoction of the fruit is styptic, laxative, diuretic and given to cure internal haemorrhages and diseases of the respiratory tract. For centuries, it has been used in many empirical applications in India for various ailments such as gastro intestinal tract problems like dyspepsia and burning sensation, heart disease, vermifuge, diabetes and urinary disease. The fruit is an important source of water-soluble and hemicellulosic polysaccharides (Mazumder and Lerouge, 2005).

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Journal of Tropical Agriculture 56 (1): 69-72, 2018



Short communication

# Diffusion treatment of coconut palm wood using organic preservatives

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Received 13 September 2017; received in revised form 02 June 2018; accepted 04 June 2018

**Abstract**

Sawn coconut palm wood of differing wood densities (high and medium) were treated with three organic preservatives, viz., neem oil, cashew nut shell liquid (CNSL) and turpentine. The method adopted was diffusion treatment at various diffusion periods viz., 40, 80 and 120 minutes and absorption percentage of preservatives by sawn coconut wood samples (5 cm × 5 cm × 50 cm) was studied. Both high density wood (HDW) and medium density wood (MDW) samples of coconut palm showed no significant difference in absorption percentage with varying diffusion periods and no significant difference was observed between the chemicals and interaction between the chemicals and diffusion periods.

**Keywords**: Cashew nut shell liquid (CNSL), Coconut palm wood, Neem oil, Organic, Preservative treatment, Turpentine.

Coconut (*Cocos nucifera* L.) palm wood belongs to the class of perishable timbers which can be used as an alternative wood source with effective preservation. Preservative treatment of coconut wood can enhance its service life, so that it can be used as a potential alternative for conventional timber species. Effective utilization of coconut palm wood resource can be a solution for the diminishing timber supply. High density wood (dermal, over 600 kg/m$^3$) and medium density wood (sub-dermal, 400-600 kg/m$^3$) of coconut palm can be used for structural purposes. Conventional wood preservative was found to be effective in treating wood of commercial timbers; however, it also causes major environmental pollution and has mammalian toxicity (Onuorah, 2000). Over the past few decades, there has been substantial global awareness to develop eco-friendly wood preservatives, and those which do not cause any ill effects to the health of mammals. Researchers across the world have been attempting to develop eco-friendly preservatives with reasonably good results (Xu et al., 2013).

Green plants act as an inexhaustible source of innocuous fungicides or pesticides, which are mammalian non-toxic and are easily biodegradable. Plant extract based preservatives have large potential due to their target toxicity towards micro organisms and termites and safety for mammals. Plant products like terpenes, alkaloids, phenols and alcohols have anti-fungal and anti-bacterial properties (Saxena and Dev, 2002), and neem (*Azadirachta indica*) possesses a number of constituents exhibiting high toxicity against wood-destroying microbes (Dhyani et al., 2004). Efforts have been made by many workers to use these plant products for the amendment of toxic metals, and tested them for durability against termites or fungi (Dev and Nautiyal, 2004). Venmalar and Nagaveni (2005) evaluated the effectiveness of CNSL and neem oil in the preservation of rubber wood and

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# ecomposition and nutrient release dynamics of Thyrsostachys oliveri gamble in l erala, Southern India.

ironment . Nov2018, Vol. 37 Issue 2, p152-159. 8p.
il, Jijeesh Choyi; Kodikunnath, Seethalakshmi Kolankara

achys oliveri is a bamboo species native to Myanmar cultivated in Arunachal Pradesh, Uttar Pradesh, Kerala and Tamil Nadu, India. Due to multifarious uses, this species l ale cultivation all over India. Little is known about litter production, decomposition and nutrient release dynamics of this species. Litter dynamic studies are imperative, pr ntation program or agroforestry systems. The present study is framed to investigate the litter production, decomposition and nutrient release dynamics of T. oliveri. Litter p l using specially designed litter traps made of bamboo baskets with a diameter of 1 m and depth 10 cm. Litter decomposition was studied using nylon litter bag techniques. pecies was to the tune of 4.488 t ha<sup>-1</sup>. The major share of total litterfall in T. oliveri was contributed by leaves (93.60±0.99 %) followed by branches (5.82±0. er production followed a biphasic pattern with a major peak in February 2011 and minor peak in July 2010. Weight loss expressed as percentage of the original dry weight ass loss in T. oliveri was a good fit to exponential decay model. The decomposition rate constant of T. oliveri was 0.009 day<sup>-1</sup> and the half-life was 77 days. ng litter was in the order Mg > N > Ca > P > K.

Range Mgmt. & Agroforestry 40 (1) : 109-117, 2019
ISSN 0971-2070

# Fodder production and carbon stock of calliandra under coconut plantation

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Received: 13th July, 2018 Accepted: 10th March, 2019

**Abstract**
The influence of management factors like tree densities and pruning intervals on forage yield and carbon stocks of three-year old calliandra hedgerows underneath coconut plantation indicated significant enhancement in forage and coconut yields and carbon fixation due to calliandra intercropping and management practices. Intercropping calliandra with tree density of 27,777 trees $ha^{-1}$ and harvesting fodder at an interval of 12 weeks yielded maximum dry forage of 35.16 Mg $ha^{-1}$, apart from an additional carbon capture of 90 Mg $ha^{-1}$ against coconut monoculture, over three-year period. High density calliandra cultivation also had favourable impact on coconut productivity. Establishment and management of such fodder banks in the unutilized interspaces of existing coconut gardens is a promising practice to enhance quality forage production and carbon sequestration in land crunch humid tropical areas.

**Keywords**: Calliandra, Carbon stocks, Coconut, Forage yield, Pruning interval, Tree density



## Introduction

Since time immemorial, livestock rearing has been an integral part of global rural economy. The increasing demand for livestock products in developing countries in the coming two decades offers vast opportunities to poor livestock farmers to increase their income from livestock farming (Hall *et al.*, 2007). However, scarcity of good quality feed and fodder is the major obstacle for livestock production, especially during the dry periods in the tropics (Ogunbosoye and Babayemi, 2010). In India, there is a shortage of 40.4% dry fodder and 24.7% green fodder (Mathukia *et al.*, 2016). The forage tree species contain appreciable amounts of nutrients that are lacking in other feeds such as grasses during dry periods due to extraction of water and nutrients from deeper soil horizons (Aregawi *et al.*, 2008). In addition, forage based economical feeding strategies can reduce the cost of livestock production as the feed alone comprises 60-70% of the total milk production cost (IGFRI, 2015). Trees and shrubs can play a significant role not only in improving fodder production but also providing assured supply of fodder throughout the year (Singh and Singh, 2017).

Calliandra (*Calliandra calothyrsus* Meissn.), a native of Central America, is a fast growing, multipurpose leguminous tree, grown primarily for forage. The high palatability of calliandra to various livestock, including cattle, goats, sheep, rabbits and chickens has been reported earlier (Roothaert *et al.*, 1998; Franzel *et al.*, 2003; Nyeko *et al.*, 2004). Studies conducted in milch cows of Kerala also confirmed the nutritional superiority of calliandra with relatively high protein (18.45 %), minerals, ether extract and energy contents and suitability as a partial substitute for concentrate feeds without affecting animal health and productivity (Jayaprakash, 2016). Moreover, calliandra is a proficient coppicer and can withstand severe pruning, which makes it an ideal species for high density hedgerow planting. The trees grow well in the areas with rainfall exceeding 1100 mm (Roothaert and Paterson, 1997). The tolerance of calliandra to acid soils has also encouraged its use as fodder tree in the humid tropics (Berhe and Mohamed-Saleem, 1996; Palmer *et al.*, 1989). However, due to high demographic pressure and consequent land constraints in tropical areas, the scope for growing calliandra as a monocrop in open lands is rather limited. Only alternative is to integrate calliandra with the existing cropping systems in these areas. Coconut, being one of the most prominent plantation crop in the world stretching over an area of 122 lakh ha (APCC, 2015), any attempt to integrate forage trees like calliandra with coconut would be a desirable strategy for profitable animal rearing.

While integrating calliandra with coconut, hedgerow planting of trees with higher tree densities and harvesting at optimum interval are the possible management options for enhancing productivity from limited land area. Moreover, calliandra being a tree species with fast growth

Physiological and Molecular Plant Pathology 103 (2018) 8–15

Contents lists available at ScienceDirect

Physiological and Molecular Plant Pathology

journal homepage: www.elsevier.com/locate/pmpp

# Stress analysis and cytotoxicity in response to the biotic elicitor, *Piriformospora indica* and its' cell wall extract in *Centella asiatica* L. Urban

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ARTICLE INFO

*Keywords:*
Endosymbiosis
*Centella asiatica*
Oxidative stress
*Piriformospora indica*
Total antioxidant capacity

ABSTRACT

Study reports prominent findings on the analysis of oxidative stress generated in *Centella asiatica*, a multifunctional medicinal plant on co-cultivation with *P. indica* and its extract, *P. indica* Cell Wall Extract. The presence of *P. indica* had protective role in alleviating stress, evidenced by lack of significant change in $H_2O_2$, increased total antioxidant capacity and phenolics in *P. indica* colonized and PiCWE treated plants. No variation was observed between IC50 values and the cell integrity in *P. indica* colonized *C. asiatica* appeared intact by TEM analysis. The study preludes the possible role of *P. indica* in conferring drought tolerance to *C. asiatica*.

## 1. Introduction

Plants are under constant interaction by various microorganisms that aim to acquire adequate amount of nutrients from them. As a result of these interactions, the outcome can be neutral, harmful (as in the case of parasitism), or beneficial (in the form of mutualistic symbiosis) to the host [41,50]. In mutualistic associations, plant-microbe interaction is considered to be well-balanced [5]. Among this, fungi play an essential role in upgrading plant growth, vigour and survival by a positive impact on the nutritional [43] status of the plant and on soil aggregation [6,51] and the microsymbiont in turn perceives its resource for nutrition *ie*. carbon provided by the plant for its physiological functions, growth and development. Biochemical, physiological and molecular characterization on plant–microbe interactions at different levels found that microbial interactions mostly lead plant responses toward stresses [12]. The enhanced generation of free radicals or reactive oxygen species (ROS) results in oxidative stress and thus antioxidant capacity of a biological system will get declined [64]. Antioxidants are free-radical scavengers that offer resistance to living organisms from damage caused by ROS. On the contrary, these microbial elicitors can be used to alter cell metabolism of many helpful plants to increase the production of economically important compounds in plants which are the major source of various distinct drugs in the pharmaceutical industry [19]. The vast majority of such elicitors in plants are produced by fungi and bacteria [31]. *Piriformospora indica*, discovered in the Indian Thar desert in 1997 [55], is related to the *Sebacinales* [ordo nov.] (form genus *Rhizoctonia*; *Hymenomycetes, Basidiomycota*) and is a known symbiotic fungus which can promote plant growth [59].

*P. indica* was originally isolated from the spore of *Glomus mosseae* from the rhizosphere of two shrubs namely *Prosopis juliflora* and *Ziziphus nummularia* [24] and was named as DSM 11827 [54]. The endosymbiotic fungus *P. indica* is axenically cultivable, possesses a broad host spectrum and positively affects different aspects of plant performance [56]. Qiang et al. [35] reported that *P. indica* may represent a missing link between a saprophytic fungus and an obligate biotrophic mutualist. This unique combination of attributes makes *P. indica* and its close relatives among the *Sebacinales* very interesting tools for crop improvement [13]. It grows inter- and intracellularly and forms pear shaped, auto fluorescent chlamydospores within the cortex of the colonized roots and in the rhizosphere zone, but it does not invade the endodermis and the aerial parts of the plants [43]. Further, it is shown to stimulate biomass production, early flowering, seed production and is a potential microorganism imparting biological hardening to tissue culture-raised plants [54,61]. *P. indica* Cell Wall Extract (PiCWE) is the active fraction from the liquid culture of *P. indica*. Fungal cell wall can be isolated and autoclaved to obtain the active fractions of *P. indica*. Vadassery et al [53] reported that these active constituents of the endophytic fungus *P. indica* also stimulate enhanced growth and seed production in *Arabidopsis thaliana*. This heat-stable fraction is able to

*Abbreviations:* PiCWE, *P. indica* Cell Wall Extract; HRP, Horse Radish Peroxidase; MTT, 3- (4, 5- dimethylthiazol-2-yl)-2, 5- diphenyltetrazolium bromide; PDA, Potato Dextrose Agar; PDB, Potato Dextrose Broth; ATCC, American Type Cell Culture; ELISA, Enzyme Linked ImmunoSorbent Assay; DMSO, Dimethyl sulfoxide; DMEM, Dulbecco's Minimum Essential Medium; FBS, Foetal Bovine Serum; TEM, Transmission Electron Microscopy

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https://doi.org/10.1016/j.pmpp.2018.04.001
Received 15 December 2017; Received in revised form 3 April 2018; Accepted 4 April 2018
Available online 10 April 2018

Plant Physiology and Biochemistry 125 (2018) 106–115

Contents lists available at ScienceDirect

Plant Physiology and Biochemistry

journal homepage: www.elsevier.com/locate/plaphy

Research article

# *Piriformospora indica* cell wall extract as the best elicitor for asiaticoside production in *Centella asiatica* (L.) Urban, evidenced by morphological, physiological and molecular analyses

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ARTICLE INFO

*Keywords:*
*Piriformospora indica* cell wall extract
*Centella asiatica*
HPLC
β amyrin synthase

ABSTRACT

Vascular plants synthesise a multitude of organic molecules or phytochemicals, referred to as "secondary metabolites". These molecules are involved in a variety of roles in the life span of plants, ranging from structural ones to protection. *Centella asiatica* (L.) Urban has probably been used since prehistoric times and has been reported to have been used for various medicinal and cosmetic purposes. The plant contains several active constituents, of which the most important is asiaticoside, a triterpenoid. Asiaticoside content in *C. asiatica* can be enhanced by the use of biotic elicitors like *Piriformospora indica*. *P. indica* has been used as a model to study the mechanisms and evolution of mutualistic symbiosis. *P. indica* is similar to Arbuscular Mycorrhizal (AM) fungi in terms of plant growth promotional effects. The autoclaved fraction from *P. indica* (PiCWE) was found to be the most active fraction in promoting the plant biomass and asiaticoside content. To date, there are no reports on the potential role of PiCWE in enhancement of asiaticoside over the control and *P. indica* colonized plants, which was evidenced by the differential expression of key genes involved and final asiaticoside content along with the determination of phytohormones. Moreover, differential expression of selected miRNAs in PiCWE - *C. asiatica* root interactions over the control and *P. indica* treated *C. asiatica* leaf samples was also scrutinized. The important consequence of induction with PiCWE was the significant enhancement of asiaticoside in the PiCWE induced plants in comparison with the asiaticoside content in control and *P. indica-C. asiatica* interaction. In addition, the role of miRNAs in *C. asiatica* – PiCWE would enable more in-depth studies for deciphering the molecular and physiological mechanisms of the association and regulation of PiCWE - *C. asiatica* interactions.

## 1. Introduction

Elicitation is the process of inducing or enhancing synthesis of secondary metabolites by the plants to ensure their survival, persistence and competitiveness (Gorelick and Bernstein, 2014, 2017). Plant cells *in vitro* show physiological and morphological responses to microbial, physical or chemical factors which are the elicitors. Various elicitors have been reported to control metabolic flux between the steroid and the triterpene pathways, probably by acting at the level of cyclases. Efforts to elicit the biosynthesis of centellosides mainly focus on usingMethyl Jjasmonate (MJ), thidiazuron (Kim et al., 2004), and a permeabilization and feeding strategy by treatment with DMSO alone or in combination with β Amyrin (Hernandez-Vazquez et al., 2010) in cell cultures, roots and whole plants of *Centella asiatica*. Efforts to improve the triterpenoid content of *C. asiatica* in *in vitro* shoot cultures by elicitation with exogenously supplied MJ resulted in a significant enhancement of the triterpenoid content at the expense of plant growth and decreased free sterol content (Mangas et al., 2006). However, eliciting transformed hairy root cultures of *C. asiatica* with MJ enhanced asiaticoside production as well as root biomass (Kim et al., 2007). The raise in secondary metabolite production effected by endosymbiosis is apparently due to elicitation of plant defense in response to fungal elicitors like lipopolysaccharides and glycoproteins formed by the action of plant derived hydrolases secreted in response to endophyte colonization (Gao et al., 2010; Netzker et al., 2015). Symbiotic nitrogen fixation is a longer term relationship often involving a special structure to house a microbial partner. Nitrogen fixing symbiotic association involves a nitrogen fixing symbiotic organism - the microsymbiont like

*Abbreviations:* MJ, Methyl Jasmonate; DMSO, Methyl Sulfinyl Methane; AM, Arbuscular Mycorrhiza; DSM, Deutsche Sammlung fur Mikroorganismen; PiCWE, *P. indica* Cell Wall Extract; SQS, Squalene Synthase; β AS, β Amyrin Synthase; CYS, Cycloartenol Synthase; miRNA, micro RNA; IAA, Indole Acetic Acid; t-ZR, trans-Zeatin Riboside; PDA, Potato Dextrose Agar; PDB, Potato Dextrose Broth; BHT, Butylated HydroxylToluene

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https://doi.org/10.1016/j.plaphy.2018.01.021
Received 18 December 2017; Received in revised form 16 January 2018; Accepted 22 January 2018
Available online 07 February 2018
0981-9428/ 

# Forest laws, for whom, by whom? A concept mapping study of the Ecologically Fragile Lands Act, 2003 in Wayanad, Kerala, India

*Jiss K. Varkey, S. Gopakumar*, K. Vidyasagaran, Joy Mathew and A. V. Santhosh Kumar*

*Kerala enacted the Kerala Forest (Vesting and Management of Ecologically Fragile Lands) Act, 2003 to conserve 'fragile ecosystems' lying contiguous to reserve forests. As this Act led to several litigations and conflicts, the current concept of Ecologically Fragile Lands (EFL) was concept mapped among the different stakeholders, including 'small and marginal' farmers in the context of Wayanad district, Kerala. Several dimensions of EFL, viz. 'Ecological', 'Situational', 'Socio-economic', 'Framework' and 'Better EFL' were developed and debated to evolve a more acceptable EFL concept. The study also accentuates the relevance of public participation in conceiving socially inclusive forest laws and policies.*

**Keywords:** Concept mapping, ecologically fragile lands, participatory approaches, Wayanad, Western Ghats.

IN India, forests which occupy 21.54% of the total landed area remain a 'state' property[1]. After 1947, all 'privately owned' forests were 'vested' rooting on the 'doctrine of public trust'[2]. In 1976, the subject 'forest and wildlife' was shifted to the 'concurrent list' of the constitution. Kerala occupies only 1.18% of the land area of India, but has 29.1% under forest cover[3]. The per capita forest and tree cover of Kerala is 0.07 ha (ref. 1). Since its formation in 1956, Kerala has framed many forest laws, including the Kerala Forest Act, 1961, and more recently, the Kerala Forest (Regulation of Sawmills and other Wood Based Industrial Units) Rules, 2012. In the mid-2000s, the state Government promulgated 'The Kerala Forest (Vesting and Management of Ecologically Fragile Lands) Act, 2003' (hereafter referred to as EFL Act) and vested 'ecologically fragile lands (EFLs)'. This Act defined an EFL as 'any land lying contiguous to a legally defined forest predominantly supporting natural vegetation, or any land declared under section 4 of the EFL Act'[4]. The area under EFLs is 141.525 sq. km (ref. 3). The goal of the Government is to conserve and manage all 'privately owned lands having vegetation cover similar to that of forests and which lie contiguous to reserved forests', or to conserve biological diversity, even if that biodiversity is located in non-forest areas and is lying contiguous with the forests. In Kerala (density of population according to the 2011 census is 860 persons/sq. km), this new Act created multiple social ripples.

Wayanad district, Kerala, formed in 1980 (Figure 1) cradles the Western Ghats. It is predominantly a forested district (37% of the geographic area), which also houses a sizeable tribal (17.4%) and agrarian population (almost 60%). It has two territorial forest divisions (a forest division is an administrative unit in the Indian forestry establishment for managing territorial forests), apart from one wildlife division.

The livelihood of the indigenous people is predominantly land and forest-based[5]. Under the British rule, the indigenous sects practised shifting cultivation and collected forest produce for exchange[6]. It was the Britishers who later established a plantation economy. Wayanad forests later suffered intense 'internal colonization' by Syrian-Christian settlers from central Kerala[7]. Wayanad also attracted numerous impoverished settlers from erstwhile Travancore[6]. In 2012, the Kerala State Forest and Wildlife Department (KFD) notified 2688 ha land as EFL[8] in Wayanad Forest Division (FD), an action through which more than 350 'small and marginal' farmers faced the threat of being 'stripped' off their land rights at short notice[9]. They alleged that the Government 'notified and acquired' their legally owned farm lands in the name of 'EFLs' and usurped their only livelihood opportunity. Naturally, many legal and political tussles ensued. Farmers later filed review petitions for which final judgments are awaited[10].

Our field visits in Wayanad confirmed the limitations in actual field implementation and other socio-economic impacts of this new EFL Act. We noticed that this Act, in particular, impacted the 'small and marginal' farmers

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# Allelopathic Effect of Fresh Leaf Loppings of Multipurpose Trees a

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**Publisher:** Indian Forester
**Volume:** 145
**Issue:** 1
**Keywords:** Allelopathy; Leaf Loppings; Crops; Microbes; Multipurpose Trees
**Abstract :**
A pot culture study was undertaken to investigate the allelopathic effect of leaf lopping of trees, when used as organic sources of nutrient, on the growth and yield of cowpea, maize, groundnut and ragi. The allelopathic effect of various tree leaf loppings varied with different crops. Leaf loppings of all trees except casuarina and mango reduced seed yield in cowpea with the greatest reduction caused by cashew, teak, rubber and cocoa. Leaf loppings of all the trees significantly reduced yield of maize with the maximum reduction caused by portia and cocoa. In groundnut, all trees except sapota and mango significantly reduced the yield with the maximum caused by rubber. In ragi, addition of guava leaf loppings reduced yield most. The study brought out the allelopathic compatibility of the various trees on the test crops.

# A New Subspecies of Momordica Cochinchinensis (Cucurbitaceae) from Andaman Islands, India

**Journal:** Genetic Resources and Crop Evolution
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**Publisher:** Springer Nature
**Volume:** 65
**Issue:** 1
**DOI:** 10.1007/s10722-017-0512-6
**Keywords:** Crop Wild Relatives; Endemism; Flora of the Andaman Islands; Momordica; Sweet Gourd
**EISSN:** 1573-5109
**Abstract :**
The middle Andaman Island populations of Momordica cochinchinensis are quite distinct from true M. cochinchinensis in some floral characters. Such deviating specimens are described here as a new subspecies. A full technical description, a morphological comparison between the two subspecies, ecology, phenology, confirmation of genomic distinctiveness through DNA barcoding of matK and rbcL chloroplast loci and viability under cultivation are discussed. An epitype is also designated for Momordica cochinchinensis subsp. cochinchinensis.

# A Poly(A) Ribonuclease Controls the Cellotriose-Based Interaction between *Piriformospora indica* and Its Host Arabidopsis[1[OPEN]]

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*Piriformospora indica*, an endophytic root-colonizing fungus, efficiently promotes plant growth and induces resistance to abiotic stress and biotic diseases. *P. indica* fungal cell wall extract induces cytoplasmic calcium elevation in host plant roots. Here, we show that cellotriose (CT) is an elicitor-active cell wall moiety released by *P. indica* into the medium. CT induces a mild defense-like response, including the production of reactive oxygen species, changes in membrane potential, and the expression of genes involved in growth regulation and root development. CT-based cytoplasmic calcium elevation in Arabidopsis (*Arabidopsis thaliana*) roots does not require the BAK1 coreceptor or the putative $Ca^{2+}$ channels TPC1, GLR3.3, GLR2.4, and GLR2.5 and operates synergistically with the elicitor chitin. We identified an ethyl methanesulfonate-induced mutant (*cytoplasmic calcium elevation mutant*) impaired in the response to CT and various other cellooligomers ($n = 2–7$), but not to chitooligomers ($n = 4–8$), in roots. The mutant contains a single nucleotide exchange in the gene encoding a poly(A) ribonuclease (AtPARN; At1g55870) that degrades the poly(A) tails of specific mRNAs. The wild-type *PARN* cDNA, expressed under the control of a 35S promoter, complements the mutant phenotype. Our identification of cellotriose as a novel chemical mediator casts light on the complex *P. indica*-plant mutualistic relationship.

$Ca^{2+}$ signaling controls many processes in pathogenic and beneficial plant-microbe interactions (Oldroyd, 2013; Steinhorst and Kudla, 2014). In pathogenic interactions, cytoplasmic $Ca^{2+}$ ($[Ca^{2+}]_{cyt}$) elevation is initiated by cell surface receptors after activation by microbe-associated molecular patterns (MAMPs; like the bacterial flg22 for FLS2 and elf18 for the EF-Tu receptors or the fungal chitin for CERK1). Receptors activated by flg22 or elf18 bind to the coreceptor BRI1-ASSOCIATED RECEPTOR KINASE1 (BAK1), and the phosphorylated pattern recognition receptor (PRR) complexes associate with and phosphorylate BOTRYTIS-INDUCED KINASE1 and other signaling kinases to induce $[Ca^{2+}]_{cyt}$ elevation and downstream immune responses (Lu et al., 2010; Zhang et al., 2010; Shi et al., 2013; Li et al., 2014; Kadota et al., 2015). Besides local responses at the infection site, $Ca^{2+}$, electric, and reactive oxygen species (ROS) waves transfer threat information to distal tissues (Kiep et al., 2015; Gilroy et al., 2016). In interactions with biotrophic microbes, $Ca^{2+}$ activates distinct CALCIUM-DEPENDENT PROTEIN KINASEs, which control host entry and facilitate the accommodation of pathogens in host cells by suppressing plant defense responses (Freymark et al., 2007; Chen et al., 2015). The different functions of $Ca^{2+}$ in these pathogenic interactions are elicited by different $Ca^{2+}$ signatures and decoded by a variety of $Ca^{2+}$-binding proteins (Johnson et al., 2011a).

Colonization of legume roots by arbuscular mycorrhizal fungi is initiated by low-frequency $Ca^{2+}$ spiking in epidermal cells induced by chitin tetramers and pentamers from exudates of germinating fungal spores (Kosuta et al., 2008; Chabaud et al., 2011; Genre et al., 2013; Gutjahr and Parniske, 2013). As soon as the fungus enters the cells, a shift from low- to high-frequency

 

# The beneficial root-colonizing fungus *Mortierella hyalina* promotes the aerial growth of Arabidopsis and activates calcium-dependent responses which restrict *Alternaria brassicae*-induced disease development in roots

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