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Growth and biomass production of fodder trees and grasses in a silvipasture system on non-arable land of semi-arid India

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Abstract

Silvipasture experiment was conducted for five years (2010-11 to 2014-15) to find out the suitable tree grass combination for biomass production under rainfed condition of semi arid region of India. The treatments comprised of four fodder trees namely *Ficus infectoria*, *Madhuca latifolia, Morus alba, Acacia nilotica;* three grass species *viz*., *Cenchrus ciliaris*, *Chrysopogon fulvus, Panicum maximum* and two legumes *Clitoria ternatea* and *Stylosanthes seabrana.* The results showed maximum tree height (369.5 cm) and collar diameter (8.03 cm) in *A. nilotica*. The survival percentage is also higher (93%) in *A. nilotica* compared to others. Even though the total tree pruned biomass over five years was higher in *M. alba*, the *A. nilotica* produced maximum biomass in fifth year. The leaf fodder percentage in pruned biomass which indicates quality of forage is maximum (22.5%) in *M. latifolia* and minimum in *A. nilotica*. Among the grass species *P. maximum* produced higher biomass during five years followed by *C. fulvus*. Among legume species maximum forage biomass was recorded in *S. seabrana* due to enhanced biomass in the last three years compared to *C. ternatea*.

Keywords: Biomass, Degraded land, Fodder tree, Grass, Legumes, Silvipasture

Introduction

In India about 146.8 million hectares of the geographical area is degraded as per estimate of NBSS&LUP, 2004 (Bhattacharyya *et al.,* 20115). Tree based pasture system is recognized as indigenous agroforestry in dry areas of India (Roy, 2016). Silvipasture system is one of the means to rehabilitate such marginal/ non-arable/degraded lands. Bundelkhand region covers about 7.08 m ha in central part of India (Gupta *et al*., 2014) with about 35-70% area as rainfed (NRAA, 2012). Bundelkhand landscape is rugged, ravenous, undulating terrain with rocky outcrops, narrow valley and hillocks bound by Vindhyan Plateau. Soil of the region is predominantly blend of red and black soil with shallow depth, limited organic matter and poor moisture content. The rainfall pattern is erratic and irregular with average annual rainfall 906.5 mm (Singh *et al*., 2005). High undulating terrain of the region makes irrigation difficult and by end of each November, the area starts becoming dry. Incorporation of fodder trees with grasses is perceived as a climate change-resilient cropping system for farmers linking climate change mitigation with adaptation (Mbow *et al*., 2014). Animal production systems in the arid and semiarid regions are based on the use of forage grasses and they are characterized by their relatively low nutritive value and irregular availability due to the seasonal performance of rainfall and temperature in these regions. The silvopasture systems involving suitable multi-purpose trees specially fodder trees and range grass species provide resilience by ensuring continued and multiple outputs such as, forage, fuelwood, fibre and industrial raw material, besides other positive environmental effects. However, tree and crop based interaction has been reported by (Pandey *et al*., 2010) In addition, perennial crops have a higher potential for soil carbon (C) sequestration compared to annual crops, as a result of the continuous ground coverage, reduced soil disturbance and enhanced root biomass production (Jarchow *et al*., 2015). Complimentarily between tree and grass species grown in association as a multi-layered canopy is important for increased growth and biomass production. The synergies of tree-grass association need to be explored and exploited by evaluating different fodder tree species with combination of grass species under degraded soil and climatic condition. In many low input agro-ecosystems, grasses are intercropped with legumes since legumes have an importance as a primary source of nitrogen and improved soil fertility (Bhandari *et al.,* 2016). This study was planned to develop a silvipasture system with suitable tree and grass species on degraded land of semi arid condition.

Materials and Methods

Location and climate: The study was carried out at the Research Farm of ICAR-Indian Grassland and Fodder

Research Institute, Jhansi during 2010-11 to 2014-15. The study site represents typical Bundelkhand region as soil is coarse with gravelly texture, reddish to brownish in colour, depth varies from 1-2 inches to about 2 feet with parent rock, poor productivity coupled with no irrigation facility and non arable land at latitude 25.27° and longitude 75.35° with altitude of 275 amsl, in the central part of India. The climate of study site is semi arid, undulated topography with average annual rainfall of around 906 mm. Soil pH ranges between 6.2 to 7.8 and organic matter content is 0.3 to 0.5 percent. Soil nutrient ranges between nitrogen 140-173, phosphorus 5.94 – 15.84 and potash 57-170 kg/ha.

***Experimental details*:** Four native fast growing fodder trees namely *Ficus infectoria*, *Madhuca latifolia*, *Morus alba* and *Acacia nilotica* occurring naturally in most of arid and semiarid region were selected for suitability as round the year fodder availability (fodder from August to February from grasses and from March to June from top leaf of tree lopping). Combination of three grass species *viz*., *Cenchrus ciliaris*, *Chrysopogon fulvus* and *Panicum maximum* and two legumes *Clitoria ternatea* and *Stylosanthes seabrana* were tried along with tree component to see their compatibility for higher biomass and quality. One year old seedlings of the each fodder tree were transplanted at the onset of rainy season in the month of July, 2010 at a spacing of 5 x 5 m in 1 x1x 1 m pits. A total of 144 plants were transplanted in each plot of size 60 x 60 m. Grasses and legumes were seeded in furrow of spacing of 45 cm in rows followed by gentle covering of seed in July of 2011. The seed rate of grasses, *S. seabrana* and *C. ternatea* were 2-3, 3- 4 and 8 kg/ha respectively. Three lines of grass and three lines of legume alternatively, were made between each rows of fodder tree. Thus, nine lines at spacing of 45 cm of grass and legume were maintained between one rows of each fodder tree. Split plot design was applied with three replications. Trees were kept in main plot, while grasses and legumes in sub plot. Life saving irrigations was provided to each fodder tree plant in prepared basin of 1.5 m diameter in the summer months from April to June and one irrigation in the month of January to avoid frost injury. Grasses and legumes were put to survive and produce yield only on rainwater. Gap fillings were done in third and forth years of transplanting during month of July. However, they were not considered for data recording. Fodder tree plants were pruned once (December) in year to provide good architecture during initial growth period. During fourth year (2013-14), *M. alba* was pruned two times (December 2013 and August 2014 due to its faster growth.

***Data recording and analysis*:** Growth parameters of the trees *viz*., per cent survival, collar diameter (cm), height (m), crown spread (north-south and east-west directions) were measured every year once in December. Biomass of forage from grass and legumes was recorded at the time of harvesting. Grasses and legumes were harvested twice every year in September and December uniformly at 20 cm above ground. Fodder tree branches were pruned to provide good architecture of plant as and when required and weighed for pruned biomass. Wood and leaves ratio of pruned biomass was calculated by separate leaves from branches. Data were statistically analyzed following SPSS13 (www.iasri.res.in/design).

Results and Discussion

***Fodder tree survival*:** The tree survival varied from 97.9 to 98.8 percent during 2010-11 in the year of transplanting. Mortality varying from 11.1 % in *M. latifolia* to 1.6 % in *A. nilotica* was observed in second year. In the fifth year (2014-15) of observation, highest 93.1 percent was recorded in *A. nilotica* which was significantly better than *M. alba* (88.2) and least survival of *M. latifolia* (80.6) percent (Table1).

Table 1. Fodder tree survival percent

Tree species	Survival percentage				
	2010 -11	2011 -12	2012 -13	2013 -14	2014 -15
F. infectoria	98.8	97.7	93.8	86.6	86.3
M. latifolia	97.9	88.9	88.6	88.3	80.6
M. alba	98.6	91.4	90.5	88.2	88.2
A. nilotica	98.4	98.4	97.9	93.1	93.1
C D>0.5	N/A	3.7	5.1	5.1	6.8
SE(m)	1.5	1.0	1.4	1.2	1.9

***Tree height and collar diameter*:** The fodder tree height (cm) and collar diameter (cm) indicated that year wise tree height and collar diameter is higher in *A. nilotica* followed by *M. alba*, *F. infectoria* and *M. latifolia*. In the fifth year, plant height (cm) and collar diameter (cm) were 369.5 and 8.03 for *A. nilotica*, 266.2 and 5.83 for *M. alba,* respectively (Fig 2 and 3). Fodder tree, *M. alba* had wide adoptability in temperate to tropical climate. Yadav *et al*. (2014) also observed that *A. nilotica* found best in degraded land and improve soil quality of silvipasture system. *M. latifolia* though survive in semiarid climate but during establishment phase it requires sufficient moisture as have wide leaves which evaporate more water. Reason for higher plant mortality may be the soil of experimental site has more gravel and the water holding capacity is less. Plant mortality was higher during 2011 - 12 and 2013 - 14 because of delayed monsoon coupled with high temperature during month of May and June. Samir and Mohamed (2011) from Sudan reported that Acacia tree is a dominant species under reduced rain. Wani and Ahmad (2013) reported that considerable genetic differences exist in all the important characters of germination and seedling growth among genotypes of genus *Madhuca*. Maximum tree height and collar diameter observed in *Acacia nilotica* and lowest in *Madhuca latifolia* clearly indicates that under poor soil condition and low rainfall, *Acacia nilotica* perform better than *M. latifolia*. Both *F. infectoria* and *M. latifolia* are considered as slow growing plant in India in initial period of establishment and the gestation period is more than other fodder trees tested.

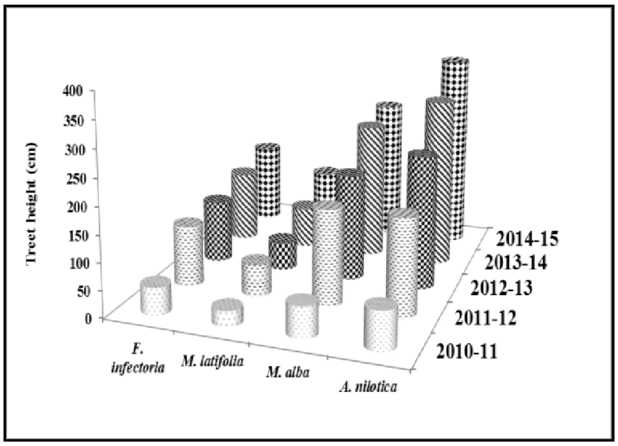

Fig. 1. Tree height

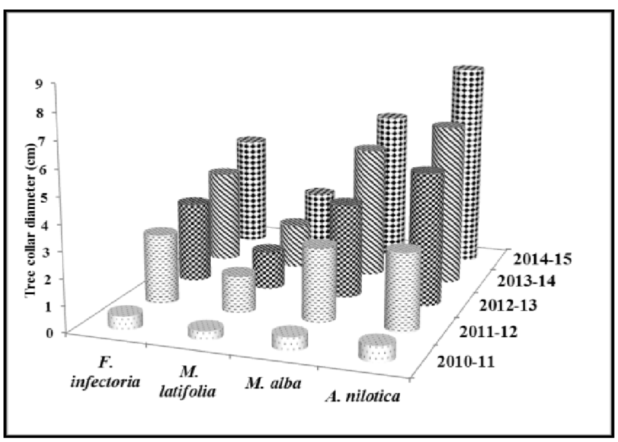

Fig. 2. Collar diameter

***Contribution (%) of fodder in pruned biomass*:** Pruned biomass of fodder trees showed that among all tree species, *M. alba* provided higher biomass in the year 2012-13 and 2013-14 which was 0.54 and 1.89 t/ha respectively. However in the fourth year *i.e.* in 2014-15, *A. nilotica* had a maximum of 3.04 t/ha followed by *M. alba* (Fig 3). Leaf fodder and hardwood ratio of pruned biomass of tree species indicated that *M. latifolia* had maximum leaf fodder (22.5%) in pruned biomass (Fig 4). Higher pruned biomass obtained from *Acacia nilotica* may be due to differences in fodder tree species growth pattern. Higher leaf fodder obtained from *Madhuca latifolia* and least from *Acacia nilotica*, is due to difference in percentage of wood in their total biomass. Less leaf is also a characteristic feature of arid region plant of *Acacia*, which needs low evaporation for their survival. *M. latifoia* plant has long and wider leaf and less woody portion in their total biomass. Datt et al. (2008) have observed different potential of different fodder trees.

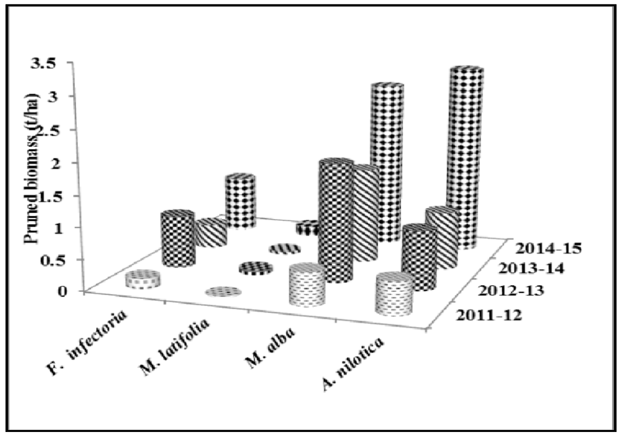

Fig 3. Pruned biomass of fodder tree

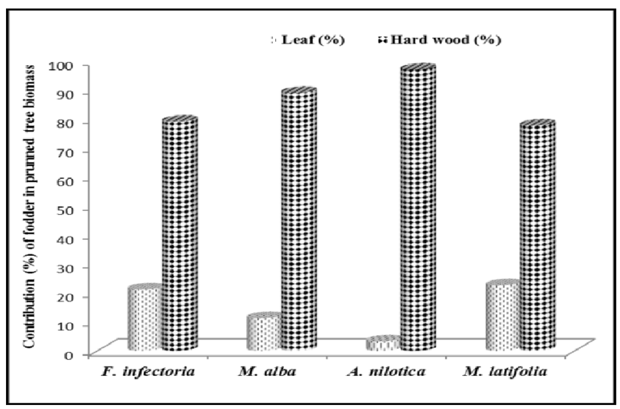

Fig 4. Fodder percentage of pruned biomass

***Grass production*:** Forage production from grass and legume species with different fodder tree combination were presented in table 2. The increasing trend in grass production was observed from first year to third year of grass growth. Among grasses, *P. maximum* produced higher forage yield than *C. fulvus* and *C. ciliaris* over the years. Boyer *et al*. (2013) reported that soil type and landscape has effect on biomass production of perennial grasses. Among legumes, higher mean yield was recorded in *C. ternatea* in comparison to *S. seabrana* during 2011-12. However, during 2012-13, 2013-14 and

Table 2. Forage production from tree, grass and legume based silvipasture system

Tree/grass	Forage production (t/ha)					
	2011-12					
	C. fulvus	*P. maximum*	*C. ciliaris*	*C. ternatea*	*S. seabrana*	Mean
F. infectoria	3.20	6.80	2.30	4.65	2.58	**3.90**
M. latifolia	3.30	5.70	2.10	4.30	2.41	**3.56**
M. alba	7.50	7.80	2.50	5.80	2.60	**5.25**
A. nilotica	7.60	6.93	2.70	5.70	6.50	**5.88**
Mean	**5.40**	**6.81**	**2.40**	**5.11**	**3.52**	
		CD>0.05	SEM			
Tree (A)		1.33	0.37			
Grass/legume (B)		1.08	0.37			
B at same level of A		2.28	0.84			
A at same level of B		2.34	0.77			
			2012-13			
F. infectoria	7.30	12.33	2.76	5.40	4.31	**6.42**
M. latifolia	8.86	12.90	3.40	4.36	6.46	**7.20**
M. alba	8.20	11.26	3.20	5.43	4.53	**6.52**
A. nilotica	6.76	11.53	4.56	5.43	7.40	**7.14**
Mean	**7.78**	**12.01**	**3.48**	**5.15**	**5.67**	**6.42**
		CD>0.05	SEM			
Tree (A)		0.42	0.12			
Grass/legume (B)		0.47	0.16			
B at same level of A		0.97	0.26			
A at same level of B		0.94	0.31			
			2013-14			
F. infectoria	8.23	8.53	3.00	6.00	5.26	**6.20**
M. latifolia	8.76	8.89	2.16	2.90	5.60	**5.66**
M. alba	10.36	15.00	3.16	4.08	4.63	**7.45**
A. nilotica	15.46	10.35	3.60	2.40	3.60	**7.08**
Mean	**10.70**	**10.69**	**2.98**	**3.84**	**4.77**	
		CD>0.05	SEM			
Tree (A)		0.25	0.07			
Grass/legume (B)		0.45	0.15			
B at same level of A		0.92	0.16			
A at same level of B		0.85	0.29			
			2014-15			
F. infectoria	15.34	19.06	5.56	4.34	10.53	**10.97**
M. latifolia	9.30	16.80	6.46	3.53	8.35	**8.88**
M. alba	16.96	21.43	5.43	3.78	9.18	**11.35**
A. nilotica	9.83	18.33	5.60	3.50	7.50	**8.95**
Mean	**12.86**	**18.90**	**5.76**	**3.78**	**8.89**	
		CD>0.05	SEM			
Tree (A)		0.66	0.18			
Grass/legume (B)		0.93	0.32			
B at same level of A		1.91	0.42			
A at same level of B		1.80	0.60			

2014-15, higher forage yield was obtained from *S. seabrana* in comparison to *C. ternatea* (Table 2). Similarly in legume, mean forage production with all fodder tree combination during initial year 2011-12, *C. ternatea* had higher production (5.11 t DM/ha) than *S. seabrana* (3.52 t DM /ha), while in 2012-13, 2013-14 and 2014-15, *S.*

seabrana produced higher forage yield. Similar trend was observed in *M. latifolia*, *M. alba* and *A. nilotica* based silvipasture system. *P. maximum* had higher biomass among all the grass tested. Among legume species, *Clitoria ternatea* yielded higher forage during initial years of sowing than *Stylosanthes seabrana.* However after two years *S. seabrana* produced more yield. Differences in forage yield among legume forage species may be due to its genetic potential and competitive ability. Higher forage production of *S. seabrana* along with *P. maximum* in third and fourth years of sowing is due to its regeneration potential and increased number of branches due to harvesting by cutting. Ram and Trivedi (2016) have reported similar findings. Carlsson *et al*. (2017) reported that perennial species mixtures managed with low inputs promote synergies between productivity and biodiversity and multifunctional biomass production. In comparison of silvipasture system for higher biomass production from tree leaves (pruned biomass) and forage from grass and legume, the fodder tree *M. alba* in combination of *P. maximum* as grass fodder and *S. seabrana* as legume fodder was found best combination.

Conclusion

The results showed that in non-arable land *A. nilotica* had higher tree survival (93.1%) and growth in term of plant height and collar diameter. The *Morus alba* tree species has consistently higher pruned biomass and among grasses, *P. maximum* had higher mean forage production potential under rainfed condition. Similarly, among legume species maximum forage biomass was recorded in *S. seabrana*. The best tree pasture combination for higher forage yield (>10 t/ha) is *Morus alba*/ *F. infectoria* with *P. maximum* and *S. seabrana* under rainfed conditions in non-arable lands.

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