PERFORMANCE OF CALLIANDRA (*Calliandra calothyrsus* MEISSN.) UNDER DIVERSE MANAGEMENT REGIMES IN A COCONUT BASED HEDGE ROW FODDER PRODUCTION SYSTEM

By

ANU SAGARAN, K.

(2013-17-104)

THESIS

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR -680 656

KERALA, INDIA

2017

DECLARATION

I hereby declare that this thesis entitled **"Performance of calliandra *(Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara,

Date: 19/09/17

ANU SAGARAN, K.

(2013-17-104)

32

CERTIFICATE

Certified that this thesis, entitled **"Performance of calliandra *(Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system"** is a record of research work done independently by **Ms. Anu Sagaran, K. (2013-17-104)** under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara,

Date: 19.09.2017

Dr. Asha K Raj

Chairman

Advisory committee

Dr. ASHA K. RAJ
Assistant Professor
AICRP on Agroforestry
College of Forestry
KERALA AGRICULTURAL UNIVERSITY
Thrissur - 680 656

CERTIFICATE

We, the undersigned members of the advisory committe of Ms.Anu Sagaran K. (2013-17-104), a candidate for the degree of Master of Science in Forestry, agree that this thesis entitled "**Performance of calliandra (*Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system**",may be submitted by Ms.Anu Sagaran K.(2013-17-104) in partial fulfilment of the requirement for the degree.

Dr. Asha K. Raj
(Major Advisor)
Assistant Professor
Dept. of Silviculture & Agroforestry
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. T. K. Kunhamu
Professor and Head
Dept. of Silviculture & Agroforestry
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur

Dr . C George Thomas
Professor and Head
Dept. of Agronomy
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

Dr. A.V. Santhosh Kumar
Professor and Head
Dept. of forest biology & tree improvement
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur

Shri K P Pradeep
Associate Professor
(Agronomy)
Instructional Farm
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

External examiner
Dr. ALLY K. M.V.Sc; PhD
Professor (Animal Nutrition)
College of Veterinary
& Animal Sciences
Mannuthy, Thrissur - 680 651

ACKNOWLEDGEMENT

With immense admiration, respect and great devotion, I place on record my deep sense of gratitude and indebtedness to my project advisor ***Dr. Asha K Raj,*** *Department of Silviculture and Agroforestry, College of forestry for her excellent guidance, critical suggestions, amiable support, constant evaluation and comments throughout the study period .I express my heartfelt and sincere thanks to her.*

I owe my sincere thanks to ***Dr. T K, Kunhamu****, Head of Department, Department of Silviculture and Agroforestry, College of Forestry , who provided the required infrastructure and moral support for me during the execution of the work.*

I extend my heartfelt thanks to ***Dr. C George Thomas****, Professor and Head of Department of Agronomy, College of Horticulture, and member of my advisory committee for his whole hearted co-operation, immense help and valuable suggestions provided during the course of my study.*

I owe my whole hearted gratitude to ***Dr. A. V. Santhosh Kumar*** *, Professor and Head , Department of Tree Physiology and Breeding , College of Forestry, and member of my advisory committee for his guidance during the course of my study.*

I express my heartfelt gratitude to ***Shri. K P. Pradeep****, Assistant Professor (Agronomy), Instructional Farm, College of Horticulture and member of my advisory committee for his co-operation, support rendered throughout this work.*

I would like to acknowledge the academic and technical support provided by the Kerala Agricultural University and my esteemed institution, The College of Forestry in the successful completion of my studies and thesis work.

I owe my sincere thanks to The Dean, College of Forestry, who provided the required infrastructure and moral support for me during the execution of the work.

I would like to thank ***Miss Kiroshima****, Mrs.* ***Divya, Mrs. Sindhu, Sajith*** *and all the workers of Instructional farm for their valuable guidance and timely help during various stages of my work .*

I express my heartfelt thanks to my friends ***Haseena, Adarsh, Anand, Devika, Soosy*** *,* ***Anju Chechee*** *and* ***Mithun*** *and all members of 2013 Msc batch for their support and co-operation throughout my work.*

I would like to thank ***Aunty*** *for the constant support, co-operation and prayers from her.*

*Words cannot express the support and love from **Amma, Achan** and **Vava** and their immense support throughtout my life.*

A word of apology to those have not mentioned in person and note of thanks to one and all who worked for the successful compilation of this endeavour.

I bow my head before God for his blessings that enabled me to undertake this venture successfully.

Anu Sagaran K

TO MY FAMILY...

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Dairy sector is fast growing in India. Many people are dependent on dairy sector and it contributes to household livelihoods, food security and nutrition. With 16 percentage of global milk production, India is the largest milk producer in the world (FAO, 2014). This increase in milk production was mainly due to increase in number of producing animals rather than rise in productivity per head.

One of the main factors that affect the productivity of animals is the availability of adequate quality fodder. However, in India the supply has always remained short of normative requirement (Ramachandra *et al.*, 2005) restricting the true potential of livestock.

The scenario in Kerala is not different from the national perspective. Being a milk deficit state, prospects for dairy farming is high in Kerala. The major constraints that limit the growth of dairy sector in Kerala are the high cost of feeds and scarcity of quality fodder. It is estimated that the state produces only 60 per cent of the roughage requirement for cattle in Kerala (GOK, 2010). Hence, dairy farmers are forced to depend on high priced concentrate feeds which in turn increase the cost of production. The average productivity of cattle is restricted to 5-6 litres/day due to poor nutrition, although the genetic potential of our cattle is moderate with a productivity of 8-10 litres of milk/day. Thus, cultivation of nutrient rich fodder is of prime importance for the maintenance of better health standards of animals and thereby ensuring sustainable and profitable milk production

Fodder trees, with their nutrient rich leaves, constitute a potential source of quality green fodder to livestock especially during summer season. By cultivating fodder trees in the farm at cost effective modest management levels, instead of buying costly dairy feed, farmers can save money, and can achieve substantial increases in milk production.

Among fodder trees, *Calliandra calothyrsus* Meissner is a promising fodder tree by virtue of its nutritive foliage and ability to withstand severe pruning (Pye-Smith, 2010). Calliandra is native to Central America and Mexico. It is a fast growing multipurpose leguminous tree grown primarily for forage as a supplement to low quality roughages for livestock. Since the agro-climatic requirement of the crop suits well to that of Kerala, there is a good possibility of utilizing this crop as a nutrient rich fodder source in our state. However, due to acute land scarcity in Kerala, the possibility of growing calliandra as a sole crop in open lands is rather limited. The only alternative is to integrate with the existing cropping systems in the state. Coconut, being the most dominant plantation crop in Kerala stretching over an area of 0.82 M ha (GOK, 2012), offers substantial scope for integrating fodder trees like calliandra.

Calliandra has been widely documented as a useful component in agroforestry systems (Palmer *et al.*, 1994), with shade tolerance (Kaligis *et al.*, 1991). Hence, there is good scope for introducing calliandra to the existing coconut based cropping systems of the state. However, to avoid the possible competition between the coconut and to facilitate easy harvesting, it is desirable to maintain fodder trees as hedges. Higher biomass productivity, sustainability and better survival of fodder tree hedges can be ensured through their optimum management involving judicious regulation of key factors such as tree planting density, pruning height and pruning frequency (Horne *et al.,* 1986). Although information exists on the effects of various management practices on forage yields of calliandra in different regions, but in some cases it is contradictory and

17

preliminary, hence it is important to validate this research under Kerala conditions.

With this background, the proposed study has been conducted to evaluate the effect of stand management practices like tree density, pruning height and pruning frequencies on initial growth and survival, forage yield and nutritional qualities of calliandra intercropped in coconut gardens under humid tropical conditions of Kerala.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Fodder trees like calliandra are excellent source of crude protein for livestock in the humid tropics and can be integrated with the existing cropping systems like coconut gardens in land crunch Kerala. However, in spite of its potential, calliandra is not popular among farmers mainly because of the insufficient knowledge on the nutritive aspects of the fodder, as well as on the standard management practices to derive optimal productivity of quality forage from a limited land area. Trials conducted on various fodder trees indicated that, the management aspects such as spacing, cutting height and pruning frequency not only affect the forage yield per unit area but also the sustainable productivity and quality of the forage, which should be considered while establishing and managing high density fodder banks.

The objective of the present study is to examine the effect of stand management practises like plant density, pruning height and pruning frequencies on initial growth, forage yield and nutritive parameters of calliandra hedgerows as an understorey component in coconut gardens of Kerala. Relevant literature pertaining to the above aspects is reviewed hereunder.

2.1 RELEVANCE OF FODDER TREES IN LIVESTOCK NUTRITION

Insufficient feed and fodder along with poor nutritive value has been identified as the major reason for low productivity and fertility in Indian livestock (Chatterjee and Acharya, 1992). During dry season tropical grasses mature more rapidly and crude protein content falls, lignin content rises making them less palatable (Norton, 1994). Apart from the scarcity of quality forage, seasonal fluctuation of forage yield and quality from grasses is also considered another hindrance for animal production (Sarwar *et al.*, 2002). As per the reports from Indian

Grassland and Fodder Research Institute, Jhansi, in India, the current deficit in green and dry fodder accounts to 63.50 and 23.56 per cent, respectively and the projected deficit of CP and TDN expected during 2015 will be 45.76 and 33.71 million tonnes (IGFRI, 2015). Hence, farmers depend on expensive commercial concentrates which enhances the cost of livestock production and reduces their profit to considerable extent. It is estimated that cost involved in feed and fodder accounts for 60- 70 per cent of the cost of milk production (IGFRI, 2015).

Although livestock sector makes significant contribution to the economy of Kerala state, it is facing serious constraints due to inadequate fodder base. It is estimated that the state produces only 60 per cent of the roughage requirement for cattle in Kerala (GOK, 2010). Insufficient quantity and quality nutrition is one of the major hindrances in livestock production in Kerala (Ajith *et al.*, 2012). Hence production of quality fodder is of utmost importance for profitable livestock production and for enhancing the income of farmers.

During dry season fodder trees and shrub legumes are of importance as they are capable of providing high quality fodder (Adjemo, 1992: Costa *et al.*, 1992). Cultivation of trees has been recognized as one of the effective means for enhancing the production of quality forage in tropical smallholder livestock systems, especially during the summer period (Gutteridge and Shelton, 1994). Fodder trees are increasingly recognized as important components of animal feeding, especially as suppliers of protein. Moreover, tree fodders are long living and they require low maintanence and help in enhancing the sustainability of the farming systems. Leguminous tree species are favoured than non leguminous because of their high foliar content and ability to fix nitrogen (Gutteridge and Shelton, 1994).

Robertson (1988) reported that as the tree leaves are rich in nutrients and protein content, it can either be used as a supplement of low quality forages or as a source of forage alone. Cultivation of nutrient rich fodder ensures sustainable and profitable milk production and also helps to maintain animal health (Norton *et al.*, 1994). When fodder trees were used as supplements it was found to increase the fodder intake by helping in improving the rumen environment (Ummuna *et al.*, 1995).

Nitrogen fixing trees bring atmospheric nitrogen to the ecosystem (Huxley, 1999), which in turn enrich the soil nutrient content. Green fodder from nitrogen-fixing leguminous trees, in particular, contains much higher levels of protein than the poor quality basal feeds. Jamala *et al.* (2013) claimed that leguminous species contain 25 to 50 per cent more crude protein than non-leguminous plants. Fodder trees and shrubs contain high level of digestible protein, minerals and vitamins and also pay a major role in improving intake of roughages.

Fodder tree leaves may supplement the existing feed resources for small as well as large ruminant and can help to bridge the wider gap between demand and supply of nutrients. Tree leaves may become a rich source of supplementary protein, vitamins and minerals and their use in ruminant help to enhance microbial growth and digestion (Cheema *et al.*, 2011).

2.2 CALLIANDRA – A POTENTIAL FODDER TREE SPECIES FOR HUMID TROPICS.

Calliandra (*Calliandra calothyrsus* Meissner) is a multipurpose tree, native to Central America and Mexico and suitable for different ecological zones. It is adapted to areas where mean annual temperature is greater than 20^0C, having an annual rainfall more than 1000 mm (Palmer *et al*., 1994). It performs well on acidic soils with low aluminium saturation (Powell, 1995) and will be able to tolerate drought period of about three to six months (NAS, 1983). Calliandra is known for its fast growth, coppicing ability and high biomass production of foliage and wood (Tuwei *et al*., 2003). It has comparable performance to that of leucaena, which is widely and popularly used in various agroforestry systems. Moreover, susceptibility of leucaena to Psyllid attack and its large scale destruction in recent times also underscores the need to promote an alternate species suitable for agroforestry systems (Basavaraju and Rao, 1996).

Calliandra is widely used for fodder production, soil improvement, erosion control and fuel wood production. Annual forage yield is reported to be in the range of 7-10 t/ha dry matter (Ella *et al*., 1989). It has high coppicing ability (Duguma and Tonye, 1994). Paterson *et al*. (1996) reported that calliandra when managed as hedges and when cut frequently for fodder has shown high productivity in areas of Central and East Africa. Pye-Smith (2010) reported that calliandra, by virtue of its ability to withstand severe pruning and nutritive value, can be considered as a promising fodder tree.

The *in vitro* dry matter digestibility of leaves, green stem and woody pods were respectively reported as 35, 43 and 28 per cent (Baggio and Heuveldop, 1984). Calliandra has an average CP content of 220g/kg of dry matter (Romeo and Simmonds, 1989). Wiersum and Rika (1992) reported 22 per cent crude protein content, 30-70 per cent fibre content, 4-5 per cent ash and 2-3 per cent fat in dried leaves of calliandra.

The farmers of Uganda use calliandra in boundaries and for soil conservation (Nyeko, 2003). Calliandra can increase the nitrogen content of the soil (Buresh and Tian, 1997).

In Kenya when calliandra was given as a concentrate substitute, it was found to improve milk yield without any adverse effect (Paterson *et al.*, 1999). Calliandra is also reported to have high contents of condensed tannin (Maasdorp *et al.*, 1999; Hess *et al.*, 2003; Lascano *et al.*, 2003). When calliandra was used as a supplement to cows (6 kg fresh leaves/day) to an existing basal diet of 2 kg dairy meal, it was observed that in addition to obtaining increased income, there was improvement in cows condition and improved butter content in the milk (Chakeredza *et al.*, 2007). Jayaprakash *et al.* (2016) reported that, calliandra had relatively high protein (18.45 %), minerals, ether extract and energy content and thus have the potential to be a good alternate feed source for ruminant animals.

2.3 INTERCROPPING CALLIANDRA UNDER COCONUT GARDENS

In Kerala, growing fodder trees as sole crop is not a feasible option as there is acute scarcity of land. A possible alternative is to integrate it with the existing cropping systems in the state. One of the methods through which fodder trees can be grown is to integrate these along with the existing cropping systems. Coconut occupies the largest share of gross cropped area in Kerala (7.9 lakh hectare) (GOK, 2016), thus offering a good avenue for establishing fodder tree banks in the interspaces.

Studies conducted by Lakshmi (1998) confirm that fodder crops can be cultivated under coconut plantation. When additional care and fertilizers are given for the intercropped fodder species, the main crop will also be benefited. Occurrence of weeds can be reduced. The suitability of cultivation of different fodder trees like leucaena, mulberry, glyricidia and calliandra under coconut gardens was studied and analysed by several workers (Liyanage and Jayasundara, 1987; Arachchi and Liyanage, 1998; Raj, 2016).

On account of the wide inter spaces between coconut rows (7.6 m x 7.6 m) there is ample scope for intercropping especially during the early growth phase (up to 8 years) and later mature phase (>25 years) of the coconut plantation. However, while intercropping with coconut, it would be desirable to grow calliandra as hedge rows to regulate the possible competition between the coconut and the tree intercrop and to facilitate easy harvesting of fodder.

2.4 MANAGEMENT OF CALLIANDRA FODDER BANKS UNDERNEATH COCONUT PLANTATION

In land crunch small holder farms, most fodder banks are managed through a cut-and-carry system in which the fodder is harvested and then carried to the livestock. Important management factors to consider for a cut-and-carry system of fodder banks are plant density, cutting height and cutting frequency which not only affect fodder yield per unit area but also total long-term productivity and quality of the forage. Sustainable fodder production can be obtained through optimal management of tree height, cutting frequency and cutting height (Horne *et al.*, 1986). Ivory (1990) observed that foliage yield is affected by plant density and harvesting management (age of first cutting, cutting frequency, cutting height and season of cut).

2.4.1 Effect of plant density on forage yield and nutritive value of fodder trees with special reference to calliandra hedge rows

Ella *et al.* (1989) found that, for *Leucaena spp., Gliricidia spp., Calliandra spp.* and *Sesbania spp.*, as plant spacing was reduced, yield per plant decreased owing to competition, but total forage yield per unit area increased. Leaf: stem ratio also increased with increasing density in gliricidia and calliandra whereas less difference was observed in leucena. Dry matter production of leaves and wood was also found to be higher in high density stands.

Savory and Breen (1979) compared still higher densities (10,000, 30,000, 60,000 trees ha^{-1}) and found the highest yield in plants with 60,000/ha, indicating a positive relation of yield with plant density. El-Morsey (2009) reported higher yields from sesbania at the closest spacing from 10 cm, followed by 20 and 30 cm.

In a sole plantation of mulberry, Raj *et al.* (2015) observed higher biomass yields and leaf-stem ratio from higher tree density of 27,777 plants ha^{-1}, than lower densities of 22,222 and 17,777 plants ha^{-1} under humid tropical conditions of Kerala. However, Raj (2016) obtained the maximum forage yield in mulberry and subabul from still higher density of 49,382 plants ha^{-1} (45x45cm spacing), when grown as an intercrop in coconut. The studies indicate the need for closer planting of trees for maximum production and utilization of resources in land limited areas.

High tree densities result in increased production and in some cases with the advantage of weed suppression and improved soil fertility (Sanchez and Sanchez, 2002).

Unlike yield parameters, nutritive parameters showed diverse response in relation to plant density for various species of fodder trees. El-Morsey (2009) reported elevated CP % and lower CF % at higher population density in *Sesbania aegyptica.* In mulberry, Raj (2016) observed higher CP % in leaf and total fraction in the highest density stand, but total CF and ash % showed no significant differences with respect to density.

Bharadwaj *et al.* (2001) observed that the nutrient accumulation in the fodder biomass differed with tree density. However, Sanchez *et al.* (2006) reported that the nutritive composition of Moringa was not affected by planting density.

2.4.2 Effect of pruning height on forage yield and nutritive value of fodder trees with special reference to calliandra hedge rows

Maintaining proper cutting height is highly essential for retaining adequate foliage to ensure rapid regrowth and tree longevity and also for the ease of harvest without much bending and reaching by the harvester. Several studies indicate a great variety of cutting heights ranging from 50-150 cm for maximizing production and ensuring the tree longevity. In the study conducted on calliandra and *Flemingia congetsa* by Siregar (1983), optimum cutting height was suggested as 1 m. Studies conducted in calliandra at Karnataka (Basavaraju and Rao, 1996) revealed maximum herbage yields from calliandra at cutting height of 100 cm compared to lower levels.

It was observed by Munegowda and Krishnamurthy (1984), that *Sesbania aegyptica* when cut at 50 cm gave higher yields than higher cutting heights. However, in southeast Queensland, cutting height of 100 cm for *S. sesban* var. nubica produced higher yields compared to cutting heights of 150 and 50 cm (Galang *et al.*, 1990).

Gliricidia sepium yielded more dry matter when cut at 30 cm than at 50 cm and 70 cm (Tarawali *et al*., 1999).

Catchpole and Blair (1990) found that, leaf yield of *Leucaena leucocephala* remained unaffected by cutting heights of 1.5-2.5 metre. It was observed by Stur *et al.* (1994) that cutting height usually does not have much effect on forage yield. El-Morsey (2009) obtained highest fresh and dry forage yield in sesbania from cutting at 10 cm from ground surface whereas the 40 cm cutting level produced the lowest yield, with no significant difference between 20 and 30 cm cutting levels.

Tipu *et al.*(2006) reported that in leucaena, yield of shoot biomass increased significantly with the increase in pruning heights from 50 to 150 cm. Higher pruning heights also had a significantly higher number of branches, length of branches and leaves per plant than those of the lower heights. The increase in biomass production with increasing pruning height was possibly due to more reserve materials in taller stocks (100 and 150 cm) of *Leucaena leucocephala* that resulted in faster growth of young shoots and higher number of branches in longer cuttings.

Costa *et al.* (1992) reported that total biomass production, edible forage yield and protein content of ipil-ipil were significantly affected by cutting heights. Hariah *et al.* (1992) reported that lower pruning heights led to less biomass production and an increase in the number of branch roots originating from the stem base with six leguminous tree species such as *Calliandra calothyrsus*, *Cassia siamea*, *Erythrina orientalis*, *Peltophorum pterocarpum*, *Gliricidia sepium* and *Albizia falcatum*. Duguma *et al.* (1998) reported that the biomass (leaves + small green branches) of some legumes increased with increased pruning height.

2.4.3 Effect of pruning Frequency on forage yield and nutritive value of fodder trees with special reference to calliandra hedge rows

Several studies in different fodder tree species indicate that pruning frequency had a marked effect on forage yield and nutritional parameters. In a study by Ella *et al.*(1989), it was observed that *L. leucocephala*, *C calothyrsus* and *G sepium* gave higher biomass yield at longer harvesting interval of 12 weeks compared to 6 weeks. Studies conducted in calliandra at Karnataka (Basavaraju and Rao, 1996) revealed maximum herbage yields from calliandra at cutting interval of 60 days compared to higher intervals.

Horne *et al.* (1986) reviewed cutting management on *L. lecocephala* and it was concluded that with increase in cutting intervals, the total yield increased and this was found to be related to decrease in leaf/stem ratio. Similar observation was reported by Ella *et al.* (1989) for leucaena, calliandra and gliricidia. Raj (2016) reported higher leaf-stem ratio in mulberry and subabul at shorter harvest interval of 8 weeks than longer intervals.

A reduction in yield was observed in case of leucaena from 30.04 tons/ha to 10.3 tons/ha, when cut at 12 weeks interval and 6 weeks interval. Mortality was observed to be higher in 6 weeks interval (ILCA, 1988). Fadiyimu *et al.* (2011) studied effect of cutting regimes on seasonal fodder yields of *Moringa oleifera* in the tropical rainforest of Nigeria. They found that in the rainy season, frequent harvests (4 to 6 weeks intervals) at the height of 150 cm gave the highest yields.

Wide variations have been noticed in the bio-chemical composition of calliandra biomass depending on the age and cutting interval. Kaitho *et al.* (1993) found that crude protein levels of calliandra leaves declined from 28.2 to 23.5 percent and crude fibre content increased from 22.0-30.9 per cent in dried shoot material when cutting interval increased from 12 to 28 weeks. Saddul *et al.* (2004) from Malaysia reported that the optimum stage to harvest the whole plant of mulberry is 5 weeks, which is a compromise between yield, nutrient composition (crude protein and fibre components), and the annual number of cuts, with good crop persistence to repeated harvests.

Raj (2016) reported higher crude protein and phosphorus content and lower fibre content in mulberry and subabul fodder when pruned at shorter intervals of 8 weeks than prolonged intervals of 12 and 16 weeks. However, ash content was higher at longer pruning intervals.

MATERIALS AND METHODS

MATERIALS AND METHODS

The field study entitled "Performance of calliandra *(Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system" was carried out at Instructional Farm, College of Horticulture, Vellanikkara, during 2014-2015. The main objective of the study was to assess the influence of management practices like tree density, pruning height and pruning frequencies on initial growth and survival, forage yield and nutritional qualities of calliandra intercropped in coconut gardens under humid tropical conditions of Kerala. The materials used and the methods adopted for the study are briefly explained in this chapter.

3.1. LOCATION

The experiment was carried out in mature coconut garden (7.6 x 7.6 m spacing) located at Instructional Farm, College of Horticulture, Vellanikkara, Thrissur District. The site is situated at 10° 33' 04.9" N latitude, 76° 18' 03.1'' E longitude; and 40.29 m altitude.

3.2. CLIMATE AND SOIL

Typical humid tropical climate is experienced in the area. The mean weekly minimum and maximum temperature ranged from $22.1^{0}C$ to $25.7^{0}C$ and $26.90^{0}C$ to $36.70^{0}C$ respectively during 2014-15 cropping season. The mean weekly relative humidity ranged between 55 and 87 per cent. A total of 3457 mm rainfall was received during the crop growth season. Data on weather conditions such as temperature, rainfall and relative humidity obtained from the Department of Agricultural Meterology, College of Horticulture, Vellanikkara are given in Appendix I and graphically depicted in Fig. 1. The soils of the experimental site fall under the family of Loamy Kaolinitic Isohyperthermic Typic Plinthustult, with sandy clay loam texture. Initial soil tests indicated acidic soil reaction (pH: 5.5), with medium levels of organic carbon (1.2%), available nitrogen (0.16 g kg^{-1}), exchangeable potassium (0.11 g kg^{-1}) and low level of phosphorus (3.39 mg kg^{-1}).

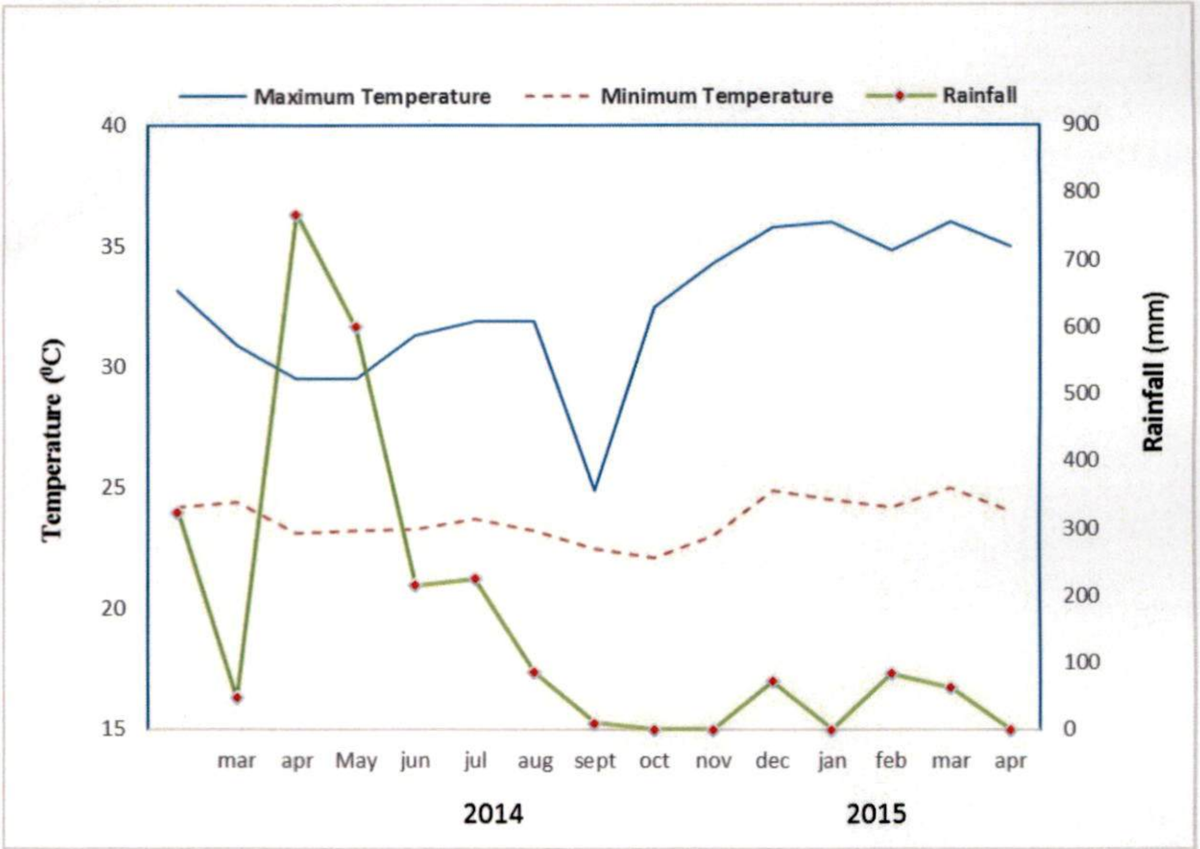

Fig 1. Climate data for Vellanikkara, Kerala, during the trial period 2014-15

3.3 MATERIALS

3.3.1. Crop

Calliandra calothyrsus is a multipurpose, fast growing leguminous tree native to Central America and Mexico. Naturalized throughout the tropics, this species is widely used for fodder production, soil improvement, erosion control and fuel wood production (Palmer *et al.* 1994). It is adapted to areas with annual precipitation between 1000 and 4000 mm, mean annual temperature above 20°C, and elevations up to 1800 meters. It performs moderately well on acid soils with high aluminum saturation (Powell, 1995) and tolerates droughts of three to six months (NAS, 1983). Calliandra has also been widely documented as a useful component in agroforestry systems (Palmer *et al.*, 1994), with shade tolerance (Kaligis *et al.,* 1991).

3.3.2. Manures and Fertilizers

Farm yard manure (FYM) @ 20 t ha^{-1} and $N:P_2O_5:K_2O$ each @ 50 kg ha^{-1} were applied uniformly for all treatments. FYM was applied as basal before the onset of south west monsoon. Fertilizers were applied as N: P: K mixture (18: 18: 18) in two split doses before the onset of south west and north east monsoons.

3.4. METHODS

The experiment was conducted in mature coconut garden planted at 7.6 x 7.6 m spacing. Calliandra seedlings were planted in the interspaces of coconut (excluding area of 2 m radius around the palm) to evaluate its performance under variable tree densities, pruning heights and frequencies following standard experimental design.

3.4.1. Design and Layout of the Experiment

Design : Factorial RBD with tree density, pruning height and pruning frequency as factors.

Treatments : 3x2x3 = 18

Replication : 3

Plot size : 4 m x 3 m

3.4.2 Treatment details

The treatments consisted of 3 levels of tree density, 2 levels of pruning height and 3 levels of pruning frequency in all possible combinations, the details of which are given below.

(1) Tree density (3 levels)

D1 – 27,777 plants ha^{-1} (60 x 60 cm spacing)
D2 – 22,222 plants ha^{-1} (75 x 60 cm spacing)
D3 – 17,777 plants ha^{-1} (75 x 75 cm spacing)

(2) Pruning height from ground (2 levels)

H1 - 0.5 m
H2 - 1 m

(3) Pruning frequency (3 levels)

F1 - 8 weeks interval
F2 - 12 weeks interval
F3 - 16 weeks interval

The layout plan of the trial is shown in Fig.2.

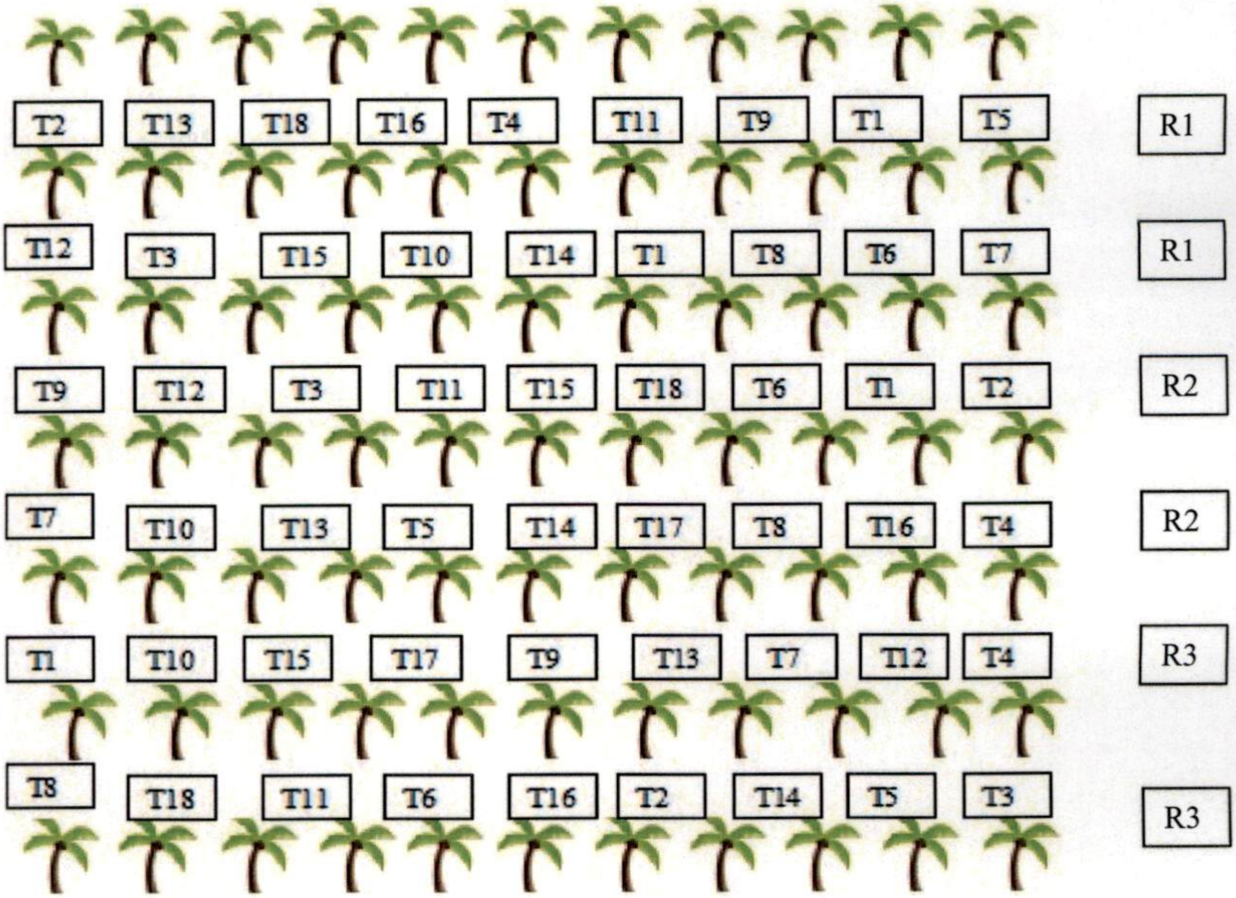

Fig. 2. Layout plan of the experimental plot

Treatment combinations of calliandra

T1 - D1H1F1

T2 – D2H1F1

T3- D3H1F1

T4 – D1H2F1

T5 – D2H2F1

T6 – D3H2F1

T7 - D1H1F2

T8 - D2H1F2

T9 - D3H1F2

T10 - D1H2F2

T11 - D2H2F2

T12 - D3H2F2

T13 - D1 H1F3

T14 – D2 H1F3

T15 – D3 H1F3

T16 - D1 H2F3

T17 – D2 H2F3

T18 – D3 H2F3

3.4.3 Raising of calliandra seedlings

Seeds of calliandra were procured from Kerala Livestock Development Board, Dhoni Farm, Palakkad District. Seedlings of calliandra were raised in a temporary shade house. Calliandra seeds were soaked in water for 48 hours prior to planting for enhancing germination and sown in nursery beds of standard size. Healthy and uniform seedlings were transplanted to polythene bags filled with potting mixture (soil: coir pith: FYM) in 2:1:1 ratio, one month after sowing. Irrigation, weeding and plant protection were carried out as and when required. Seedlings were transferred to the experimental main field after 3 months with the onset of monsoon showers.

Plate 1. Seeds of *Calliandra calothyrsus*

Plate 2. Calliandra underneath coconut plantation

3.4.4 Field culture

The field area in the interspaces of coconut was ploughed twice and the layout was done allocating a plot size of 4 m x 3 m (12 sq.m) for each treatment. Pits were taken at prescribed spacing for each treatment and seedlings of calliandra were transplanted to the main field with the onset of pre-monsoon showers. Manures and fertilizers were applied as detailed in section 3.3.4. Plants were weeded as and when required. Irrigation was given at weekly intervals during summer months.

3.4.5 Harvest of trees

After attaining a height over 1 m, an initial uniform cut was given to all plants in June 2014 at pruning height of 1m. Subsequent cuttings were taken as per harvest intervals, and annually six, four and three cuts were given for intervals of 8, 12 and 16 weeks respectively up to June 2015, at prescribed pruning heights of 0.5 m and 1 m.

3.5 OBSERVATIONS

Five trees per plot were selected at random avoiding border plants and the following observations were recorded.

3.5.1 Growth parameters at initial uniform cut

3.5.1.1 *Plant height*

The plant height was measured from the base of the plant to the top of the apical meristem and expressed in cm.

3.5.1.2 Collar diameter

Collar diameter (cm) was measured at the base of the plant stem by using digital vernier caliper.

3.5.1.3 *Branches per plant*

Number of main branches per plant was counted for each treatment.

3.5.1.4 Green biomass yield

After harvesting, the biomass from 5 trees per plot was separated into leaf and stem and their individual fresh weights and total biomass determined.

3.5.2 Coppice parameters during subsequent cuts

3.5.2 .1 Number of coppices per plant

Number of coppices per plant for each treatment was counted for every harvest and expressed as mean values over the period of study.

3.5.2.2 Coppice length

Length of the coppices were measured from the base to the tip of the apical meristem and expressed in cm.

3.5.3 Green fodder yield

Biomass from 5 trees per plot avoiding border plants was measured directly at each harvest. Biomass was separated into leaf and stem and their individual fresh weights and total biomass determined. Thereafter, yield from all harvests in a year was pooled to get annual yields and using the net harvested area and fresh weight, annual green fodder yield was scaled up to an area of 1 hectare coconut garden.

3.5.4 Dry fodder yield

Three sub-samples taken from the leaf and stem samples of calliandra of each harvest were oven-dried at 70^0C for 48 hours for dry matter (DM) determination. The fresh fodder yields from each harvest were multiplied with the

DM content, summed up to get annual dry fodder yield and was expressed on hectare basis.

3.5.5 Leaf-stem ratio

The leaf - stem ratio was calculated by dividing the dry weight of leaves with dry weight of stem.

3.5.6 Survival percentage of trees

The number of trees in each treatment plot was counted after the period of trial and expressed as survival percentage

3.5.7. Incidence of pest and diseases

No serious pest and disease incidence was noticed in calliandra during the study period.

3.5.8 Plant nutrient analysis

Triplicate subsamples of the leaf and stem components of the fodder biomass from each treatment were oven dried separately and subjected to dry matter (at 80°C) analysis following standard analytical procedures (Jackson, 1973). Nitrogen content was estimated by modified microkjeldahl method. Phosphorus content was determined calorimetrically by vanado–molybdo phosphoric yellow colour method and potassium was determined by flame photometery (Jackson, 1973). All nutrient concentrations were expressed on dry matter basis.

3.5.9. Quality aspects of green biomass

3.5.9.1 Crude protein yield

Total nitrogen of oven dried fodder samples (leaf and stem separately) was determined by the micro Kjeldahl procedure and multiplied with 6.25 to get the crude protein (CP) content (AOAC, 1995). CP content was multiplied with annual leaf and stem DM yields and summed up to get annual crude protein yields per hectare.

3.5.9.2 Crude fibre content

Oven –dried leaf and stem samples were refluxed first with 1.25 per cent H_2SO_4 and subsequently with 1.25 per cent NaOH for 30 minutes each to dissolve acid and alkali soluble component present in it. The residue containing crude fibre (CF) was dried to a constant weight and the dried residue was ignited in muffle furnace, loss of weight on ignition was calculated to express it as CF in percentage (AOAC, 1995).

3.5.9.3 Ash content

Oven dried samples were ignited in muffle furnace at 550°C to burn all the organic matter and left over was weighed as ash (AOAC, 1995).

3.5.10 Economics & B:C ratio

Cost of cultivation of various systems and the economical yield obtained from calliandra and coconut was used for calculating the B:C ratio.

3.5.11 Statistical analysis

The data were subjected to statistical analysis by analysis of variance (ANOVA) using general linear model procedure in SPSS version 20.0 (SPSS Inc.,USA), to ascertain the significance of various parameters. The Duncan's Multiple Range Test (DMRT) was used to test the differences among treatment means at 5 per cent significance level.

RESULTS

RESULTS

The salient findings of the study, "Performance of calliandra *(Calliandra calothyrsus* Meissn) under diverse management regimes in a coconut based hedge row fodder production system", are presented hereunder.

4.1 GROWTH AND YIELD OBSERVATIONS OF CALLIANDRA AT INITIAL UNIFORM CUT

All the treatments were given an initial uniform cut at 1 m height at the stage of three months after transplanting to the field. Growth and yield parameters of calliandra at the stage of initial cut are given below.

4.1.1 Height

Table 1 shows the influence of plant density on plant height of calliandra. Plant height at initial stage did not show any significant difference between the three densities. However, a marginal increment in plant height was noticed in medium density D2 (161.77 cm), followed by D1 (159.11) and lowest in D3 (142.13)

4.1.2 Collar diameter

As indicated in Table 1, plant density had no significant effect on collar diameter of calliandra at the early establishment phase.

4.1.3 Number of branches

The data given in Table 1 indicated that, plant density had no significant effect on the number of branches of calliandra at the early establishment phase.

4.1.4 Fodder biomass obtained from initial cut

Table 1. shows the fodder biomass of calliandra cut at initial stage. Among the three densities, total fodder yield was observed to be significantly higher in the highest density D1 (2.86 Mg ha^{-1}) and medium density, D2 (2.01 Mg ha^{-1}) when compared to the lowest density D3 (1.57 Mg ha^{-1}). Fractional yield from calliandra at initial cut also showed the same trend. Leaf yield was significantly higher in D1 (1.71 Mg ha^{-1}), followed by D2 (1.22 Mg ha^{-1}) and then D3 (0.938 Mg ha^{-1}). Stem yield also showed similar trends.

Table 1. Growth parameters of calliandra under varying tree densities at the stage of initial cut.

Treatments	Height (cm)	Collar diameter (mm)	Number of branches	Fodder yield (Mg ha^{-1})		
				Leaf	Stem	Total
27777 plants ha^{-1} (D1)	159.11	14.38	2.94	1.71^{a}	1.14^{a}	2.86^{a}
22,222plants ha^{-1} (D2)	161.77	14.49	3.10	1.22^{b}	0.79^{b}	2.02^{b}
17,777plants ha^{-1} (D3)	142.13	14.75	2.75	0.938^{c}	0.632^{c}	1.57^{c}
P value	0.274^{ns}	0.725^{ns}	0.468^{ns}	0.001***	0.004**	0.002**

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns = not significant $p>0.05$

Values with the same superscripts in column do not differ significantly

4.2 INFLUENCE OF PLANT DENSITY, PRUNING HEIGHT AND FREQUENCY ON COPPICE PARAMETERS OF CALLIANDRA

4.2.1. Coppice length

Different plant densities did not show any significant difference on coppice length of calliandra (Table 2). Pruning frequency had a significant effect on the coppice length of calliandra. Coppice length was higher in prolonged harvest interval of 16 weeks (216.98 cm), followed by 12 weeks(138.47 cm) and then 8 weeks (111.08cm). Pruning height did not show any significant difference in the coppice length.

4.2.2. Leaf : stem ratio

Plant density and pruning height did not show any significant difference on the leaf-stem ratio of the coppices of calliandra (Table 2). However, there was significant difference in leaf-stem ratio of coppices with varying pruning frequency. Leaf-stem ratio decreased with increasing pruning frequency. It was observed higher in 8 weeks (1.33) and 12 weeks (1.32) and lowest in 16 weeks interval (0.607).

4.2.3 Number of coppices

Plant density did not show any significant effect on the number of coppices (Table 2) of calliandra after harvest. However, pruning frequency and pruning height had significant impact on the number of coppices. Number of coppices was higher for 12 weeks (4.44) when compared to 8 weeks (3.94) and 16 weeks (3.01).

Number of coppices (4.43) also increased at greater pruning height of 1m, when compared to lower height (3.17).

Table 2. Influence of plant density, pruning height and frequency on coppice parameters of calliandra in coconut garden.

Treatments	Coppice length (cm)	Leaf: stem ratio	Number of coppices
Plant density (Main effect)			
27,777 plants ha ha^{-1} (D1)	155.57	1.12	3.74
22,222 plants ha ha^{-1} (D2)	156.77	1.13	3.81
17,777 plants ha ha^{-1} (D3)	154.18	1.13	3.83
P value	0.760^{ns}	0.864^{ns}	0.863^{ns}
Pruning frequency			
8 weeks (F1)	111.08^{c}	1.46^{a}	3.94^{b}
12 weeks (F2)	138.47^{b}	1.23^{b}	4.44^{a}
16 weeks (F3)	216.98^{a}	0.69^{c}	3.01^{c}
p value	0.000***	0.000***	0.000***
Pruning height			
0.5 m (H1)	152.83	1.12	3.17^{b}
1.0 m (H2)	158.19	1.14	4.43^{a}
P value	0.061^{ns}	0.344^{ns}	0.000***
D*F	0.711^{ns}	0.258^{ns}	0.453^{ns}
D*H	0.455^{ns}	0.034^{ns}	0.143^{ns}
F*H	0.301^{ns}	0.903^{ns}	0.000***
D*F*H	0.000***	0.248^{ns}	0.606^{ns}

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns = not significant $p>0.05$. Values with the same superscripts in column do not differ significantly

Table 3. Interaction effect of plant density, pruning height and frequency on coppice parameters of calliandra in coconut garden.

Treatments	Coppice length	Leaf: stem ratio	Number of coppices
Density *Height*Frequency			
D1 H1F1	107.36 ^{f}	1.46	3.45
D2 H1F1	107.82 ^{f}	1.48	3.52
D3 H1F1	114.94 ^{ef}	1.39	3.52
D1 H2F1	113.61 ^{ef}	1.45	4.15
D2 H2F1	115.78 ^{ef}	1.45	4.52
D3 H2F1	106.99 ^{f}	1.51	4.47
D1 H1F2	128.73 ^{d}	1.31	3.27
D2 H1F2	133.42 ^{cd}	1.17	3.00
D3 H1F2	135.82 ^{cd}	1.19	3.60
D1 H2F2	153.31 ^{c}	1.21	5.17
D2 H2F2	139.76 ^{cd}	1.25	6.03
D3 H2F2	139.80 ^{cd}	1.26	5.60
D1 H1F3	227.65 ^{ab}	0.67	2.87
D2 H1F3	223.42 ^{ab}	0.69	2.47
D3 H1F3	196.31 ^{b}	0.71	2.83
D1 H2F3	202.79 ^{b}	0.62	3.57
D2 H2F3	220.45 ^{ab}	0.75	3.37
D3 H2F3	231.27 ^{ab}	0.71	2.97
P value	0.000***	0.041 ^{ns}	0.606 ^{ns}

*** significant at $p<0.001$, ns = not significant $p>0.05$.

D1, D2 and D3 – Tree density of 27,777; 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2 and F3- Pruning intervals of 8, 12 and 16 weeks respectively.

LP1

As indicated in Table 3, the interaction effect of three management regimes; plant density, pruning height and pruning frequency showed significant influence on the coppice length and leaf-stem ratio, whereas coppice number showed only marginal variation. All treatment combinations with longer pruning interval of 16 weeks had greater coppice length ranging from 196.31 to 231.27 cm, and declined consistently with the decreasing intervals. However, leaf-stem ratio was significantly lower at prolonged harvest interval (0.62 to 0.75) and showed an increasing trend with shorter intervals (1.39 to 1.51). Better coppice length (153.31 cm) with more leaf fraction (1.47) was observed in the combination of D1H2F2 (27,777 plants ha^{-1}, pruning height 1.0 m and pruning interval 12 weeks), whereas rest of the combinations produced either smaller coppices or coppices with more stem fraction.

4.3 EFFECT OF PLANT DENSITY, PRUNING HEIGHT AND FREQUENCY ON ANNUAL FRESH FODDER YIELD AND SURVIVAL PERCENTAGE OF CALLIANDRA IN COCONUT GARDEN.

4.3.1 Fractional and total fresh fodder biomass

Table 4 shows annual fractional and total fresh fodder biomass of calliandra under coconut plantation. Plant densities, pruning height and pruning frequency showed significant impact on the annual fresh fodder yield of calliandra. Fodder biomass was significantly higher (34.68 Mg ha $^{-1}$) in high density planting D1 (27,777 plants ha $^{-1}$) when compared to the medium density of 22,222 plants ha^{-1} D2 (28.57 Mg ha^{-1}), whereeas the yield (22.62 Mg ha^{-1}) from D3 (17,777 plants ha^{-1}), was significantly inferior. Fractional fodder biomass also had a similar trend. Leaf fodder yield decreased from D1 (17.41 Mg ha^{-1}) to D2 (14.67 Mg ha^{-1}) and with the least value in D3 (11.51 Mg ha^{-1}). Similarly, the stem fodder biomass also reduced from D1 (17.28 Mg ha^{-1}) to D2 (13.91 Mg ha^{-1}) and to D3 (11.11 Mg ha^{-1}).

Comparing pruning intervals, total biomass was found to be significantly higher in longer interval of 16 weeks (32.56 Mg ha^{-1}) than other intervals. Total yield was comparable in 12 weeks (26.85 Mg ha^{-1}) and 8 weeks (24.47 Mg ha^{-1}) cutting interval. Stem yield also showed similar trend, where it increased from 10.82 to 19.28 Mg ha^{-1}) from 8 weeks to 16 weeks interval. However, leaf yield showed the reverse trend wherein higher foliage yield was obtained at shorter and medium intervals of 8 and 12 weeks (15.65 and 14.66 Mg ha^{-1}) compared to longer interval of 16 weeks (13.28 Mg ha^{-1}).

Total fodder biomass yield showed an increasing trend with increase in pruning height from 0.5 m to 1 m (24.79 to 32.46 Mg ha^{-1}). Similar trend was observed in leaf and stem yield. Leaf fodder yield increased from H1 (12.42 Mg ha^{-1}) to H2 (16.62 Mg ha^{-1}). Stem yield also increased from H1 (12.36 Mg ha^{-1}) to H2 (15.84 Mg ha^{-1}).

The interaction effects of plant density , pruning height and pruning frequency had no significant effect on annual fresh fodder yields as well as the leaf and stem forage fractions of calliandra (Table 5 & 7). The highest yielding combination (42.93 Mg ha^{-1} yr^{-1}) was found to be D1H2F2 (27,777 plants ha^{-1} + pruning height 1 m + pruning interval 12 weeks), closely followed by D1H2F2. Leaf fraction (23.41 Mg ha^{-1}) was also found to be higher for D1H2F2, followed by D1H2F1 (20.99 Mg ha^{-1}) which included the highest density, higher pruning height and shorter intervals, whereas the stem fraction was found to be higher in combinations with longer pruning intervals than shorter ones.

4.3.2 Survival percentage of calliandra in coconut garden

The results indicated in Table 4 and 5 reveals that the management factors like plant density, pruning height and frequency had no significant influence on survival percentage of trees at the end of the experimental year. Almost 98 percent of the trees survived irrespective of the treatments.

Table 4. Effect of plant density, pruning height and frequency on annual fresh fodder yield and survival percentage of calliandra in coconutgarden.

Treatments	Fractional and total fresh fodder biomass (Mg ha^{-1})			Survival percentage (%)
	Leaf	**Stem**	**total**	
Plant density (Main effect)				
27,777 plants ha^{-1} (D1)	17.41^{a}	17.28^{a}	34.69^{a}	98.52
22,222 plants^{-1} (D2)	14.66^{b}	13.91^{b}	28.57^{b}	98.00
17,777 plants ha^{-1} (D3)	11.51^{c}	11.11^{c}	22.62^{c}	98.61
P value	0.000***	0.000***	0.000***	0.681^{ns}
Pruning frequency				
8 weeks (F1)	15.65^{a}	10.82^{b}	26.47^{b}	98.22
12 weeks (F2)	14.66 ^{a}	12.19^{b}	26.85^{b}	98.44
16 weeks (F3)	13.28^{b}	19.28^{a}	32.56^{a}	98.46
P value	0.003**	0.000***	0.000***	0.938^{ns}
Pruning height				
0.5 m (H1)	12.43b	12.36b	24.79b	98.06
1.0 m (H2)	16.62a	15.84a	32.46a	98.69
P value	0.000***	0.000***	0.000***	0.309^{ns}
D*F	0.500^{ns}	0.125^{ns}	0.871^{ns}	0.784^{ns}
D*H	0.132^{ns}	0.250^{ns}	0.170^{ns}	0.672^{ns}
F*H	0.000***	0.012^{ns}	0.001**	0.510^{ns}
D*F*H	0.172^{ns}	0.198^{ns}	0.161^{ns}	0.271^{ns}

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with thesame superscripts in a column donot differ significantly.

D1,D2 and D3- Plant densities of 27,777; 22,222 and 17,777 plants ha^{-1}

H1 and H2- Pruning heights of 0.5 and 1m

F1, F2 and F3 – Pruning frequencies of 8, 12 and 16 weeks interval

Table 5. Interaction effect of plant density, pruning height and frequency on annual fresh fodder yield and survival percentage of calliandra in coconut garden.

Treatment combinations	Fractional and total fresh fodder biomass (Mg ha^{-1})			Survival percentage (%)
	Leaf	Stem	Total	
D1 H1F1	16.42	11.46	27.890	96.67
D2 H1F1	14.09	9.55	23.653	97.33
D3 H1F1	11.72	8.45	20.181	98.33
D1 H2F1	20.99	14.48	35.470	99.99
D2 H2F1	18.44	12.79	31.236	98.66
D3 H2F1	12.19	8.19	20.388	98.66
D1 H1F2	12.80	10.30	23.109	98.89
D2 H1F2	10.64	9.58	20.233	99.99
D3 H1F2	9.02	7.79	16.823	98.33
D1 H2F2	23.41	19.51	42.931	99.99
D2 H2F2	17.69	14.34	32.050	100.00
D3 H2F2	14.35	11.59	25.950	99.99
D1 H1F3	15.33	23.28	38.619	100.00
D2 H1F3	11.93	16.98	28.913	97.33
D3 H1F3	9.88	13.78	23.671	98.33
D1 H2F3	15.49	24.60	40.107	99.99
D2 H2F3	15.12	20.19	35.318	97.33
D3 H2F3	11.87	16.84	28.719	100.00
P value	0.172^{ns}	0.198^{ns}	0.161^{ns}	0.199^{ns}

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2 and F3-Pruning intervals of 8, 12 and 16weeks respectively

4.3.3. Annual dry fodder yield

Table 6 shows the significant effect of density, pruning height and pruning frequency on dry fodder yield of calliandra. Total dry fodder biomass decreased from the highest density stand D1 (11.73 Mg ha^{-1}) to lower densities of D2 (9.10 Mg ha^{-1}) and D3 (7.53 Mg ha^{-1}). Leaf yield also declined from D1 (5.53 Mg ha^{-1}) to D2 (4.33 Mg ha^{-1}) and D3 (3.64 Mg ha^{-1}). Stem yield also showed similar trends.

Comparing pruning frequencies, total dry fodder biomass was found to be significantly higher in longer intervals of 16 weeks (13.29 Mg ha^{-1}) than shorter ones of 8 weeks (7.08 Mg ha^{-1}) and 12 weeks (8.00 Mg ha^{-1}), which in turn were on par. Stem dry matter yield showed almost similar values for 8 weeks (3.04 Mg ha^{-1}) and 12 weeks interval(3.47 Mg ha^{-1}) and showed an increase in 16 weeks (8.36 Mg ha^{-1}). Leaf dry matter yield also increased significantly from 8 weeks (4.04 Mg ha^{-1}) to 12 weeks (4.53 Mg ha^{-1}) and 16 weeks (4.93 Mg ha^{-1}) pruning interval.

Comparison of pruning heights indicated that the total dry fodder yield increased significantly at greater pruning height of 1m (10.81 Mg ha^{-1}) than lower height of 0.5m (8.10 Mg ha^{-1}). Leaf and stem fodder yields also showed similar trends.

The interaction effects of plant density, pruning height and pruning frequency had no significant effect on the annual dry fodder yield as well as the leaf and stem forage fractions of calliandra. Among various combinations, the dry fodder yield(17 Mg ha^{-1})was found to be the highest from the highest density stand, with 1m pruning height and longest harvest interval (D1H2F3), followed by D1H1F3 and D2H2F3.

4.3.4. Leaf-stem ratio

Plant density did not show any significant impact on the leaf-stem ratio (Table 6). Pruning frequency had significant impact on the leaf-stem ratio, wherein significantly higher leaf- stem ratio was shorter interval of 8 weeks (1.33) and medium interval of 12 weeks (1.32), compared to longer interval of 16 weeks (0.61). Pruning height also had no significant effect on the leaf - stem ratio of calliandra fodder.

Comparing the interaction effects which were non significant, the leaf-stem ratio was comparatively higher for D1H2F1 (1.60), followed by D1H2F2 (1.46), comprising of shorter and medium pruning intervals. However, all combinations with longer pruning intervals had lower leaf-stem ratio, irrespective of their higher forage yields.

55

Table 6. Effect of plant density, pruning height and frequency on annual dry fodder yields and leaf-stem ratio of calliandra in coconut garden.

Treatments	Fractional and total dry fodder biomass ($Mg\ ha^{-1}\ yr^{-1}$)			Leaf-stem ratio
	Leaf	Stem	Total	
Plant density (Main effect)				
27777 plants ha^{-1}(D1)	5.53^{a}	6.02^{a}	11.73^{a}	1.14
22,222 plants ha^{-1} (D2)	4.33^{b}	4.77^{b}	9.10^{b}	1.06
17,777 plants ha^{-1}(D3)	3.64^{c}	3.90^{c}	7.53^{c}	1.07
P value	0.000***	0.000***	0.000***	0.102^{ns}
Pruning frequency				
8 weeks (F1)	4.05^{b}	3.04^{b}	7.09^{b}	1.33^{a}
12 weeks (F2)	4.53^{ab}	3.47^{b}	8.00^{b}	1.32^{a}
16 weeks (F3)	4.93^{a}	8.36^{a}	13.29^{a}	0.61^{b}
P value	0.002**	0.000***	0.000***	0.000***
Pruning height				
0.5 m (H1)	3.73^{b}	4.38^{b}	8.11^{b}	1.05^{b}
1.0 m (H2)	5.27^{a}	5.54^{a}	10.81^{a}	1.12^{a}
P value	0.000***	0.000***	0.000***	0.035*
D*F	0.017^{ns}	0.000***	0.765^{ns}	0.000***
D*H	0.006^{ns}	0.454^{ns}	0.115^{ns}	0.004*
F*H	0.001**	0.078^{ns}	0.012^{ns}	0.308^{ns}
D*F*H	0.473^{ns}	0.269^{ns}	0.332^{ns}	0.041^{ns}

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3-Pruning intervals of 8, 12 and 16 weeks respectively

Table 7. Interaction effect of plant density, pruning height and frequency on annual dry fodder yield and leaf-stem ratio of calliandra in coconut garden.

Treatments	Fractional and total dry fodder biomass (Mg ha^{-1})			Leaf-stem ratio
	Leaf	Stem	Total	
Density *Height*Frequency				
D1 H1F1	4.40	3.38	7.78	1.31
D2 H1F1	3.20	2.44	5.63	1.32
D3 H1F1	3.05	2.55	5.60	1.17
D1 H2F1	6.29	4.08	10.38	1.61
D2 H2F1	4.32	3.51	7.83	1.23
D3 H2F1	3.02	2.28	5.30	1.37
D1 H1F2	4.01	2.90	6.91	1.44
D2 H1F2	3.20	2.79	5.99	1.31
D3 H1F2	2.48	2.16	4.64	1.14
D1 H2F2	7.94	5.46	13.39	1.47
D2 H2F2	4.85	4.28	9.13	1.14
D3 H2F2	4.68	3.24	7.91	1.45
D1 H1F3	4.52	10.43	14.95	0.45
D2 H1F3	4.70	6.95	11.65	0.67
D3 H1F3	3.99	5.81	9.80	0.68
D1 H2F3	6.03	10.97	17.00	0.55
D2 H2F3	5.72	8.67	14.39	0.67
D3 H2F3	4.61	7.34	11.95	0.63
P value	0.473^{ns}	0.269^{ns}	0.332^{ns}	0.041^{ns}

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3- Pruning intervals of 8, 12 and 16weeks respectively

4.4 PLANT QUALITY AND NUTRIENT ANALYSIS

4.4.1 Crude protein (CP) content

Plant densities showed a significant effect on total CP %, whereas there was no significant difference in the CP % of leaves and stem fractions due to densities (Table 8). Total CP content in fodder increased from 15.40 to 16.26 percent from lower to higher density stands.

Comparing pruning intervals, a significant difference in CP content was observed in leaves and in total fodder with varying intervals. CP content in leaves for shorter and medium intervals of 8 weeks (27.47 %) and 12 weeks (27.90 %) were significantly higher, whereas it declined to 25.10 percent in longer interval of 16 weeks. Similarly, total CP content were observed to be comparable in 8 weeks (17.92 %) and 12 weeks (17.88 %) whereas it declined to 11.93 percent in 16 weeks interval.

As indicated in Table 8, pruning height had no significant impact on the CP content of fodder.

4.4.2 Crude protein yield

Plant densities had significant impact on the CP yield of calliandra. Total CP yield of calliandra decreased from D1(1.82 Mg ha^{-1}) to D2 (1.40 Mg ha^{-1}) and to D3 (1.10 Mg ha^{-1}). Similar result was observed in leaves and stem CP yield. CP yield of leaves decreased from D1 (1.50 Mg ha^{-1}) to D2 (01.17 Mg ha^{-1}) and to D3(0.934 Mg ha^{-1}). Same trend was observed for stem CP yield where the yield decreased from D1 (0.32 Mg ha^{-1}) to D2 (0.23 Mg ha^{-1}) and to D3 (0.16 Mg ha^{-1}).

Pruning frequency had significant impact on the stem and total CP yield, whereas the leaf CP yield did not show any significant difference. The total CP yield increased from 1.27 to 1.60 Mg ha^{-1} by increasing the harvest interval from 8 to 16 weeks. The overall CP yield and the yield from stem fraction was found to be higher in 16 weeks interval, but the CP yield from edible foliage fraction was found to be highest in 12 weeks interval.

Total CP yield increased with increase in pruning height. When pruning height increased from 0.5 to 1m total CP yield increased from 1.22 to 1.67 Mg ha^{-1}.Similarly, the leaf CP yield was observed higher for H2 (1.40 Mg ha^{-1}) than H1 (1.01 Mg ha^{-1}). Stem CP yield was also higher for H2 (0.27 Mg ha^{-1}) when compared to H 1(0.21 Mg ha^{-1}).

The interaction effects of plant density, pruning height and pruning frequency on CP content of harvested fodder was also found to be non-significant. Highest CP content (19.08 %) in fodder biomass of calliandra and CP yield (2.59 Mg ha^{-1} of coconut garden) was found in the treatment combination of D1H2F2 (27,777plants ha^{-1} + pruning height 1 m + pruning interval 12 weeks) (Table 9).

Table 8. Effect of plant density, pruning height and frequency on crude protein content and crude protein yield of calliandra fodder in coconut garden

Treatments	Crude protein content (%)			Crude protein yield (Mg ha^{-1})		
	Leaf	Stem	Total	Leaf	Stem	Total
Plant density (Main effect)						
27,777plants ha^{-1} (D1)	27.22	5.23	16.26^{a}	1.50^{a}	0.32^{a}	1.82^{a}
22,222plants ha^{-1} (D2)	27.09	5.00	16.06^{a}	1.17^{b}	0.23^{b}	1.40^{b}
17,777plants ha^{-1}(D3)	26.15	4.70	15.40^{b}	0.94^{c}	0.16^{c}	1.10^{c}
P value	0.308^{ns}	0.523^{ns}	0.001*	0.000**	0.000***	0.000***
Pruning frequency						
8 weeks (F1)	27.47^{a}	5.67	17.92^{a}	1.10	0.17^{b}	1.27^{b}
12 weeks (F2)	27.90^{a}	5.15	17.88^{a}	1.27	0.19^{b}	1.45^{a}
16 weeks (F3)	25.10^{b}	4.12	11.93^{b}	1.24	0.36^{a}	1.60^{a}
P value	0.001*	0.006^{ns}	0.000*	0.037^{ns}	0.000***	0.000***
Pruning height						
0.5 m (H1)	27.18	5.00	15.88	1.01^{b}	0.21^{b}	1.22^{b}
1.0 m (H2)	26.47	4.96	15.93	1.40^{a}	0.27^{a}	1.67^{a}
P value	0.254^{ns}	0.919^{ns}	0.800^{ns}	0.000**	0.000***	0.000***
D*F	0.976^{ns}	0.168^{ns}	0.000*	0.010^{ns}	0.000***	0.204^{ns}
D*H	0.894^{ns}	0.249^{ns}	0.000*	0.005^{ns}	0.003*	0.002*
F*H	0.845^{ns}	0.871^{ns}	0.702^{ns}	0.001**	0.044^{ns}	0.001**
D*F*H	0.809^{ns}	0.653^{ns}	0.011^{ns}	0.489^{ns}	0.248^{ns}	0.551^{ns}

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3-Pruning intervals of 8, 12 and 16weeks respectively

Table 9. Interaction effect of plant density, pruning height and frequency on crude protein content and crude protein yield of calliandra fodder in coconut garden

Treatments	Crude protein content (%)			Crude protein yield (Mg ha^{-1})		
	Leaf	Stem	Total	Leaf	Stem	Total
Density *Height*Frequency						
D1 H1F1	28.06	5.83	18.10	1.21	0.20	1.41
D2 H1F1	28.40	5.74	18.47	0.91	0.14	1.05
D3 H1F1	26.38	5.90	16.79	0.79	0.15	0.94
D1 H2F1	27.03	5.18	18.54	1.70	0.21	1.91
D2 H2F1	27.49	4.52	17.15	1.19	0.16	1.35
D3 H2F1	27.47	6.84	18.45	0.82	0.15	0.97
D1 H1F2	28.80	5.36	18.90	1.14	0.15	1.29
D2 H1F2	27.80	5.94	18.13	0.91	0.18	1.09
D3 H1F2	28.13	4.07	16.85	0.69	0.09	0.78
D1 H2F2	28.21	5.80	19.08	2.25	0.33	2.59
D2 H2F2	27.92	4.97	16.95	1.34	0.21	1.55
D3 H2F2	26.55	4.76	17.62	1.24	0.16	1.40
D1 H1F3	26.00	3.88	10.65	1.17	0.41	1.59
D2 H1F3	26.59	4.72	13.42	1.26	0.35	1.60
D3 H1F3	24.43	3.53	11.91	0.98	0.20	1.19
D1 H2F3	25.24	5.34	12.29	1.52	0.59	2.11
D2 H2F3	24.35	4.10	12.25	1.42	0.36	1.78
D3 H2F3	23.96	3.12	11.06	1.10	0.23	1.33
P value	0.809^{ns}	0.653^{ns}	0.011^{ns}	0.489^{ns}	0.248^{ns}	0.551^{ns}

ns= not significant at p>0.05

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3- Pruning intervals of 8, 12 and 16 weeks respectively.

4.4.2 Crude fibre (CF) content

Plant density had significant influence of CF content of stem and total fodder, whereas the leaf fraction did not show any prominent changes. CF percentage of stem and total fodder increased with decreasing plant density. CF content in total fodder was observed higher in D3 (40.53) when compared to D2 (39.43) and D1 (37.73).

Pruning frequency had a significant impact on the CF content of total fodder and various fractions. Shortest pruning interval of 8 weeks yielded fodder with lower CF content in stem (39.25%), leaf (19.83%) and total (28.33%) and highest CF was observed for longest cutting interval of 16 weeks.

Pruning height did not have any major effect on the CF content as such. Interaction effect of various management factors had prominent influence on the CF content of fodder biomass, wherein the effect of pruning interval showed more profound impact than other factors. All combinations with longer pruning intervals showed higher fiber content in forage compared to medium and shorter intervals (Table 11).

Table 10. Effect of plant density, pruning height and frequency on crude fibre content of calliandra fodder in coconut garden

Treatments	Crude fibre content (%)		
	Leaf	Stem	Total
Plant density (Main effect)			
27777 plants ha $^{-1}$(D1)	32.89	43.58^{c}	37.73^{c}
22,222 plants ha^{-1} (D2)	34.53	44.92^{b}	39.43^{b}
17,777 plants ha^{-1}(D3)	33.97	47.61^{a}	40.53^{a}
P value	0.228^{ns}	0.002**	0.004**
Pruning frequency			
8 weeks (F1)	19.83^{c}	39.25^{c}	28.33^{c}
12 weeks (F2)	35.11^{b}	44.75^{b}	39.37^{b}
16 weeks (F3)	46.44^{a}	52.11^{a}	49.99^{a}
P value	0.000***	0.000***	0.000***
Pruning height			
0.5 m (H1)	32.98	45.15	38.76
1.0 m (H2)	34.61	45.59	39.70
P value	0.043^{ns}	0.603^{ns}	0.087^{ns}
D*F	0.990^{ns}	0.462^{ns}	0.790^{ns}
D*H	0.047^{ns}	0.372^{ns}	0.043^{ns}
F*H	0.180^{ns}	0.321^{ns}	0.236^{ns}
D*F*H	0.104^{ns}	0.332^{ns}	0.206^{ns}

*** significant at p<0.001, ** significant at p<0.01, * significant at p<0.05, ns= not significant at p>0.05; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777; 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2 and F3 - Pruning intervals of 8, 12 and 16weeks respectively

Table 11. Interaction effect of plant density, pruning height and frequency on crude fibre content of calliandra fodder in coconut garden

Treatments	Crude fibre content (%)		
	Leaf	Stem	Total
Density *Height*Frequency			
D1 H1F1	19.00	39.50	28.00 [d]
D2 H1F1	19.50	38.00	27.68 [d]
D3 H1F1	19.00	42.33	29.70 [d]
D1 H2F1	19.17	36.67	26.21 [d]
D2 H2F1	22.00	39.00	29.62 [d]
D3 H2F1	20.33	40.00	28.79 [d]
D1 H1F2	32.33	40.00	35.51 [c]
D2 H1F2	33.00	46.00	39.06 [c]
D3 H1F2	34.67	46.33	40.16 [c]
D1 H2F2	35.67	45.83	39.80 [c]
D2 H2F2	38.33	44.83	41.41 [c]
D3 H2F2	36.67	45.50	40.26 [c]
D1 H1F3	43.33	48.50	46.89 [b]
D2 H1F3	46.00	49.83	48.36 [ab]
D3 H1F3	50.00	55.83	53.51 [a]
D1 H2F3	47.83	51.00	49.99 [ab]
D2 H2F3	48.33	51.83	50.44 [ab]
D3 H2F3	43.15	55.67	50.75 [ab]
P value	0.104 [ns]	0.206 [ns]	0.000***

*** significant at $p<0.001$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777; 22,222 and 17,777 plants ha^{-1}
H1 and H2 – Pruning heights of 0.5 and 1m
F1, F2and F3 – Pruning intervals of 8, 12 and 16 weeks respectively

64

4.4.3 Ash content

Plant density had a significant impact on the total ash content of calliandra (Table 12). High density D1 plants had higher ash content of (3.30 %), when compared to D2 (3.07 %) and D3 (3.12 %).

Pruning frequency had a significant impact on the ash content of total fodder as well as on leaf and stem fractions. Total ash content was observed to be highest for 16 weeks cutting interval (3.30 %) and decreased with reduction in cutting interval from 12 weeks (3.16 %) to 8 weeks (3.03 %). Ash content in leaves increased from 8 weeks (2.32 %) to 16 weeks (4.43 %) interval, whereas for stem fraction, ash content decreased with increasing cutting interval.

Pruning height had a significant impact on the ash content of total fodder, wherein higher values (3.25 %) were observed at lower pruning height than greater one. Interaction effect of various management factors had prominent influence on the CF content of fodder biomass, wherein all combinations with longer pruning intervals showed higher ash content in forage compared to medium and shorter intervals.

4.4.4 Dry matter content

Plant density had an influence on the total DM content. DM content was the highest for D1 (33.88 %) and lowest for D 3 (32.75 %)

65

Table 12. Effect of plant density, pruning height and frequency on ash content and total dry matter content of calliandra fodder in coconut garden

	Ash content (%)			DM content (%)		
Treatments	Leaf	Stem	Total	Leaf	Stem	Total
Plant density (Main effect)						
27777 plants ha^{-1}(D1)	3.47	3.41	3.30[a]	31.85	34.06	33.88[a]
22,222 plants ha^{-1} (D2)	3.24	3.07	3.07[b]	30.47	32.73	31.97[b]
17,777 plants ha^{-1}(D3)	3.26	3.19	3.12[b]	31.59	33.34	32.75[b]
P value	0.189[ns]	0.243[ns]	0.000***	0.170[ns]	0.038[ns]	0.002**
Pruning frequency						
8 weeks (F1)	2.32[c]	3.96[a]	3.03[a]	25.60[c]	28.33[b]	27.06[c]
12 weeks (F2)	3.21[b]	3.08[b]	3.16[b]	30.38[b]	28.38[b]	29.93[b]
16 weeks (F3)	4.43[a]	2.63[c]	3.30[a]	37.93[a]	43.42[a]	41.61[a]
P value	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Pruning height						
0.5 m (H1)	3.38	3.36	3.25[a]	30.63[b]	33.35	32.59
1.0 m (H2)	3.27	3.09	3.08[b]	31.97[a]	33.40	33.14
P value	0.316[ns]	0.117[ns]	0.000***	0.004**	0.893[ns]	0.208[ns]
D*F	0.851[ns]	0.342[ns]	0.197[ns]	0.000***	0.007[ns]	0.014[ns]
D*H	0.986[ns]	0.335[ns]	0.024[ns]	0.000***	0.036[ns]	0.253[ns]
F *H	0.683ns	0.445ns	0.224ns	0.823ns	0.280ns	0.797ns
D*F*H	0.851[ns]	0.966[ns]	0.161[ns]	0.000***	0.449[ns]	0.044[ns]

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, NS= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3 - Pruning intervals of 8, 12 and 16 weeks respectively

Table 13. Interaction effect of plant density, pruning height and frequency on ash content and total dry matter content of calliandra fodder in coconut garden

Treatments	Ash content (%)			Dry matter content (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Density *Height*Frequency						
D1 H1F1	2.40	4.53	3.30	26.68	30.76	28.75
D2 H1F1	2.27	3.93	3.03	22.66	25.55	24.26
D3 H1F1	2.33	4.13	3.16	25.96	30.00	27.95
D1 H2F1	2.53	4.07	3.13	29.89	28.12	29.53
D2 H2F1	2.20	3.20	2.66	23.45	27.58	25.35
D3 H2F1	2.20	3.87	2.90	24.93	27.95	26.51
D1 H1F2	3.60	3.20	3.43	31.42	28.34	30.45
D2 H1F2	3.00	3.53	3.24	31.21	28.41	30.65
D3 H1F2	3.13	3.00	3.05	26.82	27.74	27.68
D1 H2F2	3.27	2.87	3.11	33.61	27.63	31.18
D2 H2F2	3.07	3.00	3.08	26.76	29.89	28.84
D3 H2F2	3.20	2.87	3.06	32.48	28.26	30.80
D1 H1F3	4.60	3.00	3.49	29.56	44.87	40.36
D2 H1F3	4.60	2.53	3.37	40.79	42.05	41.55
D3 H1F3	4.47	2.33	3.17	40.60	42.40	41.69
D1 H2F3	4.40	2.80	3.35	39.91	44.62	43.00
D2 H2F3	4.33	2.20	3.03	37.95	42.91	41.17
D3 H2F3	4.20	2.93	3.41	38.77	43.67	41.86
P value	0.856^{ns}	0.966^{ns}	0.161^{ns}	0.473^{ns}	0.269^{ns}	0.044^{ns}

ns= not significant at p>0.05; values with the same superscripts in a column do not differ significantly

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3 - Pruning intervals of 8, 12 and 16weeks respectively.

4.4.5. Nitrogen content

There was significant difference in total N content with varying plant density. Total N content decreased from D1 (2.60 %) to D2 (2.57%) to D3 (2.47%). Pruning frequency had significant impact on the N content of leaf and total fodder. Leaf N percentage was higher for 12 weeks (4.47%), whereas N content in total fodder was observed to be higher for 8 weeks cutting interval (2.87%). Pruning height did not have any significant impact on the N percentage.

4.4.6. Phosphorus Content

Phosphorus content in fodder was significantly influenced by plant density. In general P content decreased when density increased. It was highest for D1 (leaf: 0.25%, stem 0.20%:, total: 0.23%) and lowest for D3 (leaf: 0.14%, stem 0.09%:, total: 0.12%).

Pruning frequency, pruning height and various treatment combinations had no significant impact on the phosphorus content of fodder.

Table 14. Effect of plant density, pruning height and frequency on nitrogen and phosphorus content of calliandra fodder in coconut garden

Treatments	Total N (%)			Total P (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Plant density (Main effect)						
27,222 plants ha^{-1} (D1)	4.36	0.84	2.60^{a}	0.25^{a}	0.20^{a}	0.23^{a}
22,222 plants ha^{-1} (D2)	4.33	0.80	2.57^{a}	0.18^{b}	0.13^{b}	0.15^{b}
17,777 plants ha^{-1}(D3)	4.18	0.76	2.47^{b}	0.14^{c}	0.09^{c}	0.12^{c}
P value	0.306^{ns}	0.545^{ns}	0.001**	0.000***	0.000***	0.000***
Pruning frequency						
8 weeks (F1)	4.40^{a}	0.91	2.87^{a}	0.20^{a}	0.13	0.17^{a}
12 weeks (F2)	4.47^{a}	0.83	2.86^{a}	0.19^{ab}	0.15	0.17^{a}
16 weeks (F3)	4.01^{b}	0.66	1.91^{b}	0.18^{b}	0.14	0.16^{b}
P value	0.001**	0.006^{ns}	0.000***	0.029^{ns}	0.310^{ns}	0.000***
Pruning height						
0.5 m (H1)	4.35	0.80	2.54	0.19	0.14	0.17
1.0 m (H2)	4.23	0.80	2.55	1.19	0.14	0.17
P value	0.249^{ns}	0.941^{ns}	0.786^{nns}	0.547^{ns}	0.240^{ns}	0.719^{ns}
D*F	0.977^{ns}	0.178^{ns}	0.000***	0.579^{ns}	0.206^{ns}	0.000***
D*H	0.882^{ns}	0.234^{ns}	0.000***	0.576^{ns}	0.905^{ns}	0.000***
F*H	0.827^{ns}	0.870^{ns}	0.674^{ns}	0.538^{ns}	0.350^{ns}	0.001**
D*F*H	0.795^{ns}	0.644^{ns}	0.010^{ns}	0.490^{ns}	0.900^{ns}	0.003**

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3-Pruning intervals of 8, 12 and 16 weeks respectively

Table 15. Interaction effect of plant density, pruning height and frequency on nitrogen and phosphorus content of calliandra fodder in coconut garden

Treatments	Total N (%)			Total P (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Density *Height*Frequency						
D1 H1F1	4.49	0.93	2.90	0.26	0.19	0.23^{a}
D2 H1F1	4.54	0.92	2.96	0.18	0.10	0.15^{bc}
D3 H1F1	4.22	0.94	2.69	0.14	0.10	0.12^{cd}
D1 H2F1	4.33	0.83	2.97	0.26	0.19	0.24^{a}
D2 H2F1	4.40	0.72	2.75	0.18	0.11	0.15^{bc}
D3 H2F1	4.40	1.10	2.95	0.16	0.10	0.13^{cd}
D1 H1F2	4.61	0.85	3.02	0.25	0.22	0.24^{a}
D2 H1F2	4.45	0.95	2.90	0.17	0.15	0.16^{b}
D3 H1F2	4.50	0.65	2.65	0.14	0.11	0.12^{cd}
D1 H2F2	4.51	0.93	3.05	0.26	0.20	0.24^{a}
D2 H2F2	4.47	0.79	2.71	0.18	0.12	0.15^{bc}
D3 H2F2	4.25	0.77	2.82	0.13	0.08	0.11^{d}
D1 H1F3	4.16	0.62	1.70	0.23	0.19	0.20^{ab}
D2 H1F3	4.25	0.76	2.15	0.18	0.15	0.16^{b}
D3 H1F3	3.91	0.57	1.91	0.14	0.09	0.11^{d}
D1 H2F3	4.04	0.86	1.97	0.25	0.20	0.22^{a}
D2 H2F3	3.88	0.66	1.95	0.17	0.14	0.15^{bc}
D3 H2F3	3.83	0.50	1.77	0.12	0.08	0.10^{d}
P value	0.798^{ns}	0.644^{ns}	0.010^{ns}	0.490^{ns}	0.900^{ns}	0.003**

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, NS= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777; 22,222 and 17,777 plants ha^{-1}
H1 and H2 – Pruning heights of 0.5 and 1m
F1, F2and F3 - Pruning intervals of 8, 12 and 16 weeks respectively

4.4.7. Potassium content

Planting density had significant impact on the K content of total fodder. K content was observed higher for D2 (0.99 %) and lower for D3(0.92%). Pruning frequency also had significant impact on K content wherein higher values (1.00 %) were observed for shorter pruning intervals than longer one of 16 weeks (0.92 %). Pruning height did not have any impact on the K content of fodder. Comparing interaction effects significantly higher potassium content was observed in all treatment combinations with shorter pruning intervals, than rest of the combinations.

Table 16. Effect of plant density, pruning height and frequency on potassium content of calliandra fodder in coconut garden

Treatments	Potassium content (%)		
	Leaf	Stem	Total
Plant density (Main effect)			
27777 plants ha $^{-1}$(D1)	0.99	0.95	0.97[a]
22,222 plants ha^{-1} (D2)	1.04	0.95	0.99[a]
17,777 plants ha^{-1}(D3)	0.96	0.88	0.92[b]
P value	0.303[ns]	0.422[ns]	0.000***
Pruning frequency			
8 weeks (F1)	0.99	1.02	1.00[a]
12 weeks (F2)	1.02	0.88	0.95[b]
16 weeks (F3)	0.98	0.89	0.92[b]
P value	0.806[ns]	0.044[ns]	0.000***
Pruning height			
0.5 m (H1)	1.02	0.92	0.96
1.0 m (H2)	0.98	0.93	0.96
P value	0.310[ns]	0.840[ns]	0.966[ns]
D*F	0.338[ns]	0.999[ns]	0.007[ns]
D*H	0.385[ns]	0.145[ns]	0.062[ns]
F*H	0.450[ns]	0.012[ns]	0.000***
D*F*H	0.805[ns]	0.598[ns]	0.004*

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777; 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3 - Pruning intervals of 8, 12 and 16 weeks respectively.

Table 17. Interaction effect of plant density, pruning height and frequency on potassium content of calliandra fodder in coconut garden

Treatments	Potassium content (%)		
	Leaf	Stem	Total
Density *Height*Frequency			
D1 H1F1	0.93	1.03	0.98^{bc}
D2 H1F1	0.95	1.04	0.98^{bc}
D3 H1F1	1.04	0.93	0.98^{bc}
D1 H2F1	1.06	1.04	1.05^{ab}
D2 H2F1	0.98	1.02	1.00^{ab}
D3 H2F1	0.98	1.04	1.01^{ab}
D1 H1F2	1.03	1.04	1.04^{ab}
D2 H1F2	1.10	1.07	1.09^{a}
D3 H1F2	1.04	0.80	0.92^{c}
D1 H2F2	0.90	0.75	0.84^{d}
D2 H2F2	1.08	0.74	0.93^{c}
D3 H2F2	0.94	0.84	0.90^{c}
D1 H1F3	0.98	0.93	0.94^{bc}
D2 H1F3	1.10	0.75	0.89^{c}
D3 H1F3	0.97	0.70	0.82^{d}
D1 H2F3	1.03	0.92	0.96^{bc}
D2 H2F3	1.02	1.05	1.04^{ab}
D3 H2F3	0.80	0.97	0.91^{bc}
P value	0.805^{ns}	0.598^{ns}	0.004*

*** significant at $p<0.001$, ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}
H1 and H2 – Pruning heights of 0.5 and 1m
F1, F2and F3-Pruning intervals of 8, 12 and 16 weeks respectively

4.4.7. Economics

Economics and B:C ratio of coconut – calliandra system under various management practices of calliandra are shown in Table18. Comparing plant densities, the net returns (Rs. 1,49,734) and B:C ratio (1.74) was maximum from high density stand D1 and significantly superior to D2 and D3.

Pruning frequency also had significant effect on B:C ratio, with higher values for the longest pruning interval of 16 weeks (1.78) and was comparatively higher that medium and shorter pruning intervals, which in turn were on par.

In case of pruning heights, taller stocks with a pruning height of 1m yielded maximum net returns and B:C ratio than shorter ones.

Comparing the economics of various treatment combinations (Table 19), the maximum net returns (Rs.2,08,173) and B:C ratio (2.03) from coconut-calliandra system was obtained from D1H2F2 (27,777 plants ha^{-1}, 1m pruning height and 12 weeks pruning interval), when compared to all other treatment combinations.

Table 18. Economics of calliandra –coconut fodder production system as influenced by plant density, pruning height and pruning frequency

Treatments	Net returns from calliandra – coconut fodder production system (Rs.)	B:C ratio of calliandra – coconut fodder production system
Plant density (Main effect)		
27777 plants ha^{-1}(D1)	1,49,734	1.74
22,222 plants ha^{-1}(D2)	1,19,456	1.63
17,777 plants ha^{-1}(D3)	88,752	1.49
P value	0.000***	0.005**
Pruning frequency		
8 weeks (F1)	1,00,323	1.51
12 weeks (F2)	1,07,623	1.56
16 weeks (F3)	1,49,952	1.78
P value	0.000***	0.001**
Pruning height		
0.5 m (H1)	92,432	1.48
1.0 m (H2)	1,46,105	1.76
P value	0.001	0.000
D*F	0.959^{ns}	0.974^{ns}
D*H	$.419^{ns}$	0.530^{ns}
F*H	.037*	0.038*
D*F*H	0.517^{ns}	0.582^{ns}

*** significant at p<0.001, ** significant at p<0.01, * significant at p<0.05, ns= not significant at p>0.05; values with the same superscripts in a column do not differ significantly.

D1, D2 and D3 – Tree density of 27,777; 22,222 and 17,777 plants ha^{-1}

H1 and H2 – Pruning heights of 0.5 and 1m

F1, F2and F3 - Pruning intervals of 8, 12 and 16 weeks respectively

Table 19. Economics of coconut –calliandra fodder productions system as influenced by various treatment combinations

Treatment combinations	Total cost of fodder production (Rs. $ha^{-1}yr^{-1}$)	Returns from fodder (Rs. $ha^{-1}yr^{-1}$)	Cost of harvesting coconuts (Rs. ha^{-1} yr^{-1})	Returns from coconuts (Rs. ha^{-1} yr^{-1})	Total returns from coconut-fodder production system (Rs. ha^{-1} yr^{-1})	Net returns from coconut-fodder integrated system (Rs. ha^{-1} yr^{-1})	B:C ratio of coconut-fodder integrated system
D1 H1F1	181814	195239	25950	110720	305959	98195	1.47
D2 H1F1	169202	165569	25950	110720	276289	81137	1.42
D3 H1F1	158286	141262	25950	110720	251982	67746	1.37
D1 H2F1	181813	248302	25950	110720	359022	151258	1.73
D2 H2F1	169201	218645	25950	110720	329365	134213	1.69
D3 H2F1	158286	142716	25950	110720	253436	69200	1.38
D1 H1F2	177118	161761	25950	110720	272481	69413	1.34
D2 H1F2	164506	141632	25950	110720	252352	61895	1.32
D3 H1F2	153591	117760	25950	110720	228480	48939	1.27
D1 H2F2	177118	300522	25950	110720	411242	208173	2.03
D2 H2F2	164506	224270	25950	110720	334990	144533	1.76
D3 H2F2	153591	181644	25950	110720	292364	112823	1.63
D1 H1F3	174771	270332	25950	110720	381052	180330	1.90
D2 H1F3	162159	202382	25950	110720	313102	124993	1.66
D3 H1F3	151243	165700	25950	110720	276420	99226	1.56
D1 H2F3	174771	280752	25950	110720	391472	190750	1.95
D2 H2F3	162159	247227	25950	110720	357947	169838	1.90
D3 H2F3	151243	201026	25950	110720	311746	134552	1.76
P value						ns	ns

D1, D2 and D3 – Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}
H1 and H2 – Pruning heights of 0.5 and 1m
F1, F2and F3-Pruning intervals of 8, 12 and 16 weeks respectively

DISCUSSION

DISCUSSION

The performance of calliandra hedge rows subjected to varying levels of plant density, pruning height and pruning frequencies underneath coconut garden was evaluated and the salient results are discussed below.

5.1 GROWTH PARAMETERS OF CALLIANDRA UNDER VARYING PLANT DENSITIES AT INITIAL UNIFORM CUT

The data given in Table 1 shows that plant density had no significant effect ($p>0.05$) on the plant height, collar diameter and number of branches of calliandra at the stage of initial uniform cut. This can be attributed to the early growth stage of the crop, where plants are not fully grown and developed, and exhibit minimum competition for growth factors such as space, light, water and nutrients. Hence, the differential effect of plant spacing was not properly manifested at early stages of growth. Similar findings were reported by Gadzirayi *et al.* (2013) in moringa where plant densities had no significant effect on early growth. Walker (2007) also observed no significant effect of plant density on crown diameter of four fodder tree species in eastern Botswana.

5.2 INFLUENCE OF PLANT DENSITY, PRUNING HEIGHT AND PRUNING FREQUENCY ON COPPICE PARAMETERS OF CALLIANDRA IN COCONUT GARDEN.

The results in Table 2 indicated that the coppice parameters of calliandra like length of coppices, number of coppices and leaf-stem ratio had no significant variation across different planting densities. Since the plants are in early growth phase the competition for recourses might not have started to give any significant differences in coppice parameters across densities. Similar reports were also given by Tipu *et al.* (2006), wherein plant spacing had no effect on early establishment and growth of *Moringa* plant.

However, pruning frequency showed profound influence on all the coppice parameters. Coppice length was significantly higher (216.98 cm) at the prolonged cutting interval of 16 weeks, followed by the medium interval of 12 weeks. However, the leaf-stem ratio was significantly higher and more than double at 8 and 12 weeks interval (1.46 and 1.23 respectively) than the longest one (0.69). Thus the results indicated that even though the coppice length was higher in 16 weeks pruned plants, majority of the shoots consisted of stem portions which is non edible. Leaf fraction of coppices was higher in shorter pruning intervals which constitutes the edible portion. The number of coppices was significantly higher at medium pruning interval of 12 weeks, followed by shorter interval of 8 weeks; whereas the longest interval produced the least number of coppices. This could be correlated to the rainfall pattern and time of harvest. Most of the harvests of 12 weeks interval coincided with the period of ample rains that stimulated rapid regrowth of more sprouts whereas in case of longer intervals some of the harvests were done during dry period that slowed down the regrowth and reduced the number of sprouts. Even though most of the harvests of 8 weeks interval also coincided with the rains, number of sprouts were comparatively lower than 12 weeks, which could be due to more frequent harvests at shorter intervals which reduced the photosynthesis and nutrient accumulation in plants to trigger further regrowth.

Pruning height showed significant influence on leaf-stem ratio and number of coppices, whereas coppice length showed only marginal variation. Leaf-stem ratio (1.14) and number of coppices (4.43) were significantly higher in stocks with higher pruning heights of 1m than the lower height of 0.5m (1.12, 3.17 respectively). This could be due to more carbohydrate nutrient reserve in taller stocks of calliandra that resulted in faster growth of young shoots and higher number of coppices. The above results are in conformity with Tipu *et al.* (2006) who reported higher number of branches, length of branches and leaves per plant in leucaena at higher pruning heights of 100 cm than those of the lower heights.

Interaction effect of three management regimes showed significant influence on the coppice length and leaf-stem ratio, whereas coppice number showed marginal variation only (Table 3). All treatment combinations with longer pruning interval of 16 weeks had better coppice length, but leaf-stem ratio, which indicates the edible forage fraction, was significantly lower at prolonged harvest interval. On the other hand, all combinations with shorter harvest interval (8 weeks) had better leaf-stem ratio in the coppices, but the forage yield was significantly lower. Better coppice length (153.31 cm) with more leaf fraction (1.47) was observed in the combination of D1H2F2 (27,777 plants ha^{-1}, pruning height 1.0 m and pruning interval 12weeks), where as rest of the combinations produced either smaller coppices or coppices with more stem fraction.

5.3. INFLUENCE OF PLANT DENSITY, PRUNING HEIGHT AND FREQUENCY ON SURVIVAL PERCENTAGE OF CALLIANDRA IN COCONUT GARDEN.

The results indicated in Table 4 and 5 reveals that the management factors like plant density, pruning height and frequency had no significant influence on survival percentage of trees at the end of the experimental year. Almost 98 percent of the trees survived irrespective of the treatments. The minor casualties in the stands were mainly attributed to the falling of coconut fronds that destroyed the young seedlings, rather than the treatment effects.

5.4. INFLUENCE OF PLANT DENSITY, PRUNING HEIGHT AND FREQUENCY ON FORAGE YIELD AND NUTRITIVE VALUE OF CALLIANDRA IN COCONUT GARDEN.

5.4.1 Plant density

The data shown in Table 4 indicates the significant influence of plant density ($p<0.001$) on forage yields of calliandra. Maximum annual fresh forage yield of 34.69 Mg per hectare of coconut garden was obtained from the highest density stand(Fig3). An increase of 53 percent in fresh yield was noticed with increment in plant density from 17,777 to 27,777 plants ha^{-1}. The highest dry forage yield (11.73 Mg ha^{-1}yr^{-1}) was also obtained from the highest density stand (D1), which was 20 and 55 % higher than D2 and D3 (Table 6, Fig.4), thereby indicating a need for closer planting of fodder trees for maximizing productivity and optimum utilization of resources in land limited areas. Similar findings of higher yields from higher tree densities for *Leucaena spp., Gliricidia spp., Calliandra spp.* and *Sesbania spp.*, has been reported by Ella *et al.* (1989). However, Raj (2016) reported the maximum yields from mulberry and subabul at still higher density of 49,382 plant ha^{-1}, when planted as an intercrop in coconut garden. According to Turgut *et al.* (2005) the increase in yield with narrow spacing, particularly at high populations, can be explained by greater solar energy interception.

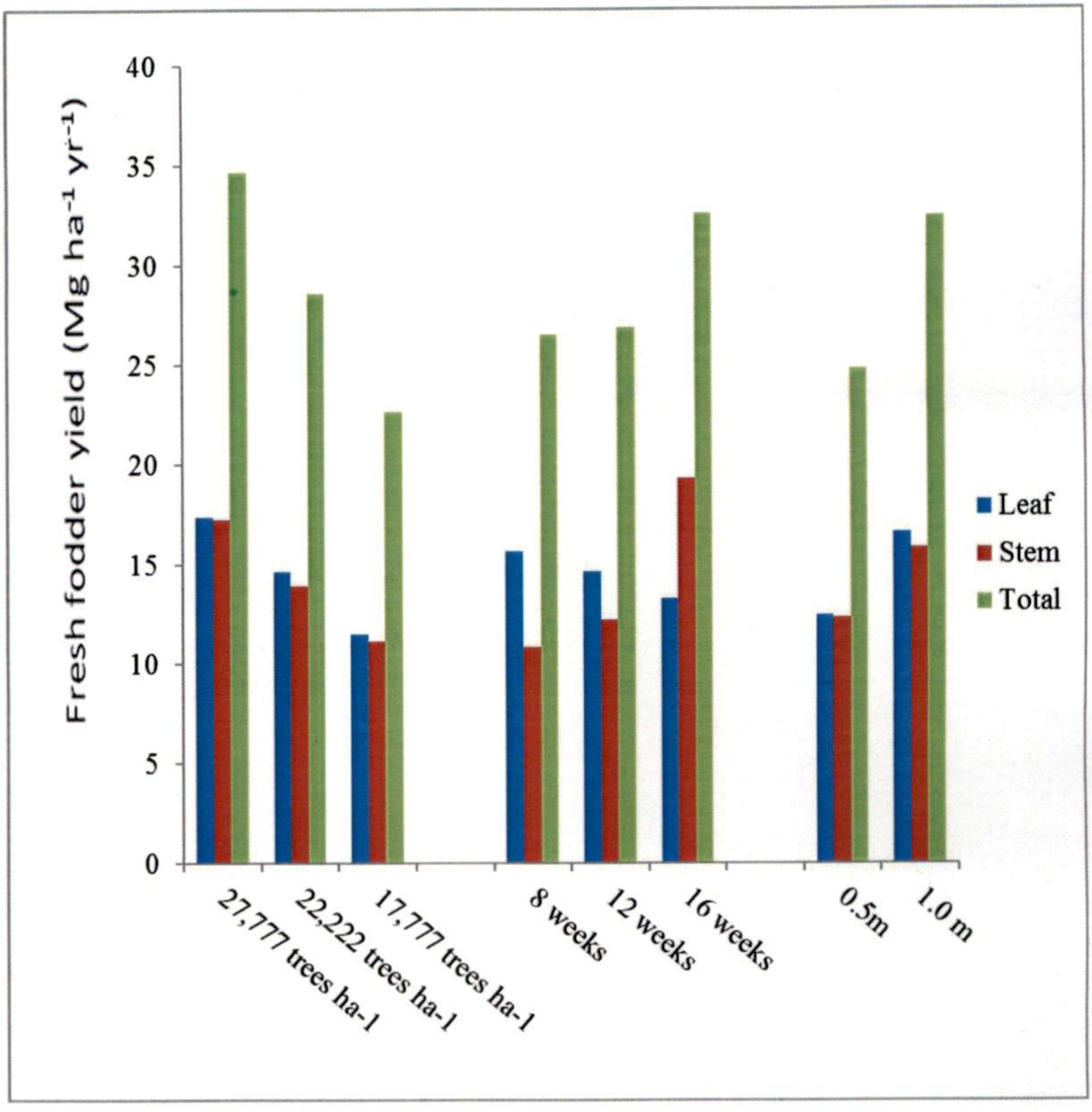

Fig . 3 Fresh fodder yield of calliandra as influenced by plant density, pruning frequency and pruning height in coconut garden.

82

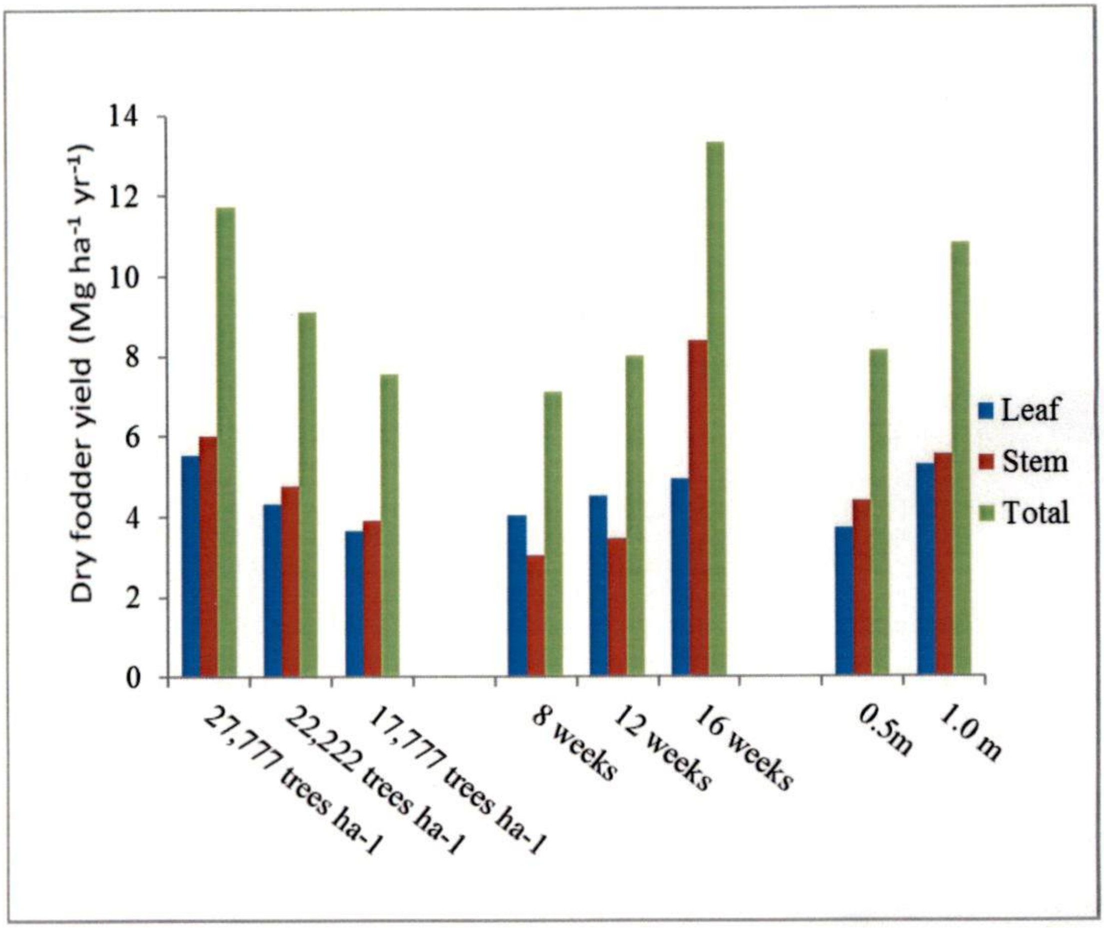

Fig .4 Dry fodder yield of calliandra as influenced by plant density, pruning frequency and pruning height in coconut garden.

Plant density also had a positive impact on foliage and stem fractions which showed an increasing trend with increasing density. The highest density stand yielded more leaf dry matter yield (5.53 Mg ha^{-1}) than the lowest one (3.64 Mg ha^{-1}), which implies the need for closer planting of trees for yielding maximum nutritive herbage per unit area (Table 6). Raj (2016) reported higher dry foliage yields (7.14 Mg ha^{-1}) from mulberry and subabul trees at highest plant density (49,382 trees ha^{-1}) than that of lowest plant density (27,777 trees ha^{-1}). Similarly, Ella (1989) reported that, for *Leucaena, Gliricidia, Calliandra* and *Sesbania,* leaf yield per unit area increased with increasing planting density. Stem fractions also showed similar trends. Despite yield differences, leaf- stem ratio showed only a marginal variation in response to tree density, with a slight increment towards the highest density (Fig.5).

Plant density significantly influenced some of the nutritive parameters of calliandra forage. Total crude protein (CP) content in fodder increased significantly from 15.40 to 16.26 percent from lower to higher density classes (Fig 6). Similar trend was also noticed leaf and stem fractions, even though the differences were marginal. In general, foliage fraction had higher CP content (26-27%) than stem fraction (4-5%). Overall CP yield (1.82 Mg ha^{-1}) and yield from foliage and stem fractions was also significantly higher in the highest density stand (Fig 7). Similar results of higher CP content in mulberry and subabul fodder at higher planting densities has been reported by Raj (2016). However, plant density had greater influence on CF content, which declined from 40.53 to 37.73 at higher densities indicating closer spacing for production of tender fodder (Fig. 8). Similar results of elevated CP % and lower CF % at higher population density in *Sesbania aegyptica* has been reported by El- Morsey (2009) and in mulberry and subabul by Raj (2016).

The overall ash (3.30%) and dry matter content (33.88%) of fodder showed significant increment at higher density than lower levels (Fig. 9, 10). The variation in leaf and stem fractions were not significant. The nitrogen (2.60 %) and phosphorus content (0.23 %) in total fodder and in leaf and stem fractions was appreciably higher in high density stands (Fig. 11 & 12). Potassium content was found to be higher in medium density (0.99%) followed by higher density (0.97 %), where as the value was lower in widely spaced stands (Fig.13). In general, an overall improvement in nutritive value of fodder was observed when trees are planted at closer spacing with higher densities. This could be attributed to the fact that in closely spaced stands the loss of nutrients from the soil is much lower due to closed canopy and limited exposure of soil to erosion, thereby enhancing the nutrient retention and uptake of nutrients by the plants.). The above resultls are in conformity with the findings of Raj (2016) in mulberry and subabul. Bhardwaj *et al.* (2001) also reported that the nutrient accumulation in the biomass increases at higher densities than lower levels.

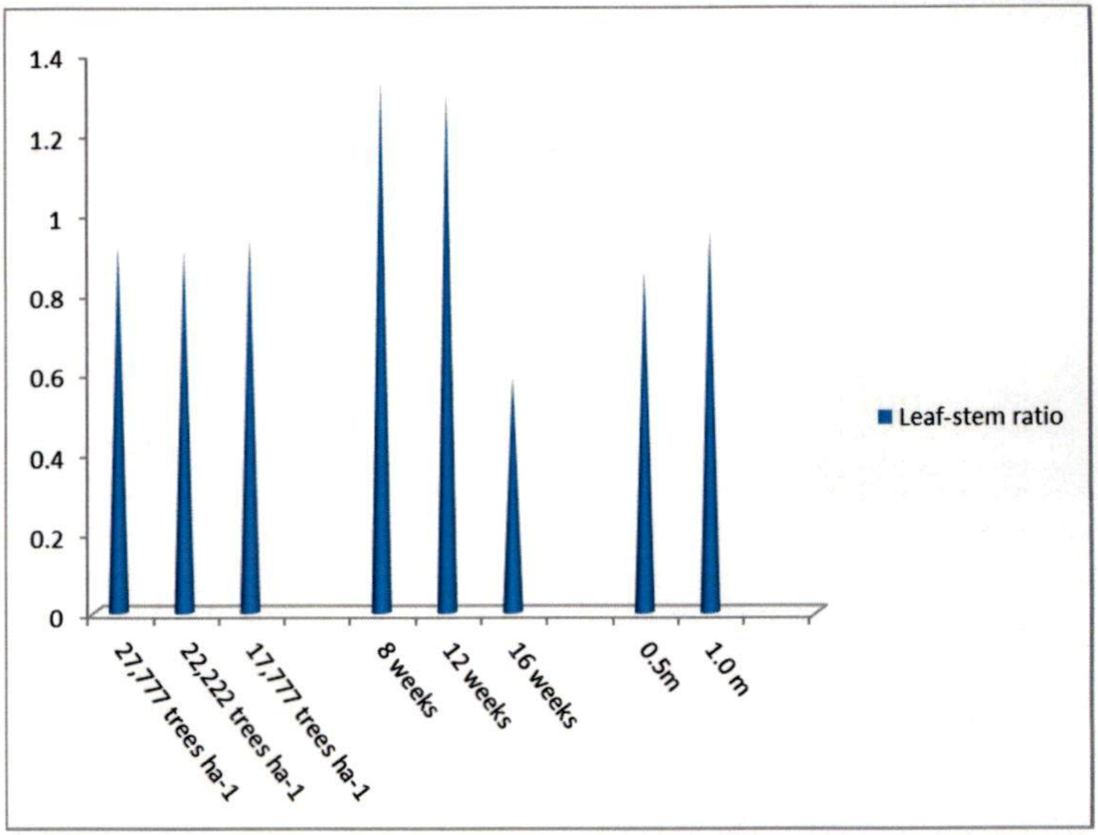

Fig .5 Leaf-stem ratio of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

85

5.4.2 Pruning frequency

Several studies on different fodder trees indicated that pruning frequency is a critical management factor that influences forage yield and quality as well as sustainable production. Our results also confirm the earlier findings (Fig.3). In calliandra pruning at the prolonged interval of 16 weeks yielded more total forage (32.56 Mg ha^{-1}), but the majority of the fodder comprised of stem fraction. In comparison, harvesting at shorter intervals of 8 and 12 weeks yielded around 26 Mg of fodder, a significant portion of which was comprised of foliage fraction (15.65 Mg ha^{-1}). Dry fodder yield also showed similar trends (Fig.4). Leaf –stem ratio of fodder harvested at 8 and 12 weeks showed an increment of 125 percent over that of the 16 weeks interval, indicating more foliage production than stem fractions when harvested at shorter intervals. Many studies also indicate that, while total forage yield continues to increase with longer harvest intervals, the additional yield beyond a certain interval consists mainly of woody stem eg., Ella *et al.,* 1989. Saddul *et al.* (2004) observed that increasing intervals between harvests significantly increased the fresh and DM yields of all plant fractions, although there was a predominance of the stem with advancing maturity. Raj (2016) also obtained higher foliage yield from mulberry and subabul by pruning at shorter interval of 8 weeks than at higher intervals. In Karnataka, Basavaraju and Rao (1996) obtained maximum herbage yields from calliandra at cutting interval of 60 days compared to higher intervals.

Pruning frequencies had profound influence on nutritive value of the forage. Harvesting at shorter and medium pruning interval of 8 and 12 weeks yielded fodder with maximum CP content (17.92 and 17.88 %) when compared to longer interval (11.93%) of 16 weeks (Fig 6). The overall CP yield and the yield from stem fraction was found to be higher in 16 weeks interval, but the CP yield from edible foliage fraction was found to be highest in 12 weeks interval (Fig.7). This could be due to the higher foliage content and tender shoots in fodder harvested at shorter interval coupled with higher CP content in the leaf fraction. Raj (2016) also reported similar findings in mulberry and subabul. Guevarra (1976) observed that an increase in harvest interval enhances dry matter yield, but reduces fodder quality because of the reduction in nitrogen content of foliage and high proportion of in-edible stem fraction. Islam *et al.* (1994) reported that young shoots contain high crude protein (CP).

Pruning intervals had more prominent influence on crude fibre content of the forage wherein the values declined sharply from 49.99 to 28.33 with the reduction in interval from 16 to 8 weeks (Fig.8). Similar results were reported by Raj (2016) in subabul and mulberry. Kaitho *et al.* (1993) also observed that the nutritive value of calliandra fodder declined when cutting interval increased from 12 to 28 weeks. The young leaves are generally high quality, but the quality decreases faster than in the leaves at longer pruning intervals, because epidermis and fibrous cells change into secondary walls, and lignin content increases with increased age of the plant (Saavedra *et al.*, 1987; Miquilena *et al.*, 1995).

Ash content (3.30) and dry matter content (41.61) was significantly higher at longest interval of 16 weeks, than shorter intervals (Fig.9 & 10). Total nitrogen, phosphorus and potassium content of the fodder was significantly higher at shorter intervals of 8 and 12 weeks than that of 16 weeks. In general, nutritive value of fodder was adversely affected at prolonged harvest intervals.

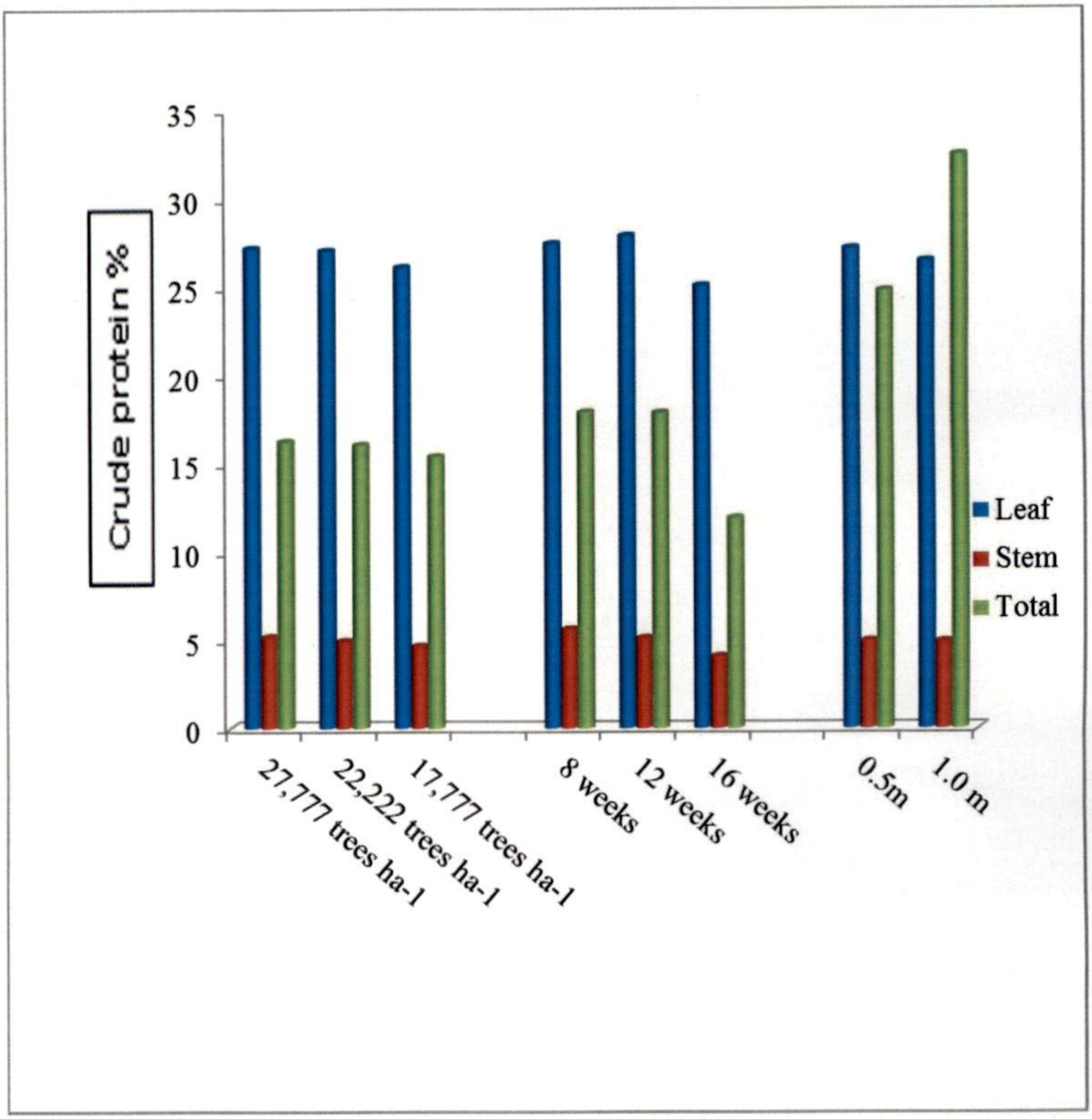

Fig .6 Crude protein content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

88

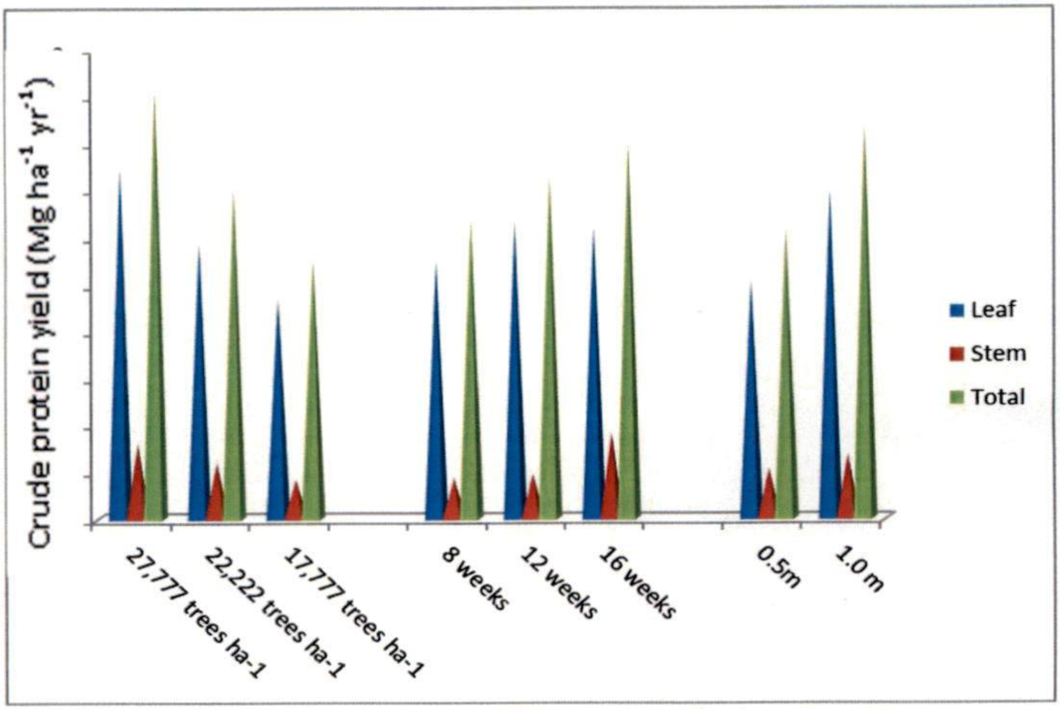

Fig .7 Crude protein yield of calliandra as influenced by plant density, pruning frequency and pruning height in coconut garden.

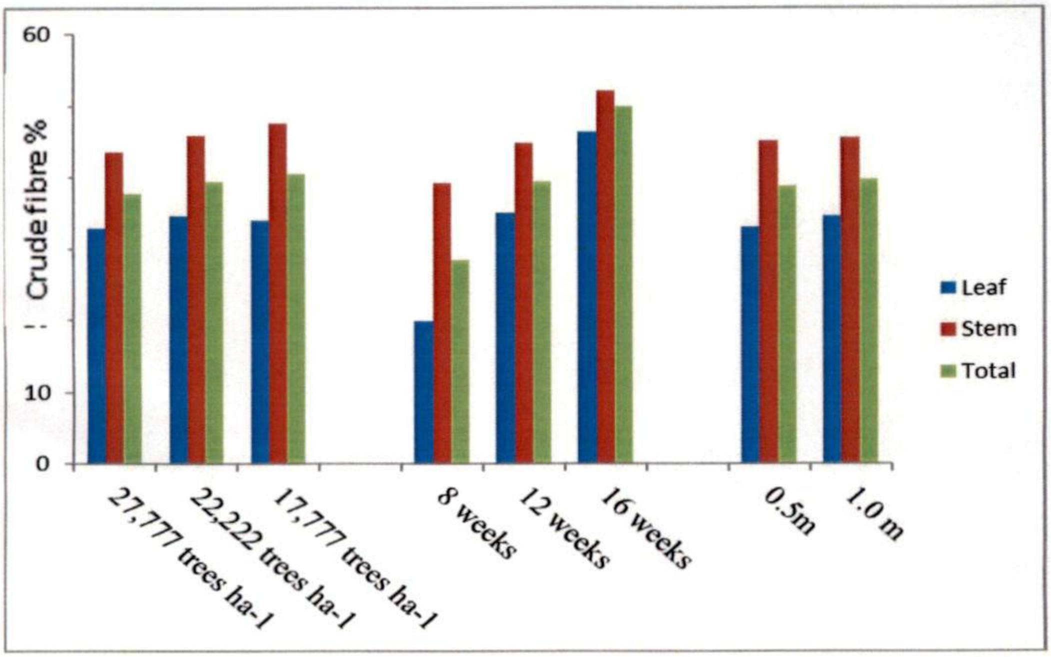

Fig .8 Crude fibre content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

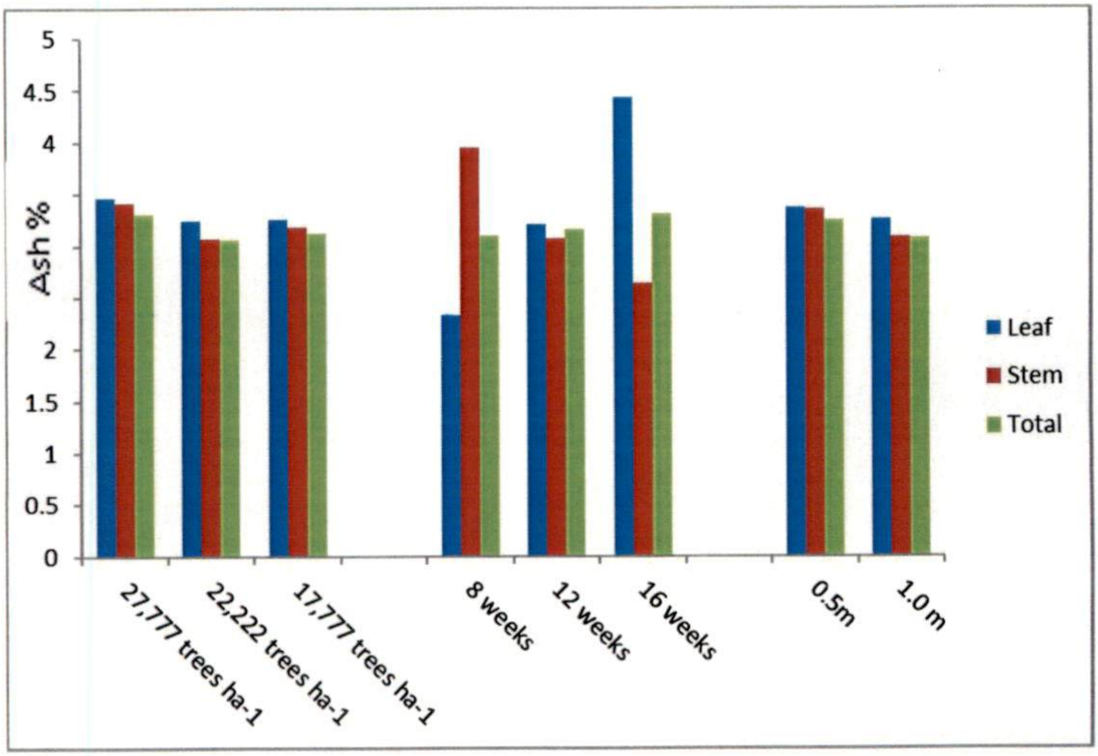

Fig .9 Ash content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

5.4.3 Pruning height

Pruning height showed significant influence on fodder yield. Fresh and dry forage yields increased by 7.68 and 2.7 Mg ha^{-1} respectively, from 0.5m to 1m pruning height (Fig.3 & 4)). The increment in forage yields with increasing pruning height was possibly due to more reserve food materials in taller stocks that promoted vigorous and rapid regrowth. It was also observed that lower pruning heights reduced the ability of the plants to withstand water stress conditions, causing drying of stems and poor regeneration, which in turn affect tree longevity in the long run. Basavaraju and Rao (1996) from Karnataka also confirmed the requirement of 1m cutting height for getting maximum yield from calliandra when compared to lower levels. Similarly, Tipu *et al.* (2006) obtained higher fodder yield from subabul when pruned at 100 cm height than 50 cm.

Similarly, taller stocks produced more foliage and less stem resulting in a higher leaf-stem ratio of about 12 percent over the lower ones (Fig.5). Increasing cutting height retain more leaves in the stump with greater available food reserves, which may lead to a shorter lag phase for new growth. Isarasenee *et al.* (1984) reported enhanced growth of leucaena cut at 120 cm compared with 60 or 30 cm. They further suggested that early regrowth was supported by movement of food reserves from stem rather than from current photosynthesis.

Even though pruning height showed pertinent effects on forage yields, most of nutritive parameters of the forage except CP content were quite unaffected by the height of pruning. Crude protein content of fodder showed marginal increment at higher pruning height but there was a significant improvement in CP yield from taller stocks (1.60 Mg ha^{-1}) when compared to shorter ones (1.27 Mg ha^{-1}) (Fig.7). This could be attributed to the higher forage yields from taller stocks coupled with the high CP content.

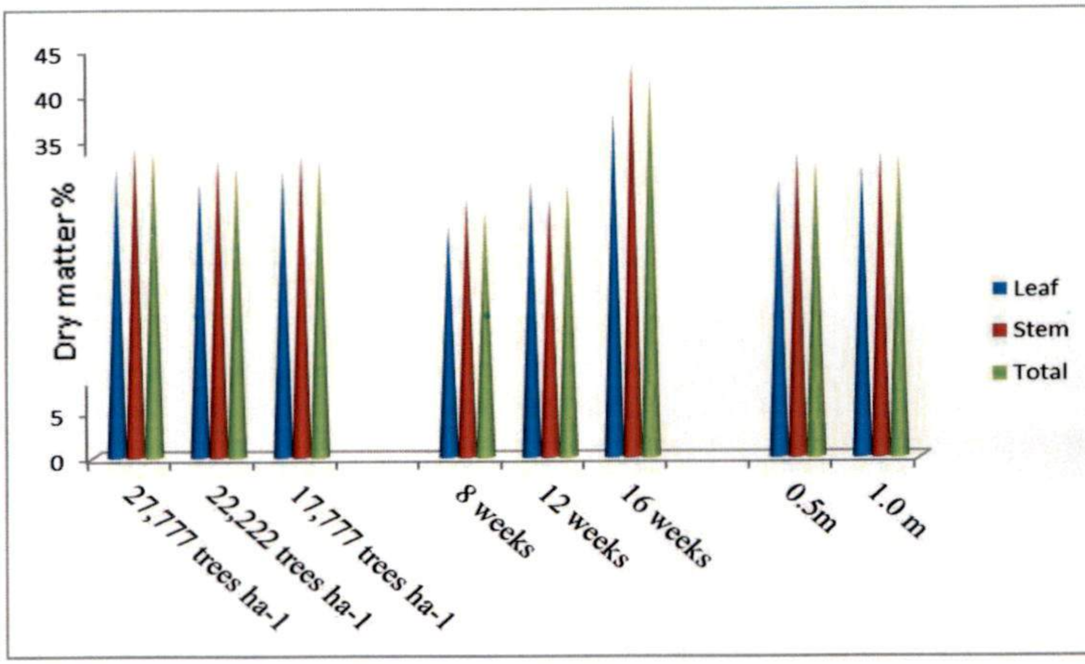

Fig .10 Dry matter content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

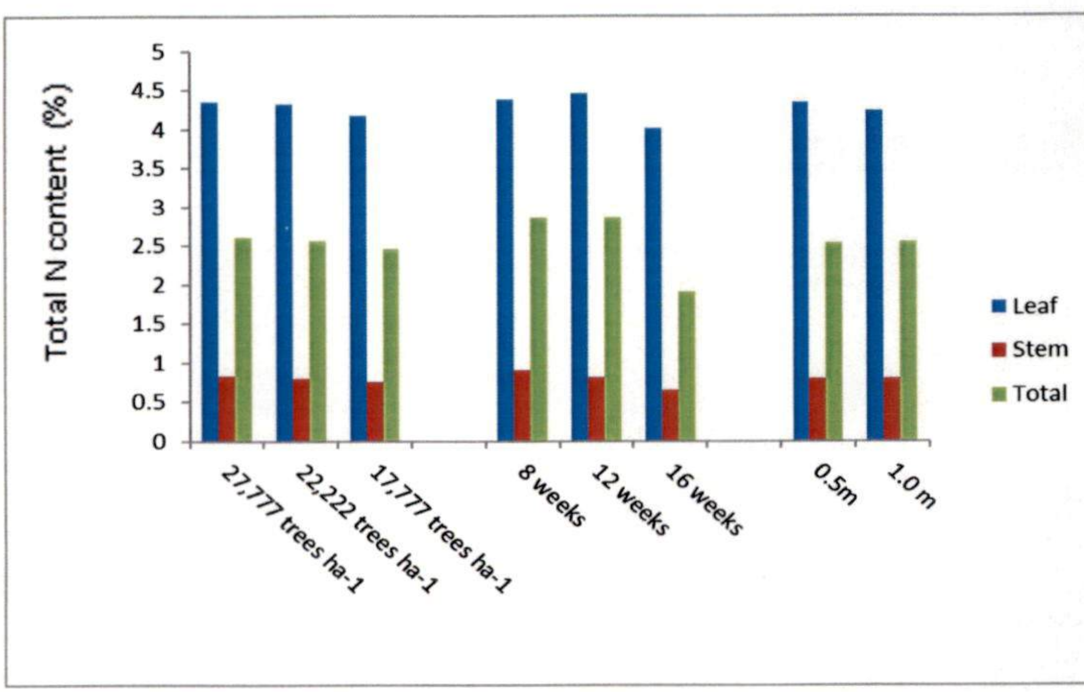

Fig .11 Total nitrogen content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

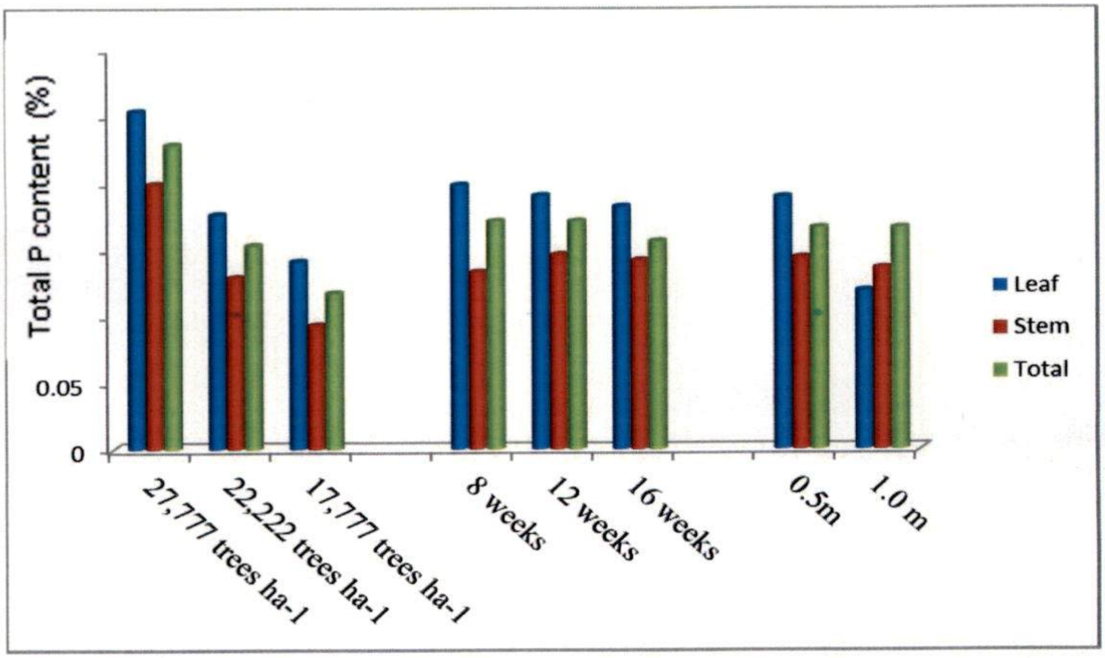

Fig .12 Total phosphorus content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

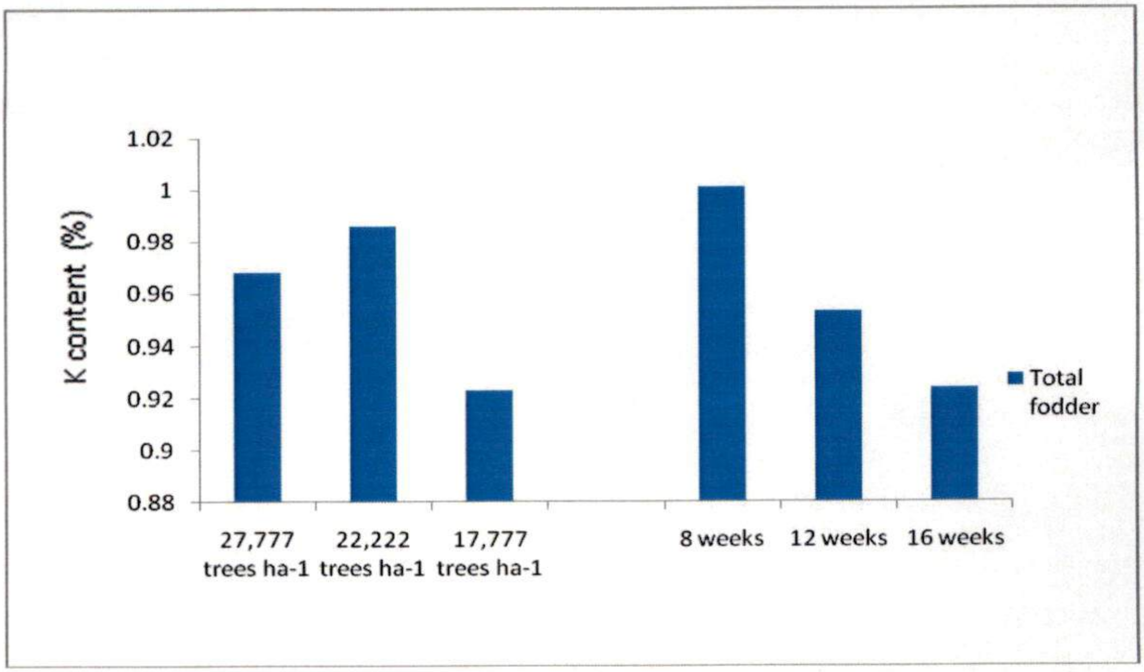

Fig .13 Potassium content of calliandra fodder as influenced by plant density, pruning frequency and pruning height in coconut garden.

5.4.4. Interaction effects of plant density, pruning height and pruning frequency on forage yield and nutritive value of calliandra in coconut garden.

The results indicates that the interaction effects of plant density, pruning height and pruning frequency had no significant effect on the annual fresh fodder yields as well as the leaf and stem forage fractions of calliandra (Table 5 and 7). The highest yielding combinations (42.93 Mg ha^{-1}) was found to be D1H2F2 (27, 777 palnts ha^{-1} + pruning height 1 m + pruning interval 12 weeks), closely followed by D1H2F3. Leaf fraction (23.41 Mg ha^{-1}) was also found to be higher for D1H2F1 (20.99 Mg ha^{-1}), which included the highest density, higher pruning height and shorter intervals, whereas the stem fraction was found to be higher in combinations with longer pruning intervals than the shorter ones.

The dry fodder yield (16.99 Mg ha^{-1}) was highest from the highest density stand, with 1m pruning height and longest harvest interval (D1H2F3), followed by D1H1F3 and D2H2F3. Even though the highest dry fodder yield was obtained for D1H2F3, the leaf-stem ratio was very low (0.55) indicating more stem fraction than leaf yields. The same trend is observed in all the combinations with longer pruning intervals. The leaf-stem ratio was comparatively higher for D1H2F1(1.61), followed by D1H2F2 (1.47), comprising of shorter and medium pruning intervals. The dry leaf yield (7.94 Mg ha^{-1}) was comparatively higher for D1H2F2 followeed by D1H2F1 (6.29 Mg ha^{-1}) with corresponding total dry fodder yields of 13.39 and 10.38 Mg ha^{-1} respectively. Numerous studies reveal that,while total forage yield continues to increase with longer harvest intervals, the additional yield beyond a certain interval consists mainly of woody stem (Ella *et al.,* 1989). Comparing fresh and dry fodder yields, leaf yield and leaf-stem ratio, the best management options in calliandra is to follow higher planting density and pruning height of 1m and harvest interval of 12 weeks. Raj (2016) also reported more edible forage yields from mulberry from high density planting and harvesting at shorter intervals of 8 or 12 weeks. In leucaena, Brewbaker *et al.* (1985) observed that, at very productive sites, harvest intervals may be 6-8 weeks and up to 12 weeks at less productive locations.

The interaction effects of plant density, pruning height and pruning frequency on proximate composition of harvested fodder was also non significant. Highest CP content (19.08 %) in fodder biomass and CP yield (2.59 Mg ha^{-1} of coconut garden) were in the treatment combination of D1H2F2 (27,777 plants ha^{-1} + pruning height 1m + pruning interval 12 weeks). The above combination also excelled in total nitrogen (3.05%) and phosphorus content (0.24%) of the fodder biomass. Crude fiber content, ash and dry matter content were more influenced by pruning intervals than other management factors, wherein all combinations with longest pruning interval recorded the maximum values. CF content showed a sharp decline with decreasing intervals. No specific trend could be observed in potassium contents, which varied from 0.819 to 1.09 for various treatment combinations. Nutritive value of foliage was found to be much better than stem fraction, hence any management strategy that increases the foliage content of the fodder has a definite advantage increasing quality forage production.. In our study, we observed that the nutritive value of foliage was much better than stem fraction, hence any management strategy that increases the foliage content of the fodder has a definite advantage increasing quality forage production. Adoption of higher plant densities, higher pruning heights with taller stocks and harvesting at an interval of 12 weeks has substantially increased foliage yields of calliandra as compared to other management levels. The longest harvest interval in combination with the highest planting density result in higher total DM yield, but nutritive value generally decreases as harvest interval increases (Maass *et al.*, 1996). Frequent pruning at closer intervals stakes away the possibility of photosynthesis and inhibits nutrient assimilation and reduces the carbohydrate reserve, which influences the leaf area development and affects the growth rate of the plants (Latt *et al*., 2000), whereas, longer intervals reduce the number of cuts and increases the stem yield which affects the quantity and quality of forage.

Thus the results indicate that the best management strategies to optimize forage yield and nutritive value of hedge row grown calliandra is to adopt a stand density of 27,777 plants ha^{-1}, maintain pruning heights of 1m and scheduling harvest at interval of 12 weeks (D1H2F2). Moreover, based on the growth performance, yield and nutritive parameters, calliandra is a promising fodder tree, which can be successfully integrated with the existing coconut gardens of Kerala, following effective stand management practices. In another study conducted in calliandra in Kerala, Jayaprakash *et al.* (2016) reported that, calliandra had relatively high protein (18.45 %), minerals, ether extract and energy content and thus have the potential to be a good alternate feed source for ruminant animals.

5.5 ECONOMICS

Economics and B:C ratio of coconut – calliandra system under various management practices of calliandra are shown in Table 18 and Fig.14. Comparing plant densities, the net returns (Rs. 1,49,734) and B:C ratio (1.74) were maximum from high density stand D1 and significantly superior to D2 and D3. This could be due to higher biomass production from dense stands as compared to widely spaced stands. Pruning frequency also significant effect on B:C ratio (1.78), with higher values for the longest pruning interval of 16 weeks (1.78) and was comparatively higher that medium and shorter pruning intervals, which in turn were on par. In case of pruning heights, taller stocks with a pruning height of 1m yielded maximum net returns and B:C ratio than shorter ones. Higher income from the above treatment could be attributed to higher fodder yields coupled with lower cost of production.

Comparing the economics of various treatment combinations, maximum net returns (Rs.2,08,173) and B:C ratio (2.03) from coconut-calliandra system were obtained from D1H2F2 (27,777 plants ha^{-1}, 1m pruning height and 12 weeks pruning interval), when compared to all other treatment combinations. All other options either resulted in reduced fodder yields or enhanced cultivation cost, ultimately making them unprofitable. However, as the fodder trees are in the initial year of establishment and continue to yield up to 10 to 15 years, the real economics of the system will be evident only in the subsequent years.

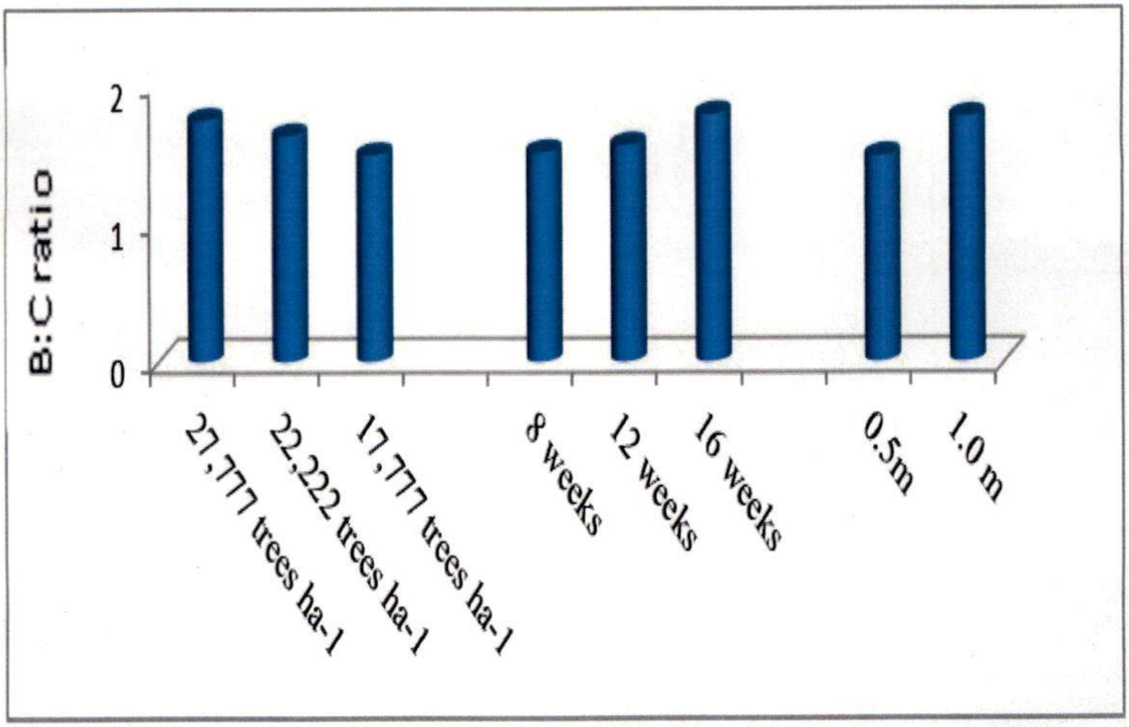

Fig . 14 B:C ratio of coconut-calliandra fodder production system as influenced by plant density, pruning frequency and pruning height of calliandra.

SUMMARY

SUMMARY

A field experiment entitled "Performance of calliandra *(Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system" was carried out at Instructional Farm, College of Horticulture, Vellanikkara during 2014-2015. The main objective of the study was to assess the influence of management practices like tree density, pruning height and pruning frequency on initial growth, forage yield and nutritional qualities of calliandra intercropped in coconut gardens under humid tropical conditions of Kerala.

The Salient findings of the experiment are summarized as follows:

- Almost all the transplanted calliandra seedlings established successfully underneath coconut plantation without showing any mortality. Early establishment and growth parameters of calliandra like plant height, collar diameter and number of branches showed no significant variation with planting density at the stage of initial uniform cut at three months after planting.

- Coppice parameters of calliandra like length of coppices, number of coppices and leaf-stem ratio showed no significant variation across different planting densities.

- However, pruning frequency showed profound influence on all the coppice parameters. Coppice length was significantly higher (216.98 cm) at the prolonged cutting interval of 16 weeks, followed by the medium interval of 12 weeks. However, the leaf-stem ratio was significantly higher and more than double at 8 and 12 weeks interval (1.33 and 1.32 respectively)

than the longest one (0.60). The number of coppices was significantly higher at medium pruning interval of 12 weeks, followed by shortest interval of 8 weeks; whereas the longest interval produced the least number of coppices.

- Pruning height showed significant influence on leaf-stem ratio and number of coppices, whereas coppice length showed only marginal variation. Leaf-stem ratio (1.12) and number of coppices (4.43) were significantly higher in stocks with higher pruning heights of 1m than the lower height of 0.5m (1.05, 3.17 respectively).

- Interaction effect of three management regimes showed significant influence on the coppice length and leaf-stem ratio. Comparing the treatment combinations, better coppice length (153.31 cm) with more leaf fraction (1.47) was observed in the combination of D1H2F2 (27,777 plants ha^{-1}, pruning height 1.0 m and pruning interval 12weeks), where as rest of the combinations produced either smaller coppices or coppices with more stem fraction.

- The management factors like plant density, pruning height and frequency had no significant influence on survival percentage of trees at the end of the experimental year. Almost 98 percent of the trees survived irrespective of the treatments. The minor casualties in the stands were mainly attributed to the falling of coconut fronds that destroyed the young seedlings, rather than the treatment effects.

- Plant density had significant influence on forage yields of calliandra per unit area, showing yield increment at higher densities. Maximum annual fresh and dry forage yields of 34.69 and 11.73 Mg per hectare of coconut garden was obtained from the highest density stand (27,777 plants ha^{-1}), which was 53 percent higher when compared to the lowest density (17,777 plants ha^{-1}), thereby indicating a need for accommodating more number of trees at closer spacing per unit area for maximizing productivity and optimum utilization of resources in land limited areas.

- Plant density also had a positive impact on foliage and stem fractions which showed an increasing trend with increasing density. The highest density stand yielded more leaf dry matter yield (5.53 Mg $ha^{-1} yr^{-1}$) than the lowest one (3.64 Mg $ha^{-1} yr^{-1}$), which implies the need for closer planting of trees for yielding maximum nutritive herbage per unit area. Despite yield differences, leaf- stem ratio showed only a marginal variation in response to tree density, with a slight increment towards the highest density.

- Plant density significantly influenced some of the nutritive parameters of calliandra forage. Total crude protein (CP) content in fodder increased significantly from 15.40 to 16.26 percent from lower to higher density classes. Overall CP yield (1.82 Mg ha^{-1}) and yield from foliage and stem fractions was also significantly higher in the highest density stand.

- Plant density also influenced crude fibre content of fodder, which declined from 40.53 to 37.73 at higher densities indicating closer spacing for production of tender fodder.

- The overall ash (3.30%) and dry matter content (33.88%) of fodder showed significant increment at higher density than lower levels.

- The nitrogen (2.60 %) and phosphorus content (0.228 %) in total fodder and in leaf and stem fractions was appreciably higher in high density stands. Potassium content was found to be higher in medium density (0.986%) followed by higher density (0.968), where as the value was lower in widely spaced stands. In general, an overall improvement in nutritive value of fodder was observed when trees are planted at closer spacing with higher densities.

- Forage yield of calliandra also showed significant variation with different pruning intervals. Pruning at the prolonged interval of 16 weeks yielded more total forage (32.56 Mg $ha^{-1}yr^{-1}$), but the majority of the fodder comprised of stem fraction. In comparison, harvesting at shorter intervals of 8 and 12 weeks yielded around 26 Mg of fodder, a significant portion of which was comprised of foliage fraction (15.65 Mg $ha^{-1}yr^{-1}$). Dry fodder yield also showed similar trends.
- Leaf –stem ratio of fodder harvested at 8 and 12 weeks showed an increment of 125 percent over that of the 16 weeks interval, indicating more foliage production than stem fractions when harvested at shorter intervals.

- Pruning frequencies had profound influence on nutritive value of the forage. Harvesting at shorter and medium pruning interval of 8 and 12 weeks yielded fodder with maximum CP content (17.91 and 17.87 % respectively) when compared to longer interval (11.93%) of 16 weeks. The overall CP yield and the yield from stem fraction was found to be higher in 16 weeks interval, but the CP yield from edible foliage fraction was found to be highest in 12 weeks interval.

- Pruning intervals had more prominent influence on crude fibre content of the forage wherein the values declined sharply from 49.98 to 28.33 with the reduction in interval from 16 to 8 weeks.

- Ash content (3.30) and dry matter content (41.61) was significantly higher at longest interval of 16 weeks, than shorter intervals.

- Total nitrogen, phosphorus and potassium content of the fodder were significantly higher at shorter intervals of 8 and 12 weeks than that of 16 weeks. In general, nutritive value of fodder was adversely affected at prolonged harvest intervals.

- Dry fodder yield increased from 8.11 to 10.81 Mg $ha^{-1}yr^{-1}$ with increasing pruning height from 0.5 to 1m, indicating more productivity from taller stocks.

- Similarly, taller stocks produced more foliage and less stem resulting in a higher leaf-stem ratio of about 12 percent over the lower ones.

- Even though pruning height showed pertinent effects on forage yields, most of nutritive parameters of the forage except CP content were quite unaffected by the height of pruning. Crude protein content of fodder showed marginal increment at higher pruning height but there was a significant improvement in CP yield from taller stocks (1.67 Mg ha^{-1}) when compared to shorter ones (1.23 Mg ha^{-1}).

- The results indicates that the interaction effects of management factors like plant density, pruning height and pruning frequency had no significant effect on the annual fresh fodder yields as well as the leaf and stem forage fractions of calliandra.

- The highest yielding combination (42.93 Mg ha^{-1}) was found to be D1H2F2 (27,777 plants ha^{-1} + pruning height of 1 m + pruning interval of 12 weeks), closely followed by D1H2F3. Leaf fraction (23.41 Mg ha^{-1}) was also found to be higher for D1H2F2, followed by D1H2F1 (20.99 Mg ha-1), which included the highest density, higher pruning height and shorter intervals whereas the stem fraction was found to be higher in combinations with longer pruning intervals than the shorter ones.

- The dry fodder yield (16.99 Mg ha^{-1}) was found to be the highest from the highest density stand, with 1m pruning height and longest harvest interval (D1H2F3), followed by D1H1F3 and D2H2F3. Even though the highest dry fodder yield was obtained for D1H2F3, the leaf-stem ratio was very low (0.549) indicating more stem fraction than leaf yields.

- The leaf stem ratio was comparatively higher for D1H2F1 (1.60), followed by D1H2F2 (1.46), comprising of shorter and medium pruning intervals. The dry leaf yield (7.99 Mg ha^{-1}) was comparatively higher for D1H2F2, followed by D1H2F2 (6.29 Mg ha^{-1}) , with corresponding total dry fodde yields of 13.39 and 10.73 Mg ha^{-1} respectively

- The interaction effects of plant density, pruning height and pruning frequency on the nutritive value of harvested fodder was also found to be non significant. Highest CP content (19.08 %) in fodder biomass and CP yield (2.59 Mg ha^{-1} of coconut garden) was found in the treatment combination of D1H2F2

(27,777 plants ha^{-1} + pruning height 1m + pruning interval 12 weeks), which also excelled in the nitrogen (3.05%) and phosphorus content (0.24%). Crude fiber content, ash and dry matter content was found to be more influenced by pruning intervals than other management factors, wherein all combinations with longest pruning interval recorded the maximum values. CF content showed a sharp decline with decreasing intervals. No specific trend could be observed in potassium contents. Nutritive value of foliage was found to be much better than stem fraction, hence any management strategy that increases the foliage content of the fodder has a definite advantage increasing quality forage production.

- Economics and B:C ratio of coconut – calliandra system varied significantly under various management practices of calliandra.

- Comparing plant densities, the net returns (Rs. 1,49,734) and B:C ratio (1.74) was maximum from high density stand.

- Pruning frequency also had significant effect on B:C ratio, with higher values for the longest pruning interval of 16 weeks (1.78) and was comparatively higher that medium and shorter pruning intervals, which in turn were on par.

- In case of pruning heights, taller stocks with a pruning height of 1m yielded maximum net returns and B:C ratio than shorter ones.

- Comparing the economics of various treatment combinations, the maximum net returns (Rs.2,08,173) and B:C ratio (2.03) from coconut-calliandra system was obtained from D1H2F2 (27,777 plants ha^{-1}, 1m pruning height and 12 weeks pruning interval), when compared to all other treatment combinations. All other options either resulted in reduced fodder yields or enhanced cultivation cost, ultimately making it unprofitable. However, as the fodder trees are in the initial year of establishment and continue to yield up to 10 to 15 years, the real economics of the system will be evident only in the subsequent years.

- The results indicate that the best management strategies to optimize forage yield and nutritive value of hedge row grown calliandra underneath coconut plantation at cheapest level is to adopt a stand density of 27,777 plants ha^{-1}, maintain pruning heights of 1m and scheduling harvest at interval of 12 weeks (D1H2F2). Moreover, based on the growth performance, yield and nutritive parameters it is found that calliandra is a promising fodder tree, which can be successfully integrated with the existing coconut gardens of Kerala, following effective stand management practices.

REFERENCES

REFERENCES

Adejumo, J.O. 1992. Effect of plant age and harvest date in the dry season on yield and quality of *Gliricidia sepium* in southern Nigeria, *Trop. Grassl.* 26 (1): 21-24.

Ajith, K.S., Kumar, A.K. and Dipu, M.T. 2012. How to improve the livestock sector in Kerala: some nutritional thoughts. *J. Indian Vet. Assoc. Kerala*, 10(1): 66-68.

AOAC [Association of Analytical Chemists]. 1995. *Official Methods of Analysis of the Association of Official Analytical Chemists (16th Edn.)*, AOAC International, Washington, USA., 1141p.

Arachchi, L.P.V. and Liyanage, M. De S. 1998. Soil physical conditions and root growth in coconut plantations interplanted with nitrogen fixing trees in Sri Lanka. *Agrofor. Syst.* 39: 305–318.

Baggio, A. and Heuveldop, J., 1984. Initial performance of *Calliandra calothyrus* Meissm. in live fences for the production of biomass. *Agrofor. Syst.* 2(1):19-29.

Basavaraju, T. B. and Gururaja rao, M.R. 1996. Forage production in *calliandra calothyrsus* as influenced by different cutting heights and intervals. *Karnataka J. Agric. Sci.* 9 (3): 454-458

Bhardwaj, S. D. Panwar, P., and Gautam, S. 2001. Biomass production potential and nutrient dynamics of *Populus deltoides* under high density plantation. *Indian For.*:144-153

Brewbaker, J. L., Hegde, N., Hutton, E.M., Jones, R.J., Lowry, J.B., Moog, F., and Van den Beldt, R. 1985. *Leucaena - Forage Production and Use.* NFTA, Hawaii. 39 p.

Buresh, R.J. and Tian, G. 1997. Soil improvement by trees in sub-Saharan Africa. *Agrofor. Syst.* 38(1-3): 51-76.

Catchpoole, D.W. and Blair, G.J. 1990. Forage tree legumes. In: Productivity and N economy of Leucaena, Gliricidia, Calliandra and Sesbania and tree/green panic mixtures. *Aust. J. Agric. Res.* 41(3): 521-530.

Chakeredza, S., Hove, L., Akinnifegi, F.K., Franzel, S., Ajayi, O.C., Sileshi, G. 2007. Managing fodder trees as a solution to human-livestock food conflict and their contribution to income generation of smallholder farmers in Southern Africa. *Natl. Resour.Forum* 31:286-296.

Chatterjee, A.K. and Acharya, R.M. 1992. *Heading for 21st century in Dairy India*, Published by P.R. Gupta, New Delhi, pp.4-24.

Cheema, U.B., Sultan, J.I., Javaid, A., Akhtar, P. and Shahid, M. 2011. Chemical composition, mineral profile and in situ digestion kinetics of fodder leaves of four native trees. *Pak. J. Bot.* 43(1):397-404.

Costa, N., De, L. and Olivicra, J.R. 1992. Effect of cutting height on the yield and protein content of *Leucaena leucocephala*. *Res. Rep.* 13: 6-7.

Duguma, B. and Tonye, J. 1994. Screening of multipurpose tree and shrub species for agroforestry in the humid lowlands of Cameroon. *For. Ecol. Manag.* 64(2-3): 135-143.

Duguma, B., Kang B.T. and Okali, D.U.U. 1998. Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an Alfisol. *Agrofor. Syst*. 6: 19-35.

Ella, A., Jacobsen, C., Stür, W.W. and Blair, G. 1989. Effect of plant density and cutting frequency on the productivity of four tree legumes. *Trop. Grassl.* 23: 28-34.

El-Morsy. M.H.M. 2009. Influence of cutting height and plant spacing on Sesbania (*Sesbania aegyptiaca* [Poir]) productivity under hyper-arid conditions in El-kharga Oasis, El-Wadi El-Gaded, Egypt. *Int. J. Pl. Prod.* 3(2): 77-84.

Fadiyimu A A, Fajemisin AN, Alokan JA, Aladesanwa RD. 2011: Effect of cutting regimes on seasonal fodder yields of Moringa oleifera in the tropical rainforest of Nigeria. Livestock Research for Rural Development 23 (Article 27). Retrieved July 6, 2015, from http://www.lrrd.org/lrrd23/2/fadi23027.htm

FAO [Food and Agriculture Organisation]. 2014. *Annual Report 2013-2014.* Food and Agriculture Organisation, Rome, Italy, 278p.

Gadzirayi, C.T., Kubiku, F.N.M., Mupangwa, J.F., Mujuru, L. and Chikuvire, T.J., 2013. The effect of plant spacing and cutting interval on growth of *Moringa oleifera. J. Agric. Sci. and Appl.* 2(2): 131-136.

GOK (Govermentment of Kerala). 2010. *Economic Review, Kerala 2010*. Kerala State Planning Board, Thiruvanathapuram, 235p.

GOK (Govermentment of Kerala). 2012. *Economic Review, Kerala 2012*. Kerala State Planning Board, Thiruvanathapuram, 246p.

GOK (Govermentment of Kerala). 2016. *Economic Review, Kerala 2016*. Kerala State Planning Board, Thiruvanathapuram, 419p.

Galang, M.C., Gutteridge, R.C. and Shelton, H.M. 1990. The effect of cutting height and frequency on the productivity of *Sesbania sesban* var. Nubica in a subtropical environment. *Nitrogen Fixing Tree Research Reports* 8: 161-164.

Guevarra, A.B., Whitney, A.S. and Thompson, J.R., 1976. Influence of intra-row spacing and cutting regimes on the growth and yield of Leucaena. *Agron. J.* 70(6): 1033-1037.

Gutteridge, R.C. and Shelton, H.M. 1994. The role of forage tree legumes in cropping and grazing systems. *Forage Tree Legumes in Tropical Agriculture*: CAB International, UK. 389p.

Hariah, K., Van Noordwijk, M., Santoso, B., and Syekhfani, M.S. 1992. Biomass production and root distribution of eight trees and their potential for hedgerow inter-cropping on an ultisol in southern Sumatra. *Agrivita* 15: 54-58.

Hess, H.D., Monsalve, L.M., Lascano, C.E., Carulla, J.E., Diaz, T.E. and Kreuzer, M. 2003. Supplementation of a tropical grass diet with forage legumes and *Sapindus saponaria* fruits: effects on *in vitro* ruminal nitrogen turnover and methanogenesis. *Aust. J. Agric. Res.* 54(7): 703-713.

Horne, P.M., Catchpoole, D.W. and Ella, A., 1986. Cutting management of tree and shrub legumes. In: *Forages in Southeast Asian and South Pacific Agriculture*. Proceedings of an International Workshop, August 19-23, 1985, Cisarua, Indonesia, edited by G. J. Blair, D.A. Ivory and T.R. Evans. ACIAR Proceedings Series No.12, Canberra, Australia: Australian Centre for International Agricultural Research, 202p.

Huxley, P. 1999. *Tropical Agroforestry*. Oxford and Blackwell Science Ltd.140p.

IGFRI [Indian Grassland and Fodder Research Institute], Indian Council of Agricultural Research. 2015. *Vision 2050*. Indian Grassland and Fodder Research Institute, Jhansi, Indian Council of Agricultural Research, 22p.

ILCA(International Livestock Centre for Africa). 1988. The use of locally available feeds for supplementing calves in Southern Ethiopia. *ILCA Annual Report* 1987. ILCA, Addis Ababa, Ethiopia, pp.6-7.

Islam, M.A., Hossain, M.D., Balbul, S.M. and Howlider, M.A.R. 1994. Unconventional feeds for broilers. *Indian Vet. J.* 71(8): 775-780.

Isarasenee, A., Shelton, H.M. and Jones, R.M. 1984. Accumulation of edible forage of *Leucaena leucocephala cv.* Peru over late summer and autumn for use as dry season feed. *Leucaena Res. Rep.* 5: 3-4.

Ivory, D.A., 1990. Major characteristics, agronomic features, and nutritional value of shrubs and tree fodders. In: *Shrubs and Tree Fodders for Farm Animals: Proceedings of a Workshop in Denpasar, Indonesia, 24-29 July 1989*. IDRC, Ottawa.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, 498 p.

Jamala, G.Y., Tarimbuka, I.L., Moris, D. and Mahai, S. 2013. The scope and potentials of fodder trees and shrubs in Agroforestry. *J. Agric. Vet. Sci.* 5: 11-17.

Jayaprakash, G., Shyama, K., Gangadevi, P., Ally, K., Anil, K.S., Raj, A.K., Sathiyabarathi, M. and Robert, M.A., 2016. Biomass yield and chemical composition of *Calliandra calothyrsus*, *Desmanthus virgatus* and *Stylosanthes hamata*. *Int. J. Sci. Environ. Tech.,* 5 (4): 2290 – 2295.

Kaligis, D.A., Stür, W.W. and Mamonto, S., 1991. Growth of tree legumes under coconuts in North Sulawesi. In: *Forages for Plantation Crops. ACIAR Proc.* 32: 72-74.

Kaitho, R.J., Tamminga, S. and Bruchem, J. 1993. Rumen degradation and *in vivo* digestibility of dried *Calliandra calothyrsus* leaves. *Anim. Feed Sci. Technol.* 43(1-2): 19-30.

Lascano, C. and Stewart, J. 2005. Intake, digestibility and nitrogen utilization by sheep fed with provenances of *Calliandra calothyrsus* Meissner with different tannin structure. *Archivos Latinoamericanos de Producción Animal*, 11(1): 1-8

Lakshmi, S. 1998. *Proc. Nat. Seminar on Strategy for Maximization of Forage Production by 2000 AD*. May 5-7 BCKV, Kalyani, West Bengal. pp:65-70.

Latt, C.R., Nair, P.K.R. and Kang, B.T. 2000. Interactions among cutting frequency, reserve carbohydrates, and post-cutting biomass production in *Gliricidia sepium* and *Leucaena leucocephala*. *Agrofor. Syst.* 50: 27-46.

Liyanage, L.V.K., and Jayasundara H.P.S. 1987. Potential for use of nitrogen fixing trees in coconut plantations. In: H.P.M. Gunasena (ed), *Proc. Nitrogen Fixation and Soil Fertility Symposium,* pp. 785-789.

Maasdorp, B.V., Muchenje, V. and Titterton, M. 1999. Palatability and effect on dairy cow milk yield of dried fodder from the forage trees *Acacia boliviana*, *Calliandra calothyrsus* and *Leucaena leucocephala*. *Anim. Feed Sci. and Technol.* 77(1): 49-59.

Maass , B. L. , Schultze -Kraft , R. and Algiers, P.J. 1996. Evaluation and review of agronomic shrub species. In: Pizarro, E.A. and Coradin, L. (eds.). Cratylia potential as forrajera. EMBRAPA legume, Cenargen , CPAC and CIAT , Proceedings of Workshop on Cratylia , July 19 to 20, 1995 , Brasilia, Brazil. pp. 107-114.

Miquilena, E., Ferrer, O.J. and Clavero, T. 1995. Effect of three frequencies and three planting densities on nitrogen fractions in leaves and Gliricidia stalks. *Rev. Fac. Agron.* 12: 193-207.

Munegowda, M. K. and Krishnamurthy, K. 1984. Forage yield of *Sesbania aegyptica* L. (Shevri) in dry-lands. *Nitrogen Fixing Tree Research Reports* 2: 5-6.

NAS [National Academy of Sciences]. 1983. *Calliandra: A Versatile Small Tree for the Humid Tropics.* National Academy Press, Washington DC, 42 p.

Norton, B.W. 1994. The nutritive value of tree legumes. In: Gutteridge, R.C. and Shelton, H.M.(eds), *Forage Tree Legumes in Tropical Agriculture*. CAB International, pp. 177-191.

Nyeko, P., Stewart, J., Franzel, S. and Barkland, P., 2004. Farmers experiences in the management and utilization of *Calliandra calothyrsus*, a fodder shrub in Uganda. Agricultural Research and Extension Network (AgREN No.140): 55p.

Palmer, B., Macqueen, D.J. and Gutteridge, R.C., 1994. *Calliandra calothyrsus* - A Multipurpose Tree Legume for Humid Locations. In: Gutteridge, R.C. and Shelton, H.M.(eds), *Forage Tree Legumes in Tropical Agriculture*. CAB International, pp. 65-74.

Paterson, R.T., Kiruiro, E. and Arimi, H.K., 1999. *Calliandra calothyrsus* as a supplement for milk production in the Kenya Highlands. *Trop. Anim. Health Prod.* 31(2): 115-126.

Paterson, R. T., Roothaert, R. L., Nyaata, O. Z., Akyeampong, E. and Hove, L. 1996. Experience with *Calliandra calothyrsus* as a feed for livestock in Africa. *Proceedings; International Workshop on the Genus Calliandra*; Bogor, Indonesia, pp. 23-27.

Powell, M. H. 1995. Nitrogen fixing trees and shrubs for acid soils - an overview. In: D.O. Evans and L.T. Szott (eds.), *Nitrogen Fixing Trees for Acid Soils. Nitrogen Fixing Tree Research Reports* Special Issue. 1995. Winrock International. Morrilton, Arkansas, USA. p. 185-194.

Pye-Smith , C. 2010. Fodder for a better future: How agroforestry is helping to transform the lives of smallholder dairy farmers in East Africa. *ICRAF Trees for Change No. 6*. World Agroforestry Centre, Nairobi, 48p.

Raj, A.K., Kunhamu, T.K., and Kiroshima, S. 2015. Optimizing management practices in mulberry for intensive fodder production in humid tropics of Kerala. *Indian J. Agrofor.* 17(2): 36-41.

Raj, R.M. 2016. Comparative performance of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based fodder production system. M.Sc. thesis, Kerala Agricultural University, Thrissur, 88p.

Ramachandra, K.S., Raju, S.S., Anandan, S. and Angadi, U.B., 2005. Animal feed resources and its impact on livestock production in India. *Indian Dairyman*, 57(6): 39.

Robertson, B.M., 1988. The nutritive value of some tree legumes as supplements to goats offered a basal diet of rice straw. Master of Agricultural Studies Thesis, The University of Queensland, Brisbane, Qld, Australia.152p.

Romeo, J.T. and Simmonds, M.S. 1989. Nonprotein amino acid feeding deterrents from Calliandra. *Insecticides of Plant Origin*. ACS Symposium series, Vol.387,Chapter 5, pp: 59-68.

Saddul, D., Jelan, Z.A., Liang, J.B., and Halim, R.A. 2004. The potential of mulberry (*Morus alba)* as a fodder crop: The effect of pant maturity on yield, persistence and nutrient composition of plant fractions. *Asian – Aust. J. Anim. Sci.* 12: 1657-1662.

Sanchez, S.F.J and Sanchez, S.B. 2002. Integrating fodder trees into animal production systems in the tropics. *Trop. Subtrop. Agroecosyst.*1: 1-11.

Sanchez, N.R., L. Stig and L. Inger, 2006. Biomass Production and Chemical Composition of *Moringa oleifera* under Different Management Regimes in Nicaragua. *Agrofor. Syst.*66: 231–242.

Sarwar, M., Khan, M. A. and Iqbal, Z. 2002. Feed resources for livestock in Pakistan. *Int. J. Agri. Biol.* 4: 186-192.

Saavedra, C.E., Rodriguez, N.M. and De Souza, N.M. 1987. Forage production, nutritional value and consumption of *Leucaena leucocephala*. *Pastures Tropicales*. 9 (2): 6-10.

Savory, R. and Breen, J. 1979. The production of *Leucaena leucocephala* in Malawi. (iii) Plant population studies. United Nations Development Programme/Food and Agriculture Organization Project MLW/757020. United Nations Development Programme, New York, NY, USA. Working Paper 17.

Siregar, M.E. 1983. Effect of cutting management on the yield and quality of tropical forage species. In: *New Strategies for Improving Animal Production for Human Welfare: Proceedings/the Fifth World Conference on Animal Production, August 14-19, 1983*. Tokyo, Japan: Japanese Society of Zootechnical Science.

Stür, W.W., Shelton, H.M. and Gutteridge, R.C., 1994. Defoliation Management of Forage Tree Legumes. Available: http://www.fao.org/ag/agp/agpc/doc/publicat/gutt-shel/x5556e0h.htm (12 July 2017).

Tarawali, S.A., Peters, M., Schulze-Kraft, R. 1999. Forage legumes for sustainable agriculture and livestock production in subhumid West Africa. ILRI Project Report. ILRI (International Livestock Research Institute), Nigeria, Kenya.132p

Tipu, S.U., Hossain, K.L., Islam, M.O. and Hossain, M.A. 2006. Effect of Pruning Height on Shoot Biomass Yield of Leucaena leucocephala. *Asian J. Pl. Sci*. 5: 1043-1046.

Turgut, I., Duman, A., Bilgili, U. and Acikgoz, E., 2005. Alternate row spacing and plant density effects on forage and dry matter yield of corn hybrids (*Zea mays* L.). *J. Agron. Crop Sci.* 191(2):146-151.

Tuwei, P.K., Kangara, J.N., Harvey, I.M., Poole, J., Ngugi, F.K., and Stewart, J.L. 2003. Factors affecting biomass production and nutritive value of *Calliandra Calothyrsus* leaf as fodder for ruminants. *J. Agric. Sci.*141: 113-127.

Umunna, N.N., Nsahlai, I.V. and Osuji, P.O. 1995. Degradability of forage protein supplements and their effects on the kinetics of digestion and passage. *Small Ruminant Res.*, 17(2): 145-152.

Walker, K.P., 2007. Productivity of four fodder tree species, their nutritional value and potential role in ruminant production in Eastern Botswana. Doctoral dissertation, University of Stellenbosch, Stellenbosch, South Africa.215p.

Wiersum, K. F. and Rika, I. K. 1992. *Calliandra calothyrsus* Meissn. In: Westphal, E. and Jansen, P.C.M. (eds.), *Plant Resources of Southeast Asia: Forages.* Pudoc Wageningen, Netherlands, pp. 68-70.

PERFORMANCE OF CALLIANDRA (*Calliandra calothyrsus* MEISSN.) UNDER DIVERSE MANAGEMENT REGIMES IN A COCONUT BASED HEDGE ROW FODDER PRODUCTION SYSTEM

By

ANU SAGARAN, K.

(2013-17-104)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR -680 656

KERALA, INDIA

2017

ABSTRACT

A study entitled "Performance of calliandra *(Calliandra calothyrsus* Meissn.) under diverse management regimes in a coconut based hedge row fodder production system" was carried out at Instructional Farm, College of Horticulture, Vellanikkara during 2014-2015. The main objective of the study was to assess the influence of management practices like tree density, pruning height and pruning frequency on initial growth, forage yield and nutritional qualities of calliandra intercropped in coconut gardens under humid tropical conditions of Kerala. The treatments consisted of three levels of plant density (27,777; 22,222 and 17,777 plants ha^{-1}), three levels of pruning frequency (8, 12 and 16 weeks interval) and two levels of pruning height (0.5m and 1m) in all possible combinations laid out under factorial randomized block design with three replications.

The results revealed that various management practices had a profound influence on the forage yield and quality aspects of calliandra when grown as an intercrop in coconut garden. Comparing plant densities, highest density stand (27,777 plants ha^{-1}) yielded 55 percent more forage (11.73Mg $ha^{-1}yr^{-1}$, dry basis) than the lowest density (17,777 plants ha^{-1}), with higher foliage fraction. Quality parameters of forage like crude protein, ash, dry matter, phosphorus and potassium content increased and crude fibre content decreased at higher densities indicating closer spacing for production of tender nutritive fodder. Pruning at the prolonged interval of 16 weeks yielded more total forage, but the majority of the fodder comprised of stem fraction as indicated by the poor leaf-stem ratio. Leaf –stem ratio of fodder harvested at 8 and 12 weeks showed an increment of 125 percent over that of the 16 weeks interval, indicating more foliage production than stem fractions when harvested at shorter intervals. Pruning frequencies also had profound influence on nutritive value of the forage. Harvesting at shortest interval of 8 weeks and 12 weeks yielded fodder with maximum crude protein, phosphorus and potassium content when compared to 16 weeks. Ash and dry matter content in

fodder was significantly higher at the longest interval of 16 weeks. Crude fibre content of forage increased sharply from 28.33 to 49.98 percent by prolonging the harvest interval from 8 to 16 weeks thereby adversely affecting the palatability of the forage.

Pruning height showed more prominent influence on forage yield of calliandra than the nutritive parameters. Dry fodder yield increased from 8.11 to 10.81 Mg $ha^{-1}yr^{-1}$ with increasing pruning height from 0.5 to 1m, with a higher leaf-stem ratio for taller stocks. Similarly there was a significant improvement in CP yield from taller stocks (1.67 $Mgha^{-1}$)when compared to shorter ones (1.23 $Mgha^{-1}$)

The interaction effects of plant density, pruning height and pruning frequency had no significant effect on yield and quality parameters of callianrda. The highest yielding combination (13.39 Mg ha^{-1}dry basis) was found to be D1H2F2 (27,777 plants ha^{-1} + pruning height 1 m + pruning interval 12 weeks) with higher foliage fraction and better nutritive parameters, compared to all other management levels, which were inferior either in forage yield or nutritive value or palatability of forage.

On the whole, the study revealed that forage yield and quality of young stands of calliandra underneath coconut garden could be optimized at the cheapest level by adopting a tree density of 27,777plants ha^{-1}, pruning height of 1m and pruning interval of 12 weeks. Moreover, based on the growth and yield performance and quality aspects, it is found that calliandra is a promising fodder tree, which can be successfully integrated with the existing coconut gardens of Kerala. Establishment and proper management of calliandra in coconut garden at appropriate management levels thus offers a cheap source of quality forage to Kerala farmers against the highly expensive concentrate feeds.

121