Fodder yield and nutritive value of subabul (*Leucaena leucocephala* Lam.) under diverse management regimes in coconut garden

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ABSTRACT: In spite of high protein deficits in ruminant nutrition, subabul, a potential fodder tree in tropical areas, is still under-utilized in Kerala owing to limited land availability for planting, low biomass yields and difficulty to harvest. The above problems can be solved by intercropping subabul as hedgerows in existing coconut gardens, but information on ideal management practices to maximize fodder yield and nutritive value is limited. Hence the present study was conducted to determine the optimum tree density and pruning frequency to maximise production of quality forage from subabul hedgerows underneath coconut garden, by comparing three levels of plant density viz. 49382, 37037 and 27777 plants ha^{-1} and three levels of pruning frequencies at 8, 12 and 16 weeks interval, laid out in 3 × 3 factorial randomized block design, replicated thrice. The results indicated that plant density showed prominent influence on forage yield whereas fodder nutritive value was significantly influenced by pruning frequency. Annual fodder biomass and foliage fraction was greater from the highest density stand. Crude protein (CP) and ash content showed slight increment whereas, crude fibre (CF) content significantly decreased at higher densities indicating closer spacing for production of tender nutritive fodder. Harvesting at shortest interval of 8 weeks yielded maximum fodder, with the highest CP and least CF content compared to 12 and 16 weeks interval. However, ash content (8.70%) was significantly higher at the longest interval of 16 weeks. Thus the results conclude that in humid tropical conditions with annual rainfall of 210-300 cm, subabul should planted at the density of 49382 plants ha^{-1} in the interspaces of coconut and harvested at interval of 8 weeks to yield the maximum fresh and dry fodder (47.69 and 12.17 Mg $ha^{-1}yr^{-1}$) with superior quality, which offers a cheap source of quality forage to ruminants.

Key words: Fodder yield, fodder nutritive value, plant density, pruning frequency and subabul.

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1. INTRODUCTION

Livestock rearing form an integral part of rural living in Kerala. Prospect of livestock farming is high in Kerala owing to the deficit in milk and meat products. However, scarcity of quality fodder and high cost of concentrate feeds are the major hindrances to profitable livestock rearing in Kerala. 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 expensive concentrates which reduce their profit to a considerable extent. Of the total cost involved in dairying 70-80% is for feed alone and this can be brought down to 40-50% if good quality forage is made available. Hence, along with cattle rearing farmers should also cultivate quality fodder on farm itself for maintaining animal health and productivity, thereby ensuring sustainable and profitable livestock production.

Utilization of protein rich fodder 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). Among fodder trees, subabul (*Leucaena leucocephala* Lam.) is a highly nutritious leguminous tree fodder with 27-34 per cent protein, rich in carotene and vitamin A, and grows well under humid tropical conditions of Kerala (KAU, 2011). It yields large quantities of foliage (6 to 18 tonnes dry matter/ha/year) when pruned regularly (Balasundaran and Ali, 1987). Considering its potential, subabul had been introduced to the farmers of Kerala long back but planting and utilization for ruminant feed are still low. The main reasons could be attributed to limited availability of land for cultivation, difficulty and high labour cost in harvesting the tree and low biomass yields from staggered planting.

A possible alternative to enhance subabul cultivation and utilization in land crunch Kerala is to integrate it 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 tree under coconut plantation. On account of the wide inter spaces between coconut rows (7.6 m × 7.6 m) there is ample scope for intercropping especially during the early growth phase (up to 8 years) and later mature phase (>25 years) of the coconut plantation.

However, it would be desirable to maintain fodder tree as hedges by regular pruning to regulate the possible competition between the coconut and the tree intercrop, to maximize biomass productivity and quality of forage and to facilitate easy harvesting of fodder. Moreover, the invasion of subabul to cropped areas, which is a major menace in Kerala can also be controlled by repeated pruning that avoids the reproductive phase of the tree. Numerous studies on fodder trees indicate that, higher forage yields per unit area, quality of forage and long-term survival of fodder tree hedges can be ensured through their optimum management involving judicious regulation of key factors such as tree density and pruning frequency, 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. 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.

Information exists on the influence of various management practices on forage yields of subabul in different regions, but in some cases it is contradictory, hence it is important to validate this research under Kerala conditions. Moreover, there is a paucity of information on management practices for optimizing forage yield and quality from subabul hedges when intercropped in coconut gardens. Hence, the objective of this study was to evaluate the effect of tree density and pruning frequency on forage yield and nutritional qualities of subabul hedgerows underneath coconut plantation in humid tropical conditions of Kerala.

2. MATERIALS AND METHODS

The experiment was conducted during 2015-2016 at College of Forestry, Vellanikkara, Kerala, situated at 10^0 32' N latitude and 76^0 16' E longitude at an altitude of 22.5 m above MSL. Vellanikkara experienced a warm humid tropical climate with a total rainfall of 2639.4 mm during the experimental period from January 2015 to July 2016. 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, moderately acidic (pH-5.76), and sandy clay loam oxisol, fairly rich in organic matter (0.79%) and available N, P and K @ 559, 3 and 454 kg ha^{-1}.

Seedlings of subabul (*L. leucocephala*) (variety Cunningham) was raised in nursery. The seeds were pre-treated by soaking in concentrated sulfuric acid for 4 minutes, followed by washing with hot water at 80 ^{0}C and planted in nursery beds of standard size (KAU, 2011). 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.

The field experiment was conducted in mature coconut garden spaced at 7.6 m × 7.6 m. Subabul was planted in the interspaces of coconut, excluding coconut basin of 2 m radius to avoid competition for nutrients. Treatments were laid out in 3 × 3 factorial randomized block design replicated thrice, with three levels of plant density *viz*., 49382 plants ha^{-1} (45 × 45 cm spacing), 37037 plants ha^{-1} (60 × 45 cm spacing), 27777 plants ha^{-1} (60 × 60 cm spacing) and three pruning intervals of 8 weeks, 12 weeks and 16 weeks. The field area was ploughed twice and the layout was done allocating a plot size of 4 m × 3 m (12 m^2) for each treatment. The seedlings were transplanted to the main field as per prescribed spacing for various treatments. A blanket application of FYM was given @ 20 t ha^{-1} as basal dose. N, P_2O_5, K_2O each @ 50 kg ha^{-1} were applied uniformly for all treatments through NPK fertilizer mixture (18:18:18). FYM was applied as basal and fertilizer in two split doses before south west and north east monsoons. Plants were weeded and irrigated as and when required.

After attaining a height over 1 m, an initial uniform cut was given for all treatments at 1 m height in July 2015. Subsequent cuttings were taken at 1 m height 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. Five trees/plot were selected at random avoiding border plants for taking observations on yield and quality parameters. For each harvest, 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 fresh yields and using the net harvested area and fresh weight, annual fodder yield was scaled up to a hectare basis (excluding the area under coconut). Subsamples (200 g) of leaf and stem fractions from each harvest were oven dried at 70 ^{0}C for 48 hours for dry matter (DM) determination. The fresh fodder yields from each harvest were multiplied with dry matter content and summed up to get annual dry fodder yield per hectare. The leaf - stem ratio was calculated by dividing the dry weight of leaves with dry weight of stem.

Proximate composition of oven dried leaf and stem fractions were analysed following standard procedures (AOAC, 1995). Total nitrogen (N) was determined by the micro Kjeldahl procedure and crude protein (CP) calculated from N content (CP = N×6.25) according to the official methods of 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 crude fibre (CF) was dried to a constant weight and the dried residue was ignited in muffle furnace, loss of weight on ignition was calculated to express it as CF in percentage. Oven dried samples were ignited in muffle furnace at 550 ^{o}C to burn all the organic matter and left over was weighed as ash and expressed as percentage.

The data were subjected to statistical analysis by analysis of variance (ANOVA) in SPSS version 18 to ascertain the significance of yield and quality parameters. The Duncan's Multiple Range Test (DMRT) was used to separate the differing treatment means at 5% significance level.

3. RESULTS AND DISCUSSION

Plant density

As indicated in Table 1, plant density significantly ($p<0.001$) influenced fodder yields of subabul; higher densities caused an increase in total forage yield per unit area. Yield increased from 25.68 to 45.70 Mg ha^{-1}yr^{-1} from lower (D1) to higher density classes (D3).

The highest dry fodder yield (13.71 Mg ha^{-1}yr^{-1}) was also obtained from the highest density stand D1 (49382 plants ha^{-1}), which was 68 and 85% higher than D2 (37073 plants ha^{-1}) and D3 (27777 plants ha^{-1}), thereby indicating a need for closer planting of fodder trees for getting maximum yield per unit area and for optimum utilization of resources. It was observed that even though per plant yield was lower for higher tree densities total

Table 1. Influence of plant density and pruning frequency on fresh and dry fodder yield and leaf stem ratio underneath coconut garden

Treatments	Fresh fodder biomass (Mg ha^{-1}yr^{-1})			Dry fodder biomass (Mg ha^{-1}yr^{-1})			Leaf: stem ratio
	Leaf	Stem	Total	Leaf	Stem	Total	
Plant density							
49,382 plants ha^{-1}	28.05^a	17.65^a	45.70^a	7.75^a	5.52^a	13.71^a	1.43
37,037 plants ha^{-1}	25.59^b	17.48^a	43.07^b	6.80^a	5.16^a	12.51^b	1.32
27,777 plants ha $^{-1}$	15.23^c	10.45^b	25.68^c	4.00^b	3.24^b	7.42^c	1.23
F Value	108.01***	43.71***	76.30***	24.86***	13.54***	20.16***	0.86^{ns}
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.55
Pruning frequency							
8 weeks	24.56^a	15.66^{ab}	40.22^a	6.74	4.91	12.64	1.37
12 weeks	21.52^b	13.85^b	35.38^b	5.58	4.55	10.12	1.23
16 weeks	22.78^{ab}	16.07^a	38.85^b	6.22	4.47	10.87	1.39
F value	5.42*	3.61*	4.02*	2.21^{ns}	0.49^{ns}	3.02^{ns}	1.18^{ns}
P value	0.01	0.04	0.03	0.14	0.62	0.07	0.33

*** 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 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).

Plant density also affected the production of foliage and stem fractions showing an increasing trend with increasing plant density. Highest density yielded more fresh and dry foliage yield (28.05 and 7.75 Mg $ha^{-1}yr^{-1}$) than the lowest one (15.23 and 4.00 Mg $ha^{-1}yr^{-1}$), indicating the need for closer planting of trees for maximum production of nutritive herbage per unit area. Ella (1989) reported that, for *Leucaena, Gliricidia, Calliandra* and *Sesbania,* leaf yield per unit area increased with increasing planting density. Stem fractions also showed similar trends. Leaf- stem ratio showed a slight increment with increasing density but the differences were non-significant.

Unlike yield parameters, quality aspects of subabul fodder did not show prominent changes with respect to density. Total CF, CP and ash per cent showed no significant differences with respect to density (Fig. 1 and 2). However, the CP% in stem fraction was highest and CF% in both leaf and stem fractions were found to be least in the highest density stand, indicating closer spacing for production of tender nutritive fodder. Similar results of elevated CP% and lower CF% at higher population density in *Sesbania aegyptica* has been reported by El-Morsey (2009). 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, Sanchez (2006) reported that the nutritive composition of Moringa was not affected by planting density.

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 of the forage. Significantly higher fresh yield was recorded at the shortest pruning interval of 8 weeks (40.22 Mg $ha^{-1}yr^{-1}$), whereas fodder yield from 12 weeks (35.38 Mg $ha^{-1}yr^{-1}$) and 16 weeks (38.85 Mg $ha^{-1}yr^{-1}$) interval were found to be on par (Table 1). Dry fodder yield as well as the foliage yield was also higher when harvested at shortest interval. This could be attributed to good soil fertility conditions coupled with adequate fertilisation and irrigation that facilitated rapid regrowth and biomass production. The above findings are in tune with Brewbaker *et al.,* (1985), who reported that in leucaena, harvest intervals may be reduced to 6-8 weeks at very productive sites, and enhanced to 12 weeks at less

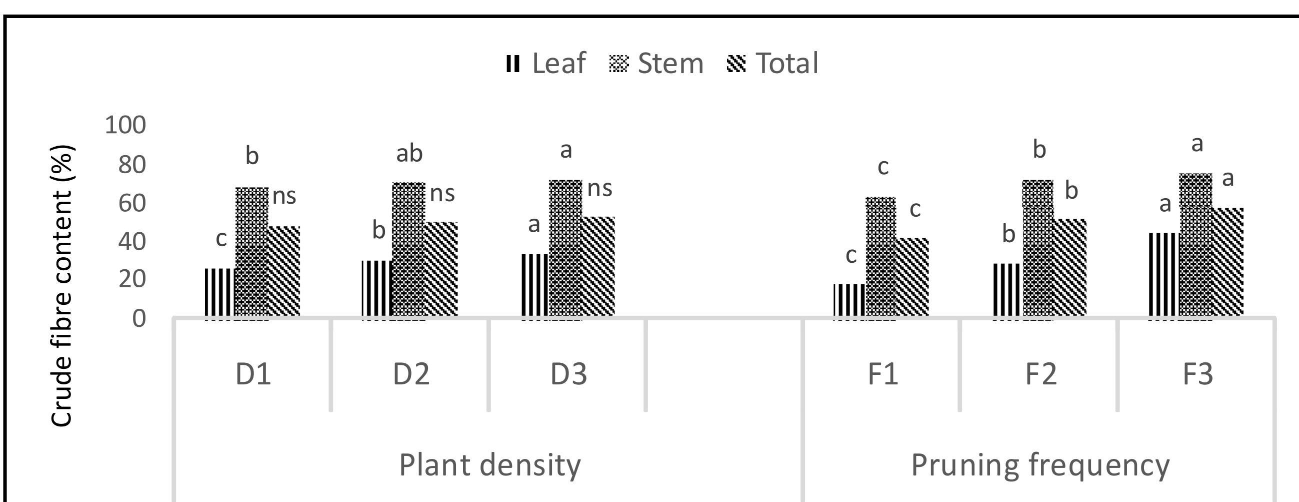

Fig. 1. Influence of plant density and pruning frequency on CF content of subabul fodder underneath coconut garden.

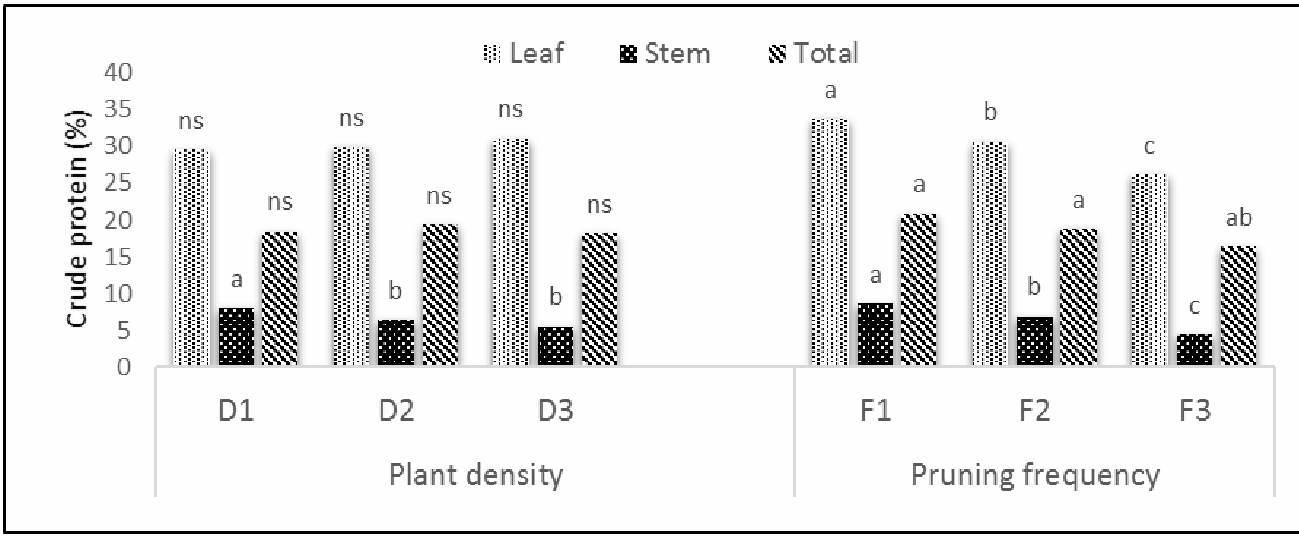

Fig. 2. Influence of plant density and pruning frequency on CP content of subabul fodder underneath coconut garden.

productive locations.

Pruning frequency had a profound influence on proximate composition. CP content was highest at shortest interval of 8 weeks (20.86%) whereas, CF content (42.11%) was significantly inferior (Fig. 1 and 2). 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.,* (1995) reported that the young shoots and seeds contain high crude protein (CP). 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). Maass *et al*., (1996) observed that in leucaena, the longest harvest interval with highest planting density result in higher total DM yield, but nutritive value generally decreases as harvest interval increases. However, ash content (8.45%) was significantly higher at longest interval of 16 weeks (Figure 3) whereas 8 and 12 weeks had comparable values. In general, nutritive value of fodder was adversely affected at prolonged harvest intervals.

Interaction effect

Interaction between density and pruning frequency

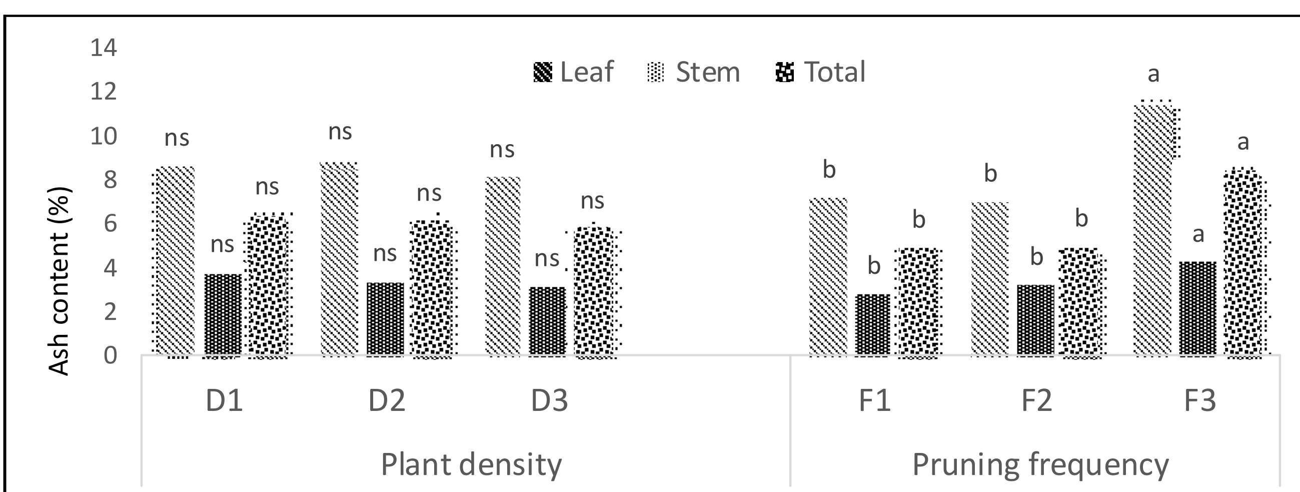

Fig. 3. Influence of plant density and pruning frequency on ash content of subabul fodder underneath coconut garden.

significantly influenced the yield and quality parameters of subabul. The fresh and dry fodder yields were significantly higher for treatments T8, T1 and T7 which involve planting at high and medium density and pruning at interval of 8 or 16 weeks (Table 2). Leaf-stem ratio was higher (1.53) for T7 (D1F3) and T1 (D1F1) (1.42) indicating higher foliage yields from above treatments. The interaction effects showed significant influence on proximate composition of harvested fodder (Table 3). The highest crude CP content (20.52%) in fodder biomass was observed in subabul fodder planted at density of D2 and harvested at 8 weeks interval (T2) and was on par with that of T1. The least CF content was also observed for the above treatments. However, the ash content was highest (8.94%) at the highest density and longest pruning interval of 16 weeks (T7).

Hence, comparing various yield and quality parameters of subabul under different management practices, the best treatment combination was T1 involving highest density and shortest pruning interval of 8 weeks, 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) and ash content (5.19%). Even though treatments T7 and T8 produced higher fodder yields, the quality of the fodder was quite poor especially with higher CF content (52 and 61%, respectively) which reduces the palatability and digestibility of the fodder.

Table 2. Interaction effect of plant density and pruning frequency on annual fresh and dry fodder yield and leaf-stem ratio underneath coconut plantation

Treatments	Fresh fodder biomass (Mg ha^{-1}yr^{-1})			Dry fodder biomass (Mg ha^{-1}yr^{-1})			Leaf-stem ratio
	Leaf	Stem	Total	Leaf	Stem	Total	
T1- D1F1	29.07^{a}	18.61^{ab}	47.69^{ab}	7.13^{abc}	5.03^{abcd}	12.17^{ab}	1.42
T2- D2F1	25.76^{bc}	15.75^{cd}	41.51^{bc}	6.26^{bcd}	4.38^{abcd}	10.64^{bc}	1.43
T3- D3F1	18.84^{cd}	12.62^{d}	31.47^{cd}	4.50^{cd}	3.64^{bcd}	8.15^{c}	1.27
T4- D1F2	26.18^{bc}	16.19^{cd}	42.37^{bc}	7.01^{abc}	5.54^{abc}	12.56^{ab}	1.27
T5- D2F2	23.17^{bc}	15.34^{cd}	38.52^{cd}	5.86^{bcd}	4.70^{abcd}	10.56^{bc}	1.26
T6- D3F2	15.22^{cd}	10.03^{de}	25.25^{cd}	3.88^{d}	3.39^{cd}	7.27^{c}	1.15
T7- D1F3	28.90^{ab}	18.15^{ab}	47.05^{ab}	7.85^{ab}	5.13^{abcd}	12.97^{ab}	1.53
T8- D2F3	27.83^{ab}	21.36^{a}	49.19^{a}	7.19^{abc}	5.60^{abc}	12.79^{ab}	1.34
T9- D3F3	11.62^{cd}	8.71^{e}	20.33^{d}	3.07^{d}	2.34^{d}	5.41^{c}	1.31
F value	6.89***	8.59***	9.87***	5.32**	3.24*	5.36**	0.62^{ns}
P value	0.000	0.000	0.000	0.002	0.018	0.002	0.753

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

D1, D2 and D3 – Tree density of 49382, 37037 and 27777 plants ha^{-1}

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

Table 3. Interaction effect of 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- D1F1	14.50^{e}	66.41^{def}	41.89^{e}	33.56^{ab}	8.72^{a}	20.41^{abc}	6.39^{b}	4.15^{ab}	5.19^{b}
T2- D2F1	16.95^{e}	61.25^{f}	40.70^{e}	34.31^{a}	8.53^{a}	20.52^{abc}	8.59^{b}	2.51^{bc}	5.29^{b}
T3- D3F1	21.95^{d}	63.85^{ef}	43.74^{de}	27.44^{cd}	9.19^{a}	17.85^{bcd}	6.44^{b}	1.72^{c}	4.04^{b}
T4- D1F2	23.80^{d}	71.21^{cd}	50.75^{bc}	26.19^{cd}	6.84^{b}	15.28^{d}	7.47^{b}	2.95^{abc}	4.86^{b}
T5- D2F2	29.34^{c}	70.50^{cd}	48.41^{cd}	24.94^{d}	4.80^{cd}	16.11^{cd}	6.93^{b}	3.63^{ab}	5.27^{b}
T6- D3F2	32.10^{c}	75.25^{bc}	54.53^{b}	27.78^{cd}	6.13^{bc}	16.60^{cd}	6.44^{b}	3.08^{abc}	4.66^{b}
T7- D1F3	41.75^{b}	69.00^{de}	52.27^{bc}	33.41^{ab}	3.72^{d}	19.95^{abc}	11.95^{a}	4.16^{ab}	8.94^{a}
T8- D2F3	44.45^{ab}	80.75^{a}	61.43^{a}	30.69^{bc}	3.30^{d}	17.89^{bcd}	11.14^{a}	3.89^{ab}	7.75^{a}
T9- D3F3	46.53^{a}	79.10^{ab}	59.70^{a}	32.75^{bc}	3.50^{d}	18.75^{abc}	11.40^{a}	4.61^{a}	8.65^{a}
F value	122.52***	14.20***	19.01***	6.52***	20.69***	3.97**	11.26***	3.38*	17.16***
P value	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.02	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.

D1, D2 and D3 – Tree density of 49382, 37037 and 27777 plants ha^{-1}

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

Hence, the results conclude that adopting plant density of 49382 plants per hectare (45 cm × 45 cm spacing) and harvesting at 8 weeks interval is advantageous for maximizing forage and nutrient yields from young stands of subabul underneath coconut garden, until the above and below ground competition starts. However, the long term effects of these management practises on crop competition, fodder yield and quality and long term persistence of trees are yet to be studied.

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