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Assessment of growth and productivity of Fodder Tree Species with Intercrops under Agroforestry Systems

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ABSTRACT

Fodder shrubs and trees (browse) play a significant role both in farming systems, where they are protected as fallow species, and in livestock production. A field experiment was conducted to assess the growth and productivity of fodder tree species with intercrops under agroforestry systems in Northern Transitional zone of Dharwad region of Karnataka in India during 2018-19 and 2019-20 in kharif and rabi seasons. The fodder plantation was established in 2014 with seven fodder tree species with a spacing of 5m × 3m Viz.,1.Calliandra calothyrsus, 2.Albizia lebbeck, 3.Leucaena leucocephala, 4.Sesbania grandiflora, 5.Gliricidia sepium, 6.Moringa olifera, 7.Bauhinia purpurea and 8. Sole Field Crops (soybean and safflower). The experiment was conducted with Randomized Block Design (RBD) with three replications. Among seven fodder tree species evaluated under agroforestry systems, the highest MAI in volume of wood was reported in Moringa olifera (5.042 and 5.625 m3 ha-1) followed by Leucaena leucocephala (4.414 and 4.880 m3 ha-1). Gliricidia sepium produced the highest MAI in total tree biomass (4.18 and 4.90 t ha-1) followed by Moringa olifera (3.81 and 4.25 t ha-1) as compared to other fodder tree species studied. The pooled data of 2018 and 2019 reported maximum green fodder yield recorded in Calliandra calothyrsus (474.17, 586.07 and 429.46 kg ha-1) followed by Leucaena leucocephala (444.26, 555.33 and 388.73 kg ha-1) which varied significantly from other fodder tree species at all the stages of pruning intervals. Total fodder yield recorded for the year 2018 and 2019 showed significantly higher values of green fodder yield which were recorded in Calliandra calothyrsus (1462.89 and 1516.52 kg ha-1 respectively) followed by next best fodder tree Leucaena leucocephala (1365.88 and 1410.75 kg ha-1) for the year 2018 and 2019 respectively which varied significantly from other fodder tree species. The maximum per cent dry matter production recorded in T1 - Calliandra calothyrsus + FC (50.01, 51.05 and 52.03 %) followed by T3 - Leucaena leucocephala + FC (47.13, 48.20 and 49.24 %) at all the stages of pruning intervals. There was a gradual increase in dry matter from rainy to spring and winter seasons in all the fodder tree species examined. Green tree fodder yield was positively correlated with light interception (0.544) at 5 per cent significant level and negatively correlated with light transmission ratio (-0.383). Hence, these agroforestry systems have an additional role of improving socioeconomic status of farming community providing them additional income.

Keywords: Fodder banks, Woody perennials, Mean annual increment, Pruning height and interval, Lops and tops, Cutting frequency, Total tree biomass

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INTRODUCTION

Agroforestry is a sustainable land use strategy for improving farm productivity and ensuring the livelihood security. It has both fruitful and defensive perspective to meet out the demands of ever mounting human and domestic animals population. In India, there is scarcity of green fodder (net deficit 35.6 %) despite large area under cultivation and common grazing lands. Under such circumstances, fodder tree species play a significant role to fulfill the demands of green fodder, particularly during lean periods. Some of the important fodder tree species which are rich in protein, fibre, minerals etc. are suitable for integration in agroforestry systems, viz., Grewia optiva, Morus alba, Ailanthus excelsa, Artocarpus heterophyllus, Anogeissus latifola, Bauhinia variegata, Albizia lebbeck, Leucaena leucocephala, Prosopis cineraria, Moringa oleifera, Celtia australis, Robinia pseudoacacia, etc. Many studies conducted on tree crop interactions indicated that trees improved soil properties and increased fodder availability round the year. In India, fodder trees can be mixed with different systems such as agrisilvicultural, silvipastoral systems etc. ensuring availability of fodder, fuel wood, small timber and wood for paper and plywood industries and also to increase the farm

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income (Nareshkumar et al., 2018).

Most of the fodder banks are maintained through a cut-and-carry system in which the green tree fodder is provided to the livestock after harvesting. A cut and carry system reduces wastage of fodder from animal damage and the inevitability to monitor animals. Major issues of management to be considered for a cut and carry system are cutting height, cutting frequency, and dry season management. But these issues are influenced by the many factors viz., rainfall, temperature, soil type, species, plant spacing etc.

Fodder trees are contributing a major task in reducing the fodder deficiency problem in India. Animals experience deficiently due to lack of protein rich diet in most parts of our country after rainy season. The situation turns out to be serious for farmers in dry season under rainfed situations during fallow and unproductive periods. In such situations, shrubs and fodder trees are capable to survive the drought, stay green, and supply a nutritious fodder for livestock (Dhyani, 2003). The scarcity of forage in our country can be resolved inequitably by integrating fodder tree species capable of sustained production of palatable forage which are rich in protein and total digestible nutrients. Fodder availability can be improved through the plantations of these species on degraded lands under silvi-pastoral systems and in farmers' field under several agroforestry systems. Oak, Grewia optiva, Celtis australis in Western Himalaya, and Ficus spp., Alnus nepalensis and Bauhinia spp., in Eastern Himalayas have been used as chief fodder trees. Lopping is a common practice of Prosopis cineraria (Khejri) in western Rajasthan, Albizia lebbeck, Albizia procera, Azadirachta indica in northern and central India for leaf fodder, utilizing pods of Acacia nilotica and Prosopis juliflora for fodder during lean periods.

A study reported that the fodder requirement in India is 883.95 Mt of green fodder and 583.66 Mt of dry fodder. However, the approximate fodder production of green fodder is 664.73 Mt and dry fodder is 355.93 Mt. Therefore adequate policy and research level initiatives have to be taken to strengthen the existing fodder resources to reduce the existing gap of 218.22 Mt of green fodder and 227.73 Mt of dry fodder (Yadav et al., 2017).

Fodder is harvested through selective cutting of leafy parts, flowers and fruits of shrubs and trees; pruning of shrubs and trees which are suitable for livestock; pollarding of tree crowns (Osemeobo, 2006). Fodder trees and shrub components play an important role in ruminant production and feeding browse has become an important practice particularly during dry season when herbaceous forages are limited (Bamikole et al., 2004) and less in nutritive value (Aregheore, 2001).

MATERIALS AND METHODS

The present field investigation was carried out in an existing fodder plantation for two years during kharif and rabi seasons of 2018-19 and 2019-20 to study the performance of different fodder tree species with intercrops under agroforestry systems at the premises of University of Agricultural Sciences, Dharwad, Karnataka. Seven fodder tree species were planted at a spacing of 5 × 3m, viz., Calliandra calothyrsus, Albizia lebbeck, Leucaena leucocephala, Sesbania grandiflora, Gliricidia sepium, Moringa oleifera and Bauhinia purpurea during 2014. The experiment was laid out in Randomized Block Design (RBD) with three replications (Fig. 1 and 2) in an established plantation. Fodder trees were planted at a spacing of 5 × 3 m and the plot size was 15 × 12 m with 12 trees per treatment. Annual cultural operations were carried out in fodder based agroforestry system as per the package of practices.

Fig. 1: Fodder tree + Soybean / Safflower intercrop based agroforestry system

Fig. 2: Tree fodder harvesting under fodder trees based agroforestry systems

The Biometric and yield observations of fodder trees under agroforestry system were measured. Stem diameter (cm) was measured by using tree callipers as per Chaturvedi and Khanna (1982) and expressed in centimetres. The observations were recorded at initial stage, 3 MAT, 6 MAT, 9 MAT and 12 MAT after initiation of the experiment. Total number of branches arising from the main stem and at the point of cutting height was counted. The observations were recorded at initial stage, 3 MAT, 6 MAT, 9 MAT and 12 MAT after initiation of the experiment. The average number of branches was worked out and expressed in number. Tree canopy cover was calculated by measuring the spread of tree crown in North – South and East – West direction with the help of measuring tape and expressed in m^2. Weight of fodder was recorded at the time of harvest and expressed in kilogram per hectare. Percent dry matter was calculated by the formula, Percent Dry Matter = 100 % - moisture %. Feed values and nutrient requirements for ruminants were expressed on a dry matter or moisture-free basis to compensate for the large variation in moisture content of feeds commonly fed to cattle. The green foliage was randomly selected from tree parts and then kept for oven drying at 70 °C to constant weight. Average dry matter per plant was recorded at harvest and expressed as gram per plant. Total volume of wood was estimated by the formula as suggested by Chaturvedi and Khanna (1982). The total volume of sample trees was used to calculate the total volume of wood per hectare and expressed in cubic meter per hectare.

Volume of wood = Total tree height × Basal area × Form factor

Total tree biomass

Aboveground biomass and belowground biomass were determined separately by non destructive method and expressed in tons per hectare. Aboveground biomass was determined by the formula as suggested by MacDicken (1997). The standard densities of wood for fodder tree species were considered for calculation of tree biomass yield and expressed in tons per hectare.

Biomass yield (t ha^{-1}) = Density of wood × Volume of tree

Belowground biomass includes all biomass of live roots excluding fine roots having < 2 mm diameter. The below ground biomass was calculated by the following formula by multiplying aboveground biomass (AGB) with a multiplication factor 0.26. Total tree biomass was calculated by adding aboveground biomass and belowground biomass and expressed in tonnes per hectare.

Current Annual Increment (CAI) in growth parameters

Current annual increment (CAI) in various fodder tree growth parameters namely diameter at breast height (cm), tree canopy cover (m^2), volume of wood (m^3 ha^{-1}) and total tree biomass (t ha^{-1}) were computed. It was calculated by the formula:

$CAI = V_{n+1} - V_n$

Where, V_{n+1} is the growth value produced in n+1 years and V_n is growth value in 'n' years.

RESULTS AND DISCUSSION

Growth attributes of fodder trees under agroforestry systems

In the present study, an attempt was made to assess the growth and productivity of fodder tree species in northern transitional zone (zone 8) of Karnataka. The increased (MAI) canopy cover (1.89 and 1.89 m^2) in *Moringa oleifera* + FC (T_6) during 2018-19 and 2019-20 may be due to absorption of higher amount of solar radiation resulting in increased production of photosynthates. The higher value of number of coppices (branches) may be attributed to higher canopy cover of trees. Increased distribution of these photosynthates into main stem resulted higher number of coppices and crown area (Table 1 and 2).

Among seven fodder tree species evaluated under agroforestry systems, the highest mean annual increment (MAI) in diameter at breast height (DBH) was recorded in *Moringa olifera* (2.31 and 2.12 cm) followed by *Leucaena leucocephala* (2.21 and 1.98 cm). *Moringa olifera* noticed

Table 1: Current annual increment in growth attributes of fodder trees as influenced by fodder tree based agroforestry systems

Agroforestry system	Current annual increment (CAI) in growth attributes of fodder trees							
	2018				2019			
	Stem Diameter (cm)	Tree canopy cover (m^2)	Volume of wood (m^3 ha^{-1})	Total tree biomass (t ha^{-1})	Stem Diameter (cm)	Tree canopy cover (m^2)	Volume of wood (m^3 ha^{-1})	Total Tree biomass (t ha^{-1})
T_1 - *Calliandra calothyrsus* + FC	1.83	1.56	2.704	2.21	2.01	1.62	3.327	2.72
T_2 - *Albizia lebbeck* + FC	1.73	1.54	1.973	1.64	1.88	1.40	2.642	2.20
T_3 - *Leucaena leucocephala* + FC	1.98	1.49	4.414	3.56	2.21	1.45	4.880	3.94
T_4 - *Sesbania grandiflora* + FC	1.88	1.44	2.845	1.79	2.11	1.34	3.415	2.15
T_5 - *Gliricidia sepium* + FC	1.93	1.69	3.239	3.06	2.16	1.62	3.796	3.59
T_6 - *Moringa oleifera* + FC	2.12	1.89	5.042	3.81	2.31	1.89	5.625	4.25
T_7 - *Bauhinia purpurea* + FC	1.83	1.46	2.349	1.98	1.90	1.42	3.157	2.67
T_8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-
SEm ±	0.019	0.034	0.119	0.111	0.056	0.038	0.040	0.037
CD @ 5%	0.060	0.105	0.364	0.340	0.171	0.115	0.121	0.115

FC – Field Crop; Age of the fodder tree plantation – 5 years (2018) and 6 years (2019)

Table 2: number of coppices of fodder trees as influenced by agroforestry systems at different growth stages

Agroforestry system	Number of coppices per tree									
	2018					2019				
	Initial	3 MAT	6 MAT	9 MAT	12 MAT	Initial	3 MAT	6 MAT	9 MAT	12 MAT
T1 - Calliandra calothyrsus + FC	20.78	24.81	28.38	32.25	35.61	22.18	26.25	29.96	33.74	37.82
T2 - Albizia lebbeck + FC	7.94	11.97	15.54	19.41	22.77	9.34	13.41	17.12	20.90	24.98
T3 - Leucaena leucocephala + FC	20.08	24.11	27.68	31.55	34.91	21.48	25.55	29.26	33.04	37.12
T4 - Sesbania grandiflora + FC	16.33	20.36	23.93	27.80	31.16	17.73	21.80	25.51	29.29	33.37
T5 - Gliricidia sepium + FC	16.44	20.47	24.04	27.91	31.27	17.84	21.91	25.62	29.40	33.48
T6 - Moringa oleifera + FC	16.28	20.31	23.88	27.75	31.11	17.68	21.75	25.46	29.24	33.32
T7 - Bauhinia purpurea + FC	10.86	14.89	18.46	22.33	25.69	12.26	16.33	20.04	23.82	27.90
T8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-	-	-
SEm ±	0.032	0.070	0.179	0.307	0.444	0.052	0.065	0.188	0.382	0.410
CD @ 5%	0.098	0.215	0.549	0.941	1.360	0.160	0.198	0.577	1.169	1.257

MAT – Months After Treatment (harvesting); FC – Field Crop; Age of the fodder tree plantation – 5 years (2018) and 6 years (2019)

maximum MAI in tree canopy cover (1.89 and 1.89 m2) followed by Gliricidia sepium (1.69 and 1.62 m2) during 2018 and 2019 respectively. The highest MAI in volume of wood was reported in Moringa olifera (5.042 and 5.625 m3 ha-1) followed by Leucaena leucocephala (4.414 and 4.880 m3 ha-1). Gliricidia sepium produced the highest MAI in total tree biomass (4.18 and 4.90 t ha-1) followed by Moringa olifera (3.81 and 4.25 t ha-1) as compared to other fodder tree species studied (Table 1).

In a similar study, Datta and Singh (2007) revealed that, among 12 multipurpose tree species (MPTs), Acacia auriculiformis is shown to fulfil timber / fuelwood need due to production of more wood with mean annual increment (MAI) in a short rotation period of 10 years. On the other hand, at 16 years of age, Eucalyptus hybrid and Michelia champaca produced appreciably high timber volume due to higher aboveground biomass in tree based agroforestry systems, which could have enhanced the turnover of nutrients, thus declining the soil acidity while increasing the accessibility of nutrients. Similar results were observed in teak growth attributes (Sharma et al., 2011), Acacia nilotica (Gill, 2005) and in Ailanthus excelsa Roxb. (Rajalingam et al., 2013). Kaushik et al. (2015) noticed that the significant variation in growth performance of top feed tree species might be due to differences in genetic make-up of different tree species and may be due to its inherent fast growing habit.

Based on the comparison of growth among study periods (2018 and 2019), maximum current annual increment (CAI) in diameter at breast height of fodder trees was found in 2018, whereas, maximum current annual increment (CAI) in tree canopy cover, volume of wood and total tree biomass (above and below ground) was recorded during the period of 2019. The growth improvement in 2019 could be attributed to higher precipitation for increasing number of coppices leading to higher above ground biomass under agroforestry systems. The study on fodder trees and shrubs conducted (Henry and Houerou, 2010) in United States of America, South Africa, South America and Australia concluded that the deep rooting enables the fodder trees to reach water resources unavailable to herbaceous species. Their Rain Use Efficiency (RUE) and Water Use Efficiency (WUE) rates increase productivity three to five times higher than rangelands.

Similar results were observed on five fodder tree species viz., Morus indica (mulberry), Sesbania grandiflora (agathi), Moringa oleifera (moringa), Gliricidia sepium (gliricidia) and Calliandra calothyrsus (calliandra) under homegarden in Kerala during rainy season and three months during summer which were found to be ideal for hedgerow planting in the understorey of homesteads (Patric et al., 2020). Similarly exotic Acacias viz., Acacia ampliceps and Acacia bivenosa along with indigenous fodder plant species in Rajasthan with different planting techniques in two different environmental settings showed high potential to be introduced as fodder species in afforestation programmes in salt affected soils in arid Rajasthan and Rann of Kachchh of Gujarat (Arya et al., 2020).

Productivity of fodder trees under agroforestry systems

Production levels of any fodder plants will vary greatly depending upon climate, soil type and management practices. Under a range of conditions, tree species of the genera Calliandra and Leucaena have often given annual yields from 5–15 t ha-1 of edible dry matter when grown in block planting arrangements (Karanja et al., 1996).

Green foliage yield indicates the potentiality of fodder tree species to produce fodder under agroforestry system (Table 3). In the present study, green fodder yield of different fodder trees at various pruning intervals (1st pruning at 4 MAT, 2nd pruning at 8 MAT and 3rd pruning at 12 MAT) differed significantly among different fodder tree based agroforestry systems during both the periods of investigation (2018 and 2019). The results of both the periods (2018 and 2019) revealed that the highest green fodder yield was reported in T1 - Calliandra calothyrsus + FC (463.05, 565.54 and 434.30 kg ha-1) during 2018 and (485.29, 606.61 and 424.62 kg ha-1) during 2019. But the performance of the Albizia lebbeck + FC (T2) was not satisfactory attaining least values of 124.95, 147.58 and 122.41kg ha-1 during 2018 and 136.69, 170.86 and 119.60 kg ha-1 during 2019 at various pruning intervals (4, 8 and 12 MAT).

This difference in biomass production is partly attributed to pollarding ability of the tree species. In the present study, Calliandra calothyrsus demonstrated good coppicing and pollarding ability influencing higher rate of biomass production as compared to Albizia lebbeck. Calliandra has a capacity to withstand pruning or pollarding stress at regular intervals of 4 months whereas, Albizia lebbeck failed to withstand pollarding stress under agroforestry system.

The better growth from established trees may be attributed to larger stumps, better carbohydrate reserves, deeper and more widespread root system (Ivory, 1990; Gutteridge and Shelton, 1993). In similar investigations, Orwa, et al. (2009) opined that Calliandra calothyrus produces good quantity of fodder under agroforestry system through pruning and pollarding as the main management activities. Sebuliba et al. (2012) indicated that calliandra grow quickly up to 2.3 – 3.5 m in 180 days and up to 3 – 5 m within the first year.

The results revealed that biomass production was higher to the extent of 3.54 per cent in the year 2019 (1516.52 kg ha-1) as compared to 2018 (1462.89 kg ha-1) which can be explained by relating the biomass production to the rainfall that occurred during the year 2019 (1316.2 mm) as compared to 2018 (892.2 mm), since the higher yields were achieved during higher rainfall year. Results also suggest that there was direct influence of rainfall in the year on fodder production.

Table 3: Green fodder yield of trees as influenced by fodder tree based agroforestry systems at different pruning levels

Agroforestry system	Green fodder yield of trees (kg ha^{-1})											
	2018				2019				Pooled			
	I pruning	II pruning	III pruning	Total yield	I pruning	II pruning	III pruning	Total yield	I pruning	II pruning	III pruning	Total yield
T_1 - *Calliandra calothyrsus* + FC	463.05	565.54	434.30	1462.89	485.29	606.61	424.62	1516.52	474.17	586.07	429.46	1489.70
T_2 - *Albizia lebbeck* + FC	124.95	147.58	122.41	394.95	136.69	170.86	119.60	427.14	129.55	159.22	122.28	411.05
T_3 - *Leucaena leucocephala* + FC	437.08	546.35	382.45	1365.88	451.44	564.30	395.01	1410.75	444.26	555.33	388.73	1388.32
T_4 - *Sesbania grandiflora* + FC	379.07	473.84	331.69	1184.60	391.73	489.67	342.77	1224.17	385.40	481.75	337.23	1204.39
T_5 - *Gliricidia sepium* + FC	359.94	441.48	303.88	1105.31	358.88	448.59	314.02	1121.49	359.41	445.04	308.95	1113.40
T_6 - *Moringa oleifera* + FC	332.69	413.98	239.46	986.13	327.80	409.75	286.83	1024.39	330.25	411.87	263.14	1005.26
T_7 - *Bauhinia purpurea* + FC	163.29	186.48	139.41	489.17	160.46	200.57	140.40	501.43	161.87	193.52	139.91	495.30
T_8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-	-	-	-	-
SEm ±	23.84	29.56	25.28	73.76	13.23	16.54	11.58	41.35	16.66	20.66	15.78	51.22
CD @ 5%	73.02	90.53	77.41	225.89	40.53	50.66	35.46	126.64	51.03	63.27	48.32	156.85

FC – Field Crop; I pruning at 4 months; II pruning at 8 months and III pruning at 12 months after harvesting of tree fodderAge of the fodder tree plantation – 5 years (2018) and 6 years (2019)

The most visible effect of rainfall will be on the primary productivity of fodder crops and rangelands. The interplay among the factors such as warmer temperatures, elevated carbon dioxide, as well as widely fluctuating water availability due to changing precipitation patterns will decide the actual impact on plant growth and yield. The quantum of response is dependent on the interactions among the nature of crop, soil moisture, and soil nutrient availability. Due to the wide fluctuations in distribution of rainfall in growing season in regions, the forage production will be greatly impacted (Kandalam and Samireddypalle, 2015).

In a similar study, Mukangango et al. (2019) reported that variations in rainfall causes the difference in the production of shoot biomass observed between growing periods for all species (Acacia angustissima, Leucaena pallida and Mimosa scabrella). The mean annual shoot production calculated from the five harvests of Acacia angustissima was higher than reported by Nyoka et al. (2012) at two Zimbabwean research stations with mean annual rainfall of 880 and 895 mm, respectively.

The reasons for better growth of fodder trees under intercropping situation might be due to the utilization of nutrients for the trees and also less competition for light as it has been established long back before intercrops.

With respect to green fodder yield productivity, Calliandra calothyrsus + FC (T1) resulted 262.41 per cent and Leucaena leucocephala + FC (T3) 237.75 per cent more green fodder yield than Albizia lebbeck + FC (T2), which may be due to the higher growth and more number of coppices indicating its higher potentiality for production as compared to very few number of branches recorded in Albizia lebbeck + FC (T2). Upreti and Devkota (2017) opined that increased biomass was due to the increased number of branches and with other morphological traits viz., tree size and tree height in case of three fodder tree species viz., Artocarpus lakoocha, Litsea polyantha and Ficus lacor in Nepal.

The results on green fodder yield (kg ha-1) among all the fodder tree based agroforestry systems showed that II pruning done in the monsoon season attained higher yield (23.60 %) followed by I pruning in summer season and the minimum production in winter season. Higher yield during monsoon (I pruning) was attributed to availability of adequate moisture to fodder trees by frequent showers and least yield during winter season (III pruning) was due to leaf shedding nature of most of the fodder tree species (senescence) leading to reduction (26.72 %) in the foliage biomass. Green tree fodder yield had a significant positive correlation with light interception (0.544) and SPAD values (0.722).

The poor performance of T2 - Albizia lebbeck + FC yielded significantly lower values of green fodder among all the fodder trees due to lack of attainment of adequate number of coppices. This might be due to its lack of suitability in agroforestry system under severe competition for resources with other associated components.

Gunasekaran et al. (2017) reported that the edible fresh fodder biomass yield from Gliricidia sepium (4 harvests yr-1) from silvipasture model in degraded wastelands was 8.33 ± 0.28 kg tree-1 (2.49 kg in terms of dry matter) where an average rainfall of 1168 mm and mean maximum and minimum temperature of 33.5°C and 25.4°C were recorded during the study period.

The per cent dry matter production of tree fodder indicates the potential performance of fodder tree species to yield dry fodder under agroforestry system. The results depicted significant variation in per cent dry matter production among fodder tree species at various pruning intervals (4, 8 and 12 MAT) during 2018 and 2019 (Table 4).

The pooled data of 2018 and 2019 showed the maximum per cent dry matter production recorded in T1 - Calliandra calothyrsus + FC (50.01, 51.05 and 52.03 %) followed by T3 - Leucaena leucocephala + FC (47.13, 48.20 and 49.24 %) at all the stages of pruning intervals. Whereas, the minimum per cent dry matter production was registered in T2 - Albizia lebbeck + FC (29.99, 31.06 and 32.19 %) at various stages of pruning intervals (Table 4).

It is observed that the dry matter content of fodder tree species increased with the increasing maturity as the growth advanced from 4 to 8 months and 8 to 12 months after treatment (summer to winter season). There was a gradual increase in dry matter from rainy to spring and winter seasons in all the fodder tree species examined.

Average per cent dry matter production presented separately for the individual year 2018 and 2019 showed the highest average per cent dry matter production recorded in T1 - Calliandra calothyrsus + FC (51.02 and 51.03 %) followed by T3 - Leucaena leucocephala + FC (47.78 and 48.60 %) for 2018 and 2019 respectively which varied significantly from other fodder tree species. However, the lowest dry fodder yield was registered in Albizia lebbeck + FC (T2) with values of 30.70 and 31.46 per cent during 2018 and 2019 respectively.

Finally, the pooled average per cent dry matter production was noticed the highest value of 51.03 per cent for both the years in T1 - Calliandra calothyrsus + FC followed by T3 - Leucaena leucocephala + FC with a value of 48.19 per cent as compared to other fodder tree species in the system. However, the lowest average pooled per cent dry matter production was registered in T2 - Albizia lebbeck + FC with a value of 31.08 per cent.

Calliandra calothyrsus + FC (T1) has attained 39.09 per cent and Leucaena leucocephala + FC (T3) 55.05 per cent more average per cent dry matter production than Albizia lebbeck + FC (T2) among the agroforestry systems. In a similar study, Shah et al. (2019) found the gradual increase in

Table 4: Dry matter production of tree fodder as influenced by fodder tree based agroforestry systems at different pruning levels

Agroforestry system	Dry matter production (DMP, %) of tree fodder											
	2018				2019				Pooled			
	I pruning	II pruning	III pruning	Average DMP (%)	I pruning	II pruning	III pruning	Average DMP (%)	I pruning	II pruning	III pruning	Average DMP (%)
T1 - Calliandra calothyrsus + FC	49.75 (44.86)	50.99 (45.57)	52.32 (46.33)	51.02 (45.59)	50.27 (45.15)	51.10 (45.63)	51.73 (45.99)	51.03 (45.59)	50.01 (45.00)	51.05 (45.60)	52.03 (46.16)	51.03 (45.59)
T2 - Albizia lebbeck + FC	29.43 (32.85)	30.68 (33.64)	31.99 (34.44)	30.70 (33.65)	30.55 (33.55)	31.43 (34.10)	32.40 (34.69)	31.46 (34.12)	29.99 (33.20)	31.06 (33.87)	32.19 (34.57)	31.08 (33.88)
T3 - Leucaena leucocephala + FC	46.50 (42.99)	47.77 (43.72)	49.07 (44.47)	47.78 (43.73)	47.75 (43.71)	48.63 (44.21)	49.41 (44.66)	48.60 (44.20)	47.13 (43.35)	48.20 (43.97)	49.24 (44.56)	48.19 (43.96)
T4 - Sesbania grandiflora + FC	46.03 (42.72)	47.29 (43.45)	48.57 (44.18)	47.30 (43.45)	47.05 (43.31)	47.93 (43.81)	48.73 (44.27)	47.90 (43.80)	46.54 (43.02)	47.61 (43.63)	48.65 (44.23)	47.60 (43.62)

Agroforestry system	Dry matter production (DMP, %) of tree fodder											
	2018				2019				Pooled			
	I pruning	II pruning	III pruning	Average DMP (%)	I pruning	II pruning	III pruning	Average DMP (%)	I pruning	II pruning	III pruning	Average DMP (%)
T5 - Gliricidia sepium + FC	36.70 (37.29)	37.96 (38.03)	39.23 (38.78)	37.96 (38.03)	37.88 (37.99)	38.75 (38.50)	39.55 (38.97)	38.73 (38.49)	37.29 (37.64)	38.36 (38.27)	39.39 (38.87)	38.35 (38.26)
T6 - Moringa oleifera + FC	34.48 (35.96)	35.73 (36.70)	37.01 (37.47)	35.74 (36.71)	35.58 (36.62)	36.48 (37.15)	37.28 (37.63)	36.45 (37.14)	35.03 (36.29)	36.10 (36.93)	37.15 (37.55)	36.09 (36.92)
T7 - Bauhinia purpurea + FC	33.92 (35.62)	35.18 (36.38)	36.46 (37.14)	35.18 (36.38)	35.13 (36.35)	36.01 (36.87)	36.87 (37.38)	36.00 (36.87)	34.53 (35.98)	35.59 (36.63)	36.66 (37.26)	35.59 (36.63)
T8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-	-	-	-	-
SEm ±	0.301	0.303	0.302	0.302	0.336	0.330	0.352	0.339	0.315	0.313	0.322	0.316
CD @ 5%	0.938	0.943	0.942	0.940	1.047	1.029	1.096	1.055	0.982	0.975	1.002	0.986

FC – Field Crop; I pruning at 4 months; II pruning at 8 months and III pruning at 12 months after harvesting tree fodder
Age of the fodder tree plantation – 5 years (2018) and 6 years (2019)
Figures in parenthesis are arcsine transformation value

dry matter from rainy to spring and winter season in four species (Thysanolaena maxima, Artocarpus lakoocha, Ficus roxburghii and Bauhinia purpurea) except Ficus semicordata. Similarly, Murugan et al. (2003) observed that dry biomass yield of Stylosanthes hamata was 3.14 and 2.83 t ha-1, respectively during the lush and lean season, respectively.

With respect to total quantity of dry matter productivity, the results depicted significant variation in dry matter production among fodder tree species at various pruning intervals (4, 8 and 12 MAT) during 2018 and 2019. However, the pooled total dry matter production for both the years observed maximum in T1 - Calliandra calothyrsus + FC (709.59 kg ha-1) followed by T3 - Leucaena leucocephala + FC (512.89 kg ha-1) and there was a consistent reduction in pooled total dry matter production recorded in T2 - Albizia lebbeck + FC (178.62 kg ha-1). This could be due to higher percentage of dry matter accumulation by T1 - Calliandra calothyrsus + FC (51.03 %) and T3 - Leucaena leucocephala + FC (48.19 %) as compared to T2 - Albizia lebbeck + FC (31.08 %) among agroforestry systems.

In a similar study, Khanal and Upreti (2007) reported that the dry matter (DM) content was higher for Bauhinia purpurea ($P < 0.05$) than Artocarpus lakoocha and Ficus roxburghii, but there was no variation ($P>0.05$) between other tree fodder species. The values were in comparison with earlier reports for the similar species of tree fodder harvested at similar times of the year (Khanal and Subba 2001). The dry matter content could increase with the increasing maturity, which was probably another reason why it is higher for Bauhinia purpurea that was approaching fruit bearing stage.

Correlation study of green fodder yield parameters with biophysical parameters and soil chemical properties

Correlation and regression analysis indicated the impact of biophysical parameters and soil chemical properties on the yield of green tree fodder under agroforestry systems. In order to study the influence of biophysical parameters and soil chemical properties on the yield of green tree fodder under agroforestry systems, a simple correlation analysis was carried out using Pearson's correlation coefficient. Green tree fodder yield was positively correlated with light interception (0.544) at 5 per cent significant level and negatively correlated with light transmission ratio (-0.383). The SPAD values (0.722) showed positive correlation at 1 per cent significant level. Soil moisture (-0.348), available N (-0.202) and available P (-0.311) exhibited negative correlation with green tree fodder yield. However, available K (0.160) showed positive correlation with tree fodder yield but it was non-significant (Table 5).

Table 5: Correlation analysis to study the effect of biophysical parameters and soil properties on green tree fodder yield under agroforestry systems.

Variables	Green Tree fodder yield (kg ha-1)	Light Interception (%)	Light Transmission Ratio (%)	SPAD values	Soil moisture (%)	Available N (kg ha-1)	Available P (kg ha-1)	Availabl e K (kg ha-1)
Green Tree fodder yield (kg ha-1)	1	0.544*	-0.383NS	0.722**	-0.348NS	-0.202NS	-0.311NS	0.160NS
Light Interception (%)	0.544*	1	-0.143NS	0.511*	0.191NS	-0.262NS	-0.298NS	0.192NS
Light Transmission Ratio (%)	-0.383NS	-0.143NS	1	-0.359NS	0.693**	0.573**	0.685**	-0.342NS

Variables	Green Tree fodder yield (kg ha-1)	Light Interception (%)	Light Transmission Ratio (%)	SPAD values	Soil moisture (%)	Available N (kg ha-1)	Available P (kg ha-1)	Available K (kg ha-1)
SPAD values	0.722**	0.511*	-0.359NS	1	-0.178NS	-0.254NS	-0.158NS	0.427NS
Soil moisture (%)	-0.348NS	0.191NS	0.693**	-0.178NS	1	0.456*	0.445*	-0.252NS
Available N (kg ha-1)	-0.202NS	-0.262NS	0.573**	-0.254NS	0.456*	1	0.772**	-0.258NS
Available P (kg ha-1)	-0.311NS	-0.298NS	0.685**	-0.158NS	0.445*	0.772**	1	-0.281NS
Available K (kg ha-1)	0.160NS	0.192NS	-0.342NS	0.427NS	-0.252NS	-0.258NS	-0.281NS	1

* Significant at P < 0.05
** Significant at P < 0.01

CONCLUSION

The current annual increment in growth attributes of fodder trees as influenced by fodder tree based agroforestry system revealed that the growth performance of trees varied significantly during the periods of investigation. Moringa oleifera (T6) recorded maximum current annual increment in tree canopy cover in both the years. The highest current annual increment in volume of wood and total tree biomass was recorded in Moringa oleifera (T6) and Leucaena leucocephala (T3) as compared to other fodder tree species studied. There was a significant increase in number of coppices among the fodder tree species in various growth stages (Initial, 3, 6, 9 and 12 MAT)) and maximum number of coppices was found in T1 - Calliandra calothyrsus + FC. Green fodder yield at various pruning intervals (Ist pruning at 4 MAT, 2nd pruning at 8 MAT and 3rd pruning at 12 MAT) differed significantly among different agroforestry systems during both the periods of investigation. Among fodder tree species studied, the highest green fodder yield was recorded in Calliandra calothyrsus (T1). The highest quantity of dry matter production and maximum per cent dry matter production were recorded in T1 - Calliandra calothyrsus + FC at all the stages of pruning intervals in both the study periods. The present investigation opined that Calliandra calothyrsus (T1) and Leucaena leucocephala + FC (T3) performed better as fodder tree for higher green fodder yield under agroforestry system. These systems have an additional role of improving socioeconomic status of farming community providing them additional income.

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