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Management of calliandra (*Calliandra calothyrsus* Meissn.) in coconut plantation for boosting forage yield and nutritive value

K. Anu Sagaran, Asha K. Raj*, T. K. Kunhamu, C.G. Thomas and A.V. Santhosh Kumar
Kerala Agricultural University, Vellanikkara, Thrissur-680656, India
*Corresponding author e-mail: asha.raj@kau.in
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Abstract

Calliandra (*Calliandra calothyrsus* Meissner), a prominent agroforestry tree species, is a potential animal fodder as a supplement to poor quality roughages, but management practices that ensure both quantity and suitable quality as cattle feed underneath coconut plantation were to be standardized under humid tropical conditions of India. We therefore, investigated the comparative forage yields and nutritive value of young stands of calliandra under three levels of tree density *viz*. 27,777 plants ha^{-1} (60 x 60 cm spacing), 22,222 plants ha^{-1} (75 x 60 cm spacing) and 17,777 plants ha^{-1} (75 x 75 cm spacing), two cutting heights (0.5 and 1.0 m from ground level) and three cutting intervals of 8, 12 and 16 weeks, laid out in 3 x 2 x 3 factorial randomized block design replicated thrice. The study clearly indicated that in humid tropical conditions, calliandra should be planted at a closer spacing of 60 x 60 cm, pruned at 1.0 m height and at an interval of 12 weeks to achieve greater dry matter and nutrient yields. Establishment and proper management of calliandra hedgerows in coconut plantations thus offers a cheap source of quality forage to land crunch humid tropical farmers against the highly expensive concentrate feeds.

Keywords: Calliandra, Coconut, Cutting height, Cutting interval, Fodder yield, Nutritive value

Introduction

The livestock sector has emerged as one of the key components of agricultural growth in developing countries in recent years. Over 70 per cent of the Indian rural households depend on livestock farming for supplementary income. Though livestock sector makes significant contribution to the economy of Kerala state, it is facing serious constraints due to scarcity of cheap and quality fodder resources and high crude protein deficit for livestock nutrition. The state produces only 60 per cent of the required fodders (Kerala State Planning Board, 2010) and 90 per cent of the raw materials needed for concentrate feed are coming from nearby states, thus forcing farmers to purchase costly concentrate feeds which offset their profit to a great extent. Due to land scarcity, the scope for further expansion of area under fodder crop is also very limited. In this context, cultivation of protein rich fodder trees by integrating with existing cropping systems like coconut is a viable option to enhance quality forage production in land crunch state like Kerala. Trees and shrubs can play a significant role not only in improving fodder production but also providing assured supply of fodder throughout the year (Singh and Singh, 2017).

Among fodder trees, *Calliandra calothyrsus* Meissner (calliandra) is a promising fodder tree by virtue of its nutritive foliage, ability to withstand severe pruning and good coppicing ability (Pye-Smith, 2010). It is a fast growing, multipurpose tree legume native to Central America and Mexico and is suitable for different ecological zones. Annual forage yield is reported to be in the range of 7-10 t/ha dry matter (Ella *et al*., 1989). The leaves, flowers and twigs are edible and contain 20-25% crude protein and is a good supplement to the diet of most animals. Wiersum and Rika (1992) reported 22% crude protein content, 30-70% fibre content, 4-5% ash and 2-3% fat in dried leaves of calliandra. But higher tannin levels in calliandra reduced its digestibility and animal growth when used as a sole feed. However, when used as supplement to low to moderate quality basal diets, growth of animals supplemented with calliandra is reported to be higher than supplemented with lower tannin plants such as gliricidia, lucerne and sesbania (Rusdy, 2016). In Kenya, feeding calliandra as a concentrate substitute to dairy cows improved the milk yield without any adverse effect (Paterson *et al*., 1999). Studies conducted in crossbred cows of Kerala also confirmed the nutritive value of calliandra with relatively high protein (18.45%), minerals, ether extract and energy content, and suitability as a partial substitute for concentrate feeds to the extent of 10 to 20 per cent without affecting animal health and productivity (Jayaprakash *et al*., 2016). In addition, the fast growth and tolerance to acidic soils where other tree species like leuceana perform poorly has made it a popu-lar species in small-scale agroforestry throughout the humid tropics (Palmer *et al*., 1994). Forage legumes can also reduce the need for N fertilizer in the production system and assist in nutrient recycling process (Singh *et al*., 2015).

However, while integrating calliandra underneath coconut gardens, it would be desirable to maintain trees as hedges to avoid the possible intercrop competition with coconut, to facilitate easy harvesting and to maximize biomass productivity and quality. Calliandra, when managed as hedges and cut frequently for fodder, has shown high productivity and quality in areas of Central and East Africa (Paterson *et al*., 1999). Numerous studies on fodder trees indicated that management factors such as plant spacing, cutting height and cutting interval not only affected fodder yield per unit area but also total long-term productivity and quality of the forage, which should be considered while establishing fodder banks (Horne *et al*., 1986; Ivory, 1990). Information exists on the effects of various management practices on forage yields of calliandra in different countries, but no studies were reported so far on the management strategies of calliandra in humid tropical conditions in India, especially as an intercrop in coconut, hence it is important to validate this research under Kerala conditions, to popularize calliandra cultivation among farmers.

With this background, the present study was conducted to evaluate the effect of stand management practices like tree density, cutting heights and cutting interval on forage yield and nutritional qualities of young stands of calliandra underneath coconut plantation in humid tropical conditions of Kerala.

Materials and Methods

Study area and environmental data: The study was conducted during 2014-2015 at College of Forestry, Vellanikkara, Kerala (10^0 32' N and 76^0 16 E' at an altitude of 22.5 m above m.s.l.), with warm humid tropical climate. Mean annual precipitation was around 2900-3150 mm with a bimodal pattern; major share of the rains received during the southwest monsoon season (June to August) and short rains from September to October. The mean weekly minimum and maximum temperature ranged from 22.1 to 25.7^0 C and 26.9 to 36.7^0 C, respectively during 2014-15 cropping season. The soils of the experimental site fall under the family of loamy Kaolinitic Isohyperthermic Typic Plinthustult, with sandy clay loam texture. Initial soil tests indicated acidic soil reaction (pH 5.5), with medium levels of available nitrogen (0.16 g kg^{-1}), potassium (0.11 g kg^{-1}) and organic carbon (1.2%), and low level of phosphorus (3.39 mg kg^{-1}).

Field culture: Seedlings of calliandra were raised in a temporary shade house. Seeds were soaked in water for 48 hours prior to planting for enhancing germination and were planted in polythene bags of size 15x20 cm filled with potting mixture (soil: coir pith: FYM in 2:1:1 ratio). Seedlings were transferred to the experimental main field after 3 months with the onset of premonsoon showers. The fodder tree, Calliandra was intercropped under varying management regimes, in the interspaces of coconut (variety: west coast tall; age 35 years; spacing of 7.6 x 7.6 m), during June 2014. The treatments consisted of calliandra intercropped in coconut plantations under three levels of tree density *viz*. D_1: 27,777 plants ha^{-1} (60 x 60 cm spacing), D_2: 22,222 plants ha^{-1} (75 x 60 cm spacing) and D_3: 17,777 plants ha^{-1} (75 x 75 cm spacing); two cutting heights (H_1: 0.5 and H_2: 1.0 m from ground level) and three levels of cutting interval (F_1: 8, F_2: 12 and F_3: 16 weeks) in all possible combinations in factorial randomized block design replicated thrice. The field area (excluding coconut basin of 2 m radius) was ploughed twice and the layout was done allocating a plot size of 4 x 3 m (12 sq. m) for each treatment. The seedlings were transplanted to the main field as per prescribed spacing for various treatments. Farm yard manure (FYM) @ 20 t ha^{-1} and N: P_2O_5: K_2O each @ 50 kg ha^{-1} were applied uniformly for all treatments. FYM was applied as basal before the onset of south west monsoon. Fertilizers were applied through N: P: K mixture (18: 18: 18) in two split doses before the onset of south west and north east monsoons. Plants were weeded and irrigated as and when required.

Forage yield and nutrient estimation: After seedlings attained a height over 1 m, an initial pruning was given in June 2014 as per the prescribed pruning heights of 0.5 and 1 m. Subsequent cuttings were taken as per harvest intervals and annually six, four and three cuts were given for intervals of 8, 12 and 16 weeks, respectively up to June 2015. Five trees/plot avoiding border plants were selected at random for taking observations on yield and nutritive parameters. For each cut, biomass from 5 trees/plot was separated into leaf and stem and their individual fresh weights and total biomass were determined. Thereafter, yield from all harvests in a year was pooled to get annual yields and using the net harvested area and fresh weight, annual green fodder yield was scaled up to the area of calliandra under one-hectare coconut garden. The area under calliandra in one-hectare coconut garden is 7827 sq. m after excluding the functional area of coconut palms, in a radius of 2 m around its basin.

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 analyzed following standard procedures (AOAC, 1995).

Statistical analysis: The data were subjected to statistical analysis by analysis of variance (ANOVA) using general linear model procedure in SPSS ver.18 to ascertain the significance of yield and quality parameters. The Duncan's multiple range test (DMRT) was used to test the differences among treatment means at 5% significance level.

Results and Discussion

Effect of tree density on yield and nutritive parameters: Tree density profoundly influenced (Table 1) fodder yields in calliandra. The highest dry forage yield (11.73 kg ha^{-1}yr^{-1}) was also obtained from the highest density stand (D_1), which was 20 and 55% higher than D_2 and D_3, thereby indicating a need for closer planting of fodder trees for maximizing productivity and optimum utilization of resources in land limited areas. Similar findings of higher yields from higher tree densities for *Leucaena spp., Gliricidia spp., Calliandra spp.* and *Sesbania spp.*, were reported earlier by Ella *et al.* (1989). However, Raj (2016) reported the maximum yields from mulberry and subabul at still higher density of 49,382 plant ha^{-1}, when planted as an intercrop in coconut garden. According to Turgut *et al*. (1997), the increase in yield with closer spacing could be explained by greater solar energy interception per unit area. Higher plant population also provide thick canopy cover and dense root system that prevents under storey weed growth, reduces soil erosion and subsequent soil and nutrient loss during rainy season, and evaporation rate during dry season, all favouring the conservation of resources and productivity of trees.

Tree density also affected the production of foliage and stem fractions, which showed an increasing trend with increasing tree density (Table 1). The highest density stand yielded more leaf dry matter (5.53 kg ha^{-1}yr^{-1}) than the lowest one (3.64 kg ha^{-1}yr^{-1}), which implied the need for closer planting of trees for yielding maximum nutritive herbage per unit area. The above result confirmed the earlier findings in mulberry and subabul trees (Raj, 2016), and also in gliricidia, calliandra and sesbania (Ella *et al.*, 1989). Stem fractions also showed similar trends. Despite yield differences, leaf: stem ratio showed only a marginal variation in response to tree density, with a slight increment towards the highest density.

Table 1. Effect of tree density, cutting height and interval on annual dry fodder yields and leaf-stem ratio of calliandra in coconut garden

Treatments	Fractional and total dry fodder biomass (kg ha^{-1}yr^{-1})			Leaf stem ratio
	Leaf	Stem	Total	
Tree density				
27,777 plants ha $^{-1}$(D_1)	5.53^a	6.02^a	11.73^a	1.14
22,222 plants ha^{-1} (D_2)	4.33^b	4.77^b	9.10^b	1.06
17,777 plants ha^{-1}(D_3)	3.64^c	3.90^c	7.53^c	1.07
P value	0.000***	0.000***	0.000***	0.102 ^{ns}
Cutting interval				
8 weeks (F_1)	4.05^b	3.04^b	7.09^b	1.33^a
12 weeks (F_2)	4.53^{ab}	3.47^b	8.00^b	1.32^a
16 weeks (F_3)	4.93^a	8.36^a	13.29^a	0.61^b
P value	0.002**	0.000***	0.000***	0.000***
Cutting height				
0.5 m (H_1)	3.73^b	4.38^b	8.11^b	1.05^b
1.0 m (H_2)	5.27^a	5.54^a	10.81^a	1.12^a
P value	0.000***	0.000***	0.000***	0.035*

***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

Plant density significantly influenced some of the nutritive parameters of calliandra forage (Table 2). Closely spaced stands (D_1) showed better nitrogen uptake as reflected by the higher nitrogen content in the fodder biomass (2.60%). Nitrogen, being a mobile nutrient element with higher chances of leaching losses, the dense root system of closely spaced stands might had very efficiently trapped and utilized the applied nitrogen with minimal loss. Similarly the crude protein (CP) content in fodder also increased significantly from 15.40 to 16.26% from lower to higher density classes. However, plant density had greater influence on CF content, which declined from

40.53 to 37.73% at higher densities indicating closer spacing for production of tender fodder. Similar results of elevated CP% and lower CF% at higher population density was reported in *Sesbania aegyptica (*El-Morsey, 2009), and in mulberry and subabul (Raj, 2016). In general, foliage fraction had higher CP content (26.15-27.22 %) and lower CF content (32.89-33.97%) than stem fraction (4.7-5.23% and 43.58-47.61% respectively), which implied that any management strategy that enhances the foliage fraction will have a positive effect on the nutritive value of fodder.

The ash content (3.30%) of fodder showed significant increment at higher density than lower levels (Table 3). The phosphorus content (0.23%) in total fodder and in leaf and stem fractions was appreciably higher in high density stands. Potassium content was found to be higher in medium density (0.99%) followed by higher density (0.97%), where as the value was lower (0.92 %) in widely spaced stands. In general, an overall improvement in nutritive value of fodder was observed when trees are planted at closer spacing with higher densities. This could be attributed to the fact that in closely spaced stands the loss of nutrients from the soil was much lower due to closed canopy and limited exposure of soil to erosion, thereby enhancing the nutrient retention and uptake of nutrients by the plants.

Hence, planting at a closer spacing (60 x 60 cm) with the highest tree density of 27,777 plants per hectare was advantageous for maximizing forage and nutrient yields from young stands of calliandra underneath coconut plantation, until the above and below ground competition starts. However, the long term effects of tree density on the root system and fodder yield are yet to be studied.

Effect of cutting interval on yield and nutritive value: Several studies on different fodder trees indicated that harvest interval is a critical management factor that influences forage yield and quality as well as sustainable production. Our results also confirmed the earlier findings. In calliandra, harvesting at the prolonged interval of 16 weeks yielded more total forage (13.29 kg ha-1yr^{-1}), but the majority of the fodder comprised of stem fraction (Table 1). In comparison, harvesting at shorter intervals of 8 and 12 weeks yielded around 7.09 and 8.00 kg of fodder respectively, a significant portion of which was comprised of foliage fraction. Leaf: stem ratio of fodder harvested at 8 and 12 weeks showed an increment of 125% over that of the 16 weeks interval, indicating more foliage production than stem fractions when harvested at shorter intervals. Frequent pruning at closer intervals stakes away the possibility of photosynthesis and inhibits nutrient assimilation and reduces the carbohydrate reserve, which influences the leaf area development and affects the growth rate of the plants (Latt *et al.*, 2000), whereas longer intervals reduces the number of cuts and increases the stem yield which affects the quantity and quality of forage. Hence, it is ideal to harvest fodder at medium interval of 12 weeks to maintain yield and quality.

Cutting intervals also had profound influence on nutritive value of the forage. Harvesting at shorter and medium pruning interval of 8 and 12 weeks yielded fodder with maximum CP content (17.91 and 17.87%, respectively)

Table 2. Effect of tree density, cutting height and interval on nitrogen, crude protein and crude fibre content of calliandra fodder in coconut garden

Treatments	Nitrogen (%)			Crude protein (%)			Crude fibre (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
Tree density									
D_1	4.36	0.84	2.60	27.22	5.23	16.26^a	32.89	43.58^c	37.73^c
D_2	4.33	0.80	2.57	27.09	5.00	16.06^a	34.53	44.92^b	39.43^b
D_3	4.18	0.76	2.47	26.15	4.70	15.40^b	33.97	47.61^a	40.53^a
P value	0.31^{ns}	0.55^{ns}	0.001**	0.31^{ns}	0.52^{ns}	0.001**	0.228^{ns}	0.002**	0.004**
Cutting interval									
F_1	4.40^a	0.91	2.87^a	27.47^a	5.67	17.92^a	19.83^c	39.25^c	28.33^c
F_2	4.47^a	0.83	2.86^a	27.90^a	5.15	17.88^a	35.11^b	44.75^b	39.37^b
F_3	4.01^b	0.66	1.91^b	25.10^b	4.12	11.93^b	46.44^a	52.11^a	49.99^a
P value	0.001**	0.06^{ns}	0.000***	0.001**	0.06^{ns}	0.000***	0.000***	0.000***	0.000***
Cutting height									
H_1	4.35	0.80	2.54	27.18	5.00	15.88	32.98	45.15	38.76
H_2	4.23	0.80	2.55	26.47	4.96	15.93	34.61	45.59	39.70
P value	0.25^{ns}	0.94^{ns}	0.78^{ns}	0.25^{ns}	0.92^{ns}	0.80^{ns}	0.043^{ns}	0.603^{ns}	0.087^{ns}

when compared to longer interval (11.93%) of 16 weeks (Table 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. Guevarra *et al.* (1978) observed that an increase in harvest interval enhances dry matter yield, but reduces fodder quality because of the reduction in nitrogen content of foliage and high proportion of in-edible stem fraction.

Pruning intervals had more prominent influence on crude fiber content of the forage, wherein the values declined sharply from 49.98 to 28.33% with the reduction in interval from 16 to 8 weeks (Table 2). Similar results were reported by Raj (2016) in subabul and mulberry. Kaitho *et al.* (1993) also observed that the nutritive value of calliandra fodder declined when cutting interval increased from 12 to 28 weeks. The young leaves are generally high quality, but the quality decreases faster in stem 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 (Miquilena *et al.*, 1995).

Ash content (3.30%) was significantly higher at longest interval of 16 weeks, than shorter intervals (Table 3). Total nitrogen, phosphorus and potassium content of the fodder were significantly higher at shorter intervals of 8 and 12 weeks than that of 16 weeks. In general, nutritive value of fodder was adversely affected at prolonged harvest intervals, mainly due to the decline in the foliage fraction, as the nutrient outputs are positively related to foliage yields. The above results were in line with report of Boschini (2002) in calliandra.

Effect of cutting height on yield and nutritive parameters: Cutting height showed significant influence on fodder yield. Dry forage yield increased by 2.70 kg ha-1yr-1, from 0.5 m to 1 m pruning height (Table 1). The increment in forage yields with increasing cutting height was possibly due to more reserve food materials in taller stocks that promoted vigorous and rapid regrowth. It was also observed that lower pruning heights reduced the ability of the plants to withstand water stress conditions, causing drying of stems and poor regeneration, which in turn affect tree longevity in the long run. Basavaraju and Rao (1996) from Karnataka also confirmed the requirement of 1m cutting height for getting maximum yield from calliandra when compared to lower levels. Similarly Tipu *et al.* (2006) obtained higher fodder yield from subabul when pruned at 100 cm height than 50 cm.

Similarly, taller stocks produced more foliage and less stem resulting in a higher leaf-stem ratio of about 12 per cent over the lower ones (Table 1). Increasing cutting height retain more leaves in the stump with greater available food reserves, which might lead to a shorter lag phase for new growth. Isarasenee *et al.* (1984) reported enhanced growth of leucaena cut at 120 cm compared with 60 or 30 cm. They further suggested that early regrowth was supported by movement of food reserves from stem rather than from current photosynthesis.

Table 3. Effect of tree density, cutting height and interval on ash, phosphorus and potassium content of calliandra fodder in coconut garden

Treatments	Ash (%)			Phosphorus (%)			Potassium (%)		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
Tree density									
D_1	3.47	3.41	3.30^a	0.25^a	0.20^a	0.23^a	0.99	0.95	0.97^a
D_2	3.24	3.07	3.07^b	0.18^b	0.13^b	0.15^b	1.04	0.95	0.99^a
D_3	3.26	3.19	3.12^b	0.14^c	0.09^c	0.12^c	0.96	0.88	0.92^b
P value	0.19^{ns}	0.24^{ns}	<0.001**	<0.001**	<0.001**	<0.001**	0.30^{ns}	0.42^{ns}	<0.001**
Cutting interval									
F_1	2.32^c	3.96^a	3.03^a	0.20^a	0.13	0.17^a	0.99	1.02	1.00^a
F_2	3.21^b	3.08^b	3.16^b	0.19^{ab}	0.15	0.17^a	1.02	0.88	0.95^b
F_3	4.43^a	2.63^c	3.30^a	0.18^b	0.14	0.16^b	0.98	0.89	0.92^b
P value	<0.001**	<0.001**	<0.001**	0.029^{ns}	0.31^{ns}	<0.001**	0.80^{ns}	0.04^{ns}	<0.001**
Cutting height									
H_1	3.38	3.36	3.25^a	0.19	0.14	0.17	1.02	0.92	0.96
H_2	3.27	3.09	3.08^b	1.19	0.14	0.17	0.98	0.93	0.96
P value	0.32^{ns}	0.12^{ns}	<0.001**	0.547^{ns}	0.24^{ns}	0.72^{ns}	0.31^{ns}	0.84^{ns}	0.96^{ns}

D_1, D_2 and D_3: Tree density of 27,777, 22,222 and 17,777 plants ha^{-1}, respectively; H_1 and H_2: Pruning heights of 0.5 and 1 m, respectively; F_1, F_2 and F_3: Pruning intervals of 8, 12 and 16 weeks, respectively.

Even though cutting height showed pertinent effects on forage yields, most of nutritive parameters of the forage were quite unaffected by the height of pruning (Table 2-3). In general, it could be seen that management factors like plant density and cutting height had a prominent influence on forage yields of calliandra whereas cutting interval showed significant influence on nutritive parameters.

Conclusion

The present study revealed that the forage yield and quality of young stands of calliandra underneath coconut garden could be optimized by adopting a tree density of 27,777 plants ha^{-1}, cutting height of 1m and cutting interval of 12 weeks. Moreover, based on the growth and yield performances, and quality aspects, it was found that calliandra is a promising fodder tree, which could be successfully integrated with the existing coconut gardens of humid tropical regions. Establishment and proper management of calliandra fodder banks in coconut garden thus, offers a cheap source of quality forage to livestock farmers against the highly expensive concentrate feeds.

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