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Effect of grasses in the allies of multipurpose tree species

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Abstract
An experiment was conducted at the research station of All India Co-ordinated Research Project on Agroforestry, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India, during 2018-2019 to study the performance of fodder grasses with multipurpose tree species under silvipastoral system in rainfed upland situation. The experiment was laid out in Randomised Block Design with nine treatments and three replications. Among the grasses, the maximum green forage yield of 20.9 t ha^{-1} was obtained in Guinea with *Acacia mangium* system followed by *Samanea saman* with Guinea grass system (19.5 t ha^{-1}). Relative yield of grasses was highest under *Acacia mangium* (82.6%) and lowest under *Acacia auriculiformis* (73.1%). In silvipastoral system maximum soil moisture storage was recorded with guinea, followed by Thin Napier and Setaria irrespective of trees associated. In general, light interception was lower under *Acacia mangium* followed by *Acacia auriculiformis* and *Samanea saman*. The chlorophyll content of all grasses was higher under *Acacia mangium* followed by *Acacia auriculiformis* and *Samanea saman*.

Keywords: Fodder grasses, multipurpose tree species, soil moisture, chlorophyll, biomass and carbon sequestration

Introduction
The feed and forage resources of India are able to meet only 40% of the requirement leaving a vast deficit of 64 and 16% in green and dry fodder, respectively. In rainfed upland conditions, where the available grazing is not sufficient to meet the maintenance requirements of animals for round the year, the contribution from multipurpose tree species (MPT) are significant. Grasses also well suited in dry regions and require a little amount of water to survive throughout the year. Rainfed agro-ecosystem has a distinct place in Indian Agriculture, the farming systems in rain fed areas are quite diverse with a variety of crops, cropping systems, Agroforestry, horticulture and livestock production (Kaul M, 2010) [4]. It is suggested to develop silvipastoral systems by introducing trees into natural pasturelands to provide nutritious green foliage through out the year. Moreover, small ruminants are primarily maintained on natural pasturelands with in situ grazing and the productivity is constrained by the low quality of native grasses as well as the shortage of good quality forage, especially during the dry season. Hence, it is suggested to develop silvipastoral systems by introducing pasture and foliage component under trees so as to provide nutritious green forage and foliage to small ruminants for getting higher production from unit of land in rain fed areas. Where in the inter spaces between MPT are utilized for cultivation of grasses and grass legume mixtures, which provides a two tier grazing under in situ. During rainy seasons the animals prefer to graze green grass, but during dry seasons when there is no blade of grass available, they utilize foliage of the trees. Moreover, forest biomass consumption could contribute to the socio-economic development of rural areas, through the restoration of Agroforestry activities and technological advances in the bio-energy field, getting woody biomass from the Agroforestry system to the consumer presents economic and logistical challenges. Trees in managed species mixtures also have a great potential to bring about micro-site enrichment through processes such as litter dynamics. Nitrogen fixing trees have the additional potential of bringing in substantial quantities of atmospheric nitrogen into a combined form (Kaur B, 2002) [5]. Nitrogen rich legume litter decomposes rapidly in tropical environments. Under storey herbage production in silvipastoral systems is also dependent on the shade tolerance of the species involved. Tolerant grasses are likely to maintain higher under storey productivity levels in increasing levels of canopy closure.

Therefore, information on the relative shade tolerance of important tropical grasses is particularly valuable in the design and management of tropical silvipastoral systems. However, few workers in the tropics seem to have compared the long-term trends in productivity of forage crops, differing in their ability to tolerate shade, and grown in association with multipurpose trees (MPTs) possessing disparate architectural patterns. In this context, the present investigation was carried out to study the effect of trees on growth, Biomass yield of grasses and vice versa along with Carbon sequestration of this silvipastoral system.

Materials and Methods

Location and Soil characteristics

The experimental site is situated inside the AICRP on Agroforestry Research Station of O.U.A.T., Bhubaneswar The study area falls in the sub-tropical rainfed zone, the experimental field is fairly levelled and well drained. Soil is sandy loam texture. It is rich in oxides of iron and aluminium but poor in di-basic cations and soluble salts. Soil samples were taken before conducting the experiment from a depth of 0-15 cm taking all the possible precautions prescribed for soil sampling. The processed samples were subjected to appropriate physical and chemical analysis.

Experimental details

The experiment was laid out in a Randomised Block Design (RBD) with three replications, during 2018-2019 It consisted of nine treatments combinations comprising of nine silvipastoral systems involving three silvi tree species e.g. *Acacia mangium, Acacia auriculiformis and Samanea saman* and three grass species i.e. Guinea (*Megathyrsus maximus*), Thin Napier (*Pennisetum purpureum*) and Setaria (*Setaria glauca*). Three control plots of grasses were also maintained for comparing the performance of grasses under sole and silvipastoral systems. The planting geometry of silvi trees and grasses was 6 x 2 m^2 and 0.75 x 0.50 m^2 respectively. At the time of final land preparation well decomposed FYM @ 5 t ha^{-1} and recommended fertilizer dose of 80-40-40 kg N-P_2O_5-K_2O ha^{-1} was applied in the form of Urea, Diammonium phosphate (DAP) and Murate of potash (MOP), respectively. Half of Nitrogen along with full Phosphorus and Potash were applied as basal and rest of nitrogen in three splits as top dressing after each cutting.

Diameter at breast height (DBH) over bark of trees was measured at a height of 1.37 m at 42 months after planting with the help of tree caliper in two directions (major axis and minor axis) and the average was computed and expressed in centimeter (cm).

$$DBH = d_1 + d_2/2$$

Where d_1 = Diameter of major axis
d_2 = Diameter of minor axis

Solar radiation interception (%) under canopy of trees in silvipastoral system (X100, LUX 100000) was recorded by digital lux meter and expressed as percentage of open field condition during different months. The biomass of standing tree was calculated by applying following standard allometric equation Biomass of tree (above ground) = 0.1245 × $(DBH)^{(2.4163)}$ (Hung *et al*., 2012) [3] Biomass of tree (below ground) is a factor of 0.26 of the above ground biomass, The total biomass of tree is calculated by adding the above and below ground biomass of the tree. Carbon sequestration potential for the year of study was calculated with considering the total carbon stock of the tree and fodder species which was assessed by assuming 50 % of the total biomass carbon CO_2 assimilation was estimated when carbon stock was multiplied by a factor of 3.67 (44/12) (Chauhan *et al*., 2009) [1]. The Soil sample was collected in moisture box, one at 0-15cm and another at 15-30 cm by gravimetric method. Fresh weight of soil sample is taken immediately after collection of sample in moisture box and dry weight was recorded after keeping the moisture box at 105^0celsius for 24 hours in hot air oven. Then soil moisture content (%) was calculated by the formula mentioned below

$$\text{Soil Moisture Content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

The yield of fodder crops were recorded at three cuttings from time to time from a pre-marked 1 sq. meter area of each plot and the total yield (q) was calculated by adding the yield (q) from all three cuttings of respective area and converted to yield (q) per hectare. To determine the significance between the treatment means and to draw valid conclusion, statistical analysis was made. Data obtained from various observations were subjected to statistical analysis by adopting appropriate method of "Analysis of Variance". The difference of the treatments mean was tested using Critical Difference (C.D.) at 5% level of probability (Gomez and Gomez, 1984) [2].

Results and Discussion

Solar radiation interception

The mean solar radiation interception under canopy of trees in silvipastoral system (X100, LUX 200,000) was lowest in *Acacia mangium* (18.5%)followed by *Acacia* a*uriculiformis* (21.6%) and *Samanea saman* (25.9%)during August and this trend was continued in September, October, and November. The average solar radiation gradually decreased from August to November irrespective of the tree species (Table 1).

Chlorophyll content of different grasses

The higher chlorophyll content was observed with sole grasses than the system from August to October but during November it was higher in the system than the sole grasses in open field condition, which might be due to more availability of soil moisture in the system. (Table 2).

Soil moisture content (%) In this Study better moisture storage was evident with *Acacia mangium* with followed by *Acacia auriculiformis* and *Samanea saman*. The higher available soil moisture content was observed with sole grasses in open field condition during August, September and October than the system but after October onwards (November, December) the higher available soil moisture content was observed in the system than the open field condition due to more evaporation losses of moisture in open condition. (Table 3)

Growth of silvi trees in silvipastoral system

The data presented in Table 4 revealed that the height of tree species varies significantly when grown with different forage crops. At 42 months after planting the highest tree height of 12.2 m of *Acacia mangium* was recorded with Setaria followed by *Acacia mangium* with Guinea (11.60 m) and lowest tree height of 3.3 m was recorded in *S. saman* with Thin napier system. At 42 months after planting, The highest DBH of 11.8 cm was found in *Acacia mangium* with Setaria system followed by *Acacia mangium* with Thin Napier system (11.5cm) and A*cacia mangium* with Guinea system (10.7cm). The DBH of *Samanea saman* (3.4cm) found to be lowest in *Samanea saman with* Thin Napier system. The growth trend was similar to tree height in all systems. *Acacia mangium* recorded significantly higher DBH than other two tree species at all stages (Table 4). These corroborate the findings of Yadav *et al.* (2014) [6].

Biomass Production and Carbon Sequestration

The biomass of tree species recorded at 42 MAP irrespective of silvipastoral system, The highest tree biomass of (6102 kg ha-1) was recorded with *Acacia mangium* in *Acacia mangium* with Setaria system followed by *Acacia mangium* with Thin Napier (5734 kg ha-1) and *Acacia mangium* with Guinea (4816 kg ha-1) system. Similarly the highest fodder biomass of 8075 kg ha-1 was recorded with *Acacia mangium* with Setaria system followed by *Acacia mangium* with Thin Napier (7415 kg ha-1) and *Acacia mangium* with Guinea (5262 kg ha-1) system. *Acacia mangium* based silvipastoral systems have significantly higher total biomass production than other two tree based silvipastoral systems. The carbon sequestration of different silvipastoral systems was presented in Table 5. The highest carbon sequestration of 26014 kg ha-1 was recorded with *Acacia mangium* with Setaria system followed by *Acacia mangium* with Thin Napier (24128 kg ha-1) and (18493 kg ha-1) system (table 5). Simillar result were reported by Chauhan *et al.* (2009) [1].

Table 1: Solar radiation interception under canopy of trees in silvipastoral system, (X100, LUX2, 00, 000) Mean Data of 2018 and 2019

Treatments		Solar radiation interception as % of open field			
Tree Species	**Fodder grasses**	**August**	**September**	**October**	**November**
A. mangium	Guinea	19.4	13.8	12.2	9.5
	Thin Napier	18.6	13.7	11.5	9.2
	Setaria	17.4	12.6	11.3	8.9
	Mean	18.5	13.4	11.7	9.3
A. auriculiformis	Guinea	21.6	19.8	16.4	13.3
	Thin Napier	21.8	18.2	13.5	12.8
	Setaria	21.3	15.7	13.7	12.4
	Mean	21.6	17.9	14.5	12.8
S. saman	Guinea	26.5	26.2	21.2	14.5
	Thin Napier	25.8	25.8	20.7	13.7
	Setaria	24.9	25.6	20.5	12.9
	Mean	25.9	25.7	20.8	13.7

Table 2: Chlorophylll content of different grasses under canopy of tree species in silvipastoral system, (SPAD unit) Mean Data of 2018 and 2019

Treatments	August		September		October		November	
	SPAD	**%**	**SPAD**	**%**	**SPAD**	**%**	**SPAD**	**%**
A. mangium+Guinea	48.5	95.8	47.7	95.8	45.3	97.0	44.7	105.0
A. mangium+T Napier	47.4	95.7	45.6	95.6	43.9	96.2	42.2	104.4
A. mangium+Setaria	44.6	95.5	42.8	95.5	41.2	96.0	40.0	104.7
A. auriculiformis+Guinea	48.2	95.3	47.3	95.0	44.9	96.1	43.8	102.8
A. auriculiformis+T Napier	45.7	92.3	43.6	91.4	43.3	95.0	41.5	102.7
A. auriculiformis+Setaria	44.3	94.9	42.4	94.6	41.0	95.6	39.1	102.3
S. saman+Guinea	49.1	97.0	47.0	94.3	44.2	94.6	43.2	101.4
S. saman+T Napier	45.8	92.5	44.3	93.0	43.1	94.5	40.9	101.2
S. saman+Setaria	43.3	92.7	42.0	94.0	40.4	94.1	38.6	101.0
Sole Guinea	50.6	100	49.8	100	46.7	100	42.6	100
Sole Thin Napier	49.5	100	47.7	100	45.6	100	40.4	100
Sole Setaria	46.7	100	44.8	100	42.9	100	38.2	100

Table 3: Soil moisture content (%) at different depth (cm) Mean Data of 2018 and 2019

Treatments	Aug		Sept		Oct		Nov		Dec	
	0-15	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
A.mangium+Guinea	11.6	12.8	10.5	11.2	9.8	10.2	6.7	6.9	5.1	5.5
A.mangium+T Napier	10.7	11.4	10.1	10.9	9.4	9.7	6.3	6.6	4.8	5.3
A.mangium+Setaria	10.2	10.9	9.6	10.0	9.1	9.5	5.9	6.4	4.2	4.7
Mean	10.8	11.7	10.1	10.7	9.4	9.8	6.3	6.6	4.7	5.2
A.auriculiformis+Guinea	10.2	11.1	9.8	10.3	9.3	9.8	6.1	6.3	4.5	4.8
A.auriculiformis+T Napier	9.5	10.3	8.9	9.5	8.4	9.0	5.8	6.0	4.3	4.7
A.auriculiformis+Setaria	9.2	9.8	8.4	9.1	8.2	8.6	4.9	5.4	3.8	4.1
Mean	9.6	10.4	9.0	9.6	8.6	9.1	5.6	5.9	4.2	4.5
S.saman+Guinea	9.8	10.5	8.3	9.7	8.0	8.5	5.3	5.7	4.0	4.3
S.saman+T Napier	8.6	9.5	7.6	8.2	7.6	8.1	4.7	5.1	3.3	3.5
S.saman+Setaria	8.4	9.1	6.8	7.4	7.4	7.9	4.2	4.8	3.1	3.5
Mean	8.9	9.7	7.6	8.4	7.7	8.2	4.7	5.2	3.5	3.8
Sole Guinea	13.2	14.8	11.6	12.5	10.2	10.7	5.4	5.9	3.6	4.0
Sole Thin Napier	12.4	13.7	11.2	12.0	9.6	10.2	5.1	5.5	3.2	3.6
Sole Setaria	12.2	12.8	11.0	11.8	9.4	9.9	4.8	5.2	2.9	3.1
Mean	12.6	13.8	11.3	12.1	9.7	10.3	5.1	5.5	3.2	3.6

Table 4: Growth of silvi trees in silvipastoral system, Mean Data of 2018 and 2019

Treatment Months After planting		Plant height (m)	DBH (cm)	Crown Spread (m)
		42	42	42
A. mangium	Guinea	11.6	10.7	4.3
	T. Napier	10.4	11.5	4.8
	Setaria	12.2	11.8	4.2
A. auriculiformis	Guinea	6.4	6.2	3.1
	T. Napier	6.1	5.9	3.6
	Setaria	7.0	6.8	3.9
S.saman	Guinea	3.8	3.7	1.7
	T. Napier	3.3	3.4	1.5
	Setaria	4.1	4.7	2.1
CD 5%		1.18	1.27	0.92

Table 5: Total System Biomass, Carbon Sequestration, Co_2 Assimilition.

Treatments		Total System Biomass (kg ha^{-1})	Carbon Sequestration (kg ha^{-1})	CO_2 assimilation (kg ha^{-1})
A. mangium	*Guinea*	10078	5039	18493
	T. Napier	13149	6574	24128
	Setaria	14177	7088	26014
A. auriculiformis	*Guinea*	4502	2251	8261.17
	T. Napier	4318	2159	7923.53
	Setaria	4930	2465	9046
S. saman	*Guinea*	1893	946.5	3473.65
	T. Napier	2316	1158	4249.86
	Setaria	3007	1503.5	5517.84

Conclusion

The study indicated that among silvipastoral systems *Acacia mangium* with Setaria (*Setaria glauca*) has more productive biomass and carbon sequestration potential. This system has lower solar radiation interception under its tree canopy with better soil moisture storage capacity also evidenced highest tree growth and grass production.

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