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Influence of shrubs and tree densities on three-tier silvopasture components in semiarid rainfed conditions

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Abstract
A field experiment was conducted (2011-17) on sandy loam soil at Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi to study the influence of shrubs and tree densities on three-tier silvopasture components in semiarid rainfed conditions. The experiment consisted of nine treatment having three shrub species and three planting densities of shrubs and tree. Study revealed that *Ziziphus mauritiana* attained significantly higher height (2.78 m) as compared to *Acacia catechu* (2.49 m) and *Ziziphus xylopyrus* (2.32 m) during 6th year. Total top feed and fuel wood obtained from pruning of *Ziziphus mauritiana* and *Hardwickia binata* (0.363 and 0.423 t/ha) were also significantly higher as compared to *Ziziphus xylopyrus* (0.333 and 0.383 t/ha) and *Acacia catechu* (0.313 and 0.363 t/ha). Planting of *Hardwickia binata* and shrubs at 6 x 6 m spacing in three tier silvopasture system resulted in significantly higher dry forage (5.58 t/ha) and crude protein yield (542.5 kg/ha) of *Cenchrus ciliaris* and *Stylosanthes seabrana* intercropping system as compared to 6 x 4 m (5.43 t/ha and 529.2 kg/ha) and 4 x 4 m spacing (5.31 t/ha and 512.6 kg/ha), respectively. Net return (Rs. 14278/ha) and B:C ratio (1.99) were also significantly increased by planting of *H. binata* and shrubs at 6 x 6 m spacing as compared to 6x4 m (Rs. 13722/ha and 1.93) and 4 x 4 m spacing (Rs. 12420/ha and 1.78).

Keywords: *Cenchrus ciliaris, Hardwickia binata,* Shrub species, Silvopasture system, *Stylosanthes seabrana*

Introduction

In India grazing lands are generally poor in forage availability and productivity. The free and uncontrolled grazing has resulted in extensive damage to such lands. Hence, on such degraded lands efforts should be made to bring them to potential level of production through development of three-tier silvopasture systems. Development of silvopasture system on wastelands, undulating lands, degraded forest lands and industrial waste lands provides pasture yield during monsoon season and top feed during lean seasons ((Ram *et al.,* 2016; Kumar *et al.,* 2017) . The leaf fodder obtained from trees serve as an insurance against fodder scarcity during drought to the livestock. The silvopasture system provides even more benefits of resource conservation. In hot arid and semiarid regions, drought is the recurring phenomenon, establishment of suitable drought hardy trees, shrubs, grasses and legumes are recommended to increase system productivity, enhancing fodder availability and checking soil erosion (Soni *et al*., 2006; 2013; Sharma, 2014). Drought hardy shrubs and tree provide green fodder during lean period, fuel wood etc and also play important ecological role *i.e.* arresting soil erosion, phyto-remediation of degraded soils besides the micro-climate modification for creating favourable condition for associated flora and fauna. Optimum plant density is primarily a function of the growth potential of the site and the management practices. Though yield per unit area can be substantially greater at higher plant population (Shinde *et al*., 2007), poor availability of water and nutrients may limit the productivity. Plant density affects canopy closure, growth rates, rotation age, wood production, silvocultural and harvesting operations (Singh *et al*., 2004).

Hardwickia binata Roxb. is a deciduous tree with drooping branchlets. Tree provides good quality nutritious green fodder during lean period. It yields an extremely hard, heavy and durable timber (Roy, 1996) and rich fodder in terms of crude protein (Singh, 1982). This tree can thrive in dry areas and can even withstand for prolonged drought. Therefore, *Hardwickia binata* offers an excellent production potential from the degraded lands. In arid and semiarid regions shrubs and trees provides fodder in drought situation. In view of this the present study was carried out to study the influence of shrubs and tree densities on three-tier silvopasture components in semiarid rainfed conditions.

Materials and Methods

Experimental site: A study was carried out to study the effect of shrubs and tree densities on performance of three-tier silvopasture systems in semiarid rainfed conditions at Central Research Farm (25^0 27' N, 78^0 37' E and 275 m a. m. s. l.) of ICAR-Indian Grassland and Fodder Research Institute, Jhansi. The soil of the experimental field was sandy loam, low in organic carbon (0.397%), available nitrogen (166.34 kg ha^{-1}) and phosphorus (6.82 kg ha^{-1}) and medium in available potash (154.54 kg ha^{-1}). The region receives an annual rainfall of 906.5 and annual potential evapotranspiration of 1512 mm (Singh *et al*., 2007). The total rainfall received was 1087.8, 789.3, 1510.8, 651.9, 713.3 and 827 mm in 54, 50, 71, 43, 48 and 41 rainy days during 2011, 2012, 2013, 2014, 2015 and 2016, respectively. The experimental field was stony with shallow soil depth and infested with unpalatable and unwanted bushes.

***Experimental details*:** Experiment was conducted with nine treatment combinations that were replicated thrice in split plot design. The treatment consisted of establishment of three shrub species in association with *H. binata viz., Ziziphus xylopyrus*, *Z. mauritiana* and *A. catechu* and three planting densities of each shrubs and tree *viz.,* 312, 208 and 139 at planting spacing of 4 x 4 m, 6 x 4 m and 6 x 6 m. These treatments were imposed in experimental field during July 2011. Five months old poly-bags raised seedlings of *H. binata*, *Z. xylopyrus*, *Z. mauritiana* and *A. catechu* were planted as per treatment in plot size of 24 x 24 m in field during monsoon season. Basins of one meter diameter were made at the base of tree seedlings and life saving water was applied to the seedlings during the summer season in initial years of establishment. The seedlings of *Cenchrus ciliaris* was planted during monsoon season at 100 x 50 cm spacing and seeds of *Stylosanthes seabrana* @ 4 kg/ha was sown in line between two rows of *C. ciliaris* in association with shrub species and *Hardwickia binata*. Fertilizer were applied at the rate of 40 kg N, 30 kg phosphorus and 30 kg potash/ha in each year after onset of monsoon. The *H. binata* and *Z. xylopyrus*, *Z. mauritiana* and *A. catechu* were pruned once every year from second year onward during November-December for proper growth and form.

Sampling and methods of analysis*:* Pruned yields of shrub species and *H. binata* were recorded during 6^{th} year of the experiment and their growth parameters were measured every year in the month of November-December. *Cenchrus. ciliaris* and *S. seabrana* were harvested manually at 15 cm above the ground surface in second fortnight of September in each year. Fodder yield and growth parameters of grass and legume were recorded at the time of harvesting. Dry matter yield was computed by drying 500 g plant sample of each treatment and replication in hot-air oven at 70^0C. The crude protein content of the fresh samples was estimated following the standard procedure of AOAC (1995).

Results and Discussion

***Growth parameters of shrub species and H. binata*:** Growth parameters of six year old shrub species were varied significantly among shrubs. *Z. mauritiana* attained significantly higher height (2.78 m) as compared to *Acacia catechu* (2.49 m) and *Z. xylopyrus* (2.32 m). However, in collar diameter *Acacia catechu* (4.64 cm) recorded significant difference over *Z. mauritiana* (4.08 cm) and *Z. xylopyrus* (4.20 cm). Planting densities of shrubs and tree did not significantly affect the growth parameters of both shrub species and *H. binata* (Table 1).

***Growth parameters of pasture components*:** Pooled data of six year showed that growth parameters of pasture components did not vary significantly by different shrub species (Table 2). However, planting of *H. binata* and shrub species at 6 x 6 m spacing in three-tier silvopasture system resulted in significantly higher height (122.4 cm), number of tillers/plant (75.3) and tussock diameter (33.6 cm) of *C. ciliaris* as compared to 4 x 4 m spacing (height-116.0 cm, number of tillers/plant-70.3 and tussock diameter-31.1cm). Similarly, height (79.5 cm) and branches/plant (6.12) of *S. seabrana* were also significantly increased under 6 x 6 m planting spacing of *H. binata* and shrub species than 4 x 4 m spacing (height-74.6 cm and branches/plant-5.52). The higher growth parameters of pasture components at low density of tree and shrubs was probably due to less competition for moisture, nutrients, light and space as compared to high density. Similar findings were also reported earlier by Singh and Pathak (1993).

***Dry forage yield of pasture*:** Pooled data of six year showed that dry forage yields of both *C. ciliaris* and *S. seabrana* were not influenced significantly by different shrub species (Table 3). However, planting of *H. binata* and shrub species at 6 x 6 m spacing in three-tier silvopasture system resulted in significantly higher dry forage of *C. ciliaris* and *S. seabrana* intercropping system (5.58 t/ha) as compared to 6 x 4 m (5.43 t/ha) and 4 x 4 m spacing (5.31 t/ha). Contribution of *S. seabrana* in total forage yields (5.44 t/ha) was 37.13%. The higher yield of

Table 1. Growth parameters of shrubs and *H. binata* in three-tier silvopasture systems under different treatment (2016-17)

Treatment	Shrubs		*H. binata*	
	Height (m)	Collar diameter (cm)	Height (m)	Collar diameter (cm)
Shrub species				
Z. xylopyrus	2.32	4.20	2.35	3.48
Z. mauritiana	2.78	4.08	2.41	3.56
A. catechu	2.49	4.64	2.34	3.50
SEm±	0.06	0.06	0.02	0.03
CD (P=0.05)	0.23	0.25	NS	NS
Spacing (m)				
4 x 4	2.13	4.30	2.35	3.51
6 x 4	2.19	4.37	2.42	3.57
6 x 6	2.10	4.25	2.34	3.47
SEm±	0.03	0.05	0.03	0.03
CD (P=0.05)	NS	NS	NS	NS

Table 2. Effect of shrubs species and spacing on growth parameters of pasture components in three-tier silvopasture systems (pooled data of 6 years)

Treatment	*Cenchrus ciliaris*			*Stylosanthes seabrana*	
	Height (m)	Tillers/plant	Tussock diameter (cm)	Height (m)	No. of branches /plant
Shrub species					
Z. xylopyrus	119.3	72.6	32.3	76.8	5.78
Z. mauritiana	120.51	74.1	32.9	77.7	5.94
A. catechu	118.3	72.2	32.1	76.9	5.66
SEm±	0.7	0.4	0.3	0.4	0.07
CD (P=0.05)	NS	NS	NS	NS	NS
Spacing (m)					
4 x 4	116.0	70.3	31.1	74.6	5.52
6 x 4	119.6	73.3	32.6	77.3	5.71
6 x 6	122.4	75.3	33.6	79.5	6.12
SEm±	0.9	0.8	0.4	0.6	0.17
CD (P=0.05)	2.9	2.4	1.2	1.8	0.52

pasture (5.58 t/ha) at wider spacing revealed that there was less competition of tree and shrubs on pasture species at low densities (139 each tree and shrubs/ha). Khan *et al*. (2000) also concluded that in *A. tortilis* associated silvopasture system recorded higher forage yield of *C. ciliaris* and *S. hamata* at wider spacing as compared to narrow spacing. Gill and Ajit (2004) reported that as the tree densities increased the relative crop yields decreased. Keshwa and Singh (2004) also observed reverse trend in yield of *C. ciliaris* with the decrease in row spacing of *Dichrostachys cinerea.*

***Crude protein yield*:** Pooled data of six year showed that establishment of different shrub species in three-tier silvopasture systems were also not significantly affected the crude protein yields of pasture components (Table 3). However, crude protein yields of both *C. ciliaris* (276.1 kg ha^{-1}) and *S. seabrana* (266.4 kg ha^{-1}) were increased significantly when shrub species and *H. binata* were planted at 6 x 6 m spacing (267.2 kg ha^{-1}) as compared to 6 x 4 m (267.2 and 261.9 kg ha^{-1}) and 4 x 4 m spacing (261.5 and 251.1 kg ha^{-1}), respectively. This might be due to optimum availability of space, moisture, nutrients and light to *C. ciliaris* and *S. seabrana* at wider spacing of tree and shrubs which resulted in higher dry matter yield and crude protein yield as compared to narrow spacing.

***Pruned yield of shrubs and H. binata*:** Top feed and fuel wood obtained from pruning of six year old *Z. mauritiana* and *H. binata* (0.363 and 0.423 t/ha) were significantly higher as compared to *Z. xylopyrus* (0.333 and 0.383 t/ha) and *A. catechu* (0.313 and 0.363 t/ha). However top feed and fuel wood obtained from *H. binata* were not

Table 3. Effect of shrubs species and spacing on dry forage and crude protein yields of pasture in three-tier silvopasture systems (pooled data of 6 years)

Treatment	Dry forage yield (t/ha)			Crude protein yield (kg/ha)		
	C. ciliaris	*S. seabrana*	Total	*C. ciliaris*	*S. seabrana*	Total
Shrub species						
Z. xylopyrus	3.41	2.02	5.43	266.7	258.4	525.2
Z. mauritiana	3.45	2.04	5.49	272.5	265.8	538.2
A. catechu	3.39	2.00	5.39	265.7	255.2	520.8
SEm±	0.02	0.02	0.02	1.8	2.8	4.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Spacing (m)						
4 x 4	3.35	1.96	5.31	261.5	251.1	512.6
6 x 4	3.41	2.02	5.43	267.2	261.9	529.2
6 x 6	3.50	2.08	5.58	276.1	266.4	542.5
SEm±	0.04	0.01	0.02	2.7	0.98	3.4
CD (P=0.05)	0.13	0.03	0.07	8.5	3.1	10.5

Table 4. Dry top feed, fuel wood, net return and B: C ratio as influenced by shrubs species and spacing in three-tier silvopasture systems (2016-17)

Treatment	Top feed (t/ha)			Fuel wood (t/ha)			Net return (Rs/ha)	B:C ratio
	Shrubs	*H. binata*	Total	Shrubs	*H. binata*	Total		
Shrub species								
Z. xylopyrus	0.190	0.143	0.333	0.207	0.167	0.383	13428	1.89
Z. mauritiana	0.210	0.153	0.363	0.235	0.177	0.423	13858	1.92
A. catechu	0.170	0.143	0.313	0.197	0.157	0.363	13134	1.88
SEm±	0.005	0.002	0.007	0.007	0.004	0.010	132	0.01
CD (P=0.05)	0.021	NS	0.028	0.029	NS	0.040	531	0.04
Spacing (m)								
4 x 4	0.260	0.197	0.457	0.300	0.223	0.523	12420	1.78
6 x 4	0.180	0.137	0.317	0.207	0.160	0.367	13722	1.93
6 x 6	0.130	0.107	0.237	0.133	0.117	0.280	14278	1.99
SEm±	0.004	0.005	0.007	0.005	0.008	0.009	234	0.02
CD (P=0.05)	0.011	0.016	0.021	0.015	0.026	0.027	730	0.05

significantly affected by different shrub species (Table 4). Shukla *et al*. (1998) also observed that *Z. mauritiana* was a hardy shrub and could be grown successfully with grasses under semiarid rainfed condition. Planting of *H. binata* and shrub species at 4 x 4 m spacing recorded significantly higher total top feed (0.457 t/ha) and fire wood (0.523 t/ha) than 6 x 4 m (0.317 and 0.367 t/ha) and 6 x 6 m spacing (0.237 and 0.280 t/ha) respectively. Jat *et al*. (2004) also observed positive relation between tree density and top feed production of *H. binata*.

***Economic returns*:** Net return and B:C ratio were influenced significantly by different treatment (Table 4). Planting of *H. binata* and shrub species at 6 x 6 m spacing in three-tier silvopasture system recorded significantly higher net return (Rs. 14278/ha) and B:C ratio (1.99) as compared to 6 x 4 m (Rs. 13722/ha and 1.93) and 4 x 4 m spacing (Rs. 12420/ha and 1.78) respectively in six year of establishment. The higher net returns and B:C ratio from planting of *H. binata* and shrub species at 6 x 6 m spacing in three-tier silvopasture system was due to higher forage yield obtained from this treatment and also the less cost.

Conclusion

Based on initial years of study it may be concluded that planting of *H. binata* and *Z. mauritiana* at 6 x 6 m spacing in three-tier silvopasture system in sandy loam soil recorded maximum dry forage yield, crude protein yield, net return and B:C ratio closely followed by 6 x 4 m spacing under semiarid rainfed conditions. Among shrub species *Z. mauritiana* recorded highest growth attributes, top feed and fuel wood followed by *Z. xylopyrus* in three-tier silvopasture system.

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