Journal of AgriSearch, 10 (4): 275-282
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v10i03.14610

The Biochemical and Quality Parameters of Tree Fodder of different Fodder Tree Species Grown under Agroforestry Systems

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ABSTRACT

An investigation on biochemical and quality parameters of tree fodder under agroforestry systems was conducted. The quality parameters and palatability of tree fodder of seven tree species in fodder bank was studied. The study revealed that the crude protein concentration of the leaves varied significantly with a higher value in T_4 - *Sesbania grandiflora* + FC followed by T_6 - *Moringa oleifera* + FC. The crude fibre content varied significantly with higher values in T_7 - *Bauhinia purpurea* + FC followed by T_3 - *Leucaena leucocephala* + FC. There was a significant variation in crude fat content recorded with a higher value of 7.31 per cent in *Moringa oleifera* + FC (T_6) followed by T_5 - *Gliricidia sepium* + FC. The highest total ash content was recorded in T_4 - *Sesbania grandiflora* + FC followed by T_3 - *Leucaena leucocephala* + FC. The nitrogen free extract (NFE) content was recorded with a higher value in T_2 - *Albizia lebbeck* + FC followed by T_1 - *Calliandra calothyrsus* + FC. The palatability and selectivity for preferences (ranking) of seven tree fodders was studied based on the potential consumption of tree fodder by sheep and goats in different harvesting seasons (harvesting intervals at 4, 8 and 12 MAT). Palatability (%) increased from I pruning (at 4 months) to II pruning (8 months) and then decreased at III pruning (at 12 months). During the study periods, T_3 - *Leucaena leucocephala* + FC has fetched highest palatability (%) of tree fodder followed by T_4 - *Sesbania grandiflora* + FC at all the stages of harvesting intervals with significant variation. Palatability study indicated that the selective ranking of tree fodder among protein sources studied for feeding sheep and goat is followed in the order T_3 - *Leuceana leucocephala* + FC (1^{st} Rank) > T_4 - *Sesbania grandiflora* + FC (2^{nd} Rank) > T_1 - *Calliandra calothyrsus* (3^{rd} Rank) > T_6 - *Moringa oleifera* (4^{th} Rank) > T_7 - *Bauhinia purpurea* (5^{th} Rank) > T_2 - *Albizia lebbeck* (6^{th} Rank) > T_5 - *Gliricidia sepium* (7^{th} Rank). The higher nutritional parameters of tree foliage indicated *Sesbania grandiflora* + FC (T_4), *Leucaena leucocephala* + FC (T_3) and T_6 - *Moringa oleifera* + FC agroforestry systems have produced good quality fodder for livestock. Palatability study among seven tree fodders towards sheep and goat showed that *Leucaena leucocephala* + FC (T_3), *Calliandra calothyrsus* (T_1) and *Sesbania grandiflora* + FC (T_4) are mostly preferred fodder tree species among sheep and goat and economically viable systems.

Keywords: Nutritional quality, crude protein, crude fibre, palatability, nitrogen free extract, total ash, crude fat, selective ranking.

ARTICLE INFO

Received on	:	21.09.2023
Accepted on	:	11.10.2023
Published online	:	31.12.2023

INTRODUCTION

Fodder banks consist of trees or shrubs and often legumes of high-quality fodder species. Some of the legumes have the capacity to fix atmospheric nitrogen and make them protein rich feeds. In long dry season, fodder mineral deposits consist of pure grasses (energy bank), pure legumes (protein bank), or of a combination of grasses and legumes (protein-energy bank). The protein bank is a high-quality feed used to complement low quality feeds (crop residues, dry season grasses, etc.) and offer a productive ration. The protein energy bank is designed to supply a complete diet which is reasonable in terms of both digestible protein and energy. The importance of browsing fodder shrubs and trees enhances with increasing aridity and is generally most vital during dry season for livestock production, when other resources decline in quality and quantity. Hence, trees occupy an important niche in the agroforestry system and in animal production. The integration of leguminous fodder trees and shrubs into local farming systems through agroforestry is necessary to support livestock production and also to sustain rural livelihoods. The contribution of livestock sector to the gross domestic product in India has increased from 4.82 percent to 5.37 percent in recent times. In the overall agricultural economy of the country, the livestock sector contributes about 25 percent to the overall agricultural Gross Domestic Product (GDP). In spite of large indigenous stock of cattle population (87 %), India leads the world in milk production (92×10^{12} t yr^{-1}). The ruminants' productivity is associated to the supply of good quality fodder. On an average, only 4 percent of the

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cultivated area is under cultivable fodder production and the grazing land is only 3.5 percent of the total geographical area. Of the total fodder requirement in India, 57 percent is fulfilled from natural forests. The chief objective of agroforestry system is to optimize interaction between biological components like trees/shrubs and animals/crops. Multipurpose trees (MPTs) should play a significant role to provide fodder and fuel in subtropical humid climate in India. The lack of proper nutrition due to insufficiency of feeds and fodders is one of the major limitations in ruminants productivity. The foliage of fodder trees and shrubs are known to be important components of ruminant rations mostly in the hilly areas of India including north eastern region and can supply green fodder almost throughout the year. Tree foliages have various benefits over the conservative cultivated fodder crops. Fodder trees can provide green foliage fodder per unit area equivalent to cultivated crops for the following reasons; they can withstand severe undesirable climatic conditions; require low inputs (fertilizers, irrigation, labour, pesticides etc.); assist in soil moisture conservation and also protect the environment. Selected tree foliages are fed as a traditional practice in hilly areas. Therefore, determination of nutritional quality of these fodder resources is a vital in ruminant feeding and a step towards making balanced rations. Tree forages constitute an essential part of ruminant feeds and use of tree forages as components of diets is a prevalent practice in various countries. Fodder tree leaves are an alternative source of livestock feeding and tree leaves have the prospective for improving some of the feed shortages and nutritional deficiency for small ruminant and significant component of goats and sheep diets. The role of multipurpose trees (MPTs) has been advocated in the tropics for several reasons including supply of fodder to livestock. Therefore, the present investigation was conducted to know the biochemical and quality parameters of tree fodder under agroforestry systems.

MATERIALS AND METHODS

Nutrient analysis of tree fodder

Biomass from all tree fodder species were collected and air dried for analysis of proximate composition. Materials were ground to pass through a 1.25 mm screen in a laboratory hammer mill and stored in air tight bottles. Chemical components such as crude protein, crude fibre, crude fat (Ether extracts), total ash and nitrogen free extract were determined by standard methods (Anon., 2012a).

Crude Protein (CP): Crude protein was estimated by Micro Kjeldhal method. Oven dried sample was digested with H_2SO_4 in the presence of catalyst mixture containing K_2SO_4 and $CuSO_4$. A known aliquot of the diluted sample was distilled in the presence of 10 ml of 2 per cent boric acid solution and titrated against standard 0.1 N H_2SO_4. The percent of nitrogen was calculated for the estimation of crude protein (Anon., 2012a).

Crude Fibre (CF): For crude fibre, sample was reflexed first with 1.25 per cent H_2SO_4 and subsequently with 1.25 per cent NaOH for 30 min 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 (Anon., 2012a). **Crude Fat (Ether extracts):** The ether extract (crude fat) in a sample was determined by extracting with diethyl ether at 80ºC in soxhlet's apparatus (Anon., 2012a).

Total ash: For ash, sample was ignited in muffle furnace at 550ºC for 2 hours to burn all the organic matter and leftover was weighed as ash (Anon., 2012a).

Nitrogen-free extract (NFE): Nitrogen-free extract was calculated when crude protein, fat, water, ash and fiber are added and the sum is subtracted from 100, this difference is NFE. The Nitrogen-free extract was determined on dry matter basis as suggested (Anon., 2012a).

Per cent NFE = 100 - (% CP + % CF + % EE + % ash)

Palatability of fodder: Assessment of palatability of fodder was conducted at Department of Animal Husbandry, University of Agricultural Sciences, Dharwad by Cafeteria method. Fodder of seven tree species were fed to goats and sheep by cut and carry method (Gunasekaran, *et al.*, 2014). Sheep and goats were confined in separate pens of size 2 × 2m. Green tree foliage of the individual tree fodder species was collected and tied separately inside the pen. Sheep and goats were dewormed prior to the start of the experiment. The palatability trial by Cafeteria method was conducted (Fig.1) for the period of seven days in each season (summer, monsoon and winter) after harvesting green foliage at 4, 8 and 12 months interval respectively. The ranking of tree fodder palatability in goats and sheep based on the consumption (intake) was expressed in percentage preference method intake studies (Gunasekaran, *et al.*, 2014).

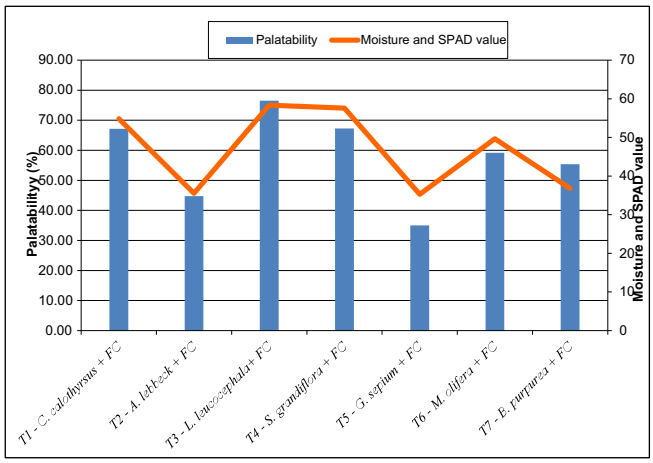

Fig. 1: Palatability (% consumption) of tree fodder as influenced by moisture and SPAD values for chlorophyll content of tree foliage under fodder tree based agroforestry system

RESULTS AND DISCUSSION

Dry matter production of tree fodder at different pruning levels

Production levels of any fodder plants will vary) greatly depending upon climate, soil type and management practices. 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

Table 1: Dry matter production of tree fodder as influenced by fodder tree based agroforestry systems at different pruning levels

Agroforestry systems	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 (%)
T_1 - *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)
T_2 - *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)
T_3 - *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)
T_4 - *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)
T_5 - *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)
T_6 - *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)
T_7 - *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)
T_8 - 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 values

MAT) during 2018 and 2019 (Table 1). The pooled data of 2018 and 2019 showed the maximum per cent dry matter production recorded in T_1 - *Calliandra calothyrsus* + FC (50.01, 51.05 and 52.03 %) followed by T_3 - *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 T_2 - *Albizia lebbeck* + FC (29.99, 31.06 and 32.19 %) at various stages of pruning intervals. 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 T_1 - *Calliandra calothyrsus* + FC (51.02 and 51.03 %) followed by T_3 - *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 (T_2) 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 T_1 - *Calliandra calothyrsus* + FC followed by T_3 - *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 T_2 - *Albizia lebbeck* + FC with a value of 31.08 per cent (Table 1). *Calliandra calothyrsus* + FC (T_1) has attained 39.09 per cent and *Leucaena leucocephala* + FC (T_3) 55.05 per cent more average per cent dry matter production than *Albizia lebbeck* + FC (T_2) among the agroforestry systems. In a similar study, Shah *et al.* (2019) found the gradual increase in dry matter from rainy to spring and winter season in four species (*Thysanolaena maxima, Artocarpus lakoocha, Ficus roxburghii and Bauhinia purpurea*) except *Ficus semicordata*. 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 T_1 - *Calliandra calothyrsus* + FC (709.59 kg ha^{-1}) followed by T_3 - *Leucaena*

leucocephala + FC (512.89 kg ha^{-1}) and there was a consistent reduction in pooled total dry matter production recorded in T_2 - *Albizia lebbeck* + FC (178.62 kg ha^{-1}). This could be due to higher percentage of dry matter accumulation by T_1 - *Calliandra calothyrsus* + FC (51.03 %) and T_3 - *Leucaena leucocephala* + FC (48.19 %) as compared to T_2 - *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. 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.

Biochemical and nutritional quality parameters of fodder tree species under agroforestry systems

Multipurpose trees species (MPTs) contribute a crucial role in agroforestry systems and have a good prospective in managing ruminants productivity by reducing the gap between demand and supply of fodders to meet out the deficit of feeds which is the focal constraint in the world. Hence, it is very important to evaluate them for balanced ration with various nutritional qualities. Feeding of selected tree leaves is a traditional practice in many areas. Therefore, determination of nutritional quality of tree fodder resources forms essential characteristics for ruminant feeding and a measure towards making balanced ration. Crude protein (%) indicates total protein present in a feed / fodder and suggests the quality and nutritional properties of tree fodder under fodder tree based agroforestry systems to feed livestock. During the present study, crude protein content differed significantly with higher values in T_4 - *Sesbania grandiflora* + FC during 2018 (23.96 %) and during 2019 (25.32 %). The extent of increase in crude protein content from 2018 to 2019 was 13.72 per cent in *Leucaena leucocephala* + FC (T_3) as compared to other tree fodder species due to adequate moisture in tree foliages as influenced by a very good rainfall benefitting particularly growth and yield of perennial components like fodder trees under agroforestry system. This variation is also due to time and season of samplings. The crude protein concentration of the leaves varied significantly from 14.48 to 24.64 per cent on dry matter basis. The higher crude protein content of *Sesbania grandiflora* + FC (T_4) and *Leucaena leucocephala* + FC (T_3) could be attributed to symbiotic nitrogen fixing ability of positive association with microorganisms compared to other fodder species and crops (Table 2).

Table 2: Biochemical and nutritional quality parameters of tree fodder (% on dry matter basis) as influenced by fodder tree based agroforestry systems

Agroforestry systems	2018			2019			Pooled		
	Dry matter (%)	Crude Protein (%)	Crude fibre (%)	Dry matter (%)	Crude Protein (%)	Crude fibre (%)	Dry matter (%)	Crude Protein (%)	Crude fibre (%)
T_1 - *Calliandra calothyrsus* + FC	45.12	15.45	15.85	46.67	17.31	17.71	45.90	16.38	16.78
T_2 - *Albizia lebbeck* + FC	35.53	15.15	15.34	37.06	16.70	16.89	36.30	15.93	16.12
T_3 - *Leucaena leucocephala* + FC	44.09	13.56	22.06	45.60	15.39	23.89	44.85	14.48	22.98
T_4 - *Sesbania grandiflora* + FC	41.93	23.96	13.71	43.30	25.32	15.12	42.62	24.64	14.42
T_5 - *Gliricidia sepium* + FC	38.35	17.67	19.66	40.12	19.17	21.21	39.24	18.42	20.44
T_6 - *Moringa oleifera* + FC	36.93	22.77	10.65	38.58	24.35	12.13	37.76	23.56	11.39
T_7 - *Bauhinia purpurea* + FC	35.68	15.60	24.19	37.40	16.95	25.54	36.54	16.28	24.87
T_8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-	-
SEm ±	**0.636**	**0.302**	**0.222**	**0.637**	**0.292**	**0.227**	**0.647**	**0.296**	**0.224**
CD @ 5%	**1.948**	**0.926**	**0.678**	**1.950**	**0.896**	**0.694**	**1.982**	**0.907**	**0.685**

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

The present results are in agreement with Udaykumar *et al.* (2017) and they noticed the crude protein concentration of *Sesbania grandiflora* and *Moringa oleifera* as 23.65 and 12.27 per cent, respectively which were in agreement with studies carried out by Nouman *et al.* (2013) for *Sesbania grandiflora* and *Moringa oleifera* (22.61 and 15.31 % respectively). In the similar way, Shah *et al.* (2019) reported the maximum crude protein (21.25 %) in *Bauhinia purpurea*. Chitra and Balasubramanian (2016) revealed that crude protein content of *Albizia* species ranged from 18.13 - 22.16 per cent. The highest crude protein value was observed in *Albizia saman* followed by *Albizia procera, Albizia lebbeck, Albizia guachapele, Albizia falcatariae*, respectively. Similarly, the present study on nutritional evaluation of foliages revealed that Albizia tree species is a good source of nutrients rich in protein and can be used as a supplemental feed in livestock. Crude fibre (%) indicates the portion of feedstuffs composed of polysaccharides such as cellulose, hemicellulose, and lignin which serve as structural and protective parts of plants and they are high in forages and low in grains. The crude fibre content (%) indicates the quality determinant and nutritional properties of tree fodder produced under fodder tree based agroforestry systems which is made available to livestock. During the study periods, the crude fibre content of the leaves varied significantly from 10.65 to 24.19 per cent and 12.13 to 25.54 per cent during 2018 and 2019 respectively on dry matter basis. This variation in crude fibre content such as cellulose and hemicellulose in tree fodder could be attributed to the stage of the pruning cut, season and available nutrients in soil during the study. The treatment T_7 - *Bauhinia purpurea* + FC noticed a higher value of 24.19 and 25.54 per cent during 2018 and 2019 respectively. The extent of increase in crude fibre content of *Moringa oleifera* + FC was 17.46 per cent during 2019 as compared to other fodder tree species was attributed to higher foliage moisture. The results of the present study opined that *Sesbania grandiflora, Bauhinia purpurea, Moringa oleifera* and *Albizia lebbeck* had relatively higher values of crude fibre indicating the potentiality to be a good alternate feed source for domestic animals. In the similar way, Shah *et al.* (2019) reported the chemical composition of fodders of Gandaki River Basin (Nepal) in which maximum value of crude fibre content was 35.01 per cent in *Bauhinia purpurea*. Similarly, Chitra and Balasubramanian (2016) also revealed that the highest crude fibre value was observed in *Albizia lebbeck* followed by *Albizia procera, Albizia saman, Albizia guachapele*, *Albizia falcatariae* respectively. Similar findings were reported by Chandra and Mali (2014) and Cheema *et al.* (2014). The present study on nutritional evaluation of foliages revealed that Albizia tree is a good source of nutrients rich in crude fibre content and can be used as a supplemental feed in livestock. Crude fat (%) is a measure of the fat content as determined by ether extraction and this may also

Table 3: Biochemical and nutritional quality parameters (% on dry matter basis) as influenced by fodder tree based agroforestry systems

Agroforestry systems	2018			2019			Pooled		
	Crude Fat (%)	Total ash (%)	Nitrogen free extract (%)	Crude Fat (%)	Total ash (%)	Nitrogen free extract (%)	Crude Fat (%)	Total ash (%)	Nitrogen free extract (%)
T_1 - *Calliandra calothyrsus* + FC	3.22	7.54	57.93	5.01	9.33	50.60	4.12	8.44	54.27
T_2 - *Albizia lebbeck* + FC	3.15	7.78	58.58	4.70	9.37	52.30	3.92	8.58	55.44
T_3 - *Leucaena leucocephala* + FC	4.01	11.13	49.23	5.84	12.99	41.78	4.93	12.06	45.51
T_4 - *Sesbania grandiflora* + FC	4.13	12.45	45.74	5.47	13.78	40.27	4.80	13.12	43.01
T_5 - *Gliricidia sepium* + FC	4.56	9.51	48.60	6.15	11.06	42.32	5.36	10.29	45.46
T_6 - *Moringa oleifera* + FC	6.53	11.10	48.96	8.09	12.59	42.78	7.31	11.85	45.87
T_7 - *Bauhinia purpurea* + FC	3.19	7.45	49.57	4.57	8.90	44.16	3.88	8.18	46.86
T_8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-	-
SEm ±	**0.094**	**0.137**	**0.484**	**0.101**	**0.151**	**0.481**	**0.097**	**0.143**	**0.471**
CD @ 5%	**0.289**	**0.421**	**1.483**	**0.310**	**0.462**	**1.474**	**0.296**	**0.439**	**1.444**

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

contain plant pigments, esters and aldehydes and indicates the quality determinant and nutritional properties of tree fodder. The study results revealed that crude fat content differed significantly with highest value in T_6 - *Moringa oleifera* + FC (6.53 and 8.09 % during 2018 and 2019) respectively. It was noticed that the extent of increase in crude fat (%) content in the year 2019 was considerably more (56.83 %) in *Albizia lebbeck* + FC (T_2) than 2018 as compared to other fodder tree based systems. This might have been influenced by congenial climatic conditions such as rainfall, temperature and relative humidity, particularly higher percentage of moisture in tree foliages as influenced by adequate rainfall received during the period (Table 3).

The results of the present study opined that *Sesbania grandiflora, Bauhinia purpurea, Moringa oleifera* and *Albizia lebbeck* had relatively higher values of crude fat to form a good alternate feed source for domestic animals. The preliminary studies of Jayaprakash *et al.* (2016) concluded that calliandra, desmanthus, stylosanthes had relatively higher crude fat (ether extract) content and thus have the potential to be a good alternate feed source for ruminant animals. The present results are in agreement with Udaykumar *et al.* (2017) who revealed that *Sesbania grandiflora* and *Moringa oleifera* showed ether extract value of 4.63 which was in agreement with studies of Nouman *et al.* (2013). In the similar way, Shah *et al.* (2019) reported the maximum value of crude fat content (4.13 %) in *Bauhinia purpurea*. The values obtained for proximate principles in the similar study were in the normal range. Total ash of tree fodder indicates the mineral matter burnt present in fodder and it is measured by burning the sample until all organic matter is removed. The total ash (%) content depicts nutritional characteristic and quality determinant of tree fodder. The total ash content differed significantly and recorded higher values in T_4 - *Sesbania grandiflora* + FC (12.45 and 13.78 %) during 2018 and 2019 respectively. Total ash in the form of mineral matter increased during the period 2019 as compared to 2018. Among the study periods, the extent of increase in total ash (%) content in the year 2018 was considerably more (24.03 %) in *Bauhinia purpurea* + *FC* (T_7) than 2019 as compared to other fodder tree based agroforestry systems. This is attributed to good growth with higher percentage of moisture in tree foliages. The results of the present study opined that *Sesbania grandiflora, Bauhinia purpurea, Moringa oleifera* and *Albizia lebbeck* had relatively higher values of total ash. This has attributed to form the potential to be a good alternate feed source for domestic animals. The preliminary studies of Jayaprakash *et al.* (2016) concluded that calliandra, desmanthus, stylosanthes had relatively higher energy content and thus have the potential to be a good alternate feed source for ruminant animals. In the similar way, Shah *et al.* (2019) reported the chemical composition of fodders of Gandaki River Basin (Nepal) in which the highest total ash content was in *Ficus roxburghii* (20.04 %) and the lowest in *Thysanolaena maxima* (10.50 %). The present results showed that ash content of *Leuceana leucocephala* (11.13 %) was higher and the ash content of *Albizzia lebbeck* (7.78 %) was slightly lower value than that reported by Gunasekaran *et al.* (2014). Nitrogen free extract (NFE, %) is consisting of carbohydrates, sugars, starch and a major portion of materials classed as hemi cellulose in feeds. The NFE (%) content indicates nutritional characteristic and quality determinant of tree fodder. The NFE concentration of the tree leaves during the periods of investigation (2018 and 2019) varied significantly with a range of 45.74 to 58.58 and 40.27 to 52.30 per cent on dry matter basis respectively. The data revealed that observations on NFE content differed significantly and recorded with higher values (58.58 and 52.30 %) in T_2 - *Albizia lebbeck* + FC. Except all other nutritional parameters, only NFE (%) content was decreased during the period 2019 as compared to 2018. The extent of decrease reported was more (16.03 %) in *Sesbania grandiflora* + FC (T_4) as compared to other tree fodder systems. The results of the present study revealed that *Sesbania grandiflora, Bauhinia purpurea, Moringa oleifera* and *Albizia lebbeck* had relatively higher values of nitrogen free extract. Hence, these fodder tree species form the potential to be a good alternate feed source for domestic animals. In the similar way, Shah *et al.* (2019) reported the chemical composition of fodders of Gandaki River Basin (Nepal) in which the nitrogen free extract content observed was the highest in *Ficus roxburghii* (64.79 %) and the lowest in *Bauhinia purpurea* (51.51 %). The present results of nitrogen free extract are higher than that reported by Gunasekaran *et al.* (2014). During the periods of investigation (2018 and 2019), the nitrogen free extract of *Albizzia lebbeck* (58.58 and 55.44 %) and *Calliandra calothyrsus* (57.93 and 54.27 %) was slightly higher than that reported by Atiya *et al.* (2011). The present study on nutritional evaluation of foliages have revealed that Albizia tree species is a good source of nutrients rich in protein content and the nitrogen free extract which can be used as a supplemental feed in livestock. In another study, Shah *et al.* (2019) noticed that nitrogen free extracts increased in *Ficus semicordata* and *Bauhinia purpurea* among five fodder tree species and they reported a gradual increase in dry matter from rainy to spring and winter seasons in four species (*Thysanolaena maxima, Artocarpus lakoocha, Ficus roxburghii and Bauhinia purpurea*) except *Ficus semicordata*.

Palatability (%) and selective ranking of tree fodder under agroforestry systems

The palatability (%) of tree fodder indicates the potential consumption of tree fodder by sheep and goats in different seasons (1st harvesting at 4 MAT, 2nd harvesting at 8 MAT and 3rd harvesting at 12 MAT). During the periods of investigation, the highest palatability (%) of tree fodder was registered in T_3 - *Leucaena leucocephala* + FC (75.22, 77.14 and 72.15 %) during 2018 and (78.32, 80.29 and 76.00 %) during 2019 at different harvesting stages. In the same case, *Gliricidia sepium* + FC (T_5) tree fodder system recorded poor palatability at various stages of harvesting intervals with minimum values such as 33.70, 35.62 and 30.63 per cent in 2018 and 36.81, 38.77 and 34.48 per cent during 2019 (Table 4). It was reported that indigenous fodder trees were desirable over the exotic plants because of their adaptation to the local environment attributable to pest and drought tolerance, palatability, high nutrient value and biomass production. The preference on the available fodder tree species differs with farmers and the ruminant animal. It may be determined by fodder yield, nutrient composition, available duration, palatability, and safe to feed animal in terms of polyphenolic content (Anon., 2012). The palatability (%) of tree fodder indicated selective preference of tree fodder by sheep and goat for consumption

among fodder trees during the periods of investigation (2018 and 2019). In a similar study, Gunasekaran *et al*. (2014) studied selectivity and palatability in sheep and goat, first preference among the tree protein sources was *Leuceana leucocephala* as indicated by dry matter intake, 33.90±3.27 and 24.41±0.67 g kg^{-1} $W^{0.75}$ respectively. This might be attributed to presence of secondary plant metabolites such as beta-carotene and xanthophyll in *Leuceana leucocephala* as reported. This study revealed that *Albizia lebeck* was least favoured tree fodder for goats and *Gliricidia sepium* for sheep. Hence the most palatable tree fodders must be fed later after feeding *Albizia lebeck* and *Gliricidia sepium* to improve and increase the dry matter intake by the livestock. The study concluded that *Leuceana leucocephala* is considered as the best among the tree fodder species in sheep and goat based on the selectivity, palatability and level of dry matter intake. The palatability (%) of tree fodder foliage was also influenced by moisture present in tree foliage under agroforestry system. In a similar investigation, Upreti and Devkota (2017) reported first top ten fodder tree species ranked by considering the farmers preference. The selected fodder tree species scored from 1.08 (*Artocarpus lakoocha*) to 1.54 (*Premna spp*). *Artocarpus lakoocha* ranked the top species out of the selected and best possible species identified among the available fodder tree. Similarly, *Litsea polyantha* ranked second and *Ficus lacor* ranked third. A similar criterion followed (Ghimire *et al*., 2011) to rank the fodder trees had relatively good understanding in ranking the species. The adaptation of selection index helps, to understand all the nutritional parameters of particular fodder tree and to evaluate their potential to the ruminant feeding.

CONCLUSION

The nutritional study revealed that higher crude protein (%) content of tree foliage in T_4-*Sesbania grandiflora* + FC (24.64 %) and T_6-*Moringa oleifera* + FC (23.56 %) agroforestry systems could produce good quality fodder for improved livestock production. Palatability study indicated ranking of tree fodder among protein sources in the following order: *Leuceana leucocephala* > *Sesbania grandiflora* > *Calliandra calothyrsus* > *Moringa oleifera* > *Bauhinia purpurea* > *Albizia lebbeck* > *Gliricidia sepium*. The higher nutritional parameters of tree foliage indicated *Sesbania grandiflora*, *Leucaena leucocephala* and *Moringa oleifera* + FC agroforestry systems have produced good quality fodder for livestock. Palatability study among seven tree fodders towards sheep and goat showed that *Leucaena leucocephala* + FC (T_3), *Calliandra calothyrsus* (T_1) and *Sesbania grandiflora* + FC (T_4) are mostly

Table 4: Palatability and ranking of tree fodder as influenced by fodder tree based agroforestry systems

Agroforestry systems	Palatability (%) and ranking of tree fodder											
	2018				2019				Pooled			
	1st pruning	2nd pruning	3rd pruning	Ranking	1st pruning	2nd pruning	3rd pruning	Ranking	1st pruning	2nd pruning	3rd pruning	Ranking
T_1 - *Calliandra calothyrsus* + FC	65.85	67.77	62.78	III	68.96	70.92	66.63	III	67.40	69.35	64.71	III
T_2 - *Albizia lebbeck* + FC	43.47	45.39	40.40	VI	46.57	48.54	44.25	VI	45.02	46.96	42.32	VI
T_3 - *Leucaena leucocephala* + FC	75.22	77.14	72.15	I	78.32	80.29	76.00	I	76.77	78.71	74.07	I
T_4 - *Sesbania grandiflora* + FC	65.98	67.90	62.92	II	69.09	71.05	66.76	II	67.54	69.48	64.84	II
T_5 - *Gliricidia sepium* + FC	33.70	35.62	30.63	VII	36.81	38.77	34.48	VII	35.25	37.20	32.56	VII
T_6 - *Moringa oleifera* + FC	57.88	59.80	54.82	IV	60.99	62.95	58.66	IV	59.44	61.38	56.74	IV
T_7 - *Bauhinia purpurea* + FC	54.08	56.00	51.01	V	57.18	59.15	54.86	V	55.63	57.57	52.93	V
T_8 - Sole Crop – Soybean - Safflower	-	-	-	-	-	-	-	-	-	-	-	-
SEm ±	**1.031**	**1.042**	**1.060**	**-**	**1.015**	**0.998**	**1.001**	**-**	**1.016**	**1.014**	**1.012**	**-**
CD @ 5%	**3.159**	**3.191**	**3.247**	**-**	**3.108**	**3.055**	**3.067**	**-**	**3.111**	**3.105**	**3.099**	**-**

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)

preferred fodder tree species among sheep and goat and economically viable systems. These systems have a significant role in influencing socioeconomic status of farming community by providing them green fodder during drought conditions with an additional income.

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Citation:

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