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Fodder yield and nutritive value of mulberry (*Morus indica* L.) under varying plant density and pruning frequency in coconut garden

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Abstract

The present study was conducted to determine the optimum plant density and pruning frequency to maximise production of quality forage from mulberry (*Morus indica L.*) hedge rows 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 x 3 factorial randomized block design, replicated thrice. The results indicated that plant density showed prominent influence on forage yield whereas fodder nutritive value and dry fodder yield was significantly influenced by pruning frequency. Annual fodder biomass and foliage fraction was greater from the highest density stand. Crude fibre (CF) and ash content showed slight increment whereas, crude protein (CP) content significantly increased at higher densities indicating closer spacing for production of tender nutritive fodder. Increasing the pruning interval up to 12 weeks increased the dry matter, foliage and nutrient yields significantly and thereafter declined at 16 weeks. Even though higher leaf-stem ratio was observed at shorter interval of 8 weeks, total annual foliage yield was higher at 12 weeks pruning interval. However, ash content (8.96%) was significantly higher at the longest interval of 16 weeks. Thus in humid tropical conditions with annual rainfall of 210-300 cm, mulberry should be planted at the density of 49,382 plants ha^{-1} in the interspaces of coconut and harvested at interval of 8 weeks to yield the maximum fresh and dry fodder (48.26 and 11.05 Mg $ha^{-1}yr^{-1}$) with superior quality, which offers a low-cost source of quality forage to ruminants.

Keywords: Coconut, Fodder yield, Mulberry, Nutritive value, Plant density, Pruning frequency

Introduction

Livestock rearing forms 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, 2010). Hence, farmers depend on expensive concentrate feeds which reduce their profit to a considerable extent. About 70-80 % of the total cost involved in dairying is for feed alone, which can be reduced to 40-50% if good quality forage is made available. Hence, cultivation of nutrient rich fodder is of prime importance 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). 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 forage diets. Since the agro-climatic conditions of Kerala suits well to mulberry, there is a good scope for utilizing it for producing quality forage in the state.

A possible alternative to enhance mulberry 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, 2012) offers substantial scope for integrating fodder tree under coconut plantation. 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 mulberry as hedge rows 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 density and pruning frequency. However, there is a paucity of information on proper management practices for optimizing forage yield and quality from mulberry hedges when integrated with coconut plantation. Hence, the objective of this study was to evaluate forage yield and nutritive value of mulberry hedges under different plant density and pruning frequencies underneath coconut plantation in humid tropical conditions of Kerala.

Materials and Methods

Study area: 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 m.s.l. 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 monsoon, 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}.

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. Here we used V1 variety. It is a selection from controlled pollinated hybrids of S-30 and Ber. C-776 during late 1990's. The variety is characterized by erect branches and greyish stem colour. Leaves are thick, succulent, large, entire and ovate with truncate base. Leaves are smooth and glossy. It has got good agronomic characters like high rooting ability, fast growth and high yield. Under irrigated conditions, with recommended package of practices it yields about 60 Mg ha^{-1} yr^{-1}. Bioassay and chemo assay tests indicated the superiority of this variety for silkworm rearing.

Field culture: The field experiment was conducted in mature coconut garden spaced at 7.6 m x 7.6 m. Mulberry was planted in the interspaces of coconut, excluding coconut basin of 2m radius to avoid competition for nutrients. Treatments were laid out in 3 x 3 factorial randomized block design replicated thrice, with three levels of plant density *viz*., 49,382 plants ha^{-1} (45 x 45 cm spacing), 37,037 plants ha^{-1} (60 x 45 cm spacing), 27,777 plants ha^{-1} (60 x 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 4m x 3m (12 sq. m.) 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 and 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 (KAU, 2011). Plants were weeded and irrigated as and when required.

Forage yield and nutrient estimation: After attaining a height over 1 m, an initial uniform cut was given for all treatments at 1m height in July 2015. Subsequent cuttings were taken at 1m 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 70^0C 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. Total nitrogen (N) was determined by the micro Kjeldahl procedure and crude protein (CP) calculated from N content (CP= Nx6.25) according to the official methods of AOAC (1984). 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. Oven dried samples were ignited in muffle furnace at 550°C to burn all the organic matter and left over was weighed as ash and expressed as percentage.

Statistical analysis: 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.

Results and Discussion

***Plant density*:** Plant density significantly ($P<0.001$) influenced fodder yields of mulberry (Table 1); higher densities caused an increase in total forage yield per unit area. Yield increased from 28.44 to 45.12 Mg ha^{-1} yr^{-1} from lower (D1) to higher density classes (D3). The highest dry fodder yield (12.39 Mg $ha^{-1}yr^{-1}$) was also obtained from the highest density stand D1(49382 plants ha^{-1}), which was 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 but the total biomass production per unit area increased with increasing plant density. Similar findings were reported earlier by Ella *et al.* (1989), who found that, for *Leucaena sp., Gliricidia sp., Calliandra sp.* and *Sesbania sp.,* 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 increased (Ball *et al*., 2000). Joy *et al*. (2019) reported that for *Calliandra sp.,* the maximum harvested dry biomass yield was obtained from highest density stand and it was significantly ($P<0.05$) higher when compared to lower densities.

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 (27.49 and 6.95 Mg $ha^{-1}yr^{-1}$) than the lowest one (17.56 and 4.10Mg $ha^{-1}yr^{-1}$), 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. Plant density showed a significant effect on leaf: stem ratio with highest (1.32) was found at the highest plant density (D1). Anu *et al*. (2018) reported that highest density stand yielded more leaf dry matter than the lowest one.

Unlike yield parameters, quality aspects of mulberry fodder did not show prominent changes with respect to density. Total CF and ash contents showed no significant differences with respect to density (Fig 1-2). However, the CP content in leaf fraction and total fraction was highest in the highest density stand, indicating closer spacing for production of tender nutritive fodder (Fig 3). Similar results of elevated CP and lower CF contents at higher population density in *Sesbania spp.* was reported by El-Morsey (2009). Bharadwaraj *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, Sanches (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 indicated that pruning interval had no significant influence on total fodder yield as well as leaf and stem fractions of the forage (Table 1). Dry fodder yield (11.18 Mg ha^{-1} yr^{-1}) was significantly higher when harvested at medium interval. Similar experiments with different forage trees also support the findings that cutting intervals up to 12 weeks increase biomass production (Ella *et al.,* 1989; Latt *et al*., 2000; Tuwei *et al*., 2003).

Pruning frequency had a profound influence on proximate composition. CP content was highest at shortest interval of 8 weeks (17.42%), whereas CF content (41.72%) was significantly low (Fig 3 and 1). 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 better in quality, but the quality decreases faster 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). Anu *et al*. (2018) reported that harvesting at shorter and medium pruning intervals of 8 and 12 weeks yielded fodder with maximum CP content when compared to longer interval of 16 weeks. Maass *et al*. (1996) observed that in subabul, the longest harvest interval with highest planting density resulted in higher total DM yield, but nutritive value decreased as harvest interval increased. However, ash content (8.96%) was significantly higher at longest interval of 16 weeks (Fig 2) whereas 8 and 12 weeks had comparable values. In general, nutritive value of fodder was adversely affected at prolonged harvest intervals.

Table 1. Influence of plant density and pruning frequency on fresh and dry fodder yields and leaf-stem ratio of mulberry 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 (plants ha^{-1})							
49382 (D1)	27.49^{a}	17.62^{a}	45.12^{a}	6.95^{a}	5.45^{a}	12.39^{a}	1.32^{a}
37037 (D2)	22.49^{b}	14.78^{b}	37.27^{b}	5.09^{b}	4.57^{b}	9.66^{b}	1.15^{b}
27777 (D3)	17.56^{c}	10.88^{c}	28.44^{c}	4.10^{c}	3.59^{c}	7.69^{c}	1.14^{b}
F value	54.23^{***}	44.76^{***}	51.48^{***}	347.26^{***}	14.73^{***}	59.69^{***}	4.75^{*}
Pruning frequency (weeks)							
8 (F1)	23.65	13.38	37.03	5.04^{b}	3.45^{b}	8.49^{c}	1.45^{a}
12 (F2)	22.58	15.01	37.59	5.86^{a}	5.32^{a}	11.18^{a}	1.10^{b}
16 (F3)	21.31	14.89	36.21	5.23^{b}	4.80^{a}	10.06^{b}	1.09^{b}
F value	3.02^{ns}	3.23^{ns}	0.36^{ns}	28.14^{***}	16.04^{***}	19.56^{***}	24.63^{***}

*** 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

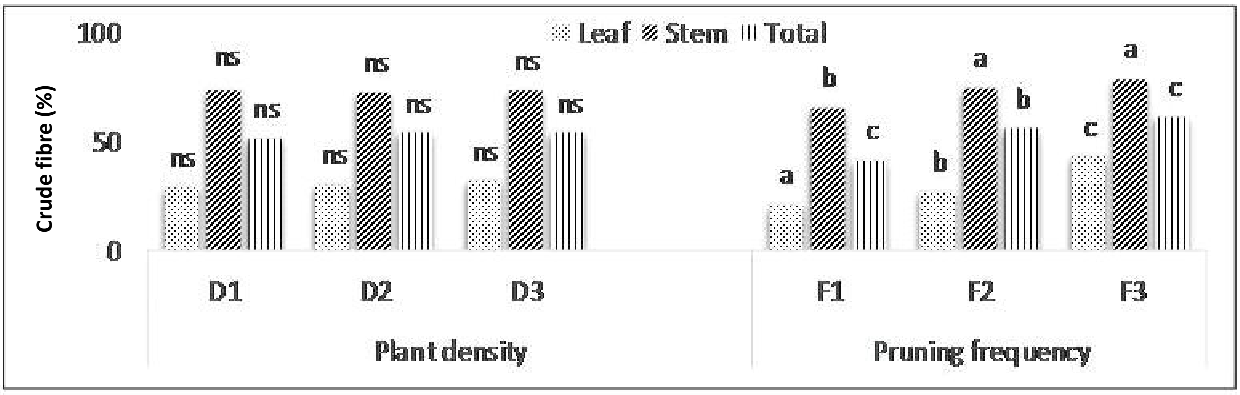

Fig 1. Influence of plant density and pruning frequency on CF content of mulberry fodder underneath coconut garden

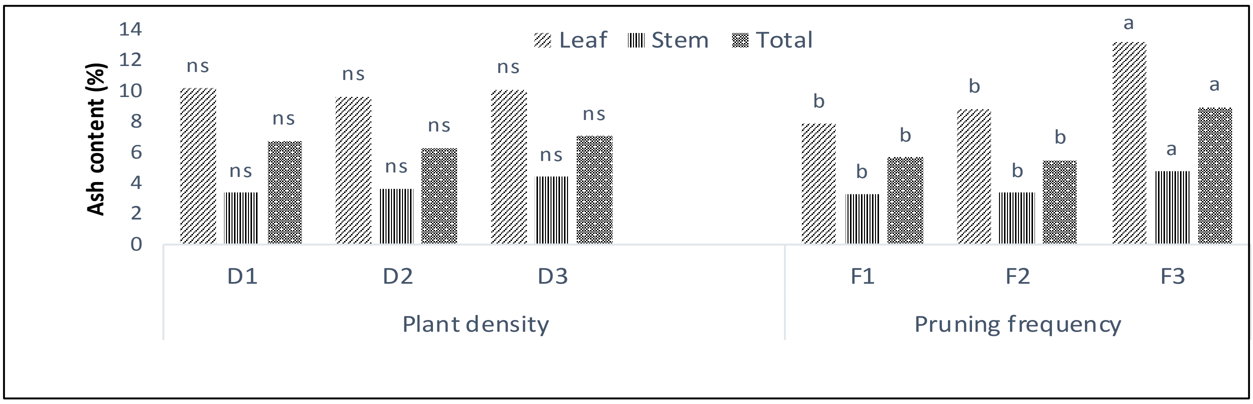

Fig 2. Influence of plant density and pruning frequency on ash content of mulberry fodder underneath coconut garden

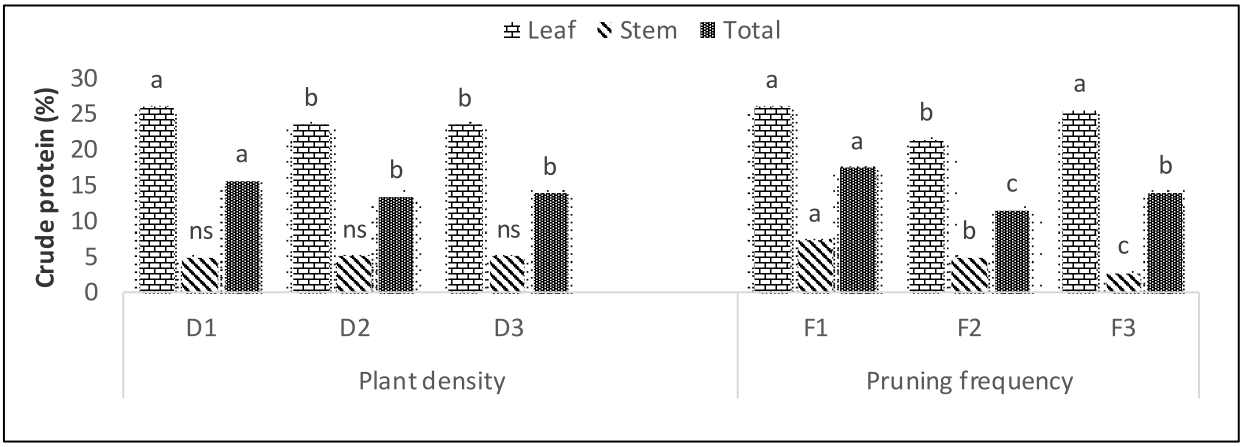

Fig 3. Influence of plant density and pruning frequency on CP content of mulberry fodder underneath coconut garden

Table 2. Interaction effect of plant density and pruning frequency on annual fresh and dry fodder yield and leaf-stem ratio of mulberry 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	30.75^{a}	17.50^{ab}	48.26^{a}	6.70^{ab}	4.35^{bc}	11.05^{bc}	1.54
T2- D2F1	22.72^{cd}	12.89^{cd}	35.61^{bcd}	4.80^{bc}	3.51^{cd}	8.31^{cd}	1.37
T3- D3F1	17.48^{de}	9.75^{d}	27.23^{cd}	3.62^{d}	2.50^{d}	6.11^{d}	1.45
T4- D1F2	23.93^{c}	15.55^{bc}	39.48^{bc}	7.16^{a}	5.13^{bc}	12.28^{a}	1.40
T5- D2F2	24.36^{c}	16.71^{ab}	41.07^{ab}	5.88^{bc}	6.10^{a}	11.98^{ab}	0.96
T6- D3F2	19.45^{de}	12.77^{cd}	32.23^{bcd}	4.55^{cd}	4.74^{bc}	9.29^{cd}	0.96
T7- D1F3	27.80^{b}	19.82^{a}	47.63^{a}	6.99^{ab}	6.86^{a}	13.85^{a}	1.02
T8- D2F3	20.38^{cd}	14.75^{bc}	35.13^{bcd}	4.58^{bcd}	4.10^{cd}	8.68^{cd}	1.12
T9- D3F3	15.75^{e}	10.11^{cd}	25.87^{cd}	4.13^{cd}	3.53^{cd}	7.66^{cd}	1.17
F value	6.89^{***}	8.59^{***}	9.87^{***}	5.32^{**}	3.24^{*}	5.36^{**}	0.89^{ns}

*** Significant at P<0.001; ** significant at P<0.01; * significant at P<0.05; ns= not significant at P>0.05; Values with the same superscripts in a column do not differ significantly; D1, D2 and D3: Tree density of 49382, 37037 and 27777 plants ha^{-1} and 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 (%)			Total ash (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
T1- D1F1	22.50^{cd}	65.10^{bc}	40.14^{b}	27.42^{a}	7.38^{a}	19.14^{a}	8.48^{bc}	3.54^{abc}	6.39^{bcd}
T2- D2F1	17.40^{d}	69.71^{abc}	43.26^{b}	25.59^{a}	7.11^{a}	16.40^{bc}	8.90^{bc}	2.72^{c}	5.74^{cd}
T3- D3F1	24.40^{c}	63.66^{c}	41.76^{b}	24.92^{a}	7.46^{a}	16.72^{ab}	6.11^{c}	3.56^{abc}	4.82^{d}
T4- D1F2	22.83^{cd}	77.48^{a}	53.07^{a}	24.23^{b}	4.71^{b}	13.56^{d}	8.87^{bc}	3.40^{b}	5.85^{cd}
T5- D2F2	31.03^{b}	72.10^{abc}	56.96^{a}	19.52^{c}	5.07^{b}	10.33^{e}	8.13^{c}	2.86^{c}	4.84^{d}
T6- D3F2	27.67^{bc}	75.81^{ab}	58.78^{a}	20.58^{bc}	4.88^{b}	10.42^{e}	9.55^{bc}	3.77^{abc}	5.81^{cd}
T7- D1F3	42.17^{a}	79.00^{a}	61.21^{a}	26.21^{a}	2.50^{c}	13.99^{cd}	13.16^{a}	3.06^{bc}	8.00^{bc}
T8- D2F3	43.80^{a}	77.67^{a}	62.01^{a}	25.46^{a}	2.92^{c}	13.45^{d}	11.91^{ab}	5.33^{ab}	8.34^{ab}
T9- D3F3	44.94^{a}	81.00^{a}	61.75^{a}	24.71^{a}	2.83^{c}	14.41^{bcd}	14.62^{a}	5.87^{a}	10.54^{a}
F value	29.85^{***}	3.34^{*}	10.27^{***}	4.07^{*}	19.72^{***}	12.36^{***}	5.69^{**}	2.20*	6.21^{**}
P value	0.000	0.02	0.000	0.01	0.000	0.007	0.001	0.04	0.001

*** 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} and F1, F2 and F3: Pruning intervals of 8, 12 and 16 weeks, respectively

Interaction effect: Interaction between density and pruning frequency significantly influenced the yield and quality parameters of mulberry. The fresh and dry fodder yields were significantly higher for treatments T1, T5 and T7 which involve planting at high and medium density and pruning at interval of 8, 12 or 16 weeks (Table 2). Leaf: stem ratio was higher (1.54) for T1 (D1F1) and T3 (D3F1; 1.45) indicating higher foliage yields from above treatments. The interaction effects showed significant influence on proximate composition of harvested fodder (Table 3). The highest crude protein (CP) content (19.14%) in fodder biomass was observed in mulberry fodder planted at density of D1 and harvested at 8 weeks interval (T1) and was at par with that of T3. The least CF content was also observed for the above treatments. However, the ash content was highest (10.54 %) at the lowest density and longest pruning interval of 16 weeks (T9).

Conclusion

Comparing various yield and quality parameters of mulberry under different management practices, the best treatment combination was T1 involving highest density and shortest pruning interval of 8 weeks, with fresh and dry fodder yields of 48.26 and 11.05 Mg $ha^{-1}yr^{-1}$, leaf: stem ratio of 1.54 and CP content of 19.14%. Even though treatments T7 and T5 produced higher fodder yields, the quality of the fodder was quite poor especially with higher CF content of 61 and 57%, respectively, which reduces the palatability and digestibility of the fodder. Hence, it was concluded that adopting plant density of 49382 plants per hectare (45 cm x 45 cm spacing) and harvesting at 8 weeks interval is advantageous for maximizing forage and nutrient yields from young stands of mulberry 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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