Range Mgmt. & Agroforestry 37 (2) : 222-227, 2016
ISSN 0971-2070

Effect of moisture conservation practices on performance of Anjan (*Hardwickia binata*) tree based silvipasture systems

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Received: 26th December, 2015 Accepted: 2nd September, 2016

Abstract

A field experiment was conducted to study the effect of moisture conservation practices on performance of *Hardwickia binata* based silvipasture systems in semi arid rainfed conditions. The treatment was consisted of establishment of three grasses *viz*., *Cenchrus ciliaris, Chrysopogon fulvus* and *Panicum maximum* and construction of three mechanical practices for moisture conservation *viz.,* staggered trenches (2x0.5x0.5m), bunding and control (without bunds and staggered trenches). Construction of staggered trenches recorded significantly higher height (1.62, 2.59, 3.03 and 4.22 m) and collar diameter (2.48, 5.44, 6.70 and 9.14 cm) during 1st, 2nd, 3rd and 4th years of study and diameter at breast height (4.61 and 7.01 cm) and canopy spread (1.75 and 2.20 m) of *H. binata* during 3rd and 4th years of study respectively as compared to control. Staggered trenches also recorded significantly higher dry leafy forage yields (0.29 and 0.44 t ha^{-1}) and fire woods (0.35 and 0.49 t ha^{-1}) of *H. binata* as compared to control (leafy forage 0.23 and 0.36 and fire wood 0.25 and 0.36 t ha^{-1}) in 3rd and 4th years of study, respectively. In pasture yield, intercropping of *Panicum maximum* with *Stylosanthes hamata* in association with *H. binata* produced significantly higher dry forage yield (5.10-8.26 t ha^{-1}) as compared to intercropping of *Chrysopogon fulvus* and *Cenchrus ciliaris* with *S. hamata*. Construction of bunds resulted in significantly higher total crude protein yields from pasture (457.0-711.4 kg ha^{-1}) than control treatment. This also recorded maximum moisture content (7.79-9.28% at 15 cm soil depth and 8.03-11.73% at 30 cm soil depth during October-April) closely followed by staggered trenches.

Keywords: *Cenchrus ciliaris, Chrysopogon fulvus, Hardwickia binata,* Moisture conservation practices, *Panicum maximum, Stylosanthes hamata*

Introduction

Adoption of silvipasture systems on wastelands, undulating lands, degraded forest lands and industrial waste lands offers an extra yield of grasses during monsoon season and top feeds during summer seasons without any significant effect on trees growth. Leaf fodders from the hardy trees and shrubs serve as an insurance against fodder scarcity during drought to the livestock. The silvipastoral systems entail even more benefits of resource conservation. Planting trees either on the field boundary or in rows in association with grasses provides valuable leaf fodder during scarcity or lean period (Gill, 2003). In arid and semi-arid rainfed condition livestock production is secondary enterprise for marginal, small and medium farmers (Raturi and Hiwale, 1993) and about 65-75 % expenditure is being incurred in feeds and fodder resources (Singh, 2009). In arid and semi-arid regions water is again an important input and *in-situ* moisture conservation is a tool to provide regular moisture to root zone for proper growth and development of silvipasture systems.

Under rainfed conditions, productivity of silvipasture system is often poor because of dominance of low yielding annual grasses and lack of moisture. In this context, introduction of suitable grasses in association with tree and construction of mechanical measures for moisture conservation can play a vital role in improving the productivity of wastelands. Yadav and Bhushan (1989) reported that in wasteland areas low cost mechanical practices may be adopted for moisture conservation. Anjan (*Hardwickia binata* Roxb.) tree belongs to the family Leguminocae sub-family Caesalpinioideae and considered to be an important multipurpose tree species in semi-arid conditions of India. It provides extremely hard, heavy and durable timber in addition to high quality fuel-wood (Roy, 1996) and quality fodder in terms of crude protein (Singh, 1982). In view of this the present study was carried out to record the effect of moisture conservation practices on performance of *Hardwickia binata* based silvipasture systems in semiarid rainfed conditions.

Materials and Methods

Experimental site and designing: A field experiment was conducted during 2009-2013 at Central Research Farm (25^0 27' N latitude, 78^0 37' E longitude and 275 m above mean sea level) of Indian Grassland and Fodder Research Institute, Jhansi. Soil of the experimental field was sandy loam comprising sand 50.75%, silt 20.64% and clay 28.61%, low in organic carbon (0.46%), available nitrogen (225.77 kg ha^{-1}) and phosphorus (8.54 kg ha^{-1}) and medium in available potash (230.51 kg ha^{-1}). The total rainfall received was 544.9, 684.1, 1077.7 and 859.7 mm in 33, 32, 54 and 53 rainy days during 2009, 2010, 2011 and 2012 respectively. There were 9 treatment combinations replicated thrice in randomized block design. The treatment consisted of establishment of three grasses *viz*., *Cenchrus ciliaris, Chrysopogon fulvus* and *Panicum maximum* and construction of three mechanical practices for moisture conservation *viz*., staggered trenches (2x0.5x0.5m), bunding and control (without bund and staggered trenches). Trench to trench horizontal and vertical distance was 5.5 m and 4.0 m, respectively. These treatments were imposed in experimental field during July 2009. Before laying out the experiment, all the bushes were uprooted and one operation with disc plough followed by two operations with disc harrow were done and thereafter all the vegetation were removed. Five months old poly-bags raised saplings of *H. binata* were planted at a distance of 6 x 6 m in field during monsoon season and maintained 24 plants in each plot. Gross and net plot size was 36 x 24 m and 24 x 12 m, respectively. Six lines of grass and 5 lines of legume were fitted in between of two rows of tree. 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 grasses were transplanted in second week of July 2009 at 100 x 50 cm spacing and *Stylosanthes hamata* seeds (@ 4 kg/ha) were sown in line between two rows of grasses in association with *H. binata*. In fertilizers, 40 kg nitrogen, 30 kg phosphorus and 30 kg potash/ha were applied each year after onset of monsoon. Full amount of nitrogen, phosphorus and potash were broadcasted in the field after onset of monsoon rain in each year.

Sampling and methods of analysis: Harvesting of pasture was done at 50 % flowering stage in second fortnight of September in each year. The trees were pruned once every year from second year onward during November-December for proper growth, form and yield. Pruned yield was recorded during 3rd and 4th years of the experiment. Dry matter content was estimated by drying 500 g plant sample of each treatment and replication in hot-air oven at 70^0C, which led to computation of dry matter yield. Crude protein content of the fresh samples was estimated by the standard procedure of AOAC (1995). Moisture data was recorded by gravimetric method at 15 and 30 cm soil depth at two month interval during October-April. The data collected on various parameters were subjected to statistical analysis by applying the procedure given by Cochran and Cox (1970).

Results and Discussion

***Growth parameters of tree*:** Growth parameters of *H. binata* were not affected significantly due to establishment of different grasses in all the years (Table 1). Staggered trenches recorded significantly higher tree height (1.62, 2.59, 3.03 and 4.22 m) and collar diameter (2.48, 5.44, 6.70 and 9.14 cm) during 1st, 2nd, 3rd and 4th years of study and the same treatment also recorded highest values of diameter at breast height (4.61 and 7.01 cm) and canopy spread (1.75 and 2.20 m) of *H. binata* during 3rd and 4th years of study as compared to control treatment (without trenches and bunds). The higher growth of *H. binata* in staggered trenches might be attributed to sufficient moisture regime in the root zone of tree during establishment phase. Enhanced tree growth was also reported under staggered trenches by Shukla *et al.* (2014) in bael.

Growth parameters of pasture: *Panicum maximum* recorded significantly higher plant height (Table 2) as compared to *C. ciliaris* and *C. fulvus* when established in association with *H. binata.* While in case of number of tillers and tussock diameter no definite trend was observed. However, in 1st year *Panicum maximum* recorded significantly higher number of tillers/plant and tussock diameter and in 2nd year *C. ciliaris* attained maximum number of tillers/plant and tussock diameter. While in 3rd and 4th years number of tillers/ plant were maximum in *C. fulvus* and tussock diameter was highest in *Panicum maximum* during 3rd year. Variation in growth parameters of different species was mainly due to their characteristic nature and performance over the years under rainfed conditions. In moisture conservation

Table 1. Effect of grasses and moisture conservation practices on growth parameters of *Hardwickia binata*

Treatment	Height (m)				DBH (cm)		Pruned dry matter yield(t ha^{-1}) 2012-13		
	2009-10	2010-11	2011-12	2012 13	2011-12	2012-13	LFY	FW	Total
Grasses									
C. ciliaris	1.50	2.49	2.91	4.08	4.35	6.82	0.42	0.45	0.87
C. fulvus	1.49	2.40	2.78	4.01	4.28	6.73	0.40	0.43	0.83
P. maximum	1.36	2.31	2.87	4.05	4.16	6.35	0.39	0.41	0.80
SEM	0.05	0.07	0.06	0.08	0.09	0.16	0.01	0.02	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
MCP									
Control	1.28	2.23	2.75	3.88	3.98	6.34	0.36	0.36	0.72
Trenches	1.62	2.59	3.02	4.22	4.61	7.01	0.44	0.49	0.93
Bund	1.45	2.37	2.80	4.04	4.21	6.56	0.41	0.45	0.86
SEM	0.05	0.07	0.06	0.08	0.09	0.16	0.01	0.02	0.03
CD (P=0.05)	0.16	0.20	0.19	0.25	0.28	0.48	0.04	0.06	0.09

DBH: Diameter at breast height, MCP: Moisture conservation practices, LFY: Leafy forage yield, FW: Fire wood

Table 2. Effect of grasses and moisture conservation practices on growth parameters of pasture species (mean of 4 years)

Treatment	Grasses			*Stylosanthes hamata*	
	Height (m)	Tillers/plant	Tussock diameter (cm	Height (cm)	No. of branches/plant
Grasses					
C. ciliaris	117.7	50.0	24.8	47.8	6.1
C. fulvus	130.2	51.3	22.7	50.9	6.6
P. maximum	155.5	40.4	24.8	42.2	5.1
SEM	0.7	0.3	0.2	0.3	0.04
CD (P=0.05)	2.1	0.8	0.5	0.8	0.12
MCM					
Control	124.4	41.9	21.1	42.6	5.4
Trenches	137.0	48.9	25.0	48.0	6.3
Bund	143.0	51.4	26.2	50.3	6.5
SEM	0.7	0.3	0.2	0.3	0.04
CD (P=0.05)	2.1	0.8	0.5	0.8	0.12

MCP: Moisture conservation practices

practices, construction of bunds attributed to significantly higher growth in grasses and *S. hamata* as compared to control treatment (without bunds and trenches). This might be due to higher moisture content in the plots where bunds were constructed. In *S. hamata*, height and branches/plant were decreased significantly when intercropped with *Panicum maximum* as compared to intercropping with *C. fulvus* and *C. ciliaris* (Table 2). Decreased growth of *S. hamata* in association with *Panicum maximum* was might be due to vigorous growth of *Panicum maximum*.

***Pruned yield of tree*:** Pruned yield of *H. binata* also was not affected significantly due to establishment of different grasses. However, construction of staggered trenches recorded significantly higher dry leafy forage yields (0.29 and 0.44 t ha^{-1}) and fire woods (0.35 and 0.49 t ha^{-1}) in *H. binata* as compared to control treatment (leafy forage-

0.23 and 0.36 and fire wood- 0.25 and 0.36 t ha^{-1}) in 3rd and 4th years of study, respectively. Bunds also recorded significantly higher pruned yield in *H. binata* than control treatment. The higher pruned yield of *H. binata* in staggered trenches and bunds might be attributed to sufficient moisture regime in the root zone of tree in these plots.

Dry forage yield of pasture: Intercropping of *Panicum maximum* with *S. hamata* in association with *Hardwickia binata* produced (Table 3) significantly higher dry forage yields (5.10, 8.09, 8.16 and 8.26 t ha^{-1}) as compared to intercropping of *Chrysopogon fulvus* (3.26, 5.40, 5.92 and 6.27 t ha^{-1}) and *Cenchrus ciliaris* (4.24, 6.80, 7.12 and 7.52 t ha^{-1}) with *S. hamata* during 1st, 2nd, 3rd and 4th year, respectively. Malaviya *et al*. (2006) also reported highest dry matter yield of *Panicum maximum* ranged from 17.31 to 18.92 t/ha under different shades of *Leuceana leucocephala* and Kumar and Shukla (2010) reported 5.1 t ha^{-1} dry matter yield of *Panicum maximum* under ber plantation. In moisture conservation measures, construction of bunds resulted in significantly higher total dry forage yields from pasture (4.53, 7.41, 7.68 and 7.94 t ha^{-1}) than control treatment, which was without bunds and trenches (3.70, 5.79, 6.21 and 6.54 t ha^{-1}) during 1st, 2nd, 3rd and 4th year, respectively. Staggered trenches also had significantly higher pasture yield than control treatment. Construction of bunds had higher moisture contents than those without any bunds, which might have resulted in higher forage yield from these plots. Kumar and Shukla (2010) also observed significantly higher yield of *Panicum maximum* by construction of bunds than those without any bunds in ber based hortipasture system, while Shukla *et al.* (2010) observed that construction of staggered trenches resulted in higher pasture yields from bael based hortipasture system.

Crude protein yield: Crude protein yields (474.4 and 708.6 kg ha^{-1}) were also significantly higher when *S. hamata* intercropped with *Panicum maximum* than intercropping of *S. hamata* with *Chrysopogon fulvus* during 1st and 2nd year, respectively. However, during 3rd and 4th year intercropping of *S. hamata* with *Cenchrus ciliaris* had significantly higher crude protein yields than intercropping of *S. hamata* with *Chrysopogon fulvus,* respectively (Table 4). This was probably due to higher dry matter yield obtained by *Panicum maximum-S. hamata* intercropping system than *Chrysopogon fulvus-S. hamata* intercropping system during 1st and 2nd year, respectively. However, during 3rd and 4th year higher crude yields by intercropping of *S. hamata* with *Cenchrus ciliaris* were due to comparatively higher contributions (17.28 and 18.22%) of *S. hamata* in total dry matter yields than contributions (8.82 and 10.41%) in association with *Panicum maximum*. In moisture conservation practices, construction of bunds resulted in significantly higher total crude protein yields from pasture (457.0, 711.4, 686.7 and 710.1 kg ha^{-1}) than control treatment with no bunds and trenches (371.3, 564.5, 545.6 and 578.6 kg ha^{-1}) during 1st, 2nd, 3rd and 4th year, respectively. This was also due to higher dry matter yields obtained under bund treatment.

Soil moisture content: Establishment of *P. maximum* in association with *H. binata* recorded maximum moisture contents (8.74, 7.66, 7.67 and 8.49% at 15 cm soil depth and 11.23, 9.11, 7.94 and 9.90% at 30 cm soil depth during October-April) followed by *Cenchrus ciliaris* and *Chrysopogon fulvus* during 1st, 2nd, 3rd and 4th year, respectively. This might be due to dense vegetative cover of *Panicum maximum* in initial years which resulted in minimum runoff and higher infiltration in these plots. In mechanical practices, construction of bund recorded maximum moisture contents (9.28, 8.01, 7.79 and 8.35% at 15 cm soil depth and 11.73, 9.24, 8.03 and 9.82% at 30 cm soil depth) closely followed by staggered trenches. The higher moisture contents in bunds and staggered trenches might be due to minimum runoff and higher infiltration in these plots. Ahmed *et al.* (2014) also observed higher moisture contents in soils by construction of trenches in aonla based hortipasture system.

Economic returns: In 4th year of establishment of pasture, the highest net return (Rs 9556/ha) and net return per rupee invested (0.47) were obtained by intercropping of *Panicum maximum* with *S. hamata* in association with *H. binata*. Construction of bunds also recorded maximum net return (Rs 8730/ha) and net return per rupee invested (0.43). The higher net returns from intercropping of *Panicum maximum* with *S. hamata* in association with *H. binata* and construction of bunds was due to higher forage yields obtained from these treatments.

Conclusion

Based on four years study, it was concluded that intercropping of *Panicum maximum* with *Stylosanthes hamata* in association with *Hardwickia binata* along with construction of bunds across the slope in sandy loam soil yielded maximum dry forage from pastures closely followed by staggered trenches. However, construction

Table 3. Dry forage yield of pasture and moisture contents as influenced by moisture conservation practices and grasses in association with *H. binata* (mean of 4 years)

Treatment	Dry forage yield (t/ha)			Moisture content (%)	
	G	L	T	0-15 cm	15-30 cm
Grasses					
C. ciliaris	4.81	1.62	6.43	7.60	8.81
C. fulvus	3.35	1.86	5.21	7.31	8.72
P. maximum	6.28	1.13	7.41	8.14	9.55
SEM	0.03	0.01	0.03	0.02	0.07
CD (P=0.05)	0.09	0.04	0.08	0.05	0.20
MCM					
Control	4.20	1.37	5.57	6.51	7.94
Trenches	5.01	1.58	6.59	7.99	9.30
Bund	5.23	1.66	6.89	8.36	9.71
SEM	0.03	0.01	0.03	0.02	0.07
CD (P=0.05)	0.09	0.04	0.08	0.05	0.20

MCP: Moisture conservation practices, G: Grasses, L: S. hamata, T: Total (grasses+ S. hamata)

Table 4. Crude protein yield (mean of 4 years) and economics as influenced by moisture conservation practices and grasses in *H. binata* based silvopasture system

Treatment	Crude protein yield (kg/ha)			Net return (Rs/ha)	Net return/ rupee invested
	G	L	T		
Grasses					
C. ciliaris	406.0	227.5	633.5	7819	0.39
C. fulvus	241.1	260.9	501.9	3063	0.15
P. maximum	475.3	157.5	632.9	9556	0.47
SEM	2.2	2.6	3.2	-	-
CD (P=0.05)	6.8	7.9	9.8	-	-
MCM					
Control	324.7	190.3	515.0	4168	0.20
Trenches	388.7	221.8	610.4	7541	0.37
Bund	407.7	233.6	641.3	8730	0.43
SEM	2.2	2.6	3.2	-	-
CD (P=0.05)	6.8	7.9	9.8	-	-

MCP: Moisture conservation practices, G: Grasses, L: S. hamata, T: Total (grasses+ S. hamata)

of staggered trenches across the slope resulted in highest values of growth parameters, pruned dry leafy forage and fire woods in *H. binata*.

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