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Research Article

Sustainable Forage Production in *Melia azedarach* Based Silvopastoral System

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ABSTRACT

Silvopasture experiment was conducted to find out the performance of *Melia azedarach* (Bakain) with fodder crops in silvopastoral model of agroforestry under rainfed condition of Ranchi, Jharkhand. Four kind of fodder grasses *viz.*, *Stylosanthes hamata* (Stylo), *Arachis glabrata* (Charabadam), *Brachiaria mutica* (Para grass) and *Pennisetum purpureum* x *Pennisetum glaucum* (NB Hybrid). Maximum growth was gained in Bakain in terms of tree height (185 cm) and collar diameter (24.97 mm) when intercropped with Stylo. Maximum green and dry fodder yield was observed in sole NB Hybrid grass, whereas Charabadam recorded maximum crude protein content in silvopastoral condition. The soil nutrient status of silvopasture was also raised as compared to sole tree/crops.

Keywords: Agroforestry; Fodder tree; Fodder grass; Silvopasture

INTRODUCTION

India is sustainably nourishing 18 percent livestock population of the world with limited grazing sources. The gap between demand and supply of quality forage is regularly increasing. Recently, India features deficiency of 61.1 percent, 21.9 percent, 64 percent in terms of green fodder, dry fodder and feeds respectively. Due to prolific growth in livestock especially genetically upgraded animals, the current scenario had more worsened. The available forages are poor in quality as being deficient in available energy, protein and minerals. To compensate low productivity of the livestock, farmers maintain a large herd of animals, which adds to the pressure on land and fodder resources. Due to increasing pressure on arable land for production of food and cash crops, there is mere chance of availability of good quality land for growing fodder crops, unless milk production becomes remunerative to the farmer as compared to other crops.

Silvopasture is a kind of agroforestry that intentionally integrates trees, forage crops and/or livestock to form a carefully designed system for sustainable forage production. The system has gained popularity in recent years as an environmentally friendly alternative land use system that is economically viable. Greater forage production with high nutritive value for pasture grown under trees is reported by many researchers. Modern silvopasture is new name for old age practice that is established on sound ecological principles and demands skills for managing complexity. A properly designed and well managed combination of trees, pasture and livestock can be more profitable than traditional agriculture or forestry as it increases the overall system productivity because of being a multiproduct system and buffer against risk of economic losses due to unfavorable environmental and market conditions. Combining long term income for timber with immediate income from forage and livestock strengthen the livelihood of farmers on sustained basis.

Bakain is identified as a potential fodder tree species whose leaves are looped for highly nutritive fodder. It is a small to medium sized deciduous tree attaining an average height of 7-12 m and average diameter of 30-60 cm, with a spreading crown and sparsely branched limbs. It is native to India, Burma, Southern China, and Iran, whereas in India it is mainly grown in Assam, Bihar, Karnataka, Maharashtra, Odisha and Punjab. It is adaptable to wide range of environmental conditions; however, it is more likely grown under semi-arid and warm climate. In its natural locality, the mean annual temperature ranges from 23°C to 26°C, mean annual rainfall from 600-2400 mm, and it prefers well drained, deep, sandy loam soil with pH range 5 to 6. Besides providing nutritive leave fodder, it also provides good timber which is used to produce agricultural implements, furniture, plywood, boxes, poles, tool handles etc.

Stylo, also known as *Caribbean Stylo*, is a semi-erect, annual or short-lived perennial tropical legume grass, grows up to 75 cm high. It is native to Caribbean Islands, Southern Florida, Central America and South America. It is also found in India, West Africa and Northern Australia, where it grows better in areas with 700 to 900 mm rainfall. *Caribbean Stylo* is drought-resistant, can grow on a wide range of soils, except heavy clays, with a pH ranging from 5.5 to 8. Successive harvesting can be done at 45 days of interval or in accordance to the growth of the crop and a maximum of 4-5

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harvests can be taken in a year for a perennial crop. The crop yield 25-30 t ha-1 green fodder per year. The species contains about 10-24 per cent dry matter as crude protein and crude fibre content varies between 24-49 per cent of dry matter. Generally, *S. hamata* is used to boost the flora of natural pastures and leys and for enhancing the creation of forage banks.

Charabadam, also known as *Rhizoma* peanut, is a summer growing perennial tropical legume and a relative of the annual peanut. It is a high-quality forage plant native to Argentina, Brazil and Paraguay. It has been introduced to Australia, United States, India, Thailand, Malaysia and Indonesia. It does well where annual rainfall is between 1000 and 2000 mm and where average monthly temperature is over 20°C [1]. It is well adapted to acidic infertile soils having pH down to 4.5 but also reported to grow on pH as high as 8.5 of alkaline soil [2]. The species can yield about 10-16 tons dry matter per ha under ideal conditions. For hay production, three cuttings are possible in favourable season at an interval of 7 to 8 weeks [3]. Protein content ranges from 10-18% of dry matter and crude fibre content ranges up to 23%-33% of dry matter [4].

Brachiaria (*Brachiaria mutica* (Forssk.) Stapf, F: *Poaceae*), also known as Para grass, Angola grass or Buffalo grass, is a semi-aquatic, palatable and good quality forage grass particularly suited to poorly drained soil. It is native to Sub-Saharan flood plains and later spreaded southward to Central and East Africa. It can be found from sea level up to an altitude of 1000 m (FAO, 2017). It thrives in moist soils of humid and sub-humid areas with annual rainfall of 1200-4000 mm, or in swampy areas of drier environments down to 900 mm rainfall. Para grass is a warm climate grass that grows effectively at temperatures around 22°C and stops growing under 15°C. It is both suited to poorly drain swampy areas and well drained moist soils. It does well on acidic soils (pH 4-5) [5]. First harvest can be done about three months after planting when the grass attains a height of about 60 to 75 cm. Subsequent cuts can be taken at 30 to 40 days interval, usually yielding 5-12 t DM/ha/year. The yield is about 70 t ha-1 annually. It makes good silage with only 10% DM losses (FAO, 2017). Para grass has a variable nutritional value, with protein content in the 7%-10% DM range and fiber contain 25.7%-43.5% DM [6].

NB Hybrid (*Pennisetum purpureum x Pennisetum glaucum, F: Poaceae*) (updated name: *Cenchrus purpureus* Schumach) [7], commonly known as Elephant grass, Napier grass, originated from sub-Saharan tropical Africa. Throughout the world it has been introduced as forage into most tropical and subtropical regions. It is a summer growing grass that grows from sea level up to an altitude of 2000 m. It thrives better in places where temperatures range from 25°C to 40°C and where annual rainfall is over 1500 mm. Growth is not seen below 15°C. It does better on drained sandy soils with a pH ranging from 4.5 to 8.2 [8]. The biomass production of the species is high i.e., about 40 tons/ha/year and can be harvested 4-6 times per year [9]. It contains 8.7%-10.2% crude protein, 28-30.5% crude fiber and 10%-11.5% ash on dry matter basis. After 65 days of plantation first cut is obtained and the successive cuts are obtained after the interval of 25 to 30 days. At least 6-8 cuts are possible annually.

Despite many studies are carried out on quality fodder production under various tree based silvopasture systems in different parts of India, very less attention has been paid to explore the possibility of integration of Bakain (*Melia azedarach*) into Silvopasture to increase the quantity as well as quality of forage production, especially under specific agroclimatic condition of Jharkhand. To compensate the low productivity of livestock in Jharkhand, exploring the possibility of quality fodder production through *Melia azedarach* based silvopasture system is critical to advise small and marginal farmers who maintain a large herd of animals and thereby adds pressure on the land and fodder resources. This paper envisages the performance of *Melia azedarach* and fodder crops under silvopasture system in Ranchi district of Jharkhand, India.

MATERIALS AND METHODS

The present study was carried out in Faculty of Forestry, Birsa Agricultural University, Ranchi, Jharkhand (23.434549 N latitude and 85.320702 E longitude with the elevation of 651 m above mean sea level) during May 2018-April 2019 (Figure 1). The experiment was conducted in randomized block design with nine treatments replicated thrice. Stylo Charabadam, Brachiaria and NB Hybride, (together abbreviated as SCBN) were intercropped with four-year-old *Melia azedarach* spaced at 4 x 4 m, and each grass were maintained under sole cropping as control, representing each as a treatment. SCBN were sown in the month of July 2018, where Brachiaria and NB Hybride spaced at 0.5 x 0.5 m, and Stylo and Charabadam spaced at 0.25 x 0.25 m.

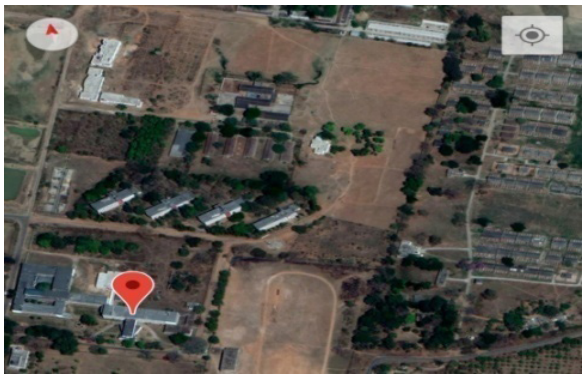

Figure 1: The study site consisting of silvopasture plots.

The site experienced warm humid tropical climate, with a mean rainfall of 1358 mm, most of which was received during the month of August. The average maximum and minimum temperature during cropping period were 32.55°C and 19.85°C respectively during 2018-19 (Figures 2 and 3).

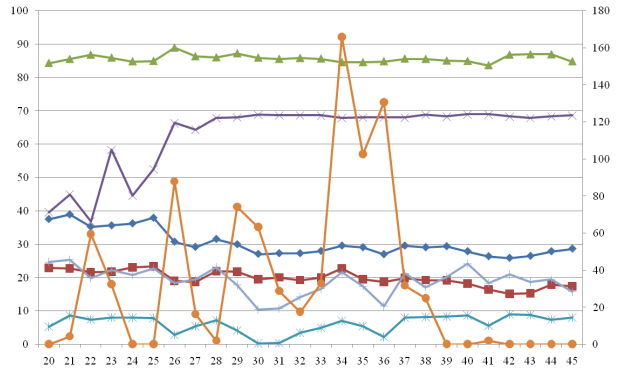

Figure 2: Mean weekly meteorological data of study site (May-Nov, 2018).**Note:** (—◆—) Temperature(Max), (—■—) Temperature(Min), (—▲—) R.H(7.a.m), (—×—) R.H(2.a.m), (—✳—) Sunshine(hr./week), (—|—) Evaporation(mm), (—●—) Rain(mm).

Figure 3: Research plot.

Initial growth parameters of four year old *Melia azedarach* (in May 2018) were taken into account and computed as, H=Height of tree (cm), CD=Collar Diameter (mm), NB=Number of Branches, CW=Crown Width (m). The final observation was recorded after one year (in April 2019) and computed the annual increment in all the growth parameters. The SCBN fodder was harvested twice (1st at 55 days and 2nd at 95 days after sowing) and their cumulative yield was considered. Growth, yield and quality parameters of SCBN fodder were computed under following parameters, Plant population (per m^2), Number of tiller or branches per m^2), Plant height (cm), Number of leaves per plant per stick, Leaf area Index (%), Leaf:Stem ratio, Green fodder yield (q/ha), Dry fodder yield (q/ha). Crude protein (%) and Crude fiber (%). Soil properties were computed by estimation of available NPK, Organic Carbon (%), and pH. The data so obtained, were properly tabulated and statistically analysed to find out the effect of different treatments on growth and yield of tree and fodder crops (Tables 1-4).

Table 1: Growth performance of Bakain under *Melia azedarach* based agroforestry system.

Treatments	Height(cm)		Avg. Collar diameter(mm)		Number of branches		Crown width (m)		Increment			
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Height	Collar diameter	No. of branches	Crown width
T_1	105.42	185.00	8.65	24.97	15.00	31.00	1.50	2.23	79.58	16.32	16.00	0.73
T_2	107.92	172.67	9.64	19.88	16.20	33.00	1.30	1.90	64.75	10.24	16.80	0.60
T_3	107.50	155.00	7.59	18..92	12.20	23.00	1.00	1.40	47.50	11.33	10.80	0.40
T_4	113.33	134.33	8.41	12.19	11.30	19.00	1.10	1.22	21.00	3.78	7.70	0.12
T_5	125.83	173.33	9.35	23.92	17.30	37.00	1.73	2.65	47.50	14.56	19.70	0.92
SE (m) ±	5.51	10.66	0.60	1.49	1.29	4.35	0.18	0.42	12.64	1.23	3.12	0.21
CD (0.05)	15.72	31.25	1.62	4.94	3.74	12.96	0.57	1.32	37.54	4.07	9.32	0.65
C V (%)	8.52	11.25	11.84	18.92	7.85	16.84	8.82	17.52	16.05	18.92	15.85	15.68

Note: T1–*Melia azedarach*+Stylo (Stylosanthes hamata), T2–*Melia azedarach*+Charabadam (Arachis glabrata), T3–*Melia azedarach*+ Brachiaria grass (Brachiaria mutica), T4–*Melia azedarach*+NB hybrid grass (Pennisetum purpureum x Pennisetum glaucum), T5 –Sole *Melia azedarach*

Table 2: Growth, yield and quality parameters of fodder crops as sole and with Bakain under *Melia azedarach* based agroforestry system.

Treatments	Plant population /m^2	Number of tillers or branches/m^2	Plant height (cm)	Number of leaves per plant per stick	Leaf Area Index (%)	Leaf: Stem ratio	Green fodder yield (q/ha)	Dry fodder yield (q/ha)	Crude protein (%)	Crude fiber (%)
T_1	16.00	397	39.67	54	1.47	1.48	111.90	23.49	13.38	41.80
T_2	16.00	553	18.67	30	1.16	1.16	121.35	38.05	14.66	43.93
T_3	4.00	95	122.67	19	2.20	2.19	245.13	66.19	6.57	49.30
T_4	4.00	134	163.34	12	8.45	8.45	633.35	209.00	5.83	69.67
T_5	-	-	-	-	-	-	-	-	-	-
T_6	16.00	410	56.00	59	1.74	1.74	194.65	36.98	13.81	42.20
T_7	16.00	620	25.00	41	1.11	1.11	319.10	70.20	14.65	42.05
T_8	4.00	119	132.67	21	2.58	2.58	438.77	122.86	8.26	47.57
T_9	4.00	158	185.00	12	9.46	9.46	860.16	266.65	7.26	72.47
SE (m) ±	4.49	17.45	2.80	2.64	0.12	0.08	12.56	3.76	0.18	1.59
CD (0.05)	NS	53.46	8.59	8.10	0.25	0.25	38.47	11.52	0.54	4.88
C V (%)	11.24	7.56	5.23	14.75	5.47	4.01	5.95	6.25	2.91	5.40

Note: T1–*Melia azedarach*+Stylo (Stylosanthes hamata), T2–*Melia azedarach*+Charabadam (Arachis glabrata), T3–*Melia azedarach*+Brachiaria grass (Brachiaria mutica), T4–*Melia azedarach*+NB hybrid grass (Pennisetum purpureum x Pennisetum glaucum), T5–Sole*Melia azedarach*, T6-Sole Stylo, T7-Sole Charabadam, T8-Sole Brachiaria grass, T9-Sole NB hybrid grass

Table 3: Chemical status of soil under *Melia azedarach* based agroforestry system.

	Soil fertility status of 0 -15 cm soil				
	pH	O.C %	Avail.N (Kg/ha)	Avail.P (Kg/ha)	Avail.K (Kg/ha)
Treatments Initial value	5.1	0.231	160	12.45	53.76
	Final value				
T_1	5.53	0.316	202.00	16.76	69.76
T_2	5.76	0.337	211.00	17.44	70.24
T_3	5.44	0.287	186.00	15.83	66.63
T_4	5.27	0.274	178.00	15.15	65.27
T_5	4.90	0.250	168.00	14.47	59.33
T_6	5.33	0.279	185.00	15.27	62.69
T_7	5.10	0.292	193.00	15.67	63.88
T_8	5.17	0.278	175.00	14.39	61.36
T_9	5.09	0.260	167.00	13.75	59.03
SE (m) ±	0.162	0.004	2.944	0.703	0.694
CD (0.05)	N/A	0.013	8.902	2.126	2.1
C V (%)	5.338	2.305	2.761	7.832	1.885

Note: T1–*Melia azedarach*+Stylo (Stylosanthes hamata), T2–*Melia azedarach*+Charabadam (Arachis glabrata), T3–*Melia azedarach*+Brachiaria grass (Brachiaria mutica), T4–*Melia azedarach*+NB hybrid grass (Pennisetum purpureum x Pennisetum glaucum), T5 –Sole *Melia azedarach*, T6-Sole Stylo, T7-Sole Charabadam, T8-Sole Brachiaria grass, T9 –Sole NB hybrid grass.

Table 4: Economics of Bakain based *Melia azedarach* based agroforestry system.

Treatments	Cost of cultivation (Rs. ha-1 y-1)	Gross return (Rs. ha-1 y-1)	Net return (Rs. ha-1 y-1)	B:C ratio
T_1	52073	205537	153464	2.95
T_2	55242	196650	141408	2.56
T_3	54770	203060	148290	2.71
T_4	54975	225900	170925	3.11
T_5	27325	96875	69550	2.54
T_6	24748	108662	83914	3.39
T_7	27917	99775	71858	2.57
T_8	27445	106185	78740	2.87
T_9	27650	129025	101375	3.66
SE (m) ±	-	-	-	0.28
CD (0.05)	-	-	-	0.86
C V (%)	-	-	-	8.56

Note: T1–*Melia azedarach*+Stylo (Stylosanthes hamata), T2–*Melia azedarach*+Charabadam (Arachis glabrata), T3–*Melia azedarach*+Brachiaria grass (Brachiaria mutica), T4–*Melia azedarach*+NB hybrid grass (Pennisetum purpureum x Pennisetum glaucum), T5–Sole *Melia azedarach*, T6-Sole Stylo, T7-Sole Charabadam, T8-Sole Brachiaria grass, T9-Sole NB hybrid grass.

Price of input and cost of cultivation of *Melia azedarach* based agroforestry system are given in Table 4. The gross and net returns from SCBN fodder and growth production of Bakain on per hectare basis under each cropping system were worked out on the basis of prevailing market rates of fresh SCBN fodder and annual standing tree of Bakain up to the age of four years (Table 4). Benefit Cost ratio (BCR) were also calculated using standard formula.

RESULTS AND DISCUSSION

Data on growth of Bakain under *Melia azedarach* based agroforestry system is presented in Table 1. A perusal of table shows the effect of different treatments on growth parameters i.e., height, collar diameter, number of branches and crown width of *M. azedarach*. Maximum annual increment in tree height (79.58 cm) and collar diameter (16.32 mm) of *M. azedarach* was observed when intercropped with *S. hamata*. Increment in number of branches and crown width was not shown increased in silvopasture treatments than sole *M. azedarach* (Table 1). As evident from Table 1, the growth of *M. azedarach* did not follow a pattern. In some cases, it was better in sole conditions, whereas in other, it was better in combinations with fodder crop. In short, no clear trend was seen in the growth and yield of *M. azedarach* in agroforestry system in the present study.

The lower values for different growth parameters of Bakain in some treatments may be attributed to the reason that those combinations may involve more ground cover of fodder crops compared to other combinations, which means that Bakain was growing in a situation of high competition for light, moisture and nutrients. The results are in line with the findings of Rao and Coe, who reported, higher competition and suppressed crop yield with the tree species ranking high in terms of height, diameter and crown spread.

Growth parameters of fodder crops under *Melia azedarach* based agroforestry system are presented in Table 2. The data reveals

significant effect of treatments on plant height (cm), number of tillers or branches/m^2, number of leaves per stick per plant, Leaf Area Index (%), Leaf Stem ratio, Green fodder yield (q/ha), Dry fodder yield (q/ha), Crude Protein (%), Crude Fiber (%). However, data on plant population/m^2 did not express any significant difference.

The plant height, number of tillers or branches and number of leaves per stick per plant, of intercrops decreased under *Melia azedarach* based silvopasture system as compare to sole intercrops. The probable reason of this reduction in morphometric parameters of intercrops is the shading effect of tree canopy. This observation was in lined with the findings who also reported reduction in tillers and leaves due to shading of tree canopies [10,11]. Average plant height of Stylo, Charabadam, Brachiaria grass and NB hybrid was 39.67 cm, 18.67 cm, 122.67 cm and 163.34 cm respectively under *Melia azedarach* based silvopasture system whereas it was 56.00 cm, 25.00 cm 132.67 cm and 185.00 cm respectively in their sole cropping. The decrease in number of leaves and tiller per tussock caused reduction in leaf area index under tree canopy. Yield reduction in both green and dry fodder in each intercrop was also observed under silvopasture system as compared to their sole cropping (Table 2). The percentage reduction in forage yield was computed as 42.52% in Stylo, 61.98% in Charabadam, 44.04% in Brachiaria and 26.37% in NB hybrid. Reduction in plant height, green fodder yield and dry fodder yield in shade grown plant has also been reported by Paudel D .

The quality of fodder crops under the shading of tree was improved due to higher accumulation of crude protein in their leaves (Table 2). The crude protein is directly related with the available nitrogen content in the leaves and it is assumed that under high shading environment the inorganic nitrogen in the form of nitrate was more, which might be due to slow process of nitrogen assimilation [13]. The above observation is in accordance with [13], who reported 55% more crude protein in *Leucaena*+hybrid Napier silvopasture model than their sole cropping. Silvopasture management remained unaffected in respect of crude fibre content of the fodder crops.

Change in soil health

The pH of the soil under silvopasture system of *Melia azedarach*+Charabadam was slightly higher than the sole pasture of Charabadam. Significant increase in organic carbon content were observed under the tree canopies of *Melia azedarach* (Table 3). The increase in organic carbon under silvopasture system may be because of more litter decomposition and available root biomass of trees and grasses. The available nitrogen, phosphorus and potassium in soil were higher under *Melia azedarach*+Charabadam based silvopasture system as compared to their sole cropping. Available phosphorus and available potassium were also higher under *Melia azedarach*+Charabadam. On average, there was improvement in soil nutrient availability at the end of growth season in the pure grass stand as well as under silvopasture system. The higher level of nutrients under *Melia azedarach* based silvopasture system over the years may be due to decay of litter, root biomass and other organic carbon matter. Many workers have also reported the more availability of nutrients under tree cover [14]. Increase in soil nutrients under silvopasture systems shows the relevance of the present study which indicates that *Melia azedarach* based silvopasture system is the sustainable forage production system for the Eastern Plateau and hill region of India.

In forestry projects, benefit and cost are often incurred over a long period of time. In combination of crops, maximum cost incurred in T2, i.e., Rs.55242 while under the sole crop maximum cost incurred in T7, i.e., Rs.27917. The gross return was maximum under T4, i.e., Rs. 225900 followed by T_1 Rs.205537, while minimum under T5 Rs.96875. Similarly, maximum net return was obtained under T4 i.e., 170925, followed by T_1 Rs.153464 and minimum under T5 i.e., Rs.69550. The B:C ratio under different sole and combination of crop were found significant with its maximum value under T9 (3.66), followed by T6 (3.39), T4 (3.11) and T_1 (2.95), which were at par with each other and minimum B:C ratio was obtained under T5 (2.54).

CONCLUSION

Bakain based agroforestry system is found suitable for the degraded or waste land. This experiment has got significant implication on the increased production and quality of nutritive fodder crops as well as improvement in soil health. There is still a substantial need to promote Bakain based agroforestry systems as well as utilization of Bakain to the possible extent in the wasteland, particularly in economically backward areas. The cumulative outcome of silvopasture system was found more than that of either sole Bakain plantation or sole pasture practices.

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