Print : ISSN 0970 – 7662
Online : ISSN 2455 – 7129

Journal of Tree Sciences
online available at www.ists.in

Volume 39 No. 1 June, 2020

Growth and Yield Performance of Fodder Tree Species With Intercrops Under Agroforestry Systems in Dharwad Karnataka, India

Girish Shahapurmath*, S. S. Inamati and S. M. Mutanal[1]
College of Forestry, UASD, Sirsi–581 401, Uttara Kannada (Karnataka),INDIA; [1]AICRP on Agroforestry, UAS, Dharwad–580 005, Karnataka, INDIA
**Email:* girishbshahapur @gmail.com

DOI: 10.5958/2455-7129.2020.00004.7

ABSTRACT

A field experiment was conducted to assess the growth and yield performance of fodder tree species with intercrops (soybean and safflower) under agroforestry systems in Northern Transitional zone of Dharwad region of Karnataka, India during 2018 and 2019 in *kharif* and *rabi* seasons. The fodder plantation at 5 x 3 m spacing was established in 2014 with seven fodder tree species. The pollarding height of fodder tree species was maintained at 2 m. The highest current annual increment (CAI) in diameter at breast height (DBH) was recorded in *Moringa oleifera* (2.31 and 2.12 cm). *Moringa olifera* attained maximum CAI in tree canopy cover (1.89 and 1.89 m^2). The highest CAI in volume of wood was reported in *Moringa oleifera* (5.042 and 5.625 m^3 ha^{-1}). *Gliricidia sepium* produced the highest CAI in total tree biomass (4.18 and 4.90 t ha^{-1}). The pooled data of 2018 and 2019 reported maximum green fodder yield 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 (4, 8 and 12 months). Total fodder yield presented for the year 2018 and 2019 showed significantly higher values in *Calliandra calothyrsus* (1462.89 and 1516.52 kg ha^{-1} respectively).

Key Words:

Agroforestry, Biomass, Intercrops, Tree Fodder

INTRODUCTION

Agroforestry is a sustainable land use strategy for enhancing the farm productivity and ensuring the livelihood security. It has both productive and protective potential to meet out the demands of ever growing human and livestock population. Despite of large area under cultivation, permanent pastures and common grazing lands, there is a deficit of green fodder (net deficit 35.6%) in India (IGFRI 2050). Under such circumstances, fodder tree species can play an important role to meet out the demands of green fodder especially during the lean period. *Grewia optiva, Morus alba, Ailanthus excelsa, Artocarpus heterophyllus, Anogeissus latifola, Bauhinia variegate, Albizia lebbeck, Leucaena leucocephala, Prosopis cineraria, Moringa oleifera, Celtia australis, Robinia pseudoacacia,* etc. are some of the important fodder tree species which are rich in crude protein, crude fibers, minerals etc. and are also suitable for integration in agroforestry systems (Thakur et al. 2005; Thakur et al. 2015 a&b). Various studies conducted on tree crop interactions showed that growing of fodder trees in agroforestry systems resulted improvement in soil properties and increase in fodder availability round the year. In India large area is available in the form of farm boundaries, bunds, wastelands etc. where fodder trees can be grown under different systems such as agrisilvicultural, silvipastoral systems etc (Thakur et al. 2004; Gupta et al. 2012). This will ensure the availability of fodder, fuel wood, small timber and wood for paper and plywood industries. Fodder shrubs and trees (browse) play a significant role both in farming systems, where they are protected as fallow species, and in livestock production (Thakur et al. 2011a). The importance of browse increases with increasing aridity and is generally most essential in the dry seasons, when most other feed resources depreciate in quality and quantity (Sukhadiya et al. 2019 & 2020). Generally, trees occupy a significant niche in the farming systems and overall way of life in animal production. The need for increased cultivation and integration of fodder trees (especially leguminous fodder trees and shrubs) into local farming systems through agroforestry is imperative in order to promote livestock production and also the support of rural livelihoods. It is also important to increased research support for the efficient cultivation, management, processing and use of fodder shrubs and trees for improved livestock production (Prajapati et al. 2020). With this background, a field experiment was conducted to assess the growth and yield performance of fodder tree species with intercrops under agroforestry systems in Northern Transitional zone of Dharwad region of Karnataka in India during 2018 and 2019 in kharif and rabi seasons.

MATERIALS AND METHODS

This investigation was carried out to study the growth and productivity of fodder tree species with intercrops under agroforestry systems in Northern Transitional zone of Dharwad region in Karnataka during 2018 and 2019 in kharif and rabi seasons. The study site is located at 15° 26' North latitude and 75° 0' East longitude, with an elevation (altitude) of 678 m above mean sea level. The experimental plot is situated in transitional tract, representing Northern Transitional climate zone (Zone 8) of Karnataka. The experimental area has medium deep black soils. The mean annual rainfall of the site is 777.95 mm. The mean maximum temperature vary from 26.61°C to 36.86°C and mean minimum temperature vary from 13.58°C to 20.92°C. The Relative humidity is experienced higher from June to September months and vary from 61.70 % to 86.07 %. The fodder tree plantation was established in 2014 (Fig 1 & 2) with seven fodder tree species *viz.* 1. *Calliandra calothyrsus*, 2. *Albizia lebbeck*, 3. *Leucaena leucocephala*, 4. *Sesbania grandiflora*, 5. *Gliricidia sepium,* 6. *Moringa oleifera* and 7. *Bauhinia purpurea.* The trees were planted at 5x3 m spacing. The pollarding height of fodder tree species was maintained at 2 m (Fig 1). The soybean and safflower crops were sown in the interspaces of fodder tree species in *kharif* and *rabi* season, respectively. The field experiment was conducted with Randomized Block Design (RBD) with three replications.

Total volume of wood (m^3): 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

Total tree biomass: Above ground and below ground biomass was determined separately and expressed in tons per hectare. Above ground biomass was determined by the formula as suggested by Mac Dicken (1997).

The standard wood densities of 648.30, 660.00, 640.00, 500.00, 1025.00, 600.00 and 670.00 kg m^{-3} for *C. calothyrus, A. lebbeck*, *L. leucocephala*, *S. grandiflora, G. sepium*, *M. oleifera* and *B. purpurea*, respectively, 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

The below ground biomass was calculated following factor 0.26 (Thakur et al. 2011b).

Below ground biomass (BGB) = Above ground biomass x 0.26

Total tree biomass was calculated by adding above ground biomass and below ground biomass and expressed in tonnes per hectare.

Fig 1. Fodder tree based agroforestry system with soybean intercrop

Fig 2. Fodder tree based agroforestry system with safflower intercrop

RESULTS AND DISCUSSIONS

Current annual increment in growth and yield of fodder tree

The current annual increment in growth attributes of fodder trees as influenced by fodder tree based agroforestry system during 2018 and 2019 is presented in Table 1. The data revealed that the growth performance of trees varied significantly during both the periods.

During the periods of investigation (2018 and 2019), the highest current annual increment (2.31 and 2.12 cm) in diameter at breast height was recorded in *Moringa oleifera* followed by 2.21 and 1.98 cm respectively in *Leucaena leucocephala*.

Whereas, the lowest current annual increment (1.88 and 1.73 cm) in diameter at breast height was respectively recorded in *Albizia lebbeck.*

Moringa oleifera recorded maximum current annual increment (1.89 m^2) in tree canopy cover in both the years. It was followed by 1.69 m^2 in *Gliricidia sepium* during 2018 and 1.62 m^2 in *Calliandra calothyrsus* and *Gliricidia sepium* during 2019 which differed significantly from other fodder tree species. On the contrary, minimum current annual increment (1.44 and 1.34 m^2) in tree canopy cover was observed in *Sesbania grandiflora* during 2018 and 2019 respectively.

Table 1. Current annual increment (CAI) of fodder trees as influenced by fodder tree based agroforestry system during the period of 2018 and 2019.

Agroforestry system	Mean annual increment (MAI) of fodder trees 2018				2019			
	Dia. at BH (cm)	Can. cover (m^2)	Vol. (m^3 ha^{-1})	Total bio. (t ha^{-1})	Dia. at BH (cm)	Can. cover (m^2)	Vol. (m^3 ha^{-1})	Total bio. (t ha^{-1})
T_1 - *C. calothyrsus* + FC	2.01	1.56	2.70	2.21	1.83	1.62	3.32	2.72
T_2 - *A. lebbeck* + FC	1.88	1.54	1.97	1.64	1.73	1.40	2.64	2.20
T_3 - *L. leucocephala* + FC	2.21	1.49	4.41	3.56	1.98	1.45	4.88	3.94
T_4 - *S. grandiflora* + FC	2.11	1.44	2.84	1.79	1.88	1.34	3.41	2.15
T_5 - *G. sepium* + FC	2.16	1.69	3.23	4.18	1.93	1.62	3.79	4.90
T_6 - *M. oleifera* + FC	2.31	1.89	5.04	3.81	2.12	1.89	5.62	4.25
T_7 - *B. purpurea* + FC	1.90	1.46	2.34	1.98	1.83	1.42	3.15	2.67
Mean	1.82	1.39	2.82	2.40	1.66	1.34	3.35	2.85
SEm ±	0.056	0.03	0.11	0.11	0.02	0.038	0.04	0.04
CD @ 5%	0.171	0.11	0.36	0.34	0.06	0.115	0.12	0.12

FC= Field Crop; Vol. = Volume; Dia. = Diameter; bio = biomass;
BH = Breast Height; Can. = Canopy

The highest current annual increment (5.042 and 5.625 m^3 ha^{-1}) in volume of wood was recorded in *Moringa oleifera* followed by 4.414 and 4.880 m^3 ha^{-1} in *Leucaena leucocephala* during 2018 and 2019 respectively. However, *Albizia lebbeck* recorded the lowest current annual increment (1.973 2.642 m^3 ha^{-1}) in volume of wood during the study periods respectively.

Gliricidia sepium recorded the highest current annual increment (4.18 and 4.90 t ha^{-1}) in total tree biomass followed by 3.81 and 4.25 t ha^{-1} in *Moringa oleifera* during 2018 and 2019 respectively as compared to other fodder tree species studied. On the contrary, the lowest current annual increment (1.64 t ha^{-1}) in total tree biomass was observed in *Albizia lebbeck* during 2018 and 2.151 t ha^{-1} in *Sesbania grandiflora* during 2019 (Table 1).

Among the similar studies examined, Pinyopusarerk and House (1993) revealed that *Casuaruna equisetifolia* on favourable sites can yield MAIs of 15 m^3 ha^{-1} at 10 years. Height growth tapers off when the trees are 7 year old, and volume increments at about 20 years. While trees can attain ages of 40-50 years, rotations of 8-15 years are used for production of wood fuel (Lamprecht 1990). Depending on site quality, a MAI of 6-20 m^3 ha^{-1} yr^{-1} can be expected.

Lamprecht (1990) reported that *Gmelina arborea* plantations attain high MAI of 20-25 m^3 ha^{-1} on fresh, well drained, fertile soils. Rotations of 5-8 years seem most common and MAI is usually between 12 and 50 m^3 ha^{-1} yr^{-1}.

Experiences from three South American countries emphasize the wide range of growth rates. In Brazil, *G. arborea* was reported to yield 38 m^3 ha^{-1} yr^{-1} on a 10 year rotation. In Colombia total volume production was 27.5 m^3 ha^{-1} at 3 years (Newman, 1981). In Costa Rica MAI ranges between 7.1 and 55 m^3 ha^{-1} yr^{-1} (Vasquez and Ugalde 1994).

Pure mahogany plantations in Indonesia reach a maximum MAI of 18 m^3 ha^{-1} yr^{-1} in 20 years on the best sites. On poor sites, the maximum MAI of 13 m^3 ha^{-1}

yr^{-1} may not be achieved until 50 years. Mahogany plantations in Martinique have a maximum MAI of over 30 m^3 ha^{-1} yr^{-1} on the best sites (Tiller 1995), although 14-25 m^3 ha^{-1} yr^{-1} are more usual. Plantations in neighbouring Guadeloupe are less productive, with the best giving 17 m^3 ha^{-1} yr^{-1} over the first 25 years (Soubieux 1983, Mayhew and Newton 1998).

Green fodder yield (kg ha-1)

The data pertaining to green fodder yield at various pruning intervals (I[st] pruning at 4 MAT, 2[nd] pruning at 8 MAT and 3[rd] pruning at 12 MAT) as influenced by fodder tree based agroforestry system during 2018 and 2019 is presented in Table 2. The green fodder data depicted that the tree fodder yield differed significantly among different agroforestry systems during both the periods of investigation.

During the periods of investigation in 2018, the highest green fodder yield (463.05, 565.54 and 434.30 kg ha^{-1}) was registered in *Calliandra calothyrsus* followed by 437.08, 546.35 and 382.45 kg ha^{-1}in *Leucaena leucocephala* at all the stages of pruning intervals. In comparison to other systems, the performance of *Albizia lebbeck* was minimum with yield values of 122.41, 147.58 and 124.95 kg ha^{-1} at various stages of pruning intervals.

During 2019, the maximum green fodder yield (485.29, 606.61 and 424.62 kg ha^{-1}) was recorded in *Calliandra calothyrsus* followed by 451.44, 564.30 and 395.01 kg ha^{-1} in *Leucaena leucocephala* at all the stages of pruning intervals. *Albizia lebbeck* showed a significant reduction in green fodder yield with the least values of 136.69, 170.86 and 119.60 kg ha^{-1} at various stages of pruning intervals (4, 8 and 12 MAT).

The pooled data of 2018 and 2019 showed the maximum green fodder yield (474.17, 586.07 and 429.46 kg ha^{-1}) in *Calliandra calothyrsus* followed by *L. leucocephala* (444.26, 555.33 and 388.73 kg ha^{-1}). Whereas, the minimum green fodder yield (129.55, 159.22 and 122.28 kg ha^{-1}) was registered in *Albizia lebbeck* at various stages of pruning intervals.

The highest pooled total fodder yield of 1489.70 kg ha^{-1} in both the years was obtained *C. calothyrsus* followed by *L. leucocephala* with 1388.32 kg ha^{-1} as compared to other fodder tree species. *A. lebbeck* significantly yielded the least total fodder yield (411.05 kg ha^{-1}).

The similar studies were conducted by Heineman et al. *(*1990) in western highlands of Kenya and reported the leafy biomass yields of hedges maintained at a height of 0.5 m were compared for *L. leucocephala, C. calothyrsus and S. sesban.* In the establishment year the fresh yields were 11.2, 17.2 and 20.3 t ha^{-1} respectively. However, in the next 8 months *C. calothyrsus* had the highest yield (36.7 t ha^{-1}), followed by *L. leucocephala* (24.3 t ha^{-1}) and *S. sesban* had the lowest (10.8 t ha^{-1}). Niang et al. (1992) in Maseno reported two harvests per season (four per year) resulted in 59 per cent tree survival compared with 67 per cent at one harvest per season in *S. Sesban.* Paterson et al. (1998) in Zimbabwe reported that many farmers plant *calliandra* in pure stands and *calliandra* yields range from 2.5 to 5.6 t ha^{-1} yr^{-1} and *A. angustissima, L. leucocephala and Gliricidia sepium* produce more than 3 t ha^{-1} yr^{-1} when cut a single time at the end of the wet season. Hove et al. (2003) in the semi-arid areas around Segou, Mali reported that *G. sepium* yields 2 t ha^{-1} yr^{-1} and *Pterocarpus spp.* yields 0.5 t ha^{-1} yr^{-1}. Wambugu et al. (2011) also reported that *Calliandra* yields 1.5 kg dry matter per tree per year on farms in central Kenya, grown in hedges pruned at 0.6 m to 1 m height, five times per year.

According to Orwa et al (2009) the leaves and pods of *Calliandra calothyrsus* are rich in protein and do not contain any toxic substances. Protein content is 22 per cent (dry matter) and annual fodder yield (dry matter) amounts to about 7-10 t ha^{-1}. Spacing of 3 x 3 m for fuelwood, and 5 x 5 m for timber is followed. Fuelwood plantations spaced at 3 x 3 m clear felled on a 10-year rotation produce about 50 m^3 ha^{-1} of stacked fuelwood. In Queensland *A. lebbek* reaches about 11 m in height and 50 cm dbh in 30 years. *L. leucocephala* is a vigorous coppicer and responds well to

Table 2. Green fodder yield (kg ha^{-1}) of fodder tree at different pruning levels during the period of 2018 and 2019

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 - *C. 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 - *A. lebbeck* + FC	122.41	147.58	124.95	394.95	136.69	170.86	119.60	427.14	129.55	159.22	122.28	411.05
T_3 - *L. 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 - *S. 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 - *G. 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 - *M. 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 - *B. 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
Mean	282.19	346.91	244.52	873.62	289.04	361.29	252.91	903.24	285.61	354.10	248.71	888.43
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 fodder pollarding and pruning. Coppiced stems sprout 5-15 branches, depending on the diameter of the cut surface, and 1-4 stems dominate after a year of regrowth. Wood yields from *L. leucocephala* over short (3-5 years) rotations compare favourably with other species, ranging from 3-4 m in height yr^{-1} and 10-60 m^3 ha^{-1} yr^{-1}.

High plant densities are recommended for solid fodder. Fodder yields range from 40 to 80 t ha^{-1} when moisture is not limiting. In well-drained, deep loamy soils, plantations raised at 0.9 x 0.9 m can yield 4 t ha^{-1} yr^{-1}. Studies on biomass production at different sites found that best production was at the riverside (65.1 kg $tree^{-1}$ at 3.5 years of age); under silvopasture, it was 20.5 kg/tree, and by canals 10.2 kg $tree^{-1}$. The height growth is extremely fast in the first year; it slows down considerably in the subsequent 1-2 years, but the diameter growth rate does not slow down. Pruning at 0.3-1.5 m will stimulate leaf production. Pollarding at 2 m or above is recommended for optimal wood biomass production. Coppicing is used where the primary objective is fuelwood production. *G. sepium* (Orwa et al. 2009) and *Grewia optiva* (Singh et al. 2018) has shown to tolerate lopping and browsing.

CONCLUSIONS

The study revealed that *Moringa oleifera* ((2.31 and 2.12 cm)) and *Leucaena leucocephala* (2.21 and 1.98 cm) have attained more growth in diameter at breast height in terms of CAI. Higher current annual increment of tree canopy cover was noticed in *Moringa olifera* (1.89 m^2), *Gliricidia sepium* (1.69 m^2) and *Calliandra calothyrsus* (1.62 m^2). *Moringa olifera* has and *Leucaena leucocephala* have attained maximum current annual increment (5.042 and 5.625 m^3 ha^{-1}) and (4.414 and 4.880 m^3 ha^{-1}) in volume of wood during 2018 and 2019 respectively. *Gliricidia sepium* and *Moringa olifera* fetched higher values of current annual increment (4.18 and 4.90 t ha^{-1}) and (3.81 and 4.25 t ha^{-1}) in total tree biomass respectively.

The maximum green fodder yield (474.17, 586.07 and 429.46 kg ha^{-1}) was produced in *Calliandra calothyrsus* and *Leucaena leucocephala* (444.26, 555.33 and 388.73 kg ha^{-1}) at 4, 8 and 12 months of pruning intervals. Total fodder yield for the year 2018 and 2019 was produced maximum in *Calliandra calothyrsus* (1462.89 and 1516.52 kg ha^{-1}) respectively. The highest pooled total fodder yield of 1489.70 and 1388.32 kg ha^{-1} in both the years was obtained by *Calliandra calothyrsus* and *Leucaena leucocephala*. However, *Albizia lebbeck* significantly yielded the least total fodder yield (411.05 kg ha^{-1}). The present study concluded that the leguminous fodder tree species such as *Sesbania grandiflora, Leuceana leucocephala, Calliandra calothyrsus, Moringa olifera, Bauhinia purpurea* and *Albizia lebbeck* examined in the present investigation can be used for the production of fodder and thus offer a means of linking livestock production with agroforestry.

ACKNOWLEDGEMENT

Authors are grateful to the staff of College of Forestry, Sirsi (Uttara Kannada) and AICRP on Agroforestry, Dharwad (UASD) for their valuable guidance, help and support during the fieldwork to conduct Ph.D (Forestry) experiment on fodder tree based agroforestry system.

REFERENCES

Chaturvedi AN. and Khanna LS. 1982. Text book of Forest Mensuration. (Ed. Singh Hahlot, R.P.), IBD publishing Co. Dehra Dun, India. pp. 77-87.

Gupta B, Thakur NS. and Bandana Chib. 2012. Survival and growth of exotic grasses under plantations of *Eucalyptus tereticornis* in North West Himalaya. Indian Journal of Forestry 35(2): 181-186.

Heineman AM, Mengich EK, Olang AD. and Otieno HJO. 1990. Afrena Project Maseno, Kenya Progress Report for the Period January 1988 to January

1990. AFRENA Report No. 27, ICRAF, Nairobi.

Hove L, Franzel S. and Moyo PS. 2003. Farmer experiences in the production and utilization of fodder trees in Zimbabwe: constraints and opportunities for increased adoption. Journal of Tropical Grasslands 37: 279-283.

IGFRI Vision. 2050. Indian Grassland and Fodder Research Institute, Jhansi, Uttara Pradesh.

Lamprecht H. 1990. Silviculture in the Tropics: tropical forest ecosystems and their tree species-possibilities and methods for their long-term utilization. GTZ, Eschborn. Germany. 296 p.

Macdicken KG. 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International Institute for Agricultural Development. Arlington.

Mayhew JE. and Newton AC. 1984. The Silviculture of Mahogany (*Swietenia macrophylla*). CAB Publishing. USA. 226 p.

Newman D. 1981. Third year growth of the species in the Pulpapel Arboretum. Research Report, Investigacin Forestal, Carton de Colombia. No. 66. 7 p.

Niang A. Steyger E. and Gahamanyi A. 1992. Fodder potential of grass and shrub combination on contour bunds in Rwere. Proc. In: East and Central African Afrena Workshop, 22–26, June, 1992, Kigali, Rwanda: Proc. Afrena Report No. 58, Nairobi, International Centre for Research in Agroforestry.

Orwa CA. Mutua. Kindt R. Jamnadass RS. Anthony. 2009. Agroforestry Database: a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/ sites/treedbs/treedatabases.asp).

Paterson RT. Karanja GM. Roothaert R. Nyaata Z. and Kariukia IW. 1998. A review of tree fodder production and utilization within smallholder agroforestry systems in Kenya. Agroforestry Systems 4: 181-199.

Pinyopusarerk K. and House APN. 1993. Casuarina: an annotated bibliography of *C. equisetifolia, C. junghuhniana* and *C. oligodon*. ICRA. Nairobi. 298.

Prajapati DR, Thakur NS, Gunaga RP, Patel VR, Mevada RJ. and Bhuva DC. 2020. Growth Performance of *Melia dubia* in Sole and *Melia dubia*-Sorghum Sudan Grass Silvi-Pasture Systems: Sorghum Sudan Grass Intercropping Implications. International Journal of Current Microbiology and Applied Science 9(4): 726-732.

Singh Charan, Singh Rambir and Himshikha. 2018. *Grewia optiva* (Drumm. Ex Burr) - A Multi-Purpose Tree Under Agroforestry in Sub–Tropical Region of Western Himalaya. Journal of Tree Sciences. 37(2): 36-43.

Soubieux JM. 1983. Croissance et production du mahogany (*Swietenia macrphylla* King) en peuplements artificiels en Guadeloupe. Ecole Nationale de Ingenieurs des Travaux des Eaux et Forêts, Direction Régionale pour la Guadeloupe, Office Natinal des Forets, Guadeloupe. and Attar SK. 2015b. Fodder production from tree-legume-grass based agroforestry systems in sub tropical hills of Western Himalayas, India. Journal of Tree Sciences 34(1): 49-55.

Sukhadiya ML, Thakur NS, Gunaga RP, Patel VR, Bhuva DC and Singh S 2019. Melia dubia Cav. drupe pulp: a new alternate livestock feed resource. Range Management and Agroforestry 40(2): 299-305.

Sukhadiya ML, Thakur NS, Patel VR, Gunaga RP, Kharadi VB, Tyagi KK. and Singh S. 2020. Provenance variations in proximate principles, mineral matter, total phenols and phytochemicals of *Melia dubia* drupes: an unexplored alternate livestock feed stock. Journal of Forestry Research 1-13.

Thakur NS, Attar SK, Gupta NK. and Gupta B. 2015a. Fodder availability from traditional agri-silvi-horticulture systems: Requirement and deficit w.r.t. livestock status in mid hills of Western Himalayas-A case study. Journal of Tree Sciences 34(2): 22-27.

Thakur NS, Gupta NK. and Gupta B. 2004. Phytosociological analysis of woody and non-woody components under some agroforestry systems in Western Himalaya - A case study. Indian Journal of Agroforestry 6(1): 65-71.

Thakur NS, Gupta NK. and Gupta B. 2005. An appraisal of biological diversity in agroforestry systems in North-Western Himalaya. Indian Journal of Ecology 32(1): 7-12.

Thakur NS, Gupta NK. and Gupta B. 2011a. Biomass, carbon Stocks and CO_2 removal by shrubs under different agroforestry systems in Western Himalaya. Indian Journal of Ecology, 38(1): 14-17.

Thakur NS, Gupta NK. and Gupta B. 2011b. Variation in community structure and biomass production of shrub and herb layer in agroforestry systems in Himachal Pradesh-A case study. Indian Journal of Agroforestry 13(1): 13-18.

Thakur NS, Verma KS and Attar SK. 2015b. Fodder production from tree-legume-grass based agroforestry systems in sub tropical hills of Western Himalayas, India. Journal of Tree Sciences 34(1): 49-55.

Tiller S. 1995. Le mahogany grandes feuilles en Martinique. Bois et Forêts des Tropiques, 244 (2): 55-56.

Vasquez W. and Ugalde L. 1994. Rendimiento y calidad de sitio para Gmelina arborea, Tectona grandis, Bombacopsis quinata y Pinus caribaea en Guanacaste, Costa Rica. Informe Final Convenio de Cooperación, Proyecto Forestal Chorotega (IDA/FAO) Proyecto Madelaña-3/CATIE 42 P.

Wambugu C. Place F. and Franzel S. 2011. Research, development and scaling up the adoption of fodder shrub innovations in East Africa. International Journal Agricultural Sustainability 9: 100-109.