COMPARATIVE PERFORMANCE OF MULBERRY (*Morus indica* L.) AND SUBABUL (*Leucaena leucocephala* Lam.) UNDER DIVERSE MANAGEMENT REGIMES IN A COCONUT BASED FODDER PRODUCTION SYSTEM

By

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(2014-17-111)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Comparative performance of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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We, the undersigned members of the advisory committee of **Miss. Reshma M. Raj (2014-07-111),** a candidate for the degree of **Master of Science in Forestry** agree that this thesis entitled **"Comparative performance of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based fodder production system"** may be submitted by **Miss. Reshma M. Raj** in partial fulfilment of the requirement for the degree.

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Reshma. M. Raj

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SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of variance
BD	Bulk density
cm	Centimetre
CF	Crude Fibre
CP	Crude Protein
DM	Dry Matter
DMRT	Duncan's Multiple Range Test
et al	And others
Fig.	Figure
g cm-3	gram per centimetre cube
ha	Hectare
K	Potassium
kg	Kilogram
Mg	Mega gram
N	Nitrogen
ns	Non-significant
P	Phosphorus
pH	Soil reaction
SOC	Soil Organic Carbon
SPSS	Statistical Package for the Social Sciences
t ha^{-1}	tons per hectare

INTRODUCTION

INTRODUCTION

Livestock rearing form an integral part of rural living in Kerala. In addition to providing regular source of income, livestock also plays an important role in maintaining soil fertility through the recycling of animal wastes. Prospect of livestock farming is high in Kerala owing to the big gap between demand and supply of milk. However, high cost of feeds and scarcity of quality fodder are the major constraints limiting the growth of dairy sector in the state. It is estimated that the state produces only 60 per cent of the roughage requirement for cattle in Kerala (Economic Review, Kerala, 2010). Hence, dairy farmers depend on highly priced concentrates which offset their profit to a considerable extent. Although the genetic potential of our cattle is moderate with a productivity of 8-10 litres of milk/day, the average production is only 5-6 litres/day due to poor nutrition. 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.

Utilization of trees has long been recognized to be one of the most effective means of improving both the supply and the quality of forage in tropical smallholder livestock systems, especially during the dry season (Gutteridge and Shelton, 1993). By growing 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. Furthermore, integration of trees in agricultural farms offers numerous ecological services that help to maintain better soil properties and overall productivity of the system.

The suitability of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) as promising fodder trees by virtue of their nutritive foliage and ability to withstand severe pruning has already been reported (Pye-Smith, 2010). Since the agro-climatic requirement of these trees suits well to that of Kerala, there is a good possibility of utilizing these trees as nutrient rich fodder source in our state. However, due to acute land scarcity in Kerala, the possibility of growing of these two fodder trees as a sole crop in open lands is rather limited. Only alternative is to integrate with the existing cropping systems in the state. Coconut, the most dominant plantation crop in Kerala stretching over an area of 0.82 M ha (Economic Review, Kerala, 2012) offers substantial scope for integrating fodder trees mulberry and subabul. 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 yrs.) and later mature phase (>25 years) of the coconut plantation.

However, it would be desirable to maintain fodder trees as hedges to regulate the possible competition between the coconut and the tree intercrop and to facilitate easy harvesting of fodder. 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. Information exists on the effects of various management practices on forage yields of subabul and mulberry in different regions, but in some cases it is contradictory and preliminary, hence it is important to validate this research under Kerala conditions. Moreover, information on suitable management options for these trees for optimizing fodder yield and quality are limited, especially when integrated with coconut plantation.

With this background, a field study has been envisaged with the following objectives: -

- To assess the influence of plant density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens.
- To explore the soil fertility changes associated with intercropping mulberry and subabul in coconut plantations.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Forage shrubs and trees are important source of protein for livestock in the humid tropics and can be integrated with the existing cropping systems. Intercropping fodder trees in coconut gardens are gaining attention as sustainable and productive land-use option. Despite its potential, fodder trees are not popular among farmers mainly because of the inadequate knowledge on the various aspects of their potential use as well as the management practices to maximize productivity and quality. The studies on management of fodder trees indicated that, the factors such as plant spacing, pruning height and pruning frequency not only affect fodder yield per unit area but also the total long-term productivity and quality of the forage, under hedge row fodder production systems. The present study is aimed to evaluate the effect of tree density, and pruning frequencies on initial growth and survival, forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens under humid tropical conditions of Kerala. Literature pertaining to the above aspects are reviewed hereunder.

2.1 Relevance of fodder trees in animal nutrition

FAO (2011) reported that livestock contribute around 12.9% of global calories and 27.9% of protein, and also contribute to crop production through the provision of transport and manure. According to FAO world demand of animal products will double in the first half of this century as a result of increasing population and economic growth (Camero *et al.*, 2014). Even though India is a leading producer of milk and meat, the productivity of animals is 20-60% lower than the global average (DARE, 2013). This is mainly due to insufficient quantity and quality of fodder production. In Kerala fodder crops are cultivated on 7,000 ha which produces green fodder to meet only about 2% of the total dry fodder requirement of the state (Lakshmi *et al.*, 1998). Moreover, there is huge scarcity of green fodder in the summer season. So, dairy farmers depend on highly priced concentrates for feeding cattle which offset their profit to a considerable extent. Hence, it is highly essential to cultivate fodder on farm itself for profitable livestock production.

Fodder trees and shrubs are potential source of protein for ruminants and are invaluable in agroforestry systems for livestock production in the tropics. According to Franzal *et al.* (2014), fodder trees are easy to grow, require little land, labour or capital, have numerous by-products and often supply feed within a year after planting. Many of them are long-lived and have low demands on maintenance. Other properties are high growth rate, high foliage productivity, capacity for vigorous coppice, tolerance to pruning, high content of digestible protein in leaves and vigorous root development as they have dry season leaf retention (Sanches, 2006). They can provide a high quality forage for feeding of livestock in the dry season and thereby improve intake of roughage by ruminants. In addition, forage shrubs and trees can generally be easily established, enhance the sustainability of the farming systems, stabilise sloping lands against erosion because of their deep-rooted growth pattern, provide a source of timber and firewood for either domestic or industrial use, can be used in farming systems as living fences and provide useful by-products, such as fruit and vegetables for human consumption (Rachie, 1983; Atta-Krah and Sumberg, 1988). Raghavan (1989) observed that tree foliage makes a significant contribution to meet the nutritional requirements of the ruminants during the winter. It is well recognised that some tree leaves are palatable, digestible and high in protein (Palmer and Schlink, 1992; Subba *et al.*, 1994; Leng, 1997).

However, until recently, these feed resources have been generally ignored in feeding systems for livestock, mainly because of inadequate knowledge on various aspects of their potential use.

2.2 Agronomical and botanical aspects of the fodder tree species used in the study

2.2.1 Mulberry (*Morus indica*)

Mulberry, originated from temperate zones in Asia, extended throughout the world (Benavides *et al.*, 1994) due to its multiple uses. It is a perennial tree or shrub easily propagated, with fast growth and with vigorous shooting. It develops a strong vertical and profuse horizontal root system (Paolieri, 1970). These features improve physical soil conditions and allow better water conservation. As forage, mulberry has shown excellent organoleptic qualities and intake for livestock (Benavides *et al.*,1994; Ortiz, 1992; Castro, 1989).

The leaves of the multipurpose perennial shrub, mulberry (*Morus indica* L.), traditionally used for silkworm rearing, is known for its high protein content with good amino acid profile, high digestibility, high mineral content, low fiber content and very good palatability (Sanchez, 2001). The high biomass yields of the plant together with its low tannin content (Patra *et al.*, 2002) make it an attractive fodder resource for ruminants particularly, as a supplement to low quality basal diets and could even be nutritionally superior to subabul due to absence of any anti-nutritional factors. Mulberry leaves have an appreciable potential as protein source in small ruminant feeding (Kandylis *et al.*,2008). Akbulut *et al.* (2009) studied the mineral composition of mulberry and reported that mulberry contain highest amount of calcium, potassium, magnesium, sodium, phosphorus and sulphur. Liang *et al.* (1995) studied on the chemical composition of mulberry and found that mulberry was a better source of minerals and could be recognized as a valuable horticultural product based on their rich and beneficial nutrient composition. Saddul *et al.* (2004) studied on the chemical composition of mulberry and found that mulberry is a good protein and mineral resource.

Research conducted on mulberry in different areas focused mostly on the utilization of the leaves as silk worm feed. The whole plant, when harvested during the early growth stages can be a potentially valuable supplemental feed resource to poor quality ruminant diets. However systematic and in-depth knowledge on the yield and nutritional composition of mulberry in early growth stages is either not available or poorly defined.

2.2.2 Subabul (*Leucaena leucocephala*)

Leucaena leucocephala is a medium sized fast growing tree belonging to the family fabaceae. It is also known as subabul or kubabul and is a native of Central America and Southern Mexico (Singh, 1985). The plant withstands a wide range of rainfall, temperature, wind, drought and altitude though growth rate decreases with an increase in elevation. It is a tropical and sub-tropical tree and grows up to an elevation of 800m. Best growth is obtained with 600-1700mm annual rainfall. However, it can grow in areas with as little as 250 mm annual rainfall (National Academy of Sciences, 1977). Optimum range of temperature for growth is between 25°C and 30°C. Subabul is known to inhabit a wide range of soil types. It is characterized by a well-developed and deep tap root system which is capable of even breaking seemingly impervious layers of the soil in sub-horizons (Gray, 1968). Light textured soil is better than clayey soil for root development and growth (Singh, 1985). Neutral to slightly alkaline soils are considered best for its growth (National Academy of Sciences, 1977), with a pH range of 5.5 and 9.0 (Bapat, 1995). It is reported to have low tolerance for acidic soils, and in soils with high aluminum content or which are waterlogged for any period of time (Bapat, 1995).

Subabul is known as the 'miracle tree' because of which is long-lived and highly nutritious forage tree, and its great variety of other uses. The leaves of leucaena are highly nutritious for ruminants. Dry matter productivity of leucaena varies with soil fertility and rainfall. It is noted for its very high nutritive value for ruminant production. Subabul has a digestibility of 55- 70%, 3-4.5% N, 18% crude protein, 6% ether extract, 6-10% ash, 30-50% N-free extract. Subabul is highly palatable to most grazing animals, when compared to other forage tree legumes such as *Calliandra calothyrsus* and *Gliricidia sepium.* Yields of up to 50 tonnes per hectare per year can be expected under a variety of conditions (Duke, 1981; Felker & Bandurski, 1979). It recovers rapidly from complete defoliation or heavy grazing and has good coppicing ability.

2.3 Intercropping fodder trees in coconut gardens

Due to acute land scarcity in Kerala, the possibility of growing fodder trees as a sole crop in open lands is rather limited. However, there is good scope for integrating fodder trees with the existing cropping systems. Coconut plantations, stretching over an area of 0.82 M ha in Kerala (Economic Review, Kerala, 2012), offers substantial scope for integrating fodder trees in the interspaces. Fodder cultivation as intercrops under coconut plantations is well established (Lakshmi *et al.*, 1998; Pillai G.R, 1987). Growing of intercrops in coconut lands produce more food and other products, ensuring food security of the people in rural and urban areas. Numerous studies have indicated the suitability of growing fodder trees like subabul, gliricidia, calliandra and mulberry in coconut gardens (Arachchi and Liyanage, 1998; Liyanage and Wijeratne, 1987; Reynolds, 1988).

2.4 Factors affecting forage yield, quality and longevity of fodder trees as an intercrop in coconut garden

The management of fodder trees for maximum production of edible forage depends on several factors. However, the most important factors influencing plant performance are the inherent capacity of species to withstand continuous pruning, pruning interval and plant density.

2.4.1 Effect of plant density on yield, quality and survival of trees.

Numerous studies on fodder trees indicate that, management factors such as plant spacing and pruning frequency not only affect fodder yield per unit area but also long-term productivity and quality of the forage, which should be considered while establishing plantations. 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, as did the leaf: wood ratio. Raj *et al.*, (2015) observed higher biomass and protein yields from higher tree density of 27,777 plants ha^{-1}, than lower densities of 22,222 and 17,777 plants ha^{-1} in mulberry.

Castillo *et al.* (1979) compared four densities (3000, 5000, 6000, 10,000 trees ha^{-1}) in leucaena and obtained significantly higher yields from the highest plant density. Savory and Breen (1979) compared still higher densities (10,000, 30,000, 60,000 trees ha^{-1}) in leucaena and reported that 60,000 trees ha^{-1} gave the highest yield. However, Blair *et al.* (1990) found that high plant density in rows appears to affect biomass production in *L. leucocephala* negatively. Boschini (2011) found that mulberry tree planted at highest plant density gave the maximum DM yield. Benavides *et al., (*1994) used densities of almost 23,000 plants per ha, with DM yields from 21 to 28 ton/ha.

Bhardwaj *et al.* (2001) studied the effect of three densities viz. 60 cm X 60 cm (27,777 plants/ha), 90cm x 90 cm (12,345 plants/ha) and 120 cm X 120 cm (6,944 plants/ha) on biomass production of *Populus deltoids* under rainfed conditions in Himachal Pradesh. After 13 years of growth, the maximum biomass was observed in the closest spacing of 60 cm X 60 cm. They also found that the nutrient accumulation in the biomass also differed with density. The maximum nutrients were present in the closest spacing. El-Morsey (2009) observed that elevated CP % and lower CF % at higher population density in *Sesbania aegyptica*. However, the nutritive composition of Moringa was not affected by planting density (Sanchez, 2006). Pathak *et al.* (1980) reported higher leaf dry matter yields (5.4 t ha^{-1} $year^{-1}$) from trees at highest plant density (40,000 trees ha^{-1}) than that of lowest plant density (15,000 trees ha^{-1}) in leucaena.

2.4.1 Effect of pruning frequency on yield, quality and survival of trees

Many studies indicate that, while total biomass yield continues to increase with longer cutting intervals, the additional yield beyond a certain interval consists mainly of woody stem (Ella *et al.,* 1989). In Malaysia, Saddul *et al.* (2004) observed 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 fiber components), and the annual number of cuts, with good crop persistence to repeated harvests. The most suitable cutting or grazing intervals to promote high yields vary with environmental factors. In general, longer intervals between defoliation have increased total yield; however, the proportion of inedible wood may also increase leading to a decline in forage quality. At very productive sites, harvest intervals may be 6-8 weeks and up to 12 weeks at less productive locations (Brewbaker *et al.*, 1985). Raj *et al.* (2015) found that, in mulberry, increasing pruning interval up to 12 weeks increased dry matter, foliage and nutrient yields significantly and declined at 16 weeks, in humid tropical conditions of Kerala.

In addition, similar experiments with different forage trees report that longer cutting intervals increase biomass production (Guevara *et al.*, 1978; Ella *et a*l., 1989; Assefa, 1998; Barnes, 1999; Latt *et al.*, 2000; Tuwei *et al.*, 2003) and consequently that frequent cutting will decrease biomass production (Ezenwa and Atta-Krah, 1992; Romero *et al.*, 1993; Douglas *et al.*, 1996; Nygren and Cruz, 1998).

Fadiyimu *et al.* (2011) studied the 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, and for 12 weeks intervals yields were lowest when the cutting height was 150cm. They also found that mean fodder yields in the wet season was about six times higher than in the dry season.

Under tropical conditions, where conditions favour plant growth, mulberry culture has been practised under various densities and cutting frequencies which results in large yield differences. In Guatemala, Blanco (1992) obtained 19 ton of DM/ha in 4 cuts every 9 weeks, with 30cm between plants and a cutting height of 75cm. Rodríguez *et al.* (1994) worked in Guatemala with planting distances of 60 and 80cm between plants and harvesting frequencies of 6, 9 and 12 weeks, with DM yields of 1 to 4.6 ton/ha/harvest. These results suggest that yield increases with density.

The nutritive composition of forage species depends on soil fertility, part of the plant (stem, leaves, fruit), age of regrowth, environmental conditions, season of the year and other factors (Lascano, 1996). 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). 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).

2.5 Soil fertility changes associated with intercropping fodder trees in coconut gardens

The incorporation of trees in cropping systems increases soil fertility, improves soil structure, and reduces soil erosion. As compared to pure agricultural systems, agroforestry systems contribute towards improved nutrient cycling and sustainability through greater mineralization of nutrients from unavailable reserves, addition of nutrients in plant litter/tree residues, more closed nutrient cycles as a result of greater uptake by plant roots and less leaching losses and achieving a balanced supply of nutrients including micronutrients. Rao *et al.* (1998) reported that increase in soil fertility is due to nitrogen input into the system through biological nitrogen fixation, reduced soil erosion, reduced leaching of nutrients and uptake from deep soil layers. Gunasena *et al.* (1991) reported that *Gliricidia sepium* and *Leucaena leucocephala* increased soil fertility due to decomposition of leaf litter. The nutrient content (especially N and P) and the lignin and polyphenol concentrations of litter strongly influence its rate of decomposition and nutrient release to the soil (Szott *et al.*, 1991). Puri *et al.* (1994) reported that in *Leucaena leucocephala* the litter fall occurred throughout the year but was highest in the dry season.

Several experiments on *L. leucocephala* conducted at Sri Lanka revealed its adaptability under coconut in different agro- climatic zones (Liyanage *et al.*,1992). The highest biomass yield (13.4 t $ha^{-1}yr^{-1}$) was observed in the dry zone areas with a soil pH of 6.0 indicating its adaptability to non-acid soils in dry area. The beneficial effects of subabul on soil properties were demonstrated by a significant improvement on Ultisols in terms of increased organic carbon content

(45%) and water holding capacity (82%) and reduced bulk density (3%) over the control.

Kang *et al.* (1990) reported that hedgerow intercropping using fast growing nitrogen fixing trees, e.g. *Leucaena leucocephala* and *Gliricidia sepium* in the humid tropics can substantially increase soil fertility in 2-3 years. Pathak and Gupta (1987) found that a two-year old plantation of Leucaena added 5.6 Mg/ha of organic matter and caused an increase in water retaining ability, CEC, bulk density and tilth; and a decrease in phosphorus of soil besides an improvement in the yield of successive grain/forage crop. Jha (1990) observed an increase in organic carbon, available potassium and phosphorus of soil under silvipastoral system combining *Leucaena leucocephala* and Napier grass at Ranchi.

Jian *et al.* (2012) reported that mulberry has very strong root system. Its roots form a greatly tangled and densely network in the soil. Mulberry plantation is highly capable of conserving water and soil. Under heavy rain, mulberry tree hedgerow had significant effect in reducing total runoff and enrichment ratio of nutrients as well (Shi *et al.,* 2005). Mulberry root system occupies a space bigger than its aerial part (Zhang *et al.*, 1996). In Loess Plateau of Shaanxi, China, length of the root system of a 1-year-old mulberry sapling could reach 1m. The distribution area of underground root system is 4–5 times to the projected area of tree canopy (Dai *et al.*, 2009). Both level and vertical roots form a spatial and crossed water absorption and soil consolidation network. Compared to un-afforested land, water conservation was 20 m^3 higher in mulberry field per year. After establishment of mulberry plantation for water and soil conservation on agricultural land with 40° steep slope, reduction of rainfall runoff is 70% and reduction of soil erosion is 79.7% (Zhang and Song, 2004).

According to Dilip *et al.* (1990), the organic mulches not only conserve the soil moisture, they also increase the soil nutrients through organic matter addition. Accumulation of SOC occurs primarily through the return of plant-fixed C to the soil mainly through leaves and roots (Lal and Kimble 2000; Oelbermann *et al*., 2006). Nitrogen synthesized by legumes act more evenly and gradually than that of nitrogenous fertilizers (Kanodia and Patil, 1983).

Research has demonstrated that inclusion of trees within agricultural systems can improve water quality (Lowrance, 1992). Water quality benefits of maintaining trees and other vegetation on farms and ranches are realized by reducing runoff, maintaining long-term water cycle, and recharging ground water aquifers (Wu *et al*., 2001; Stednick, 1996). Soil physical properties, namely infiltration rate, pore space and water holding capacity improved with tree planting. Soil organic carbon and available nutrients increased, while soil pH decreased with tree planting.

Bhardwaj *et al.* (2001) studied the influence of tree density of *Populus deltoids* on soil properties. They observed that organic carbon content in the soil decreased with decrease in density, and also an increase was observed in nitrogen, phosphorus and potassium content of the soil with increase in spacing. They observed that accumulation of nutrients in the biomass is higher in 60 cm X 60 cm spacing whereas, the nutrient return through litter fall was less as compared to the total uptake which has a nutrient deficit in the soil.

Old leaves fallen from trees can damage tender crop and which can restrict their metabolic activity. On the contrary, leaves of most of the legumes are small in size, decompose fast and add a large quantity of humus and nutrients to the soil. According to a survey report on Nitrogen fixation, Domingo (1983) reported that in South East Asia, decomposition of *Leucaena* leaves is complete within two weeks to form humus. The slow release of organic nutrients also allows the crop a better chance to absorb them, which, if released quickly, would be leached.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study entitled "Comparative performance of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based fodder production system" was carried out at Instructional farm, College of Horticulture Vellanikkara during the year 2015-2016. The main objective of the study was to assess the influence of plant density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens. The study also explored the soil fertility changes associated with intercropping these fodder trees in coconut plantations.

3.1 Location

The proposed study was conducted in mature coconut garden (7.6 x 7.6 m spacing), located at Instructional Farm, College of Horticulture, Vellanikkara. Mulberry and subabul was intercropped with coconut to evaluate their performance under variable tree densities and pruning frequencies.

3.2 Climate and Soil

Vellanikkara experienced a warm humid climate with an annual rainfall of 2639.4 mm (average from January 2015- June 2016) (Fig. 1). The area is benefited both by the southwest and northeast monsoons, with a greater share from southwest monsoon. The mean maximum temperature ranged from 30.0 to 36.3^{0}C in the months of June and March respectively. While the mean minimum temperature varied from 23.0^{0}C to 26.2^{0}C in the months of February and April respectively. The soil of experimental site was deep well drained sandy clay loam of Ultisol order (Typic plinthustult – Vellanikkara series midland laterite – Ustic moisture regimes (dry period – February to May) and Isohyperthermic temperature regimes). The soil physico-chemical properties at the beginning of the experiment were as follows: pH: 5.76, available N, P and K @ 559, 3 and 454 Kg ha^{-1} and organic C: 0.79%.

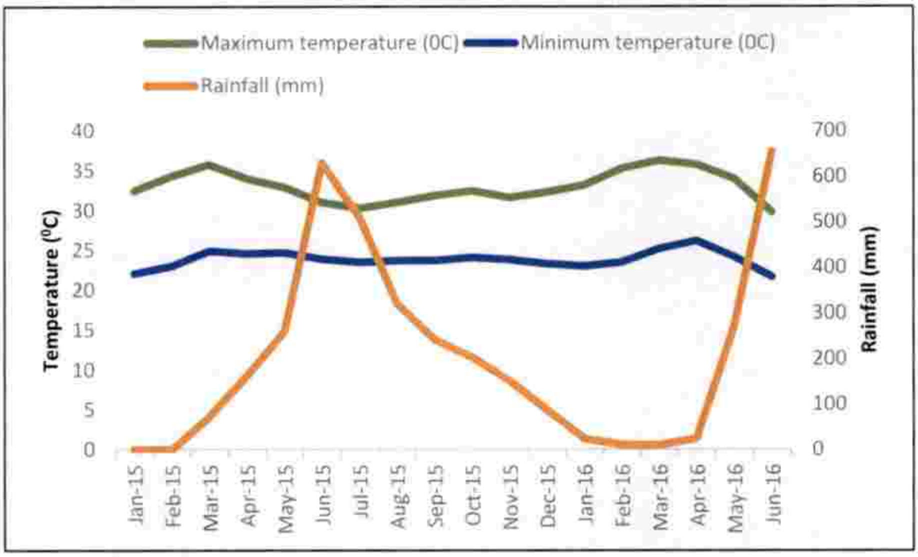


Fig. 1. Mean monthly rainfall and temperature data from January 2015 - June 2016 at Vellanikkara, Kerala.

3.3 Materials

3.3.1 Crops

Mulberry and subabul were the fodder tree species selected for the study.

3.3.1.1 Mulberry

The leaves of the multipurpose perennial shrub, mulberry, traditionally used for silkworm rearing, is known for its high protein content with good amino acid profile, high digestibility, high mineral content, low fibre content and very good palatability (Sanchez, 2001). The high biomass yields of the plant together with its low tannin content make it an attractive fodder resource for ruminants particularly, as a supplement to low quality basal diets. Being a potential fodder tree suited to the agro climatic conditions of Kerala, mulberry variety V1 (Victoria 1, a cross of S-30 and Berc 776 mulberry cultivars), released from Central Sericulture Research and Training Institute, Mysore, Karnataka was the fodder tree selected for this study.

3.3.1.2 Subabul

Leucaena leucocephala is a multipurpose leguminous tree promoted extensively for reforestation and rural development programs, as well as in ruminant production. It is a medium sized fast growing tree. The leaves of subabul are highly nutritious for ruminants. High crude protein and digestibility and low fiber content are the important factors which make subabul a good supplement for ruminant in the tropics (Islam, 1991). Dry matter productivity of *leucaena* varies with soil fertility and rainfall (Jones, 1979). This is most widely used forage tree legume in a two or three or multitier system of fodder production and in various agroforestry models. Due to the presence of *Rhizobium* bacteria, it can fix more than 500 kg nitrogen per hectare per year by the act of symbiosis. It is considered as a miracle tree because of its worldwide success as a long lived and highly nutritious forage tree (NDDB, 2012). The suitability of subabul *(Leucaena leucocephala* Lam.*)* as promising fodder trees by virtue of their nutritive foliage and ability to withstand severe pruning has already been reported (Pye-Smith, 2010). Since the agro-climatic requirement of these trees suits well to that of Kerala, there is a good possibility of utilizing these trees as nutrient rich fodder source in our state.

3.3.2 Manures and fertilizers

Farm yard manure (FYM) @ 20 t ha^{-1} and N·P_2O5·K2O each @ 50 Kg ha^{-1} were applied uniformly for all treatments. Fertilizers were applied through N: P: K mixture (18: 18:18). FYM was applied as basal and fertilizer in two split doses before south west and north east monsoons.

3.4 Methods

The field experiment was conducted in mature coconut garden planted at 7.6 x 7.6 m spacing. Mulberry and subabul were intercropped with coconut to evaluate their comparative performance under variable tree density and pruning frequency.

3.4.1 Design and layout of the experiment

Design : Split plot design

Treatments : 18

Replication : 3

Plot size : 4 m x 3 m

3.4.2 Treatment details

The treatments consisted of two fodder tree species; mulberry and subabul under three levels of tree density and 3 levels of pruning frequency in all possible combinations, the details of which are given below.

(1) Fodder trees (Main plot)

P1- Mulberry

P2- Subabul

(2) Plant density (3 levels)

D1- 49,382 plants ha^{-1} (45 x 45 cm spacing)

D2- 37,037 plants ha^{-1} (60 x 45 cm spacing)

D3- 27,777 plants ha^{-1} (60 x 60 cm spacing)

(3) Pruning frequency (3 levels)

F1- 8 weeks interval

F2- 12 weeks interval

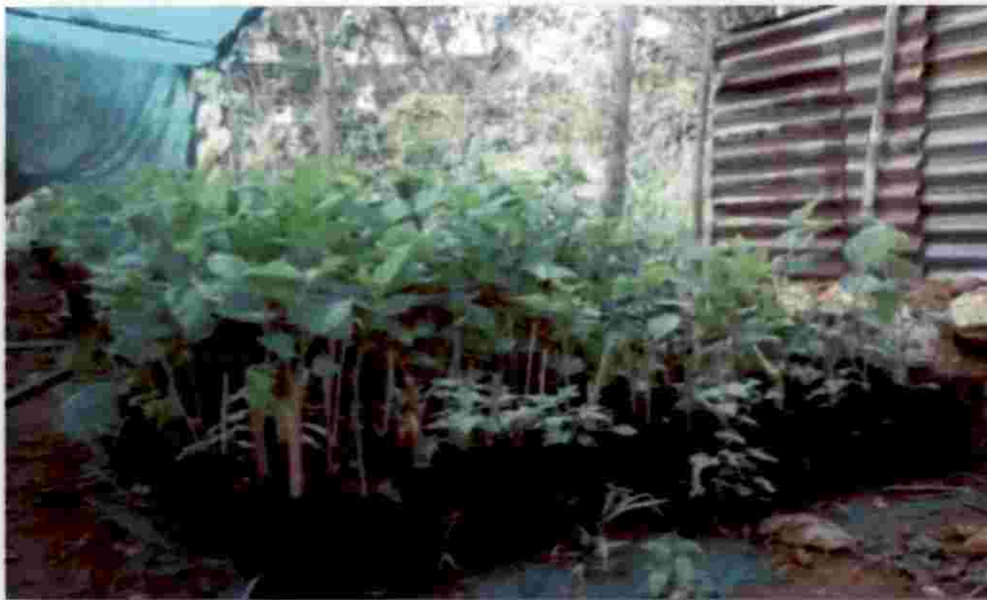
F3- 16 weeks interval

3.4.3 Raising of tree seedlings

Seedlings of subabul (variety "Cunningham") and saplings of mulberry (variety V1) were raised in nursery. The subabul seeds were pre-treated by soaking in concentrated sulfuric acid for 4 minutes, followed by washing with hot water at 80^0C and planted in nursery beds of standard size. Healthy and uniform seedlings were transplanted to polythene bags after one month and later transplanted to the main field on attaining 20-30 cm height. Mulberry was raised from uniform stem cuttings of 6-8 months maturity, 20 cm length, having three nodes and of pencil thickness in polythene bags and transplanted to main field at 3 months stage.

3.4.4 Field culture

The field area (excluding coconut basin of 2m radius) 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 mulberry and subabul were transplanted to the main field with the onset of pre-monsoon showers. Manures and fertilizers were applied as detailed in 3.3.2. Plots were weeded and irrigated as and when required.



Nursery raising of Mulberry

Nursey raising of Subabul seedlings

Plate 1. Nursery raising of seedlings

Field area

Subabul under coconut

Mulberry under coconut

Plate 2. Field culture

3.4.5 Harvesting

After attaining a height over 1 m, an initial uniform cut was given in July 2015 at the prescribed 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 2016.

3.5 Observations

Five trees/plot were selected at random avoiding border plants and the following observations were recoded

3.5.1 Growth parameters of fodder trees at first uniform cut

3.5.1.1 Plant height

The plant height was measured from ground level to the growing tip of the shoot and expressed in cm.

3.5.1.2 Collar diameter

Root collar diameter (mm) was measured on the stem at the point close to the ground level using digital vernier caliper.

3.5.1.3 Branches per plant

Number of branches per plant counted for each treatment.

3.5.2 Survival percentage of trees for various treatments.

Number of trees in each treatment plot was counted after the experimental period and expressed as survival percentage.

3.5.3 Green fodder yield from trees.

For each cut, biomass from 5 trees/ plot avoiding border plants 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 gross yields and using the net harvested area and fresh weight, annual gross fodder yield was scaled up to a hectare basis. The gross fodder yields from each treatment was multiplied with survival percentage to get annual net fresh fodder yields.

3.5.4 Dry fodder yield from trees.

After harvesting, the biomass from each plot was weighted fresh. Biomass from trees was seperated into leaf and stem and their fresh weights determined. Subsamples (200 g) of the two components were oven dried at 70^0C for 48 hours for dry matter (DM) determination. The annual fresh fodder yields were multiplied with dry matter content and expressed as dry fodder yield per hectare.

3.5.5 Leaf –stem ratio

The annual dry leaf yield was divided with annual dry stem yield for various treatments and expressed as leaf-stem ratio.

3.5.6 Incidence of pest and diseases.

No serious disease and pest incidence were noticed during the experimental period.

3.5.7 Economics.

The cost of cultivation of various systems and the economical yield was obtained by calculating the B:C ratio.

3.5.8 Plant nutrient analysis.

Sub samples (200 g) of the two components were oven dried and subjected to dry matter (at 70°C) analysis following standard procedures. Total nitrogen and total phosphorus was determined by continuous flow analyzer and total potassium was determined by flame photometer. All nutrient concentrations were expressed on oven dry basis.

3.5.9 Quality aspects of fodder biomass

3.5.9.1 Crude protein content

Total nitrogen (N) of oven dried fodder (leaf and stem) samples from each harvest was determined by micro Kjeldahl procedure and crude protein (CP) calculated from N content (CP= Nx6.25) according to the official methods of AOAC (1995).

3.5.9.2 Crude fibre content

Oven –dried leaf and stem samples were refluxed first with 1.25% H_2SO_4 and subsequently with 1.25% NaOH for 30 minutes each to dissolve acid and alkali soluble component present in it. The residue containing 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).

Ash content analysis

Crude fibre analysis

Plant nutrient analysis

Plate 3. Plant quality and nutrient analysis

3.6 Soil analysis

To study the initial changes in soil physico-chemical properties on account of intercropping fodder trees in coconut garden, representative soil samples (in triplicates) from all treatment plots and also from sole coconut plots were collected (top 0-15 cm layer), before and after the experiment and were analyzed for various parameters as detailed below.

3.6.1 Soil physical properties

3.6.1.1 Bulk density

Bulk density was estimated by taking out a core of undisturbed soil by using a core sampler (Gupta and Dakshinamurthy, 1980). The core was taken out without pressing the cylinder too hard on soil so that the natural bulk density of soil may not get disturbed. The soil was oven dried and weight determined. The volume of soil was calculated by measuring the volume of cylinder ($\pi r^2 h$). The bulk density was calculated by dividing the oven dry weight of soil samples (g) by volume of soil.

3.6.1.2 Water holding capacity (WHC)

A known quantity of soil was allowed to fully saturate and equilibrate with water and from the water held in the soil after free draining, the water holding capacity was determined (Jackson, 1973).

$$\text{WHC on dry basis (\%)} = \frac{\text{Saturated weight (g) - Dry weight (g)}}{\text{Dry weight (g)}} \times 100$$

3.6.1.3 Soil pH

Soil pH was calculated using an aqueous suspension of soil (soil and water in 1:2.5 ratio) using an Elico pH meter (Model Li 613) as described by Jackson (1973).

3.6.1.4 Soil electrical conductivity

The electrical conductivity measurement gives the total amount of soluble salts present in the soil and is expressed as decisiemens/m. EC was measured using conductiviy method, which uses a conductivity bridge for measuring EC (Jackson, 1973).

3.6.1.5 Soil organic carbon

Soil carbon was analysed by using Walkely and Black's permanganate oxidation method (Walkely and Black, 1934).

3.6.2 Soil nutrient analysis

3.6.2.1 Available nitrogen

Available nitrogen in soil was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.6.2.2 Available phosphorus

Available phosphorus was extracted using Bray-I extractant (Bray and Kurtz, 1945) and the P content was colorimetrically assayed (Chloromolybdic acid blue colour method). The reducing agent was ascorbic acid (Jackson, 1973).

3.6.2.3 Available potassium

Available potassium was determined by flame photometry using 1N neutral normal ammonium acetate solution as the extractant (Jackson, 1973).

3.7 Statistical analysis

The data were subjected to statistical analysed using ANOVA 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% significance level.

Plate 4. Soil nutrient analysis

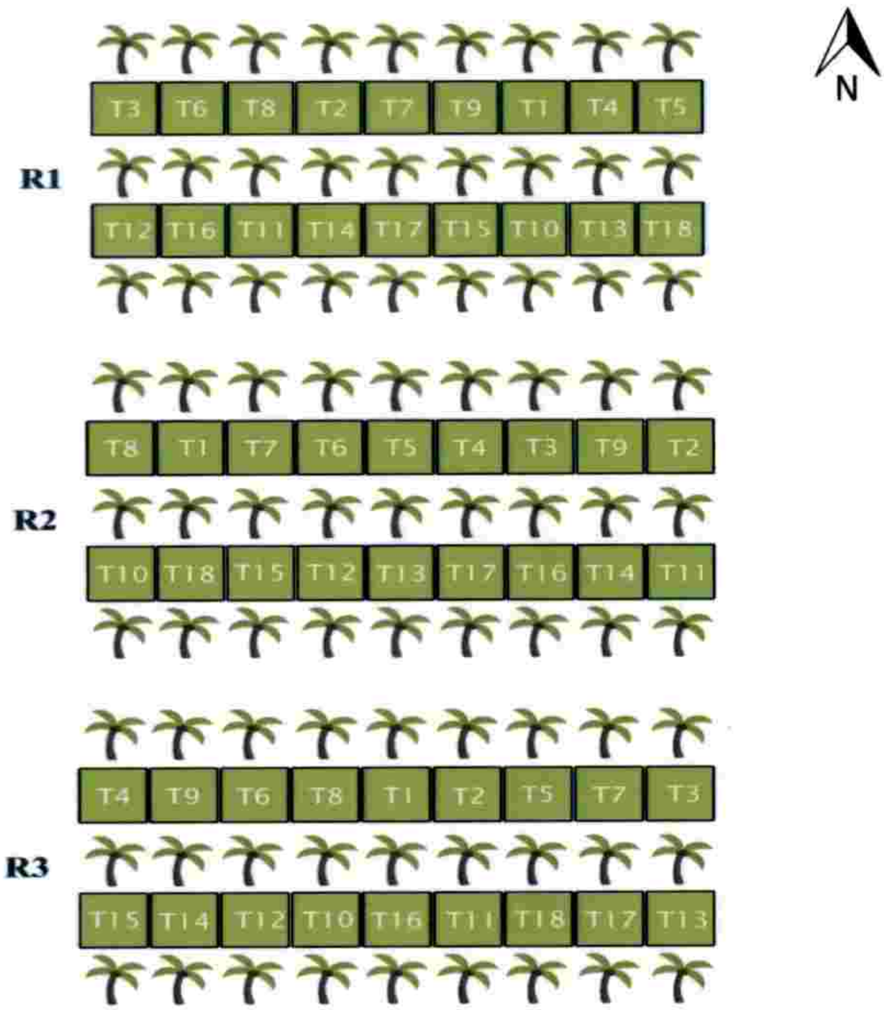


Fig.2. Layout plan of the field trial

Treatment combinations

T1- P1D1F1	T7- P1D1F3	T13- P2D1F2
T2- P1D2F1	T8- P1D2F3	T14- P2D2F2
T3- P1D3F1	T9- P1D3F3	T15- P2D3F2
T4- P1D1F2	T10- P2D1F1	T16- P2D1F3
T5- P1D2F2	T11- P2D2F1	T17- P2D2F3
T6- P1D3F2	T12- P2D3F1	T18- P2D3F3

RESULTS

RESULTS

The study on comparative performance of mulberry and subabul under diverse management regimes in a coconut based fodder production system at Vellanikkara revealed vital information on influence of planting density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul; and soil fertility changes associated with intercropping these fodder trees in coconut plantation. The salient results are presented hereunder.

4.1 Growth and yield parameters of fodder trees at first uniform cut

All the treatments were given uniform cut at one metre height at an age of 6 months. The growth and yield parameters of mulberry and subabul at varying tree densities at the stage of uniform cut are given below.

4.1.1 Height

Table 1 shows the influence of fodder trees and plant densities on plant height. Comparing fodder trees, mulberry (143.43 cm) had significantly higher plant height than subabul (139.29 cm). Among various densities, plant height was significantly higher at higher densities of D1(144.87 cm) and D2 (145.41 cm), compared to the lower density of D3. The interaction effect of fodder trees and plant density (table 1) indicated that, mulberry at density D1 had significantly more height than other combinations. In subabul the height was significantly higher at density D2.

4.1.2 Collar diameter

Table1 shows the collar diameter (CD) of different fodder trees and plant densities at first uniform cut. Comparing fodder trees, CD of mulberry (14.39 mm) was significantly higher than that of subabul (10.59 mm), whereas plant density had no significant effect on CD. Comparing the interaction effect of fodder trees and plant densities mulberry had comparable CD at all densities and was significantly superior to that of subabul.

4.1.3 Number of branches

Table1 shows the number of branches obtained from different fodder trees and plant densities. Among, fodder trees subabul (3.73) produced significantly more number of branches than mulberry (2.30). However, in genaral, plant densites had no significant influence on number of branches. Comparing treatment combinations, subabul at medium density of D2 (4.38) produced more number of branches and was superior to that of either D1 or D3, whereas in mulberry, density had no significant influence on branching.

4.1.4 Harvested fodder biomass at uniform cut

Table1 shows the harvested fresh fodder biomass obtained from different fodder trees and plant densities at uniform cut. Among fodder trees mulberry(1.89 Mg ha^{-1}) produced significantly higher biomass than subabul (0.87 Mg ha^{-1}). Comparing plant densities, fodder yield increased from 0.79 to 2.01 Mg ha^{-1} from lower (D3) to higher density classes (D1). Fractional yield obtained from leaf and stem also followed similar trends. Comparing treatment combinations, leaf (2.25 Mg ha^{-1}), stem (0.7 Mg ha^{-1}) and total (2.95 Mg ha^{-1}) harvested biomass was highest for mulberry at the highest plant density D1.

Table 1. Growth and yield parameters of fodder trees at varying tree densities at the stage of first uniform cut.

Treatments	Height (cm)	Collar diameter(mm)	Number of branches	Fodder yield (Mg ha^{-1})		
				Leaf	Stem	Total
Fodder trees (Main effect)						
Mulberry (P1)	146.43^{a}	14.39^{a}	2.30^{b}	1.51^{a}	0.38^{a}	1.89^{a}
Subabul (P2)	139.29^{b}	10.59^{b}	3.73^{a}	0.68^{b}	0.19^{b}	0.87^{b}
F Value	8.37**	160.68***	47.39***	164.60***	99.06***	162.06***
P value	0.004	0.000	0.000	0.000	0.000	0.000
Plant density (Main effect)						
49382 plants ha^{-1}(D1)	144.87^{a}	12.06	2.78	1.52^{a}	0.48^{a}	2.01^{a}
37037 plants ha^{-1} (D2)	145.41^{a}	12.84	3.29	1.13^{b}	0.21^{b}	1.34^{b}
27777 plants ha^{-1}(D3)	138.30^{b}	12.58	2.99	0.63^{c}	0.16^{c}	0.79^{c}
F Value	3.43*	2.38^{ns}	2.04^{ns}	64.05***	103.85***	76.37***
P value	0.03	0.09	0.13	0.000	0.000	0.000
Fodder trees x Plant density (interaction effect)						
P1D1	153.11^{a}	14.12^{a}	2.16^{c}	2.25^{a}	0.7^{ab}	2.95^{a}
P1D2	144.78^{b}	14.21^{a}	2.2^{c}	1.38^{a}	0.22^{b}	1.6^{a}
P1D3	141.4b^{c}	14.85^{a}	2.56^{c}	0.89^{b}	0.23^{b}	1.12^{ab}
P2D1	136.62^{d}	10.00^{b}	3.4^{b}	0.79^{b}	0.26^{b}	1.06^{ab}
P2D2	146.04^{b}	11.48^{b}	4.38^{a}	0.88^{b}	0.2^{b}	1.08^{ab}
P2D3	135.2^{d}	10.3^{b}	3.42^{b}	0.36	0.09^{c}	0.46^{b}
F value	4.35*	3.35*	3.52*	23.60***	40.43***	29.48***
P value	0.014	0.037	0.031	0.000	0.000	0.000

*** 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

4. 2 Effect of fodder tree species, plant density and pruning frequency on fodder yield and quality underneath coconut garden.

4.2.1. Gross annual fresh fodder yield

Main effect of tree species, plant densities and pruning frequencies on gross annual fresh fodder yield are given in table 2. Among fodder trees, subabul yielded the maximum fresh fodder (41.78 Mg $ha^{-1}yr^{-1}$) and was significantly superior to that of mulberry (36.95 Mg ha^{-1}). Plant density also had profound influence on fodder yield. Yield increased from 27.96 to 47.66 Mg $ha^{-1}yr^{-1}$ lower to higher density classes. Comparing the effect of pruning frequency, significantly higher yield was recorded at the shortest pruning interval of 8 weeks (43.17 Mg $ha^{-1}yr^{-1}$), whereas fodder yield from 12 weeks (36.49 Mg $ha^{-1}yr^{-1}$) and 16 weeks (38.44 Mg $ha^{-1}yr^{-1}$) interval were found to be on par. Leaf yield and stem yield also showed similar trend.

Table 3 gives the effect of treatment combinations on fodder yield. The maximum yield (61.14 Mg $ha^{-1}yr^{-1}$) was obtained from T10 (Subabul + 49382 plants ha^{-1} + 8 weeks pruning interval) and was on par with that of T11 (Subabul + 37037 plants ha^{-1} + 8weeks pruning frequency) (55.34 Mg $ha^{-1}yr^{-1}$) and significantly superior to other treatments. Mulberry yielded the maximum fodder (48.26 Mg ha^{-1}) at the highest density D1 and at the cutting interval 8 weeks but was significantly inferior to that of subabul under the same management levels.

Table 2. Effect of fodder tree species, plant density and pruning frequency on gross annual fresh fodder yields underneath coconut plantation.

Treatments	Fractional and total fresh fodder biomass ($Mg\ ha^{-1} yr^{-1}$)		
	Leaf	Stem	Total
Fodder tree species			
Mulberry (P1)	22.51^{b}	14.43^{b}	36.95^{b}
Subabul (P2)	25.16^{a}	16.62^{a}	41.78^{a}
F Value	11.84**	13.67***	12.54***
P value	0.001	0.000	0.000
Plant density			
49382 plants ha^{-1}(D1)	29.14^{a}	18.52^{a}	47.66^{a}
37037 plants ha^{-1} (D2)	25.47^{b}	17.01^{b}	42.48^{b}
27777 plants ha^{-1}(D3)	16.91^{c}	11.05^{c}	27.96^{c}
F Value	88.65***	59.13***	68.36***
P value	0.000	0.000	0.000
Pruning frequency			
8 weeks (F1)	26.90^{a}	16.27^{a}	43.17^{a}
12 weeks (F2)	22.05^{b}	14.43^{b}	36.49^{b}
16 weeks (F3)	22.56^{b}	15.87^{a}	38.44^{b}
F value	15.99***	3.55*	10.69***
P value	0.000	0.03	0.000

*** 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

Table 3. Interaction effect of tree species, plant density and pruning frequency on gross annual fresh fodder yield underneath coconut plantation.

Treatments	Fractional and total fresh fodder biomass (Mg ha^{-1}yr^{-1})		
	Leaf	Stem	Total
T1- P1D1F1	30.75^{bc}	17.50^{cde}	48.26^{bc}
T2- P1D2F1	22.72^{efg}	12.89^{fghi}	35.61^{ef}
T3- P1D3F1	17.48^{hi}	9.75^{i}	27.23^{gh}
T4- P1D1F2	23.93^{def}	15.55^{efg}	39.48^{def}
T5- P1D2F2	24.36^{def}	16.71^{def}	41.07^{cde}
T6- P1D3F2	19.45^{fghi}	12.77^{ghi}	32.23^{fgh}
T7- P1D1F3	27.80^{cde}	19.82^{bcd}	47.63^{bcd}
T8- P1D2F3	20.38^{fgh}	14.75^{efgh}	35.13^{efg}
T9- P1D3F3	15.75^{hi}	10.11^{i}	25.87^{h}
T10- P2D1F1	37.27^{a}	23.86^{a}	61.14^{a}
T11- P2D2F1	34.34^{ab}	21.00^{abc}	55.34^{ab}
T12- P2D3F1	18.84^{ghi}	12.62^{ghi}	31.47^{fgh}
T13- P2D1F2	26.18^{cde}	16.19^{defg}	42.37^{cde}
T14- P2D2F2	23.17^{efg}	15.34^{efg}	38.52^{ef}
T15- P2D3F2	15.22^{i}	10.03^{i}	25.25^{h}
T16- P2D1F3	28.90^{cd}	18.15^{bcde}	47.05^{bcd}
T17- P2D2F3	27.83^{cde}	21.36^{ab}	49.19^{bc}
T18- P2D3F3	14.71^{i}	11.02^{hi}	25.74^{h}
F value	23.15^{***}	16.45^{***}	15.56^{***}
P value	0.000	0.000	0.000

*** 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

P1 and P2 – fodder tree species mulberry and subabul respectively

D1, D2 and D3 – Tree density of 49,382, 37,037 and 27,777 plants ha^{-1}

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

4.2.3 Gross leaf yield, stem yield, leaf- stem ratio (Dry basis)

Table 4 shows the comparative effect of fodder trees, plant densities and pruning frequencies on annual dry leaf yield, stem yield and leaf -stem ratio. Comparing fodder trees, subabul yielded significantly more leaf fodder ha^{-1}(6.41 Mg $ha^{-1}yr^{-1}$) than mulberry (5.38 Mg $ha^{-1}yr^{-1}$), but stem yield was found to be comparable in both. Leaf- stem ratio was found to be slightly higher in subabul (1.33) than mulberry (1.19), but the difference was found to be non-significant. Plant density had profound influence on leaf and stem yield, wherein both parameters increased with increasing plant density. Leaf yield increased from 4.09 to 7.48 Mg $ha^{-1}yr^{-1}$ and stem yield from 3.46 to 5.57 Mg $ha^{-1}yr^{-1}$ from lower to higher density classes. Even though leaf- stem ratio declined with decreasing density, differences were found to be non-significant. Pruning frequency had no significant on leaf and stem yield. However, leaf- stem ratio varied significantly under different pruning intervals indicating higher leaf- stem ratio (1.42) under the shortest cutting interval (8 weeks), and showed declining trend at prolonged harvest intervals (12 and 16 weeks).

Table 5 depicts the effect of treatment combinations on dry leaf yield, stem yield and leaf -stem ratio. Among various treatment combinations, subabul at density D1 and pruning frequency F1 (T10) recorded the highest leaf yield (9.15 Mg $ha^{-1}yr^{-1}$), stem yield (6.45 Mg $ha^{-1}yr^{-1}$) and optimum leaf - stem ratio (1.42) and was on par with T11(P2D2F1) and T16 (P2D1F3), and with mulberry treatments like T4(P1D1F2) and T1(P1D1F1).

Table 4. Effect of tree species, plant density and pruning frequency on gross annual dry fodder yields and leaf-stem ratio in coconut plantation.

Treatments	Fractional and total harvested dry fodder biomass (Mg $ha^{-1}yr^{-1}$)			Leaf-stem ratio
	Leaf	Stem	Total	
Fodder tree species				
Mulberry (P1)	5.38^{b}	4.53	9.91	1.19
Subabul (P2)	6.41^{a}	4.80	11.22	1.33
F Value	9.67^{**}	0.89^{ns}	5.84^{ns}	2.62^{ns}
P value	0.003	0.35	0.20	0.11
Plant density				
49,382 plants ha^{-1}(D1)	7.48^{a}	5.57^{a}	13.05^{a}	1.34
37,037 plants ha^{-1} (D2)	6.11^{b}	4.98^{b}	11.08^{b}	1.22
27,777 plants ha^{-1}(D3)	4.09^{c}	3.46^{c}	7.56^{c}	1.18
F Value	35.19^{***}	18.93^{***}	35.63^{***}	1.83^{ns}
P value	0.000	0.000	0.000	0.17
Pruning frequency				
8 weeks (F1)	6.19	4.38	10.57	1.42^{a}
12 weeks (F2)	5.72	4.93	10.66	1.16^{b}
16 weeks (F3)	5.77	4.70	10.47	1.22^{b}
F value	0.78^{ns}	1.22^{ns}	0.041^{ns}	4.17^{*}
P value	0.46	0.31	0.961	0.02

*** 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

Table 5. Interaction effect of tree species, plant density and pruning frequency on gross annual dry fodder yield and leaf-stem ratio in coconut plantation.

Treatments	Fractional and total harvested dry fodder biomass (Mg $ha^{-1}yr^{-1}$)			Leaf-stem ratio
	Leaf	Stem	Total	
T1- P1D1F1	6.70^{abcde}	4.35^{cdefgh}	11.05^{bcdef}	1.53^{ab}
T2- P1D2F1	4.80^{cdef}	3.51^{fgh}	8.31^{efgh}	1.37^{cd}
T3- P1D3F1	3.62^{f}	2.50^{h}	6.11^{h}	1.49^{ab}
T4- P1D1F2	7.16^{abc}	5.13^{abcdef}	12.28^{abcd}	1.40^{bc}
T5- P1D2F2	5.88^{bcdef}	6.10^{abc}	11.98^{abcde}	1.00^{ef}
T6- P1D3F2	4.55^{def}	4.74^{bcdefg}	9.29^{cdefgh}	0.97^{f}
T7- P1D1F3	6.99^{abcd}	6.86^{a}	13.85^{ab}	1.04^{ef}
T8- P1D2F3	4.58^{def}	4.10^{defgh}	8.68^{defgh}	1.12^{def}
T9- P1D3F3	4.13^{f}	3.53^{fgh}	7.66^{fgh}	1.17^{def}
T10- P2D1F1	9.15^{a}	6.45^{ab}	15.60^{a}	1.42^{bc}
T11- P2D2F1	8.34^{ab}	5.84^{abcd}	14.18^{ab}	1.42^{bc}
T12- P2D3F1	4.50^{ef}	3.64^{efgh}	8.15^{fgh}	1.27^{def}
T13- P2D1F2	7.01^{abcd}	5.54^{abcde}	12.56^{abc}	1.27^{def}
T14- P2D2F2	5.86^{bcdef}	4.70^{bcdefg}	10.56^{bcdefg}	1.26^{def}
T15- P2D3F2	3.88^{f}	3.39^{fgh}	7.27^{fgh}	1.15^{def}
T16- P2D1F3	7.85^{ab}	5.13^{abcdef}	12.97^{abc}	1.53^{ab}
T17- P2D2F3	7.19^{abc}	5.60^{abcd}	12.79^{abc}	1.34^{cd}
T18- P2D3F3	3.89^{f}	2.96^{gh}	6.85^{gh}	1.34^{cd}
F value	5.20^{***}	4.75^{***}	15.56^{***}	75.00^{***}
P value	0.000	0.000	0.000	0.000

*** 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

4.2.4 Survival percentage of plants as influenced by fodder tree species, plant density and pruning frequency

The data given in table indicates the survival % of fodder trees under different plant densities and pruning frequencies. Comparing the main effect of tree species, 100 % survival was observed in mulberry, whereas only 92 % of the subabul plants survived, even though the differences were non- significant. Plant density had no significant influence on survival %. With regard to pruning frequencies, pruning at a medium interval of 12 weeks ensured 100 % survival of trees, whereas the survival % declined to 92.16 % at the shorter interval of 8 weeks, even though the differences were non- significant. Treatment combinations also had no significant effect on the survival % of trees.

4.2.5 Net annual fodder yield after adjusting survival percentage in various treatments

4.2.5.1 Net fresh fodder yield

The net fresh fodder yield obtained from various treatments after adjusting the survival % of trees are given in table 6. Comparing tree species, fresh fodder yield was slightly higher for subabul (38.15 Mg $ha^{-1}yr^{-1}$) than mulberry (36.95 Mg $ha^{-1}yr^{-1}$), even though the differences were non- significant. Plant density had profound influence on net fodder yield. Yield increased from 27.06 to 45.41 Mg $ha^{-1}yr^{-1}$ from lower (D1) to higher density classes (D3). Comparing the effect of pruning frequency, significant difference was observed only on leaf yield, wherein the highest yield was obtained at the shortest pruning interval of 8 weeks (38.63 Mg $ha^{-1}yr^{-1}$) compared to longer intervals.

Table 7 gives the effect of treatment combinations on fodder yield. The highest fresh fodder yield (49.19 Mg $ha^{-1}yr^{-1}$) was obtained from T17 (Subabul + 37037 plants ha^{-1} + 16 weeks pruning interval) and was on par with that of T1 (Mulberry + 49382 plants ha^{-1} + 8weeks pruning frequency) (48.26 Mg ha^{-1}), T10 (P2D1F1), T7(P1D1F3) and T16 (P2D1F3) and significantly superior to other treatments. However, leaf yield was significantly higher for T1

(30.75 Mg ha^{-1}yr^{-1}), closely followed by T10 (29.07 Mg ha^{-1}yr^{-1}). Stem yield was significantly higher for T17.

Table 6. Effect of tree species, plant density and pruning frequency on survival percentage of trees and net annual fresh fodder yield in coconut plantation.

Treatments	Survival %	Net fractional and total fresh fodder biomass (Mg ha^{-1}yr^{-1})		
		Leaf	Stem	Total
Fodder tree species				
Mulberry (P1)	100	22.51	14.43	36.95
Subabul (P2)	92.42	22.95	15.20	38.15
F Value	2.99^{ns}	0.66^{ns}	2.75^{ns}	1.51^{ns}
P value	0.09	0.42	0.10	0.23
Plant density				
49,382 plants ha^{-1}(D1)	96.33	27.77^{a}	17.64^{a}	45.41^{a}
37,037 plants ha^{-1} (D2)	95.83	24.04^{b}	16.13^{b}	40.17^{b}
27,777 plants ha^{-1}(D3)	96.46	16.39^{c}	10.67^{c}	27.06^{c}
F Value	0.008^{ns}	152.29^{***}	83.82^{***}	123.06^{***}
P value	0.99	0.000	0.000	0.000
Pruning frequency				
8 weeks (F1)	92.16	24.10^{a}	14.52	38.63
12 weeks (F2)	100	22.05^{b}	14.43	36.49
16 weeks (F3)	96.46	22.04^{b}	15.48	37.53
Fvalue	1.07^{ns}	6.37^{**}	2.12^{ns}	1.58^{ns}
P value	0.36	0.004	0.13	0.22

*** 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

Table 7. Interaction effect of tree species, plant density and pruning frequency on survival percentage of trees and net annual fresh fodder yield underneath coconut plantation.

Treatments	Survival %	Net fractional and total fresh fodder biomass (Mg $ha^{-1}yr^{-1}$)		
		Leaf	Stem	Total
T1- P1D1F1	100	30.75^{abc}	17.50^{cde}	48.26^{abc}
T2- P1D2F1	100	22.72^{efg}	12.89^{fghi}	35.61^{ef}
T3- P1D3F1	100	17.48^{hi}	9.75^{i}	27.23^{gh}
T4- P1D1F2	100	23.93^{def}	15.55^{efg}	39.48^{def}
T5- P1D2F2	100	24.36^{def}	16.71^{def}	41.07^{cde}
T6- P1D3F2	100	19.45^{fghi}	12.77^{ghi}	32.23^{fgh}
T7- P1D1F3	100	27.80^{bcd}	19.82^{bcd}	47.63^{abc}
T8- P1D2F3	100	20.38^{fgh}	14.75^{efgh}	35.13^{efg}
T9- P1D3F3	100	15.75^{hi}	10.11^{hi}	25.87^{h}
T10- P2D1F1	77.97	29.07^{abc}	18.61^{bcde}	47.69^{abc}
T11- P2D2F1	75	25.76^{cde}	15.75^{efg}	41.51^{cde}
T12- P2D3F1	100	18.84^{ghi}	12.62^{ghi}	31.47^{fgh}
T13- P2D1F2	100	26.18^{cde}	16.19^{defg}	42.37^{cde}
T14- P2D2F2	100	23.17^{efg}	15.34^{efg}	38.52^{ef}
T15- P2D3F2	100	15.22^{i}	10.03^{hi}	25.25^{h}
T16- P2D1F3	100	28.90^{bcd}	18.15^{bcde}	47.05^{abc}
T17- P2D2F3	100	27.83^{bcd}	21.36^{ab}	49.19^{abc}
T18- P2D3F3	78.79	11.62^{i}	8.71^{i}	20.33^{h}
F value	0.88^{ns}	18.56^{***}	25.63^{***}	15.56^{***}
P value	0.6	0.000	0.000	0.000

*** 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

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4.2.5.2 Net dry fodder yield

The net annual dry fodder yield obtained from various treatments after adjusting the survival % of trees are given in table 8. Subabul yielded slightly more dry fodder (10.28 Mg $ha^{-1}yr^{-1}$) than mulberry (9.91 Mg $ha^{-1}yr^{-1}$) but the difference was non-significant. Comparing the effect of plant densities, dry fodder yield increased significantly with increasing tree density, with the maximum (12.48 Mg $ha^{-1}yr^{-1}$) at the highest density of 49382 plants ha^{-1}. Pruning frequency also had a significant influence on net dry fodder yield. The maximum yield was obtained from medium interval of 12 weeks (10.66 Mg $ha^{-1}yr^{-1}$) and was on par with that of longer interval of 16 weeks (10.23 Mg $ha^{-1}yr^{-1}$), but significantly superior to the yield (9.41 Mg $ha^{-1}yr^{-1}$) at shorter interval of 8 weeks.

Comparison of various treatment combinations (table 9) indicated maximum annual net dry fodder yield from mulberry under highest density(D1) and harvested at longest interval of 16 weeks (13.85 Mg ha^{-1}) and was on par with that of T16 (P2D1F3), T17(P2D2F3), T13 (P2D1F2), T4 (P1D1F2), T10 (P2D1F1) and T5 (P1D2F2). T1 recorded slightly lower yields. Subabul planted under the highest density (D1) and harvested at longest and shortest pruning intervals (F3 and F1) also produced comparable yields. All other treatments were significantly inferior.

4.2.5.3 Leaf yield, stem yield and leaf-stem ratio.

The net annual leaf dry yield, stem yield and leaf- stem ratio obtained from various treatments are given in table 8. Results indicated that the net dry yield of leaf and stem fraction and their ratio after adjusting the survival % showed similar trends as that of the gross yields. Pruning frequency showed no significant influence on leaf yield, but highest leaf- stem ratio (1.42) and lowest stem yield was obtained at shorter interval of 8 weeks (3.90 Mg $ha^{-1}yr^{-1}$) which was significantly superior to longer intervals.

Table 9 depicts the effect of treatment combination on net dry leaf yield, stem yield and leaf-stem ratio. Among various treatment combinations, subabul at density D1 and pruning frequency F3 (T16) recorded the highest leaf yield (7.85 Mg $ha^{-1}yr^{-1}$) and was on par with T11(P2D2F1), T17 (P2D2F3), T13 (P2D1F2), T10 (P2D1F1), T4 (P1D1F2) T7 (P1D1F3), T1(P1D1F1). Net stem yield was maximum for mulberry (6.86 Mg $ha^{-1}yr^{-1}$) at highest density (D1) and pruning frequency F3 (T7) and was on par with T5 (P1D2F2), T17 (P2D2F3), T13 (P2D1F2), T4 (P1D1F2) and T10 (P2D1F1). Leaf-stem ratio was highest for T16 and T1 (1.53), followed by T3(1.49). Even though the highest dry fodder yield was obtained for mulberry at lowest density and at the longest pruning interval the leaf-stem ratio was very low (1.04) indicating more stem fraction than leaf yields.

Comparing dry fodder yield, leaf yield and leaf-stem ratio, the best management practices in mulberry is to plant at the highest density and pruning at the shortest interval of 8 weeks, whereas in subabul planting at the closest spacing and pruning at 16 weeks interval yielded the maximum dry fodder, leaf as well as the leaf-stem ratio, followed by pruning intervals of 8 weeks and 12 weeks.

Table 8. Effect of fodder tree species, plant density and pruning frequency on net annual dry fodder yields and leaf-stem ratio in coconut plantation.

Treatments	Fractional and total harvested dry fodder biomass (Mg $ha^{-1}yr^{-1}$)			Leaf -stem ratio
	Leaf	Stem	Total	
Fodder tree species				
Mulberry (P1)	5.38^{b}	4.54	9.91	1.19
Subabul (P2)	5.86^{a}	4.42	10.28	1.33
F Value	19.20^{***}	0.49^{ns}	1.98^{ns}	2.62^{ns}
P value	0.000	0.49	0.17	0.11
Plant density				
49,382 plants ha^{-1}(D1)	7.14^{a}	5.34^{a}	12.48^{a}	1.34
37,037 plants ha^{-1} (D2)	5.76^{b}	4.73^{b}	10.49^{b}	1.22
27,777 plants ha^{-1}(D3)	3.96^{c}	3.36^{c}	7.32^{c}	1.18
F Value	279.23^{***}	47.90^{***}	132.70^{***}	1.83^{ns}
P value	0.000	0.000	0.000	0.17
Pruning frequency				
8 weeks (F1)	5.5	3.90^{b}	9.41^{b}	1.42^{a}
12 weeks (F2)	5.72	4.93^{a}	10.66^{a}	1.16^{b}
16 weeks (F3)	5.64	4.59^{a}	10.23^{a}	1.22^{b}
F value	1.34^{ns}	12.82^{***}	7.91^{**}	4.17^{*}
P value	0.27	0.000	0.001	0.02

*** 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

Table 9. Interaction effect of fodder tree species, plant density and pruning frequency on net annual dry fodder yields and leaf-stem ratio in coconut plantation.

Treatments	Fractional and total harvested dry fodder biomass (Mg $ha^{-1}yr^{-1}$)			Leaf- stem ratio
	Leaf	Stem	Total	
T1- P1D1F1	6.70^{abcde}	4.35^{cdefgh}	11.05^{bcdef}	1.53^{ab}
T2- P1D2F1	4.80^{cdef}	3.51^{fgh}	8.31^{efgh}	1.37^{cd}
T3- P1D3F1	3.62^{f}	2.50^{h}	6.11^{h}	1.49^{ab}
T4- P1D1F2	7.16^{abc}	5.13^{abcdef}	12.28^{abcd}	1.40^{bc}
T5- P1D2F2	5.88^{bcdef}	6.10^{abc}	11.98^{abcde}	1.00^{ef}
T6- P1D3F2	4.55^{def}	4.74^{bcdefg}	9.29^{cdefgh}	0.97^{f}
T7- P1D1F3	6.99^{abcd}	6.86^{a}	13.85^{ab}	1.04^{ef}
T8- P1D2F3	4.58^{def}	4.10^{defgh}	8.68^{defgh}	1.12^{def}
T9- P1D3F3	4.13^{ef}	3.53^{fgh}	7.66^{fgh}	1.17^{def}
T10- P2D1F1	7.13^{abc}	5.03^{abcdef}	12.17^{abcd}	1.42^{bc}
T11- P2D2F1	6.26^{abcd}	4.38^{cdefgh}	10.64^{bcdefg}	1.43^{bc}
T12- P2D3F1	4.50^{ef}	3.64^{efgh}	8.15^{fgh}	1.27^{def}
T13- P2D1F2	7.01^{abcd}	5.54^{abcde}	12.56^{abc}	1.27^{def}
T14- P2D2F2	5.86^{bcdef}	4.70^{bcdefg}	10.56^{bcdefg}	1.26^{def}
T15- P2D3F2	3.88^{ef}	3.39^{fgh}	7.27^{fgh}	1.15^{def}
T16- P2D1F3	7.85^{ab}	5.13^{abcdef}	12.97^{abc}	1.53^{ab}
T17- P2D2F3	7.19^{abc}	5.60^{abcd}	12.79^{abc}	1.34^{cd}
T18- P2D3F3	3.07^{f}	2.34^{h}	5.41^{h}	1.31^{cd}
F value	5.20^{***}	4.75^{***}	15.56^{***}	75.00^{***}
P value	0.000	0.000	0.000	0.000

*** 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

4.3 Plant quality and nutrient analysis

4.3.1 Crude protein

Table 10 depicts the influence of fodder trees, plant densities and pruning frequencies on crude protein content of fodder biomass. The CP content varied significantly among fodder trees with maximum in subabul (30.12 % leaf; 6.07 % stem; 18.61 % total) followed by mulberry (24.29 % leaf; 4.98 % stem;14.27 % total). In both the trees CP content in leaf fraction was much higher than that of stem. Plant density had a significant influence on CP content in leaf biomass, whereas no significant influence was observed in stem CP content. Maximum CP content in leaves (28.50 %) was found in the highest density stand (D1), whereas D2 and D3 had lower values which were on par. Whereas plant densities had no significant influence on CP content in stem biomass. Pruning frequencies had profound influence on CP content. Harvesting at shortest pruning interval of 8 weeks yielded fodder with maximum CP content (28.87 % leaf; 8.06 % stem), whereas harvesting at prolonged interval significantly reduced the CP content.

Table 11 depicts the CP content of fodder biomass from various treatment combinations. The highest crude protein (CP) content in fodder biomass was observed in subabul fodder planted at density of D1 and D2 and harvested at 16 weeks and 8 weeks interval (T10 and T16). In case of mulberry CP content in both leaf (33.5 %) and stem (8.72 %) was highest in high density stand (D1) and when pruned at shortest interval of 8 weeks and was on par with that of the best subabul combinations. All other combinations in mulberry were significantly inferior. The total N content in fodder biomass also showed similar trends.

4.3.2 Crude fibre

Table 10 depicts the influence of fodder trees, plant densities and pruning frequencies on crude fibre content of fodder biomass. Stem (71.67 %) and leaf (3.75 %) fraction of mulberry had higher CF than that of subabul. Fibre content in stem was more than double than that of leaves for both the tree fodders. Plant densities also had significant effect on crude fibre content with the least CF

(27.93 % leaf; 71.37 % stem; 48.89 % total) in plants under higher density (D1-49382 plants ha^{-1}). Pruning frequencies had profound influence on CF content of fodder biomass. Harvesting at the shortest interval of 8 weeks yielded fodder with least CF (19.62 % leaf; 65.00 % stem; 41.91 % total), whereas the CF content increased consistently with longer harvest intervals of 12 and 16 weeks. Data also revealed that harvest interval has more prominent influence on leaf fibre fraction than that of stem fibre fraction. Leaf CF content was more strongly influenced by harvest interval than stem fraction, the maximum leaf crude fibre was at an interval of 16 weeks (44 %), the second best was at an interval of 12 weeks (27.80 %). The lower per cent of crude fibre was observed in an interval of 8 weeks (19.62%). Table 11 depicts the crude fibre content of fodder biomass from various treatment combinations. The overall CF content in fodder biomass was observed in mulberry at D1 and frequency F1 and was on par with that of subabul under the same management levels. However, the CF content in leaf was considerably lower in subabul than mulberry under the above management levels.

4.3.3 Ash content

Table 10 shows the influence of fodder trees, plant densities and pruning frequencies on ash content of fodder biomass. Comparing fodder trees, mulberry had singnificantly higher ash content in leaf (9.97 %) biomass than that of subabul, whereas in stem fraction both trees had comparable values. As per the results plant density had no significant influence on ash content, whereas a drastic change was noted at different pruning frequencies, with the maximum ash content (12.36 % leaf;4.49 % stem; 8.70 % total) observed at longest interval of 16 weeks. Harvesting at shorter intervals of 8 and 12 weeks produced comparable values and was significantly inferior to that of the longest interval.

Among different treatment combinations (table 11), the highest ash content in leaf (14.62 %) and stem (5.87 %) as well as total biomass (10.54 %) was observed in mulberry fodder planted at density of D2 and D3 and harvested at 16 weeks interval.

Table 10. Effect of fodder tree species, plant density and pruning frequency on fodder quality parameters in coconut garden.

Treatments	CF %			CP %			Ash content (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
Fodder tree species									
Mulberry (P1)	30.75^{a}	71.67^{a}	53.22^{a}	24.29^{b}	4.98^{b}	14.27^{b}	9.97^{a}	3.79	6.7
Subabul (P2)	30.15^{b}	68.99^{b}	50.38^{b}	30.12^{a}	6.07^{a}	18.61^{a}	8.53^{b}	3.41	6.07
F Value	0.67^{*}	4.45^{*}	6.41*	84.64^{***}	22.64^{***}	68.77***	10.55^{**}	1.64^{ns}	3.88^{ns}
P value	0.041	0.04	0.02	0.000	0.000	0.000	0.003	0.21	0.055
Plant Density									
49,382 plants ha^{-1} (D1)	27.93^{c}	71.37^{c}	49.89	28.50^{a}	5.65	17.39^{a}	9.39	3.54	6.54
37,037 plants ha^{-1} (D2)	30.50^{b}	72.00^{b}	52.13	26.75^{b}	5.28	15.78^{b}	9.27	3.49	6.21
27,777 plants ha^{-1} (D3)	32.93^{a}	73.11^{a}	53.38	26.36^{b}	5.66	16.15^{ab}	9.09	3.77	6.42
F Value	15.77^{***}	0.64^{***}	3.32^{ns}	4.32^{*}	1.17^{ns}	3.45*	0.15^{ns}	0.33	0.37^{ns}
P value	0.000	0.000	0.045	0.02	0.52	0.041	0.86	0.72^{ns}	0.69
Pruning Frequency									
8 weeks (F1)	19.62^{c}	65.00^{c}	41.91^{c}	28.87^{a}	8.06^{a}	18.51^{a}	7.48^{b}	3.03^{b}	5.25^{b}
12 weeks (F2)	27.80^{b}	73.72^{b}	53.75^{b}	23.88^{b}	5.40^{b}	16.29^{b}	7.90^{b}	3.28^{b}	5.23^{b}
16 weeks (F3)	44.00^{a}	77.75^{a}	59.73^{a}	20.94^{c}	3.12^{c}	13.54^{c}	12.36^{a}	4.49^{a}	8.70^{a}
F value	385.63^{***}	34.90^{***}	87.36^{***}	27.67^{***}	155.46^{***}	29.5^{***}	49.50^{***}	9.16^{**}	52.23^{***}
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000

*** 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

Table 11. Interaction effect of tree species, plant density and pruning frequency on fodder quality parameters in coconut garden.

Treatments	CF (%)			CP (%)			Ash content (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
T1- P1D1F1	22.50^{d}	65.10^{ef}	40.14^{g}	27.42^{bc}	7.38^{bcd}	19.14^{abc}	8.48^{defg}	3.54^{bcd}	6.39^{cd}
T2- P1D2F1	17.40^{e}	69.71^{cdef}	43.26^{eg}	25.59^{c}	7.11^{cd}	16.40^{cde}	8.90^{cdefg}	2.72^{cd}	5.74^{de}
T3- P1D3F1	24.40^{cd}	63.66^{ef}	41.76^{fg}	24.92^{c}	7.50^{bcd}	16.72^{cde}	6.11^{g}	3.56^{bcd}	4.82^{de}
T4- P1D1F2	22.83^{d}	77.48^{abc}	53.07^{bcd}	24.23^{c}	4.71^{efgh}	13.56^{e}	8.87^{cdefg}	3.40^{bcd}	5.85^{de}
T5- P1D2F2	31.03^{b}	72.10^{abcde}	56.96^{abc}	19.52^{e}	5.07^{ef}	10.33^{f}	8.13^{efg}	2.86^{cd}	4.84^{de}
T6- P1D3F2	27.67^{bc}	75.81^{abc}	58.78^{ab}	20.58^{de}	4.88^{efg}	10.42^{f}	9.55^{cdef}	3.77^{bcd}	5.81^{de}
T7- P1D1F3	42.17^{a}	79.00^{ab}	61.21^{a}	26.21^{c}	2.50^{hi}	13.99^{e}	13.16^{ab}	3.06^{cd}	8.00^{bc}
T8- P1D2F3	43.80^{a}	77.67^{abc}	62.01^{a}	25.46^{c}	2.92^{hi}	13.45^{e}	11.91^{abc}	5.33^{ab}	8.34^{b}
T9- P1D3F3	44.94^{a}	81.00^{a}	61.75^{a}	24.71^{c}	2.83^{hi}	14.41^{e}	14.62^{a}	5.87^{a}	10.54^{a}
T10- P2D1F1	14.50^{e}	66.41^{def}	41.89^{fg}	33.56^{a}	8.72^{ab}	20.41^{ab}	6.39^{fg}	4.15^{abc}	5.19^{de}
T11- P2D2F1	16.95^{e}	61.25^{f}	40.70^{g}	34.31^{a}	8.53^{abc}	20.52^{ab}	8.59^{defg}	2.51^{cd}	5.29^{de}
T12- P2D3F1	21.95^{d}	63.85^{ef}	43.74^{efg}	27.44^{bc}	9.19^{a}	17.85^{bcd}	6.44^{fg}	1.72^{d}	4.04^{e}
T13- P2D1F2	23.80^{cd}	71.21^{bcde}	50.75^{cde}	26.19^{c}	6.84^{d}	15.28^{de}	7.47^{fg}	2.95^{cd}	4.86^{de}
T14- P2D2F2	29.34^{b}	70.50^{bcde}	48.41^{def}	24.94^{c}	4.80^{efgh}	16.11^{cde}	6.93^{fg}	3.63^{bcd}	5.27^{de}
T15- P2D3F2	32.10^{b}	75.25^{abcd}	54.53^{abcd}	27.78^{bc}	6.13^{de}	16.60^{cde}	6.44^{fg}	3.08^{cd}	4.66^{de}
T16- P2D1F3	41.75^{a}	69.00^{cdef}	52.27^{bcd}	33.41^{a}	3.72^{fghi}	21.95^{a}	11.95^{abc}	4.16^{abc}	8.94^{ab}
T17- P2D2F3	44.45^{a}	80.75^{a}	61.43^{a}	30.69^{ab}	3.30^{hi}	17.89^{bcd}	11.14^{bcde}	3.89^{abc}	7.75^{bc}
T18- P2D3F3	46.53^{a}	79.10^{ab}	59.70^{ab}	32.75^{a}	3.5^{hi}	20.87^{ab}	11.40^{bcd}	4.61^{abc}	8.65^{b}
F value	435.69^{***}	2.32^{*}	12.24^{***}	2.51^{*}	0.70^{*}	10.99^{***}	7.41^{***}	2.52^{*}	8.75^{***}
P value	0.000	0.04	0.000	0.03	0.42	0.000	0.000	0.010	0.000

*** 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

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4.3.4 Nitrogen content

Table 12 shows the influence of fodder trees, plant densities and pruning frequencies on nitrogen content of fodder biomass. Nitrogen content varied significantly among fodder trees with maximum in subabul (4.82 % leaf; 0.97 % stem), followed by mulberry (3.89 % leaf; 0.80 % stem). The nitrogen content of leaf biomass also varied significantly with plant density. The N content of leaf biomass (4.56 %) was maximum in the highest plant density, whereas the content in stem biomass showed no significant variation. Comparing pruning frequency, the nitrogen content was maximum at shortest cutting interval (4.62 % leaf; 1.30 % stem) of 8 weeks.

Table 13 shows the nitrogen content of fodder biomass obtained from various treatment combinations. The highest total N content in fodder biomass was observed in subabul fodder planted at density of D1 and D2 and harvested at 16 weeks and 8 weeks interval (T10 and T16). In case of mulberry, N content in both leaf (33.5 %) and stem (8.72 %) was highest in high density stand (D1) and when pruned at shortest interval of 8 weeks and was on par with that of the best subabul combination. All other combinations in mulberry were significantly inferior.

4.3.5 Phosphorus content

Table 12 shows the influence of tree species, plant densities and pruning frequencies on phosphorus content of fodder biomass. Comparison of fodder trees the maximum phosphorus content of leaf biomass was observed in mulberry (0.82 %), whereas the stem biomass had no significant influence on P content. Among plant densities the P content of leaf biomass was maximum(0.79 %) in D2 and this was on par with D1(0.68 %), whereas in stem biomass the maximum (0.40 %) was observed at D1 (49,382 plants ha^{-1}) and this was on par with D2 (0.30 %). Comparing various pruning frequencies, the maximum P content of fodder biomass was recorded at shortest cutting interval (1.53 % leaf; 0.64 % stem), which was significantly superior to that of 12 weeks and 16 weeks.

Table 13 depicts the P content obtained from various treatment combinations. The phosphorus content in fodder was significantly higher (1.43 %) for mulberry under density D1 and frequency F1, whereas the P content in leaf was highest for mulberry under the same frequency but density D2. Subabul fodder also had the highest P content under D1 and F1 management levels, but was significantly inferior to mulberry under the same management levels.

4.3.6 Potassium content

Table 12 shows the potassium content in fodder biomass as influenced by tree species, plant densities and pruning frequencies. The K content in leaf biomass of mulberry (0.67 %) and subabul (0.59 %) had a comparable value, whereas the K content in stem biomass was maximum in subabul (0.69 %), which was significantly superior to that of mulberry (0.59 %). Comparing plant density, the K content in leaf biomass had no significant variation, whereas in stem biomass, D2 (0.69 %) was significantly superior to that of D1(0.57 %) and D3 (0.66 %) and D2 and D3 were on par. Among various pruning frequencies the K content of leaf biomass was maximum at F2 (0.77 %) and F1 (0.67 %) and they were on par, whereas in stem biomass the maximum K content was found in F3 (0.79 %) and F1 (0.69 %), which were on par.

Table 13 depicts the total potassium obtained from various treatment combinations. Comparing subabul and mulberry, the K content was highest in subabul (0.79 %) under lowest plant density (D3) and shortest pruning interval (F1) and this was on par with that of mulberry under same management levels (0.77 %).

Table 12. Effect of tree species, plant density and pruning frequency on nutrient content of fodder in coconut garden.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
Fodder tree species									
Mulberry (P1)	3.89^{b}	0.80^{b}	2.28^{b}	0.82^{a}	0.33	0.58^{a}	0.67	0.59^{b}	0.62
Subabul (P2)	4.82^{a}	0.97^{a}	2.98^{a}	0.58^{b}	0.32	0.45^{b}	0.59	0.69^{a}	0.63
F Value	84.67^{***}	22.99^{***}	68.96^{***}	14.74^{***}	0.01^{ns}	8.06^{**}	2.14^{ns}	5.48^{*}	1.91^{ns}
P value	0.000	0.000	0.000	0.000	0.93	0.007	0.15	0.03	0.16
Plant Density									
49,382 plants ha^{-1} (D1)	4.56^{a}	0.9	2.78^{a}	0.68^{ab}	0.40^{a}	0.55	0.61	0.57^{b}	0.56
37,037 plants ha^{-1} (D2)	4.28^{b}	0.85	2.52^{b}	0.79^{a}	0.30^{ab}	0.54	0.66	0.69^{a}	0.67
27,777 plants ha^{-1} (D3)	4.22^{b}	0.91	2.58^{ab}	0.63^{b}	0.26^{b}	0.45	0.63	0.66^{ab}	0.63
F Value	4.32^{*}	1.16^{ns}	3.48^{*}	2.40^{*}	2.72^{*}	1.73^{ns}	0.39^{ns}	2.66^{*}	1.73^{ns}
P value	0.02	0.53	0.04	0.32	0.04	0.19	0.68	0.04	0.19
Pruning Frequency									
8 weeks (F1)	4.62^{a}	1.30^{a}	3.16^{a}	1.53^{a}	0.64^{a}	1.1^{a}	0.67^{a}	0.69^{a}	0.68
12 weeks (F2)	3.82^{b}	0.86^{b}	2.51^{b}	0.25^{b}	0.17^{b}	0.21^{b}	0.77^{a}	0.43^{b}	0.58
16 weeks (F3)	3.25^{c}	0.50^{c}	2.11^{c}	0.32^{b}	0.15^{b}	0.24^{b}	0.46^{b}	0.79^{a}	0.6
F value	27.65^{***}	155.03^{***}	29.72^{***}	171.82^{***}	40.12^{***}	146.51^{***}	11.87^{***}	21.89^{***}	1.39^{ns}
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.26

*** 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

Table 13. Interaction effect of tree species, plant density and pruning frequency on nutrient content of fodder.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
T1- P1D1F1	4.39^{bc}	1.18^{bcd}	3.06^{abc}	1.68^{b}	1.01^{a}	1.43^{a}	0.63^{abcdef}	0.67^{cdef}	0.64^{bcd}
T2- P1D2F1	4.09^{c}	1.14^{cd}	2.62^{def}	2.11^{a}	0.46^{bc}	1.29^{ab}	0.54^{bcdef}	0.75^{bcde}	0.65^{bcd}
T3- P1D3F1	3.99^{c}	1.19^{bcd}	2.68^{def}	1.83^{ab}	0.47^{bc}	1.20^{abc}	0.82^{abc}	0.64^{cdef}	0.77^{ab}
T4- P1D1F2	3.88^{cd}	0.75^{efgh}	2.17^{f}	0.28^{e}	0.17^{c}	0.22^{e}	0.78^{abcd}	0.40^{f}	0.57^{bcd}
T5- P1D2F2	3.12^{e}	0.81^{ef}	1.65^{g}	0.25^{e}	0.16^{c}	0.19^{e}	0.74^{abcde}	0.38^{f}	0.53^{bcd}
T6- P1D3F2	3.29^{de}	0.78^{efg}	1.66^{g}	0.26^{e}	0.20^{c}	0.22^{e}	0.85^{ab}	0.46^{def}	0.60^{bcd}
T7- P1D1F3	4.19^{c}	0.40^{i}	2.24^{f}	0.31^{e}	0.16^{c}	0.23^{e}	0.45^{cdef}	0.45^{ef}	0.42^{d}
T8- P1D2F3	4.07^{c}	0.47^{i}	2.15^{f}	0.33^{e}	0.14^{c}	0.23^{e}	0.94^{a}	1.03^{ab}	0.99^{a}
T9- P1D3F3	3.95^{c}	0.45^{i}	2.31^{f}	0.34^{e}	0.15^{c}	0.25^{e}	0.29^{f}	0.49^{def}	0.39^{d}
T10- P2D1F1	5.37^{a}	1.40^{ab}	3.26^{ab}	1.27^{c}	0.72^{ab}	0.98^{c}	0.57^{abcdef}	0.61^{cdef}	0.59^{bcd}
T11- P2D2F1	5.49^{a}	1.37^{abc}	3.28^{ab}	1.55^{bc}	0.71^{ab}	1.11^{bc}	0.65^{abcdef}	0.70^{cdef}	0.67^{bc}
T12- P2D3F1	4.39^{bc}	1.47^{a}	2.85^{bcd}	0.75^{d}	0.47^{bc}	0.59^{d}	0.80^{abc}	0.78^{bcd}	0.79^{ab}
T13- P2D1F2	4.19^{c}	1.10^{d}	2.44^{ef}	0.23^{e}	0.20^{c}	0.21^{e}	0.82^{abc}	0.41^{f}	0.59^{bcd}
T14- P2D2F2	3.99^{c}	0.77^{efgh}	2.57^{def}	0.23^{e}	0.19^{c}	0.21^{e}	0.82^{abc}	0.45^{f}	0.66^{bc}
T15- P2D3F2	4.45^{bc}	0.98^{de}	2.65^{def}	0.23^{e}	0.13^{c}	0.18^{e}	0.61^{abcdef}	0.50^{def}	0.56^{bcd}
T16- P2D1F3	5.35^{a}	0.60^{fghi}	3.51^{a}	0.30^{e}	0.16^{c}	0.24^{e}	0.38^{ef}	0.86^{abc}	0.57^{bcd}
T17- P2D2F3	4.91^{ab}	0.53^{hi}	2.86^{bcd}	0.29^{e}	0.17^{c}	0.23^{e}	0.28^{f}	0.84^{abc}	0.54^{bcd}
T18- P2D3F3	5.24^{a}	0.56^{ghi}	3.34^{ab}	0.35^{e}	0.15^{c}	0.27^{e}	0.41^{def}	1.09^{a}	0.69^{bc}
F value	10.06^{***}	0.69^{*}	11.02^{***}	23.88^{***}	6.00^{***}	21.58^{***}	3.28^{**}	5.00^{***}	2.87^{**}
P value	0.000	0.40	0.000	0.000	0.000	0.000	0.001	0.000	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

4.4 Soil fertility status

4.4.1 Soil physical properties

4.4.1.1Bulk density

The result given in the table 14 indicate that fodder trees, plant densities and pruning frequencies as well as their interactions had no significant influence on soil BD. However, the least BD (1.32 g/cc) was observed in T17 and in the sole coconut plot.

4.4.1.2 Water holding capacity (WHC)

Data given in table 14 indicate that, fodder trees, plant densities and pruning frequencies had no significant influence on WHC of soil. However significant differences were noted among the treatment combinations, wherein subabul and mulberry under density D2 and pruning frequency F3 (T17; 53.74 %, T8; 50.43 %) as well as soils underneath sole coconut (Open control) had comparatively higher soil WHC than other combinations.

4.4.1.3 Soil pH

The result indicated in table 14 shows that fodder trees, plant densities and pruning frequencies had no significant influence on soil pH. However, soil pH varied significantly (Table. 15) among treatment combinations, wherein T17 (Subabul +37037 plants ha^{-1} + 16 weeks pruning interval) was significantly superior (6.59) to that of other treatment combinations. T7 (Mulberry + 49382 plants ha^{-1} + 16 weeks pruning interval) and T14(Subabul + 37037 plants ha^{-1} + 12 weeks pruning interval) had soil pH of 6.13 and 6.11 respectively, and they were on par. In open plot the soil pH was 5.72 .

4.4.1.4 Electrical conductivity

Data on EC of the soil are given in table14. Comparing fodder trees, soils under mulberry showed a slight increment in EC than that of subabul, but the differences were non- significant. Plant densities significantly influenced EC and the values increased from 0.28 to 0.47dS m^{-1} from lower to higher density stands. However, pruning frequencies had no significant effect on soil EC. The effect of treatment combinations on soil EC are given in table 15. The results revealed that T14 (Subabul + 37037 plants ha^{-1} + 12 weeks pruning interval) and T7 (Mulberry + 49382 plants ha^{-1} + 16 weeks pruning interval) had the maximum soil EC of 0.72 and 0.71 dS m^{-1} respectively. The second best (0.59 dS m^{-1}) treatment was T1 (Mulberry + 49382 plants ha^{-1} + 8 weeks pruning interval). In open plot the soil EC was 0.14 dS m^{-1}.

4.4.1.5 Organic carbon

Table 14 shows the soil organic carbon content in different fodder trees, plant densities and pruning frequencies. The study indicated that all the three factors and their interactions had no significant influence on SOC. However SOC improved significancantly in all coconut-fodder tree intercropping systems with a range of 1.14 to 1.63 % when compared to that of sole crop of coconut (0.79 %).

4.4.1.6 Available nitrogen

Table 14 shows the available nitrogen content in soil under different tree species, plant densities and pruning frequencies. The result indicated that all the above factors had no significant effect on available nitrogen. Among fodder trees the maximum was found in subabul (548 Kg ha^{-1}). When comparing the available nitrogen from different treatment combinations (table 12) the maximum (651 Kg ha^{1}) was observed in T17 (subabul +37037 plants ha^{-1} + 16 weeks pruning interval), followed by T5 (Mulberry + 37037 plants ha^{-1} + 12 weeks pruning interval) with 644 Kg ha^{-1} and T18 (subabul + 37037 plants ha^{-1} + 16 weeks pruning interval), and they were on par.

4.4.1.7 Available phosphorus

Comparing fodder trees, soil under mulberry had significantly higher available P content (10.93 %) than that of subabul (7.33 %) (table.14). Plant density showed no significant effect on P content. Comparing pruning frequencies, P content showed the trend F3 (11.06 %)>F1 (9.5 %)>F2 (6.83 %). T9 (Mulberry + 27,777 plants ha^{-1} + 16 weeks pruning interval) was significantly superior to that of other treatment combination with maximum of 14.67 Kg ha^{-1} . The second best was T16 (Subabul + 49,382 plants ha^{-1} + 16 weeks pruning frequency) with 14.33 Kg ha^{-1} of soil available phosphorus. The open plot had only 3 Kg ha^{-1} available P in soil.

4.4.1.8 Available potassium

Available potassium content in soil under different fodder trees, plant densities and pruning frequencies are given in table 14. All the above factors had no significant influence on available potassium. Table 15 depicts the available potassium obtained from various treatment combinations. The study revealed that T1 (Mulberry + 49,382 plants ha^{-1} + 8 weeks pruning interval) was significantly (601 Kg ha^{-1}) superior to that of other treatment combinations. The second best treatment (529 Kg ha^{-1}) was T2 (Mulberry + 37037 plants ha^{-1} + 8weeks pruning frequency). 454 Kg ha^{-1} of available potassium was found in open plot.

Table 14. Soil fertility status as influenced by tree species, plant density and pruning frequency in coconut plantation.

Treatments	WHC (%)	Bulk Density (g/cm3)	pH	EC (dS m^{-1})	Organic Carbon (%)	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
Fodder tree species								
Mulberry(P1)	44.62	1.38	5.53	0.44	1.34	539	10.93^{a}	363
Subabul (P2)	46.08	1.36	5.66	0.33	1.38	548	7.33^{ab}	302
F Value	0.35^{ns}	1.75^{ns}	0.61^{ns}	3.92^{ns}	0.25^{ns}	0.0^{ns}	11.26^{**}	3.63^{ns}
P value	0.23	0.19	0.5	0.06	0.62	0.99	0.002	0.07
Plant density								
49,382 plants ha^{-1}(D1)	44.48	1.37	5.65	0.47^{a}	1.38	558	9.78	350^{a}
37,037 plants ha^{-1} (D2)	47.09	1.37	5.66	0.39^{ab}	1.32	565	9.11	408^{a}
27,777 plants ha^{-1}(D3)	44.48	1.37	5.47	0.28^{b}	1.4	493	8.5	240^{b}
F Value	3.45^{ns}	0.012^{ns}	0.58^{ns}	3.76^{*}	0.42^{ns}	1.45^{ns}	0.47^{ns}	9.46^{***}
P value	0.64	0.99	0.57	0.33	0.67	0.24	0.63	0.000
Pruning frequency								
8 weeks (F1)	44.28	1.37	5.52	0.4	1.37	524	9.5^{a}	387
12 week(F2)	44.85	1.38	5.62	0.29	1.37	559	6.83^{b}	297
16 week(F3)	46.91	1.36	5.65	0.46	1.36	534	11.06^{a}	315
F value	0.42^{ns}	0.36^{ns}	0.22^{ns}	3.15^{ns}	0.005^{ns}	0.30^{ns}	5.56^{*}	2.98^{ns}
P value	0.56	0.70	0.80	0.055	1.00	0.74	0.01	0.60

*** 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

Table 15. Interaction effect of tree species, plant density and pruning frequency on soil fertility parameters in coconut plantation.

Treatments	WHC (%)	Bulk Density (g/cm3)	pH	EC ($dS\ m^{-1}$)	Organic Carbon (%)	Available N (K/ha)	Available P(Kg/ha)	Available K (Kg/ha)
T1- P1D1F1	44.29^{cde}	1.40	6.10^{ab}	0.59^{ab}	1.22^{ab}	512^{ef}	13.33^{ab}	601^{a}
T2- P1D2F1	41.02^{e}	1.36	4.92^{bc}	0.36^{abc}	1.30^{ab}	449^{ef}	13.00^{ab}	529^{ab}
T3- P1D3F1	42.90^{de}	1.41	5.03^{bc}	0.38^{abc}	1.34^{ab}	476^{ef}	7.00^{bcd}	223^{ef}
T4- P1D1F2	42.53^{de}	1.39	5.23^{bc}	0.47^{abc}	1.14^{ab}	612^{ab}	9.33^{abcd}	266^{cdef}
T5- P1D2F2	44.69^{cde}	1.40	5.81^{abc}	0.36^{abc}	1.39^{a}	644^{a}	7.00^{bcd}	452^{abcd}
T6- P1D3F2	44.77^{cde}	1.35	5.69^{abc}	0.28^{bc}	1.59^{a}	514^{ef}	13.33^{ab}	298^{cdef}
T7- P1D1F3	43.19^{de}	1.35	6.13^{ab}	0.71^{a}	1.47^{a}	551^{bcd}	10.00^{abcd}	429^{abcde}
T8- P1D2F3	50.43^{abc}	1.39	5.03^{bc}	0.29^{bc}	1.22^{ab}	505^{ef}	10.67^{abc}	231^{def}
T9- P1D3F3	47.72^{bcd}	1.36	5.86^{abc}	0.51^{abc}	1.44^{a}	578^{bcd}	14.67^{a}	243^{def}
T10- P2D1F1	46.71^{bcde}	1.34	5.79^{abc}	0.39^{abc}	1.63^{a}	$585^{b\ cd}$	7.67^{bcd}	284^{cdef}
T11- P2D2F1	47.29^{bcde}	1.39	5.50^{abc}	0.43^{abc}	1.40^{a}	622^{ab}	7.00^{bcd}	421^{abcde}
T12- P2D3F1	43.48^{de}	1.33	5.80^{abc}	0.27^{bc}	1.32^{ab}	497^{ef}	9.00^{abcd}	266^{cdef}
T13- P2D1F2	45.63^{cde}	1.39	5.66^{abc}	0.27^{bc}	1.49^{a}	555^{bcd}	4.00^{cd}	189^{e}
T14- P2D2F2	45.39^{cde}	1.36	6.11^{ab}	0.19^{bc}	1.25^{ab}	519^{ef}	3.33^{cd}	342^{bcdef}
T15- P2D3F2	46.11^{cde}	1.36	5.20^{bc}	0.15^{c}	1.33^{ab}	502^{ef}	4.00^{cd}	233^{def}
T16- P2D1F3	44.53^{cde}	1.35	5.02^{bc}	0.41^{abc}	1.31_{ab}	535^{bcd}	14.33^{ab}	333^{bcdef}
T17- P2D2F3	53.74^{a}	1.32	6.59^{a}	0.72^{a}	1.33^{ab}	651^{a}	13.67^{ab}	474^{abc}
T18- P2D3F3	41.87^{de}	1.41	5.27^{bc}	0.12^{c}	1.39^{a}	642^{a}	3.00^{d}	178^{e}
open	52.54^{ab}	1.32	5.72^{abc}	0.14^{c}	0.79^{b}	559^{bcd}	3.00^{d}	454^{abcd}
F value	568.02^{***}	35.64^{ns}	293.27^{***}	12.17^{***}	64.48^{***}	43.67^{***}	3.45^{**}	29.52^{***}
P value	0.000	0.71	0.000	0.000	0.000	0.000	0.001	0.000

*** 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

4.5 Economics

Economics and B:C ratio of fodder production as influenced by tree species and various management practices in coconut plantation are presented in Table 16. The study revealed that the B:C ratio was significantly higher for subabul (0.92) than mulberry (0.84). Comparing plant densities, the B:C ratio was maximum from high density stand D1 (0.98), and was on par with D2 (0.96), but significantly superior to D3 (0.70). Pruning frequency had no significant effect on B:C ratio, even though a slightly increment was observed at shorter intervals than prolonged intervals. When comparing the coconut- fodder intercropping system, the B:C ratio was comparable for both fodder tree species. Comparing plant densities, significantly higher B:C ratio was observed at medium (1.50) and highest (1.47) plant density when compared to the lowest density. Pruning frequency had no significant influence on B:C ratio.

Comparing the economics of various treatment combinations (table.17), T17 (P2D2F3) showed the maximum B:C ratio (1.15) for fodder production as well as for coconut-fodder intercropping system (1.73) and was on par with that of T10, T11, T1, T16, T14, T7, T5, and T13.

Table. 16 Economics of fodder production as influenced by tree species, plant density and pruning frequency underneath coconut plantation.

Treatments	B:C ratio for fodder production	B:C ratio for coconut-fodder intercropping system
Mulberry (P1)	0.83^{b}	1.41
Subabul (P2)	0.92^{a}	1.44
F Value	4.20^{*}	0.74
P value	0.04	0.40^{ns}
49382 plants ha^{-1}(D1)	0.98^{a}	1.47^{a}
37037 plants ha^{-1} (D2)	0.96^{a}	1.50^{a}
27777 plants ha^{-1}(D3)	0.70^{b}	1.31^{b}
F Value	18.98***	7.79^{**}
P value	0.000	0.002
8 weeks (F1)	0.92	1.42
12 weeks (F2)	0.85	1.42
16 weeks (F3)	0.87	1.44
Fvalue	0.85^{ns}	0.059^{ns}
P value	0.43	0.94

*** 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

Table. 17 Economics of fodder production as influenced by various treatment combinations under coconut plantation.

Treatments	Total cost of fodder production (₹ha^{-1} yr^{-1})	Annual fodder yield (Mg ha^{-1}yr^{-1})	Returns from fodder (₹ yr^{-1})	B:C ratio of fodder production	Returns from coconut (₹ ha^{-1} yr^{-1})	Gross returns from both fodder and coconut (₹ha^{-1}yr^{-1})	Net returns from coconut-fodder intercropping system	B: C ratio from coconut-fodder intercropping system
T1- P1D1F1	2,45,927.45	48.26^{abc}	2,43,767	0.99^{ab}	1,23,965	3,67,462	1,21,535	1.50^{ab}
T2- P1D2F1	2,20,595.9	35.61^{ef}	1,78,050	0.81^{bcd}	1,23,965	3,01,745	81,149	1.37^{bc}
T3- P1D3F1	2,01,304.35	27.23^{gh}	1,36,133	0.68^{cd}	1,23,965	2,59,828	58,524	1.29^{bc}
T4- P1D1F2	2,41,231.25	39.48^{def}	1,97,400	0.82^{bcd}	1,23,965	3,21,095	79,864	1.33^{bc}
T5- P1D2F2	2,15,899.7	41.07^{cde}	2,05,317	0.95^{ab}	1,23,965	3,29,012	1,13,112	1.52^{ab}
T6- P1D3F2	1,96,608.15	32.23^{fgh}	1,61,133	0.82^{bcd}	1,23,965	2,84,828	88,220	1.45^{ab}
T7- P1D1F3	2,38,883.15	47.63^{abc}	2,38,150	1.00^{ab}	1,23,965	3,61,845	1,22,962	1.51^{ab}
T8- P1D2F3	2,13,551.6	35.13^{efg}	1,75,667	0.82^{bcd}	1,23,965	2,99,362	85,810	1.40^{bc}
T9- P1D3F3	1,94,260.05	25.87^{h}	1,29,317	0.67^{cd}	1,23,965	2,53,012	58,752	1.30^{bc}
T10- P2D1F1	2,45,927.45	47.69 ^{abc}	2,36,500	1.14^{a}	1,23,965	3,60,195	1,14,268	1.46^{ab}
T11- P2D2F1	2,20,595.9	41.51^{cde}	2,07,488	1.10^{a}	1,23,965	3,31,183	1,10,587	1.50^{ab}
T12- P2D3F1	2,01,304.35	31.47^{fgh}	1,57,333	0.78^{bcd}	1,23,965	2,81,028	79,724	1.40^{bc}
T13- P2D1F2	2,41,231.25	42.37^{cde}	2,35,250	0.98^{ab}	1,23,965	3,58,945	1,17,714	1.49^{ab}
T14- P2D2F2	2,15,899.7	38.52^{ef}	2,45,967	0.89^{abc}	1,23,965	3,16,245	1,00,345	1.47^{ab}
T15- P2D3F2	1,96,608.15	25.25^{h}	1,28,717	0.65^{cd}	1,23,965	252412	55,804	1.28^{bc}
T16- P2D1F3	2,38,883.15	47.05 ^{abc}	2,352,50	0.98^{ab}	1,23,965	3,58,945	1,20,062	1.50^{ab}
T17- P2D2F3	2,48,954.1	49.19^{abc}	2,45,967	1.15^{a}	1,23,965	3,69,662	1,56,110	1.73^{a}
T18- P2D3F3	1,94,260.05	20.33^{h}	1,01,686	0.62^{d}	1,23,965	2,25,381	31,121	1.16^{c}
F value		15.56***		4.84***				2.14*

DISCUSSION

DISCUSSION

Comparative performance of Mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based fodder production system were explored and observations are discussed hereunder.

5.1 Growth Performance of fodder trees under varying plant densities at first uniform cut

Mulberry and subabul showed significant variation in growth performance at the stage of first uniform cut (table 1). Plant height (146.43 cm), collar diameter (CD), (14.39 mm), harvested biomass (1.89 Mg ha^{-1}) was significantly higher for mulberry, whereas subabul excelled in number of branches (3.73). These results indicated that rapid field establishment and vigorous growth of mulberry when compared to subabul during initial stages. Plant density had no significant effect ($p>0.05$) on collar diameter and number of leaves, whereas plant height showed significant increment at higher densities of 49,382 plants ha^{-1} (144.87 cm) and 37,037 plant ha^{-1} (145.41 cm), compared to the lowest density of 27,777 plants ha^{-1}. The closer spacing between plants cause comparatively lesser availability of space around the plants for lateral development thereby, forcing plants to grow vertically (Patel *et al.*, 1980). Similarly, fodder yield also increased from 0.79 to 2.01 Mg ha^{-1} from lower (D3) to higher density classes (D1). Fractional yield obtained from leaf and stem also followed similar trends. Similar findings were reported by Ella *et al.* (1989), who 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.

Comparing treatment combinations, growth parameters like height and yield parameters were significantly higher for mulberry at the highest density D1 than all other combinations, whereas in subabul the growth and yield parameters were found to be better at a medium density of D2. This implies growth reduction in subabul at lower densities when compared to that of mulberry. This could be due to the branching nature of subabul (table 1), which require more spacing for proper growth and yield.

5.2 Effect of different tree species, plant density and pruning frequency on fodder yield and quality underneath coconut garden.

5.2.1 Fodder tree species

Mulberry and subabul were the fodder trees selected for the study. The selected fodder trees were planted at varying densities under coconut plantation and pruned at different frequencies. The main effect of the tree species on fodder yield and quality attributes are discussed hereunder.

Comparing the main effect of fodder trees on fresh fodder yield, subabul yielded the maximum fodder (41.78 Mg $ha^{-1}yr^{-1}$) and was significantly superior to that of mulberry (36.95 Mg $ha^{-1}yr^{-1}$). However, the overall survival % of subabul as observed in the present study was found to be 92 % as against the 100 % survival of mulberry trees. Hence, the resultant net fresh fodder yields after adjusting the survival % was found to be comparable for both subabul (38.15 Mg $ha^{-1}yr^{-1}$) and mulberry (36.95 Mg $ha^{-1}yr^{-1}$) (Fig.3). Leaf yield and stem yield also showed similar trends, wherein both the tree species showed comparable values. In mulberry, yields nearly 35-45 tonnes of fresh leaf/ha/year was obtained under irrigation and with the recommended dose of fertilizer (Datta, 2008). Yields of up to 50 tonnes per hectare per year has been reported in subabul under a variety of conditions (Felker & Bandurski, 1979).

Similar to fresh yield trends, total dry fodder yield was also comparable for subabul (11.22 Mg ha^{-1} yr^{-1}) and mulberry (9.91 Mg ha^{-1} yr^{-1}). The net dry fodder yields after adjusting the survival percentage also showed similar trend, with a slight reduction in yield of subabul from 11.22 to 10.28 Mg $ha^{-1}yr^{-1}$ (Fig.4). However, net leaf yield was significantly higher for subabul (5.86 Mg $ha^{-1}yr^{-1}$) than mulberry (5.38 Mg ha^{-1} yr^{-1}).

Leaf- stem ratio was found to be slightly higher in subabul (1.33) than mulberry (1.19), but the difference was found to be non-significant. Stem fractions were comparable for both mulberry and subabul.

There were significant ($P<0.05$) variations among the tree species with regard to proximate composition. The total N content (2.98 %) in fodder biomass was significantly higher in subabul (Fig.8), which also resulted in higher CP content (30.12 % leaf; 6.07 % stem; 18.61 % total) (Fig.5) than that of mulberry (24.29 % leaf; 4.98 % stem; 14.27% total). In general, leguminous trees like subabul had higher CP content than the non-leguminous one like mulberry, which is in agreement with other studies (Valli and Murugan, 1998; Parthasarthy *et al.*, 1998; Datt and Singh., 2007). However, both the trees possessed more than 10% of CP, which is the ideal level for proper rumen fermentation (Alam *et al.,* 1994).

On an average basis, subabul (50.38 %) also had significantly lower crude fibre (CF) content than mulberry (53.22 %) (Fig.6). However, Datt and Singh (2007) observed comparable CF content in mulberry and subabul.

Mulberry had significantly higher ash content in leaf (9.97 %) biomass than that of subabul (8.53 %) (Fig.7), whereas in stem fraction and in total biomass both had comparable values. Mulberry also had significantly higher P content (Fig.9) in leaf (0.82 %) and total biomass than subabul, whereas the values in stem fraction was on par. The total K content in mulbery (0.62 %) and subabul (0.63 %) were found to be on par (Fig.10).

Sanchez (2001) studied the nutritional characteristics of mulberry and identified that, in mulberry the mineral content is high and there was no any anti-nutritional factors or toxic compounds. The nutritional value of mulberry leaf is 80%–100% higher than grass and 40%–50% higher than leguminous pasture (Xu, 2004; Sanchez,2001). Based on its high CP content (150-248 g/kg DM) and DM digestability (750-855g/kg DM) (Ba *et al.*, 2005) *M.alba* compares well with leguminous multipurpose trees (MPTs) as a feed for ruminants (Topps, 1992; Roothaert and Paterson, 1997).

In general, the fodder yields from mulberry and subabul were found to be comparable when planted as an intercrop in coconut garden. Regarding the nutitritional properties, subabul excelled in CP content, whereas mulberry was superior in ash and mineral content.

5.2.2 Plant density

The management of fodder trees for maximum production depends on several factors like plant density, pruning frequency etc.

As shown in Fig 3, plant density significantly ($p<0.001$) influenced fodder yields of mulberry and subabul; higher densities caused an increase in total forage yield per unit area. Similar trend was noticed in both gross and net fodder yields. In general, an increase of 68 percent in net fresh yield was noticed with increment in tree density from 27,777 to 49,382 plants ha^{-1}. The highest net dry fodder yield (12.48 Mg $ha^{-1}yr^{-1}$) was also obtained from the highest density stand (D1), which was 19 and 70 % higher than D2 and D3, thereby indicating a need for closer planting of fodder trees for optimum utilization of resources (Fig.4). It was observed that even though per plant yield was lower in higher tree densities, total biomass production per unit area increased with increasing plant density. Similar findings were reported by Ella *et al.* (1989), who 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. The decreased yield per plant is compensated by the higher number of plants, resulting in higher yield per unit area as plant population increases (Ball *et al.*, 2000). 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.

Tree density also affected the production of foliage and stem fractions showing an increasing trend with increasing tree density. Highest density yielded more dry foliage yield (7.14 Mg $ha^{-1}yr^{-1}$) than the lowest one (3.96 Mg $ha^{-1}yr^{-1}$), indicating the need for closer planting of trees for maximum production of nutritive herbage per unit area. Pathak *et al*. (1980) also reported higher leaf dry matter yields (5.4 t ha^{-1} yr^{-1}) from trees at highest plant density (40,000 trees ha^{-1}) than that of lowest plant density (15,000 trees ha^{-1}). Similarly, Ella *et al.* (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. Leaf- stem ratio also increased with increasing density but the differences were non-significant.

Plant density also had a significant influence on nutritive value of fodder. Total nitrogen (Fig.8) and CP content in leaf as well as in total biomass was significantly higher in the highest density stand, whereas no significant influence was observed in stem CP content (Fig.5). Bhardwaj *et al*. (2001) reported that the nutrient accumulation in the biomass differed with tree density. The maximum nutrient content was present in the closest spacing. However, CF % declined (27.93 % leaf; 71.37 % stem) at higher densities indicating closer spacing for production of tender fodder (Fig.6). Similar results of elevated CP % and lower CF % at higher population density in *Sesbania aegyptica* has been reported by (El-Morsey, 2009). However, the nutritive composition of Moringa was not affected by planting density (Sanchez, 2006).

Plant density had no significant effect on ash content (Fig.7). Phosphorus content (Fig.9) in fodder was also found to be higher in higher density, whereas no significant effect was observed in potassium content (Fig.10). In general, an overall improvement in nutritive value of fodder was observed when trees are planted at closer spacing with higher densities.

5.2.3 Pruning frequency

Pruning frequency is a critical management factor that affects sustainable biomass production as well as the nutritive value of the forage. Our results also indicated that pruning interval had significant influence on total fodder yield as well as leaf and stem fractions (Fig.3) of the forage. Significantly higher fresh yield was recorded at the shortest pruning interval of 8 weeks (43.17 Mg $ha^{-1}yr^{-1}$), whereas fodder yield from 12 weeks (36.49 Mg $ha^{-1}yr^{-1}$) and 16 weeks (38.44 Mg $ha^{-1}yr^{-1}$) interval were found to be on par. But after adjusting the survival % the significant difference was observed only on leaf yield, wherein the highest yield was obtained at the shortest pruning interval of 8 weeks (38.63 Mg $ha^{-1}yr^{-1}$) compared to longer intervals (Fig.3). However, net dry fodder yield was maximum from medium interval of 12 weeks (10.66 Mg $ha^{-1}yr^{-1}$) and was on par with that of longer interval of 16 weeks (10.23 Mg $ha^{-1}yr^{-1}$) (Fig.4). In spite of higher fresh fodder yields when pruned at 8 weeks interval, the dry fodder yield declined when compared to medium and longer intervals which could be due to high moisture content and low dry matter content in the tender fodder.

Leaf -stem ratio was higher at 8 weeks interval, indicating more foliage production than stem fractions when harvested at shorter intervals. Many studies also indicate that, while total biomass yield continues to increase with longer cutting intervals, the additional yield beyond a certain interval consists mainly of woody stem (Ella *et al.,* 1989). Saddul *et al.* (2004) found 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.

Pruning frequencies had profound influence on nutritive value of the forage. Harvesting at shortest pruning interval of 8 weeks yielded fodder with maximum CP content (28.87 % leaf; 8.06 % stem) (Fig.5), and least CF content (19.62 % leaf; 65.00 % stem) compared to medium (12 weeks) and longer intervals (16 weeks) (Fig.6). 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. Islam *et al.* (1991) reported that the young shoots and seeds contain high crude protein (CP). It was also observed that pruning frequencies has more prominent influence on leaf fibre fraction than that of stem fibre fraction. 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). The longest harvest interval with highest planting density result in higher total DM yield, but nutritive value generally decreases as harvest interval increases (Maass *et al.*, 1996).

Ash content (12.36 % leaf; 4.49 % stem; 8.70 % total) was significantly higher at longest interval of 16 weeks (Fig.7). Harvesting at shorter intervals of 8 and 12 weeks produced comparable values and was significantly inferior to that of the longest interval. Highest phosphorus content in (Fig.9) fodder biomass was recorded at shortest cutting interval (1.53 % leaf; 0.64 % stem; 1.1 % total), which was significantly superior to that of 12 weeks and 16 weeks. Total K content was maximum at F2 (0.77 %) and F1 (0.67 %) and they were on par (Fig.10). Whereas in stem biomass the maximum K content was found in F3 (0.79 %) and F1 (0.69 %) and they were on par. Pruning frequency had no significant effect on potassium content in overall biomass. In general, nutritive value of fodder was adversely affected at prolonged harvest intervals.

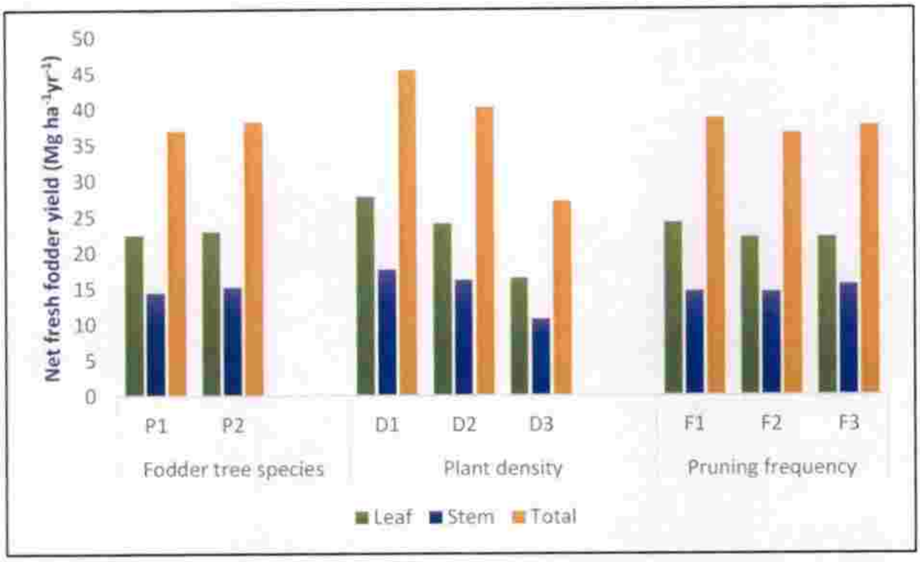

Fig 3. Net fresh fodder yield as influenced by fodder tree species, plant density and pruning frequency underneath coconut plantation.

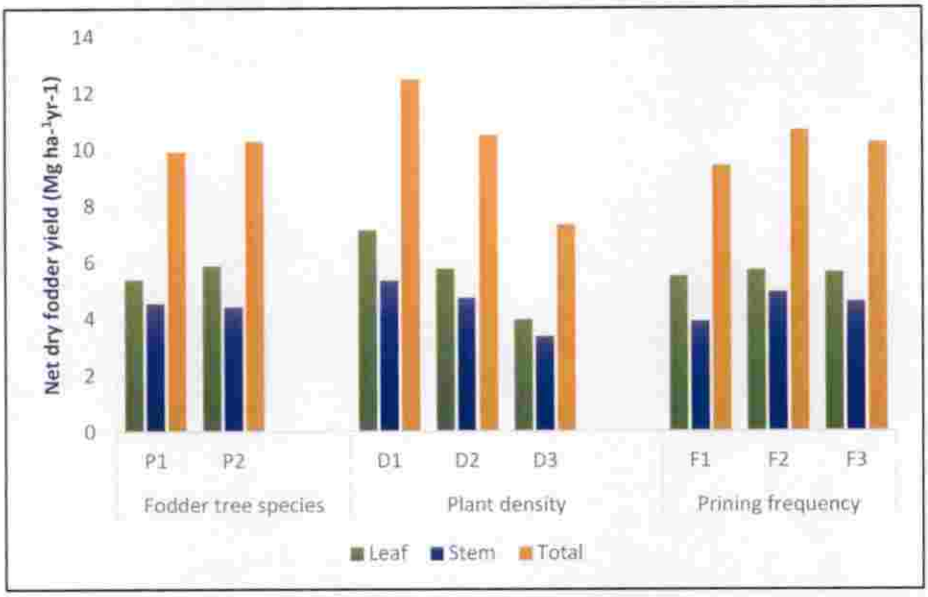

Fig. 4 Net dry fodder yield as influenced by fodder tree species, plant density and pruning frequency underneath coconut plantation.

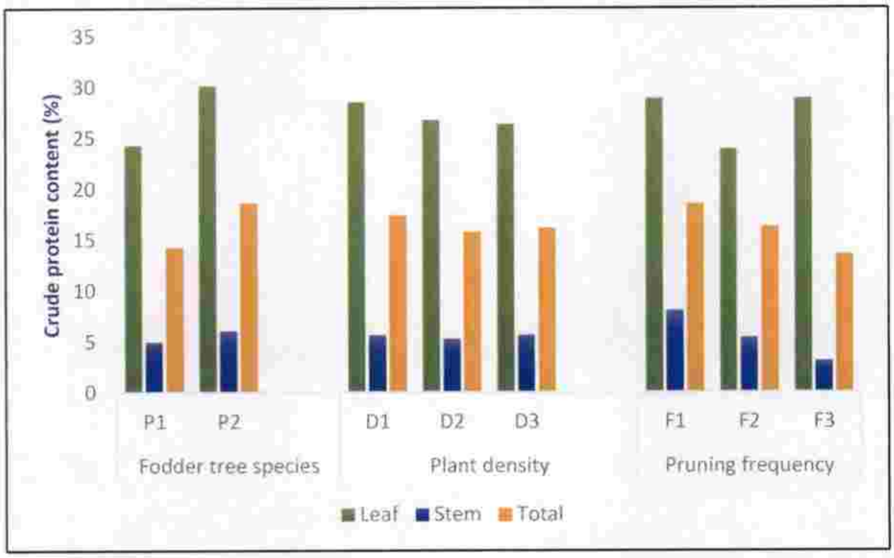

Fig 5. Influence of fodder trees, plant densities and pruning frequencies on crude protein content of fodder biomass.

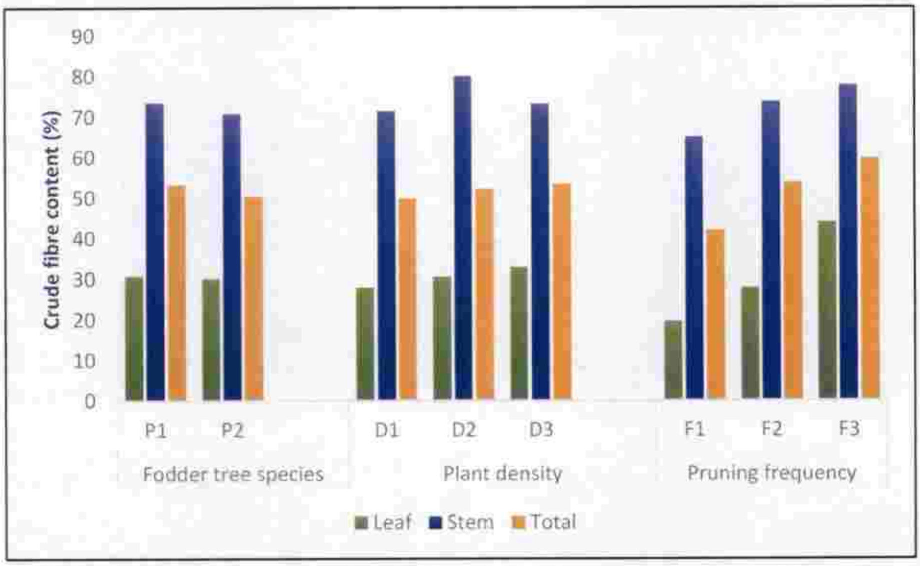

Fig 6. Influence of fodder trees, plant densities and pruning frequencies on crude fibre content of fodder biomass.

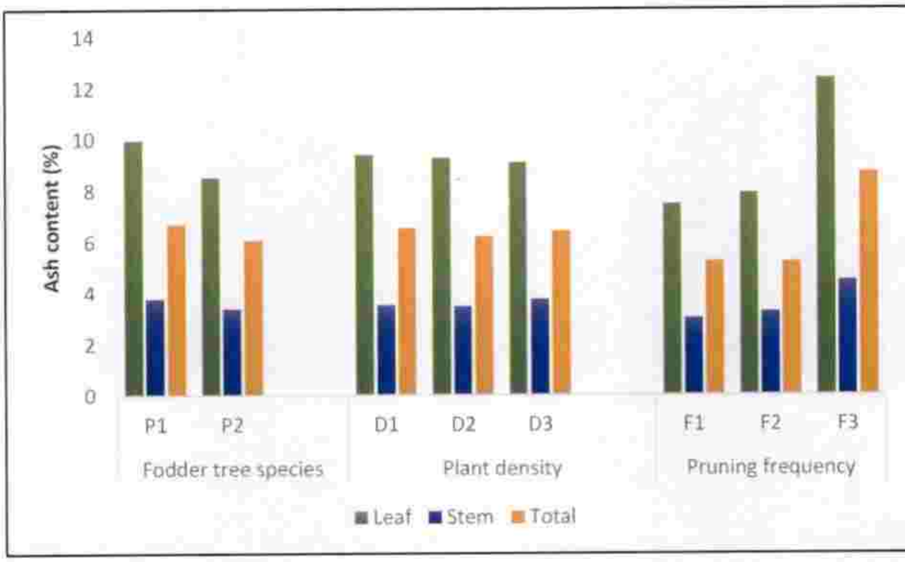

Fig 7. Influence of fodder trees, plant densities and pruning frequencies on ash content of fodder biomass.

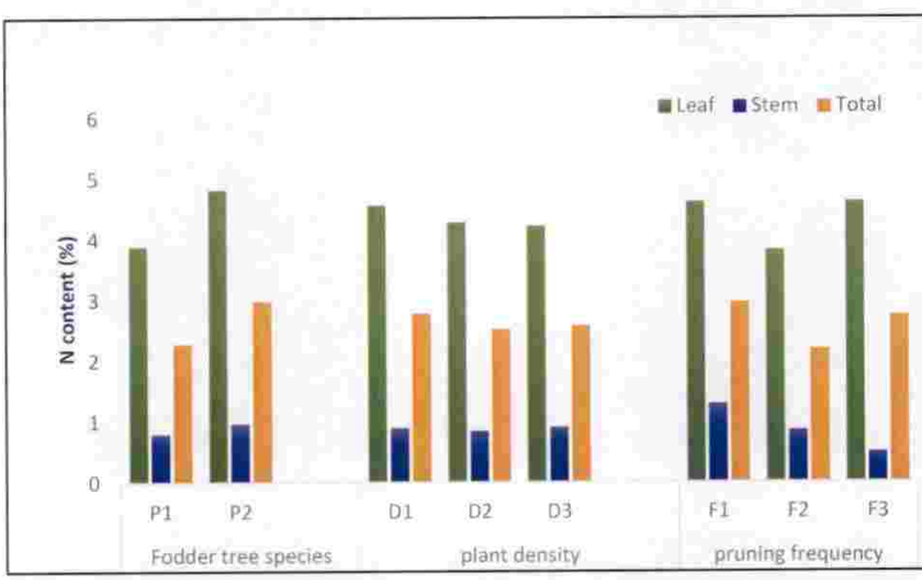

Fig 8. Influence of fodder trees, plant densities and pruning frequencies on nitrogen content of fodder biomass.

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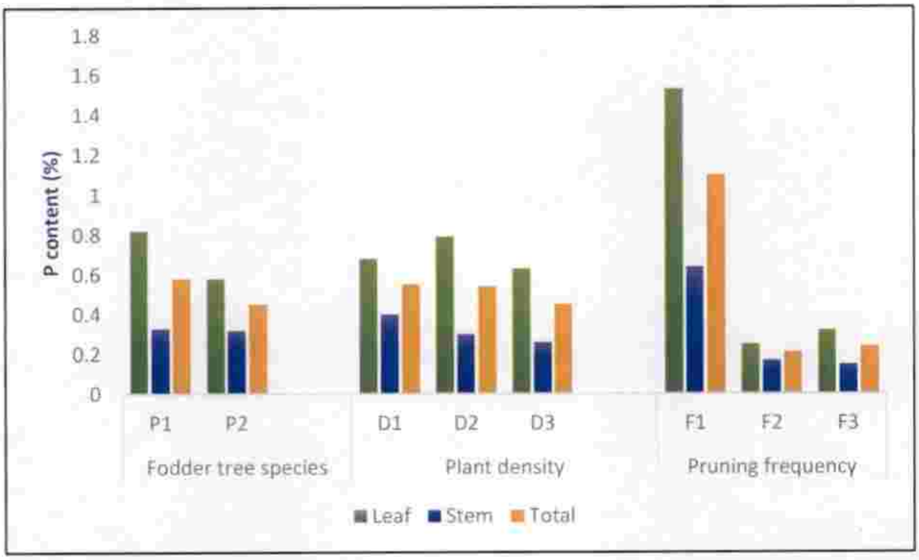

Fig 9. Influence of fodder trees, plant densities and pruning frequencies on phosphorus content of fodder biomass.

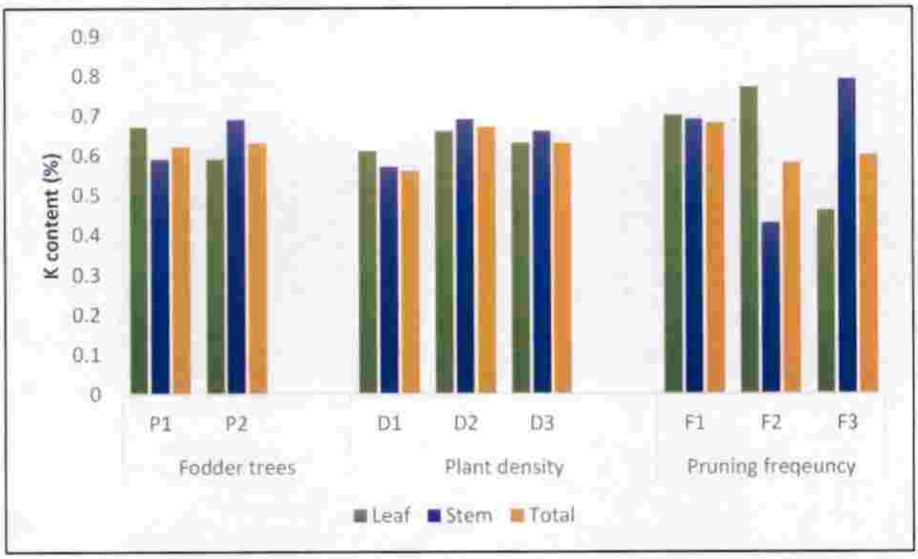

Fig 10. Influence of fodder trees, plant densities and pruning frequencies on potassium of fodder biomass.

5.3 Interaction effect of fodder trees, plant density and pruning frequency on fodder yield and quality.

Comparing the net annual fresh fodder yields from different treatment combinations, the highest yielding systems were found to be T17 (Subabul + 37,037 plants ha^{-1} + 16 weeks pruning interval) and was on par with that of T1 (Mulberry + 49,382 plants ha^{-1} + 8weeks pruning frequency) (48.26 Mg $ha^{-1}yr^{-1}$), T10 (P2D1F1), T7(P1D1F3) and T16 (P2D1F3) and significantly superior to other treatments. However, leaf yield was significantly higher for T1(30.75 Mg ha^{-1}), closely followed by T10 (29.07 Mg ha^{-1}). Stem yield was significantly higher for T17.

The net dry fodder yield (13.85 Mg $ha^{-1}yr^{-1}$) was found to be significantly higher for mulberry under highest density (D1) and harvested at longest interval of 16 weeks (T7), closely followed by T16 (P2D1F3), T17, T13, T4, T10 and T5. Even though the highest dry fodder yield was obtained for mulberry at highest density and at the longest pruning interval (T7), the leaf-stem ratio was very low (1.04) indicating more stem fraction than leaf yields. Similarly, the leaf-stem ratio was also lower at medium intervals of 12 weeks (T4). Many studies indicate that, while total biomass yield continues to increase with longer cutting 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 practices of mulberry is to plant at the highest density and pruning at shorter interval of 8 weeks (T1). Whereas in subabul planting at the closest spacing and pruning at 16 weeks interval yielded the maximum fresh (47.05 Mg $ha^{-1}yr^{-1}$) and dry fodder (12.97 Mg $ha^{-1}yr^{-1}$), leaf (7.85 Mg $ha^{-1}yr^{-1}$) as well as the leaf-stem ratio (1.53), closely followed by pruning intervals of 8 weeks (T10) which yielded 47.69 and 12.17 Mg $ha^{-1}yr^{-1}$ of fresh and dry yield respectively with leaf stem ratio of 1.42. 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. Even though, subabul pruned at 12 weeks (P2D1F2) showed comparable yields as that of other intervals, the leaf-stem ratio was significantly lower (1.27).

The interaction effect of tree species, plant densities and pruning frequencies showed significant influence on proximate composition of harvested fodder. The highest crude protein (CP) content in fodder biomass was observed in subabul fodder planted at density of D1 and D2 and harvested at 16 weeks and 8 weeks interval (T10 and T16). In case of mulberry CP content in both leaf (33.5 %) and stem (8.72 %) was highest in high density stand (D1) and when pruned at shortest interval of 8 weeks and was on par with that of the best subabul combinations. Lascano (1996) reported that nutritive composition of forage species depends on soil fertility, part of the plant (stem, leaves, fruit), age of regrowth, environmental conditions, season of the year and other factors. 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). 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).

The overall CF content in fodder biomass was observed in mulberry at D1 and frequency F1 and was on par with that of subabul under the same management levels. However, the CF content in leaf was considerably lower in subabul than mulberry under the above management levels.

Among different treatment combinations, the highest ash content in leaf (14.62 %) and stem (5.87 %) as well as total biomass (10.54 %) was observed in mulberry fodder planted at density of D2 and D3 and harvested at 16 weeks interval. Akbulut *et al.* (2009) studied the mineral composition of mulberry and reported that mulberry contain highest amount of calcium, potassium, magnesium, sodium, phosphorus and sulphur.

The phosphorus content in fodder was significantly higher for mulberry under density D1 and frequency F1 (1.43 %), whereas the P content in leaf was highest for mulberry under the same frequency but density D2. Subabul fodder also had the highest P content under D1 and F1 management levels., but was significantly inferior to mulberry under the same management levels. Saddul *et al.* (2004) studied on the chemical composition of mulberry and found that mulberry is a good protein and mineral resource.

For subabul and mulberry the K content was highest in subabul (0.79 %) under lowest plant density and shortest pruning intervals and this was on par with that of mulberry with same management levels (0.77 %).

Hence, comparing various yield and quality parameters of mulberry and subabul under different management practices, the best treatment combinations were T1 (Mulberry + 49,382 plants ha^{-1} + 8 weeks pruning interval) with fresh and dry yields of 48.26 and 11.05 Mg $ha^{-1}yr^{-1}$, leaf-stem ratio (1.53), CP % (19.14), CF % (40.14), ash content (6.39 %), P content (1.43 %) and K content (0.64 %); and T10 (Subabul + 49,382 plants ha^{-1} + 8 weeks pruning interval) with fresh and dry yields of 47.69 and 12.17 Mg $ha^{-1}yr^{-1}$, leaf-stem ratio (1.42), CP % (20.41), CF % (41.89), ash (5.19 %), P (0.98 %) and K (0.59 %). Even though treatments T7, T16 and T17 produced higher fodder yields, the quality of the fodder was quite poor especially with higher CF content which reduces the palatability and digestibility of the fodder. In Malaysia, Saddul *et al.* (2004) observed 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 fiber components), and the annual number of cuts, with good crop persistence to repeated harvests.

5.4 Soil fertility status

5.4.1 Soil physical properties

5.4.1.1 Bulk density

Fodder trees, plant densities and pruning frequencies as well as their interactions had no significant influence on soil BD. However, in comparison the least BD (1.32 g/cc) was observed in T17 and in the sole coconut plot. Gunasena (1991) observed that by growing gliricidia and leucaena, soil bulk density was reduced and infiltration capacity was increased in clay soil compared to the control.

5.4.1.2 Water holding capacity

Fodder trees, plant densities and pruning frequencies had no significant influence on WHC of soil. However significant differences were noted among the treatment combinations, wherein subabul and mulberry under density D2 and pruning frequency F3 (T17; 53.74 %, T8;50.43 %) as well as soils underneath sole coconut (Open control) (52.54 %) had comparatively higher soil WHC than other combinations. This could be atributed to the lower bulk density in the above systems as indicated in table 11. As bulk density decreases the total porosity increases which in turn increases the water holding capacity of soils. In addition to that close spacing of trees creates shading effect that prevents evaporation therby enhancing the water content in soil. Similarly unlike frequently pruned trees, trees which are harvested at prolonged intervals (F3) retain there canopy for a longer period which prevents exposure of the soil thereby reducing the evaporation and enhancing the water content. Larson *et al.* (1994) stated that soil can be loosened during crop root growth, which could result in reducing soil compaction and increasing water infiltration.

5.4.1.3 Soil pH

The result reveals that fodder trees, plant densities and pruning frequencies had no significant influence on soil pH. However, interaction effects were found to be significant, wherein treatment T17 (Subabul +37,037 plants ha^{-1} + 16 weeks pruning interval) had higher pH (6.59) than other treatment combinations, followed by T7 (Mulberry + 49,382 plants ha^{-1} + 16 weeks pruning interval) and T14(Subabul + 37,037 plants ha^{-1} + 12 weeks pruning interval) which were on par. All these treatments recorded higher soil pH than that of sole coconut (5.72). In humid tropical soils, the pH is usually slightly acidic in reaction as we obtained in soils under sole coconut plots. However, with cultivation of tree fodders more organic matter was added to soil through litterfall which gradually increases soil pH. However the effects are more pronounced in trees which are harvested at prolonged intervals of 16 weeks as they retain foliage for longer period, which is available for recycling.

5.4.1.4 Electrical conductivity

The study revealed that, soils under mulberry showed a slight increment in EC (Fig.11) than that of subabul, but the differences were non- significant. This might be due to the high mineral content in mulberry that was added to soil through litter cycling. Plant densities significantly influenced EC and the values increased from 0.28 to 0.47dS m^{-1} from lower to higher density stands. This could be the higher biomass production in densely populated stands which yielded more litter and mineral content in to the soil thereby enhancing the EC. However, pruning frequencies had no significant effect on soil EC. The effect of treatment combinations on soil EC revealed that T14 (Subabul + 37,037 plants ha^{-1} + 12 weeks pruning interval) and T7 (Mulberry + 49,382 plants ha^{-1} + 16 weeks pruning interval) had the maximum soil EC of 0.72 and 0.71 dS m^{-1} respectively. The second best (0.59dS m^{-1}) treatment was T1 (Mulberry + 49,382 plants ha^{-1} + 8 weeks pruning interval). In open plot the soil EC was 0.14 dS m^{-1}.

5.4.1.5 Organic carbon

Organic carbon content of soil (SOC) under various treatments are indicated in table 14. The study indicated that tree species, plant densities and pruning frequencies and their interactions had no significant influence on SOC. However SOC improved significantly in all coconut-fodder tree intercropping systems with a range of 1.14 to 1.63 % when compared to that of sole crop of coconut (0.79 %). The high carbon content in intercropped plots might be due to the litter fall from trees and also due to the addition of FYM. Litter production is a major process in the transfer of organic matter and nutrients from above-ground tree parts to the soil (Szott *et al.*, 1991). Gunasena *et al.* (1991) have reported that *Gliricidia sepium* and *Leucaena leucocephala* increased soil fertility due to decomposition of leaf litter. Accumulation of SOC occurs primarily through the return of plant-fixed C to the soil mainly through leaves and roots (Lal *et al.,* 2000; Oelbermann *et al.*,2006). Singh and Sharma (2012) studied the tree growth and accumulation of organic carbon and nutrients in soil under tree plantations, and reported that the concentration and accumulation of soil OC and available nutrients were higher under trees than control.

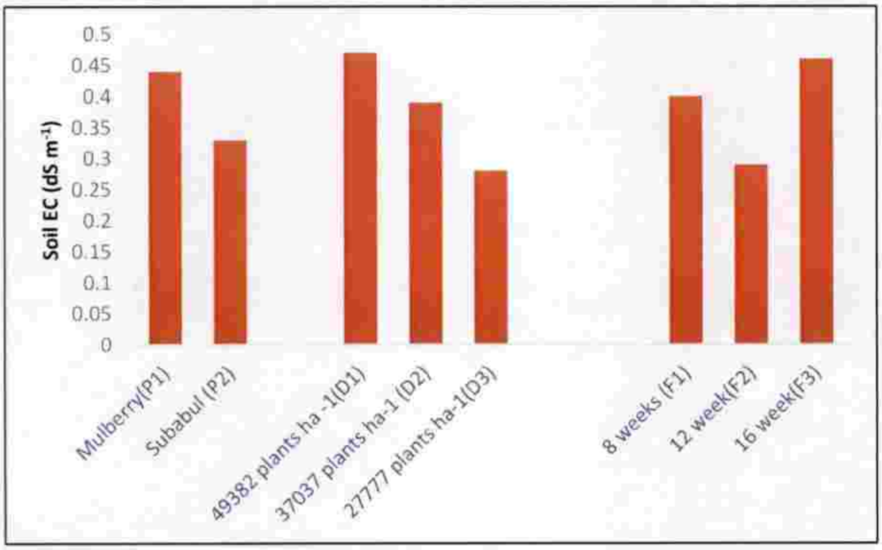

Fig 11. Influence of fodder trees, plant densities and pruning frequencies on soil electrical conductivity under coconut garden.

5.4.2 Soil nutrient status

5.4.2.1. Available nitrogen

Available nitrogen content of soil as influenced by various treatments are given in table 14. The result indicated that the tree species, plant densities and pruning frequencies had no significant effect on available nitrogen. When comparing the available nitrogen from different treatment combinations (table 15) the maximum (651 Kg ha^{-1}) was observed in T17 (subabul +37,037 plants ha^{-1} + 16 weeks pruning interval), followed by T5 (Mulberry + 37,037 plants ha^{-1} + 12 weeks pruning interval) with 644 Kg ha^{-1} and T18 (subabul + 37,037 plants ha^{-1} + 16 weeks pruning interval), and they were on par. The higher N content in subabul plots might be due to the nitrogen fixing ability of subabul. The results also indicated that available N content of soil is higher when trees are planted at medium density (D2) and harvested at longer intervals. In high density stands all the available N in soil might have been utilised by dense plant population. Similarly when trees are harvested frequently at shorter intervals, litterfall is reduced and the nitrogen in the soil is not replenished. The soils under sole coconut plot had only 559 Kg ha^{-1} available N content, which was significantly inferior to that of above combinations. This might be due to the nitrogen enrichment by litterfall and nutrient pumping by mulberry and subabul and nitogen fixation by leguminous subabul. Kang *et al.* (1990) reported that hedgerow intercropping using fast growing Nitrogen fixing trees, e.g. *Leucaena leucacephala* and *Glincidia sepium* in the humid tropics can substantially increase soil fertility in 2-3 years. Singh and Sharma (2012) studied the tree growth and accumulation of organic carbon and nutrients in soil under tree plantations, and reported that the available N concentration was higher under subabul, shisham, kikar and siris than the other tree species in the surface as well as in 0-120 cm soil depth.

5.4.2.2 Available phosphorus

Comparing fodder trees, soil under mulberry had significantly higher available P content (10.93 %) than that of subabul (7.33 %) (Fig.12). This could be due to the higher P content (0.82 %) in mulberry foliage than that of subabul (0.58 %) as indicated in table which was added to the soil through litterfall and decomposition. Akbulut *et al.* (2009) studied the intercropping of paper mulberry with azuki bean and observed that the available P content in soil increased with mulberry intercropping when compared to the sole crop of bean.

Plant density showed no significant effect on P content. Comparing pruning frequencies, P content showed the trend F3 (11.06 %)>F1 (9.5 %)>F2 (6.83 %). Higher soil P content under trees with longer harvest intervals might be due to higher litterfall as the leaves remained without harvseting for a longer duration. Moreover, biomass productions from trees under F3 was significantly lower which also implies lower nutrient uptake from soil, creating a positive balance. Among treatment combinations higher soil P content was observed in T9 (14.67 Kg ha^{-1}) and T16 (14.33 Kg ha^{-1}). The open plot had only 3 Kg ha^{-1} available P and was significantly lower than all intercropped plots, which could be attributed to the application of P fertilizers in intercropped plots coupled with litter fall and P release from trees.

5.4.2.3 Available potassium

Available K content in soil as influenced by tree species, plant densities, pruning frequencies and their interactions are given intable 14. Soils under mulberry (363 Kg ha^{-1}) had higher K content than subabul (302 Kg ha^{-1}) even though the differences were non- significant. This could be due to the enrichment of potassium in soil by mulberry leaf litter, which is rich in potassium (0.67 %) when compared to that of subabul. Zheng *et al.* (2014) reported that mulberry is a good source of minerals and the potassium content higher than that of other elements.

Comparing tree densities, soils under medium and high density stands had significantly higher K content than low density stand (table 15). This could be due to the loss of potassium by leaching by heavy rainfall from widely spaced stands with less soil cover. Pruning frequencies had no significant effect on available potassium. The available potassium obtained from various treatment combinations revealed that T1 (Mulberry + 49,382 plants ha^{-1} + 8 weeks pruning interval) was significantly (601 Kg ha^{-1}) superior to that of other treatment combinations. The second best treatment (529 Kg ha^{-1}) was T2 (Mulberry + 37,037 plants ha^{-1} + 8weeks pruning frequency). 454 Kg ha^{-1} of available potassium was found in open plot. Higher K content in T1 and T2 might be due to the addition of potassium fertilizers, nutrient enrichment through potassium rich litter from mulberry along with less leaching loss of potassium by high density planting of mulberry. Under heavy rain, mulberry tree hedgerow had significant effect in reducing total runoff and enrichment of nutrients as well (Shi *et al.*, 2005).

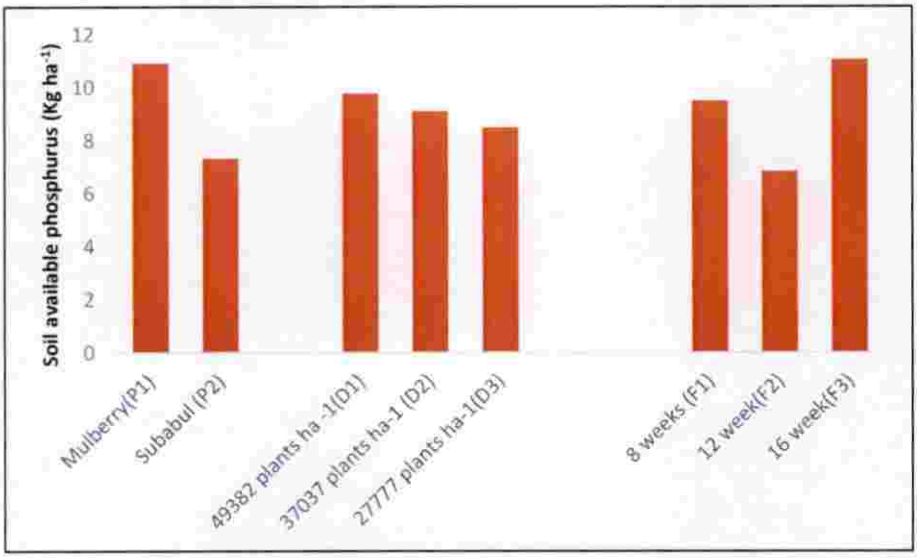

Fig 12. Influence of fodder trees, plant densities and pruning frequencies on available phosphorus content in soil under coconut garden.

5.5 Economics

Economics and B:C ratio of fodder production as influenced by tree species and various management practices in coconut plantation are presented in Table 13. The study revealed that the B:C ratio was significantly higher for subabul (0.92) than mulberry (0.84). This could be attributed to the higher yield from subabul than mulberry. Comparing plant densities, the B:C ratio was maximum from high density stand D1 (0.98), and was on par with D2 (0.96), but significantly superior to D3 (0.70). This could be due to higher biomass production from dense stands as compared to widely spaced stands. Pruning frequency had no significant effect on B:C ratio, even though a slight increment was observed at shorter intervals than prolonged intervals.

When comparing the coconut- fodder intercropping system, the B:C ratio was comparable for both fodder tree species. Comparing plant densities, significantly higher B:C ratio was observed at medium (1.50) and highest (1.47) plant density when compared to the lowest density. Pruning frequency had no significant influence on B:C ratio.

Comparing the economics of various treatment combinations (table 17), T17 (P2D2F3) showed the maximum B:C ratio for fodder production as well as for coconut-fodder intercropping system (1.73) and was on par with that of best treatment combinations of T1(1.50) and T10 (1.46) with good fodder yield and quality parameters. However, in spite of higher B:C ratio in T17 the fodder yield and quality parameters were comparatively inferior. Hence, it can be concluded that, planting both mulberry and subabul at the highest tree density of 49,382 plants/ha, and harvesting at interval of 8 weeks (T1 & T10) under coconut plantation yielded maximum fodder with good nutritive value at the cheapest level. In comparison subabul was found to be more profitable than mulberry in the initial year of field establishment. However, as the fodder trees are the initial year of establishment the B:C ratio of fodder production for most of the treatments were < 1 as the annual yield was less than the cost of production. As the trees are perennial and continues to yield up to 10 to 15 years the real economics of the system will be evident only in the subsequent years.

SUMMARY

SUMMARY

A field experiment entitled "Comparative performance of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based fodder production system" was carried at Instructional farm, College of Horticulture, Vellanikkara during the year 2015 – 2016. The main objective of the study was to assess the influence of plant density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens and to explore the soil fertility changes associated with intercropping these fodder trees in coconut plantations.

Salient results of the study are summarized as follows:

1. Comparing tree species, subabul yielded significantly more fresh fodder (41.78 Mg $ha^{-1}yr^{-1}$) than mulberry (36.95 Mg $ha^{-1}yr^{-1}$) underneath coconut plantation. However, the overall survival % of subabul was found to be 92 % as against the 100 % survival of mulberry trees. The resultant net fresh fodder yields after adjusting the survival % was found to be comparable for both subabul (38.15 Mg $ha^{-1}yr^{-1}$) and mulberry (36.95 Mg ha^{-1}). Leaf yield and stem yield also showed similar trends, wherein both the tree species showed comparable values.

2. Overall dry fodder yield was comparable for subabul (10.28 Mg $ha^{-1}yr^{-1}$) and mulberry (9.91 Mg $ha^{-1}yr^{-1}$), whereas dry leaf yield was significantly higher for subabul (5.86 Mg $ha^{-1}yr^{-1}$) than mulberry (5.38 Mg $ha^{-1}yr^{-1}$). Leaf- stem ratio was found to be slightly higher in subabul (1.33) than mulberry (1.19), with no statistical significance.
3. There were significant ($P<0.05$) variations among the tree species with regard to proximate composition. The total N content (2.98 %) and CP content (18.61 %) in fodder biomass was significantly higher in subabul

than that of mulberry (14.27%). CP content in leaf fraction was almost five times higher than that of stem fraction in both the tree species.

4. Subabul (50.38 %) fodder had significantly lower crude fibre (CF) content than that of mulberry (53.22 %).
5. Mulberry had significantly higher ash content in leaf (9.97 %,) biomass than that of subabul (8.53 %), whereas in stem fraction and in total biomass both had comparable values.
6. Mulberry had significantly higher P content in leaf (0.82 %) and total biomass than subabul(0.58 %), whereas the values in stem fraction was on par.
7. The K content in mulbery (0.62 %) and subabul (0.63 %) were found to be on par.
8. In general, subabul yielded higher dry matter and CP, whereas mulberry was found to be exceptionally superior in certain nutritional aspects like ash and mineral content.
9. Plant density significantly ($p<0.001$) influenced fodder yields of mulberry and subabul; higher densities caused an increase in total forage yield per unit area. In general, an increase of 68 percent in fresh yield was noticed with increment in tree density from 27,777 to 49,382 plants ha^{-1}. The highest dry fodder yield (12.48 Mg $ha^{-1}yr^{-1}$) was also obtained from the highest density stand, thereby indicating a need for closer planting of fodder trees for optimum utilization of resources.
10. Plant density also had a significant influence on nutritive value of fodder. Total nitrogen as well as CP content in leaf as well as in total biomass was significantly higher in the highest density stand, whereas no significant influence was observed in stem CP content. However, CF % declined (27.93 % leaf; 71.37 % stem; total 49.89 %) at higher densities indicating closer spacing for production of tender fodder.

11. Plant density had no significant effect on ash content of fodder biomass. Phosphorus content in fodder was found to be higher in high density stands, whereas no significant effect was observed in potassium content.

12. Pruning frequency had no significant influence on total fodder yield as well as leaf and stem fractions. The maximum fresh yield was recorded at the shortest pruning interval of 8 weeks (38.63 Mg $ha^{-1}yr^{-1}$) compared to longer intervals.

13. Dry fodder yield was significantly higher when harvested at medium interval of 12 weeks (10.66 Mg $ha^{-1}yr^{-1}$) and longer interval of 16 weeks (10.23 Mg ha^{-1}) than 8 weeks interval (9.41 Mg $ha^{-1}yr^{-1}$). However, leaf -stem ratio was higher at 8 weeks interval, indicating more foliage production than stem fractions when harvested at shorter intervals.

14. Pruning frequencies had profound influence on nutritive value of the forage. Harvesting at the shortest pruning interval of 8 weeks yielded fodder with the maximum CP content (28.87 % leaf; 8.06 % stem; total 18.51%), and least CF content (19.62 % leaf; 65.00 % stem; 41.91% total) compared to medium (12 weeks) and longer intervals (16 weeks).

15. Ash content (12.36 % leaf; 4.49 % stem; 8.70 % total) in fodder was significantly higher at the longest interval of 16 weeks. Harvesting at shorter intervals of 8 and 12 weeks produced comparable values and was significantly inferior to that of the longest interval.

16. The P content in fodder biomass was significantly higher at the shortest cutting interval of 8 weeks (1.53 % leaf; 0.64 % stem) than that of 12 and 16 weeks.

17. Pruning frequency had no significant effect on potassium content in fodder biomass.

18. The interaction effect of plant density and pruning frequency had significant influence on yield and quality of fodder tree species. The best treatment combinations were T1 (Mulberry + 49,382 plants ha^{-1} + 8 weeks pruning interval) with fresh and dry yields of 48.26 and 11.05 Mg $ha^{-1}yr^{-1}$, leaf-stem ratio (1.53), CP % (19.14), CF % (40.14), ash content (6.39 %), P content (1.43 %) and K content (0.64 %); and T10 (Subabul + 49,382 plants ha^{-1} + 8 weeks pruning interval) with fresh and dry yields of 47.69 and 12.17 Mg $ha^{-1}yr^{-1}$, leaf-stem ratio (1.42), CP % (20.41), CF % (41.89), ash (5.19 %), P (0.98 %) and K (0.59 %). Even though treatments T7, T16 and T17 produced higher fodder yields, the quality of the fodder was quite poor especially with higher CF content which reduces the palatability and digestibility of the fodder.
19. Economics of fodder production varied significantly with tree species and various management practices in coconut plantation. In general, the B:C ratio was significantly higher from subabul (0.92) cultivation than mulberry (0.84). Comparing plant densities, the B:C ratio was maximum from higher densities of D1 (0.98) and D2 (0.96), but significantly superior to D3 (0.70). Pruning frequency had no significant effect on B:C ratio, even though a slightly increment was observed at shorter intervals than prolonged intervals.
20. Comparing the coconut- fodder intercropping system, the B:C ratio was comparable for both fodder tree species. Comparing plant densities, significantly higher B:C ratio was observed at medium (1.50) and highest (1.47) plant density when compared to the lowest density. Pruning frequency had no significant influence on B:C ratio.
21. Comparing the economics of various treatment combinations, T17 (P2D2F3) showed the maximum B:C ratio for fodder production as well as for coconut-fodder intercropping system (1.73) and was on par with that of best treatment combinations of T1(1.50) and T10 (1.46), with good fodder yield and quality parameters.

22. Intercropping subabul and mulberry in coconut garden with different management practices produced significant changes in some soil parameters after the initial year of establishment. Comparing main effect of tree species, soils under mulberry had higher available P (10.93 Kg ha^{-1}) and K content (363 Kg ha^{-1}) than that of subabul, whereas no significant changes were observed in soil pH, EC, organic carbon, WHC, bulk density and available N. Comparing plant densities, high density stands of D1 and D2 had higher available K content and EC than widely spaced stands, whereas all other parameters were comparable. Pruning frequency had significant influence only on available P content of soil with higher values at the intervals of 8 weeks (9.5 Kg ha^{-1}) 16 weeks (11.06 Kg ha^{-1}) than medium interval of 12 weeks (6.83 Kg ha^{-1}).
23. Significant differences in soil properties were also noted among the treatment combinations. Soil organic carbon content improved significantly in all coconut-fodder tree intercropping systems with a range of 1.14 to 1.63 % when compared to that of sole crop of coconut (0.79 %). Most of the soil properties were found to be better under medium density (D2) stands with prolonged harvest intervals (F3), than other management levels. However, in comparison to the sole coconut plot, most of the soil properties significantly improved in the high yielding treatment combinations of T1 and T10. Comparing T1 and T10, all soil parameters excelled in T1 (Mulberry + 49,382 plants ha^{-1} + 8 weeks pruning interval) except available N content which was higher in T10 (Subabul + 49,382 plants ha^{-1} + 8 weeks pruning interval)

CONCLUSION

Hence, it can be concluded that, for fodder trees mulberry and subabul intercropped in coconut garden, forage yield and nutritive value could be optimized at the cheapest levels by adopting a tree density of 49,382 plants ha^{-1} and pruning interval of 8 weeks, without any appreciable loss in soil fertility. The system should be properly managed with adequate irrigation and fertilization for maintaining the yield potential. In comparison, subabul was found to be more profitable than mulberry in the initial year of field establishment. However, long term response of the trees in relation to persistence, fodder yield and quality, interaction effect of component crop and soil fertility dynamics under various management practices are to be studied to estimate the full potential of the system.

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APPENDIX

Appendix I

Mean weather parameters during the experimental period (January 2015-June 2016) recorded by the Department of Agricultural Meterology, College of Horticulture, Vellanikkara, Kerala

Months	2015		
	Maximum temperature	Minimum temperature	Rainfall (mm)
January	32.5	22.1	0
February	34.3	23	0
March	35.8	24.9	72
April	34	24.6	162.2
May	32.9	24.7	259.9
June	31	23.9	629.8
July	30.3	23.5	510.1
August	31	23.7	320.8
September	31.9	23.7	242.2
October	32.5	24.1	203.8
November	31.6	23.8	151.2
December	32.3	23.3	88.3

Months	2016		
	Maximum temperature	Minimum temperature	Rainfall (mm)
January	33.2	23	23.8
February	35.3	23.5	11.4
March	36.3	25.2	9.8
April	35.8	26.2	25.8
May	34.0	24.2	270.7
June	29.8	21.7	654.7

COMPARATIVE PERFORMANCE OF MULBERRY (*Morus indica* L.) AND SUBABUL (*Leucaena leucocephala* Lam.) UNDER DIVERSE MANAGEMENT REGIMES IN A COCONUT BASED FODDER PRODUCTION SYSTEM

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The research project entitled "Comparative performance of mulberry (*Morus indica* L.) and subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in a coconut based fodder production system" was carried out at Instructional Farm, College of Horticulture, Vellanikkara during 2015-2016. The main objective of the study was to assess the influence of plant density and pruning frequency on forage yield and nutritional qualities of mulberry and subabul intercropped in coconut gardens; and to explore the soil fertility changes associated with these intercropping systems. The treatments consisted of two fodder tree species; mulberry and subabul, under three levels of plant density (49,382 plants ha^{-1}, 37,037 plants ha^{-1} and 27,777 plants ha^{-1}) and three levels of pruning frequency (8, 12 and 16 weeks interval) in all possible combinations with split plot design replicated thrice.

The results revealed that both subabul and mulberry produced comparable dry fodder yields under coconut plantation. However, significant variation was noted with regard to proximate composition. The CP content in fodder biomass was significantly higher and CF % lower in subabul than mulberry. However, mulberry had higher ash (6.70 %) and P content (0.58 %) than subabul. Leaf- stem ratio was found to be comparable in both the tree species. Comparing plant densities, highest density yielded more dry matter (12.48 Mg $ha^{-1}yr^{-1}$) than the lowest one (7.32 Mg $ha^{-1}yr^{-1}$), with higher leaf-stem ratio (1.34). Total N, CP and P content increased and CF % decreased at higher densities indicating closer spacing for production of tender nutritive fodder. Pruning interval had no significant influence on fresh fodder yield, whereas dry yield was higher for 12 and 16 week intervals. However, leaf -stem ratio was higher at 8 week interval, indicating more foliage production than stem fraction when harvested at shorter intervals. Pruning frequencies had profound influence on nutritive value of the forage. Harvesting at shortest interval of 8 weeks yielded fodder with maximum CP (18.51 %), and phosphorus content (1.1 %), and least CF content (41.91 %)

compared to 12 and 16 weeks. Ash content (8.70 %) in fodder was significantly higher at the longest interval of 16 weeks.

Comparing interaction effects, for both mulberry and subabul, planting at the highest density (49,382 plants ha^{-1}) and pruning at shortest interval (8 weeks) yielded the maximum fodder (11.05 & 12.17 Mg $ha^{-1}yr^{-1}$ dry yields for mulberry and subabul respectively) with superior quality (T1 & T10). B:C ratio was also found to be higher in the above systems.

Intercropping subabul and mulberry in coconut garden under different management practices produced significant changes in some soil parameters after the initial year of establishment. In comparison to the sole coconut plot, soil properties like OC, pH, EC, WHC and available N, P, K content significantly improved in the high yielding treatment combinations of T1 and T10. Comparing T1 and T10, all soil parameters excelled in T1 except available N content, which was higher in T10.

Hence, in conclusion, forage yield and nutritive value of mulberry and subabul underneath coconut garden could be optimized at the cheapest levels by adopting a tree density of 49,382 plants ha^{-1} and pruning interval of 8 weeks. In comparison, subabul yielded more dry matter and CP, whereas mulberry was superior in ash and mineral content. Establishment and proper management of these tree fodders in coconut garden and feeding mixed fodders thus offers a cheap source of quality forage to Kerala farmers against the highly expensive concentrate feeds.