Range Mgmt. & Agroforestry 36 (1) : 41-46, 2015
ISSN 0971-2070

Performance of different grain legumes and pasture grasses under agri-silvi-pastoral system in arid tropics of India

K. C. Sharma*
ICAR-Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner- 334 006, India
*Present address: ICAR-Indian Agricultural Research Institute, Regional Station, Indore- 452 001, India.
*Corresponding author e-mail: kc_64sharma@yahoo.com
Received: 15th December, 2014 Accepted: 27th May, 2015

Abstract
A field experiment was conducted at Bikaner to find out an efficient agri-silviculture or silvi-pastoral model for cultivable wastelands of arid tropics of India. Three multi-purpose tree species *viz*., *khejri* (*Prosopis cineraria*), *ardu* (*Ailanthus excelsa*) and *rohida* (*Tecomella undulata*) suitable for arid tropics were selected and planted, and evaluated in association of annual grain legumes/ pasture grass species *viz*., *cluster bean* (*Cyamopsis tetragonoloba*), *moth bean* (*Vigna aconitifolia*), *sewan* grass (*Lasiurus sindicus*) and *anjan* grass (*Cenchrus ciliaris*) in split plot design with three replications. Results indicated that tree species had no adverse effect on growth and grain/fodder yields of grain crops and pasture grasses. Similarly, annual crops/grasses did not exerted any significant effect on the growth attributes of all tree species. Among grain crops and grasses, *cluster bean* recorded higher grain 818 and 915 kg/ha, and straw 1970 and 2470 kg/ha yields during 2009 and 2010, respectively over *moth bean.* Whereas, *sewan* grass out-yielded *anjan* grass with green fodder yield of 12.07 and 16.74 t/ha, and dry matter yield 4.68 and 6.02 t/ha during 2009 and 2010, respectively. *Cluster bean* equivalent yields (CEY) recorded with *cluster bean* (1.21 and 1.41 t/ha) and *moth bean* (1.15 and 1.41 t/ha) were statistically at par but significantly higher over both grass species. Slightly higher values of net returns Rs. 8450 and Rs. 14949 and B: C ratio 1.56 and 2.08 were observed with *khejri* plantation in both the years as compared to other tree species, while among crops *cluster bean* gave maximum values of net returns Rs. 15066 and Rs. 18620, and B: C ratio 1.99 and 2.12. All the treatment variables substantially improved the soil fertility status *viz*., OC (%), available N, P and K of soil in comparison to initial soil fertility status. Thus, study suggested that growing of *cluster bean* or *moth bean* with any multi-purpose tree species *viz*., *khejri*, *ardu* and *rohida* plantation holds promise to provide higher and economical grain productivity with improved fertility status of soil under agri-silviculture system in arid tropics of Rajasthan.

Keywords: Agri-silvi-pastoral system, Arid tropics, Fodder yield, Grain legumes, Multi-purpose tree species, Pasture grasses

Abbreviations: B:C: Benefit : cost ratio; **CEY:** Cluster bean equivalent yield; **K:** Potash; **N:** Nitrogen; **NR:** Net returns; **OC:** Organic carbon; **P:** Phosphorus

Introduction

The Indian arid zone extends in an area of 31.7 million hectares and the major area (about 60% of total arid zone) lies in the western part of Rajasthan covering 12 districts of the state. Moreover, almost 40% land of the region is under cultivable wastelands or degraded pastures. Due to poor and erratic rainfall pattern and low fertility soils, agri-silvi-pastoral system is the vital life support system of rural folk of this region. Although, traditional agroforestry system with *Prosopis cineraria* exists in arid tropics (Gupta, 1994), but for improvement in productivity of the system to meet increasing demand of food, fodder and fuel, new alternatives of land use system are to be explored on the basis of rainfall pattern and edaphic conditions. There are number of multipurpose tree species *viz*., *Prosopis cineraria*, *Ailanthus excelsa*, *Hardwikia binata*, *Colophospermum mopane*, *Tecomella undulata*, *Azadirachta indica* etc. suitable for the region and may provide fodder, fuel, timber or other edible and commercial products to mitigate the effect of frequent occurrence of droughts and fulfill the need of rural population. *Cluster bean* (*Cyamopsis tetragonoloba*) and *moth bean* (*Vigna aconitifolia*) are two most important legumes generally grown during *kharif* season under rainfed conditions and have capacity to bear harsh climatic situations, while *sewan* (*Lasiurus sindicus*) and *anjan* (*Cenchrus ciliaris*) are the most suitable perennial pasture grass species because of their high yielding, better palatability, good

fodder quality and suitable for available land resource and climatic situation of the region. Further, the economy of the arid zone farmers depends upon the livestock population dominated by grazing based animals like sheep and goats. The wastelands and rangelands of this region are presently not capable of producing sufficient quantity of fodder for animals even for body maintenance. It is due to continuous over-exploitation of grazing lands, frequent droughts, low and erratic rainfall distribution, people negligence etc. It is fact that the improvement in animal husbandry is directly correlated with the improvement of native pastures and in this context, adoption of agri-silvi-pastoral system specially in cultivable wastelands may play a vital role in solving the problem of fodder shortage for animals in addition to fulfill the other daily needs of ever increased human and animal population of the region (Hazra, 2014). However, information available on agri-silvi-pastoral system is still meager, hence the present investigation was carried out to find out an efficient agri-silviculture or silvi-pastoral model for cultivable wastelands in arid tropics of India.

Materials and Methods

The field experiment was conducted during 2007-10 at Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner (Rajasthan), India. The soil of experimental site was sandy and had low contents of organic carbon (0.13%), available nitrogen (74.6 kg/ha), phosphorus (6.35 kg/ha) and potassium (73.7 kg/ha). The soil topography was moderately undulated and having pH value of 8.43 and EC 0.68 dsm^{-1}. Treatments consisted of three multi purpose tree species *viz*., *khejri* (*Prosopis cineraria*), *ardu* (*Ailanthus excelsa*) and *rohida* (*Tecomella undulata*) as main plot treatment and 4 crops and grasses *viz*., *cluster bean* (*Cyamopsis tetragonoloba*), *moth bean* (*Vigna aconitifolia*), *sewan* (*Lasiurus sindicus*) and *cenchrus* (*Cenchrus ciliaris*) as sub plot treatments was laid out in split plot design with three replications. The trial was initiated in July, 2007 with preparation of field and digging of 0.53 m^3 size pits dug by tractor drawn auger (pitter). Sheep manure 10 kg and soil were mixed and filled in pits upto 15 cm below the soil surface. Six months old poly-bags raised healthy saplings of multipurpose tree species were planted at a distance of 10 x 10 m as per lay out of the trial and maintained 12 plants in each plot. In first year plantation was maintained and any dried or destroyed plants (saplings) were immediately replaced and watered to maintain full tree population in first two years of 2007-08 and 2008-09. Planted tree saplings were watered as per need. Crops and grasses were raised with recommended package of practices during *Kharif* season of 2009 and 2010 and varieties ó*RGC 936'* of *cluster bean*, ó*RMO 40'* of *moth bean* , ó*CAZRI-M-30-5*ô of *sewan* grass and ó*CAZRI-75*ô of *cenchrus* grass were used in the trial. Grain crops were sown in both the years, while perennial grasses were sown once in first year and its re-growth was observed in second year. Trees growth attributes *viz*., tree height, stem girth and tree canopy were observed at different intervals with the help of meter scale and measuring tape. Grain crops were harvested at physiological maturity, while, grasses were harvested once at flowering stage in both the years. Yield and yield attributes of crops and grasses were taken at harvest and plant samples of grasses were collected for dry matter yields. Soil samples were collected at the beginning and end of experimentation at 0-15 cm soil layer and analyzed for physical and chemical properties of soil as per standard procedures. The total annual precipitation was 239.7, 343.9 and 390.8 mm occurred in 19, 21 and 18 rainy days during 2008, 2009 and 2010, respectively. Prevalent market prices of experimental produce *viz*., grain and straw of *cluster bean* Rs. 25 and Rs. 5.0 per kg, *moth bean* Rs. 35 and Rs. 5.0 per kg , and dry grass Rs. 4.0 per kg of both grass species were used in both the years for the calculation of *cluster bean* yield equivalent and economics as prices of above were almost same in both the years.

Results and Discussion

***Growth attributes of tree species*:** Data collected on growth parameters of tree species at different intervals showed that there was substantial improvement in the growth attributes *viz*., tree height, stem girth and canopy diameter of all tree species at all stages (Table 1). Results indicated that overall, *Ailanthus excelsa* recorded maximum values of all the growth attributes at all the growth stages except canopy diameter at 12 and 18 months, where *Prosopis cineraria* recorded maximum values, and thereafter *Ailanthus excelsa* again recorded highest values of canopy diameter followed by *Tecomella undulata*. It was also noted that the growth parameters of *Ailanthus excelsa* were followed by the *Prosopis cineraria* upto the age of 12 months, but thereafter *Tecomella undulata* excelled up its growth at the stage of 18 and 24 months, and recorded higher values of all growth attributes except canopy diameter at 18 months, where *Prosopis cineraria* recorded greater values than *Tecomella undulata*. The minimum growth of *Prosopis cineraria* was mainly because of its obvious nature of growth after a certain stage when it sheds the leaves and plant convert to bushy nature and improvement in canopy

Table 1. Growth attributes of planted tree species at different intervals

Treatment	Plant/Tree height (cm.)					Stem girth (cm.)					Canopy diameter (cm.)				
	6 month	9 month	12 month	18 month	24 month	6 month	9 month	12 month	18 month	24 month	6 month	9 month	12 month	18 month	24 month
(A) Tree species															
Prosopis cineraria	31.4	33.2	33.8	71.3	89.7	1.18	1.48	2.85	5.33	6.17	4.26	11.4	19.1	75.9	97.2
Ailanthus excelsa	52.1	53.7	57.9	165.3	231.0	2.00	2.47	3.30	16.5	23.2	14.1	16.3	13.2	74.4	167.0
Tecomella undulata	21.4	21.4	22.2	62.0	121.3	1.23	1.52	1.95	5.67	10.3	6.08	10.0	15.2	56.8	103.9
SEM	2.31	2.66	4.18	4.39	9.96	0.05	0.09	0.07	0.76	1.23	0.87	1.26	1.25	3.51	8.36
CD (P<0.05)	9.05	10.44	13.78	17.23	39.09	0.18	0.35	0.26	2.98	4.84	3.43	4.97	4.90	13.78	32.83
(B) Crops and grasses															
Cyamopsis tetragonoloba	36.7	37.1	40.3	105.5	154.7	1.59	1.85	2.75	9.86	13.67	8.64	12.8	15.9	64.7	118.0
Vigna aconitifolia	34.8	34.7	38.0	100.2	147.9	1.27	1.79	2.71	10.02	11.93	8.35	11.8	14.9	70.8	122.1
Lasiurus sindicus	34.6	35.7	37.1	96.3	142.3	1.48	1.86	2.72	8.94	13.06	7.70	12.9	15.7	69.8	124.8
Cenchrus ciliaris	33.8	36.8	36.7	95.2	144.6	1.54	1.79	2.63	9.78	14.23	7.87	12.7	16.7	70.9	125.9
SEM	1.2	1.11	1.21	3.52	3.65	0.11	0.03	0.08	0.41	0.89	0.08	0.43	0.68	2.5	3.28
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

size decreases. Arya *et al.* (2008) also reported *A. excels* a suitable tree species for hot arid region and highest tree height among other multipurpose tree species. There was no special significant effect of crops and grasses on any growth parameters at all the growth stages.

***Growth and yields of grain crops and pasture grasses*:** None of the tree species had its significant effect on the growth attributes of grain crops and grasses in both the years (Table 2). It might be due to slow growing nature of all tree species, which did not affect the growth attributes of crops and grasses. However, due to different natural stature of different crops and grass species, growth data *viz*., plant height, number of plants/m^2, no. of tillers/ tussock and tussock diameter differed significantly. The results were also agreed with the view of Jhorar *et al.* (2005), who reported that trees had no effect on associated crop for initial first four years. Kaushik and Kumar (2003) also observed no effect of top feed tree species on the yield of understory crops, but crops varied significantly among themselves. Grain and straw yields recorded with *cluster bean* were significantly higher over *moth bean* in both the years, except straw yield in 2009, where difference was non-significant (Table 3). Similarly, *sewan* grass gave significantly higher green fodder (120.7 and 167.4 q/ha) and dry matter (46.8 and 60.2 q/ha) yields in both the years over *Cenchrus* grass. The magnitude of increase in green and dry fodder yields was to the tune of 34.5 and 44.0 per cent and 20.1 and 32.6 per cent over *anjan* grass during 2009 and 2010, respectively. The higher fodder yield under *sewan* grass was the function of greater number of tillers per tussock and tussock diameter than *anjan* grass. Vyas (2003) also observed enhanced values of growth and yield of senna in association of *khejri* plantation. Computation of *cluster bean* yield equivalent (CEY) showed that CEY was not significantly influenced by any of the tree species in both the years but grain crops due to better market prices of produce recorded higher values of CEY *viz*., *cluster bean* 1.21 and 1.41 t/ha and *moth bean* 1.15 and 1.41 t/ha over both grass species. The CEY values recorded with *cluster bean* and *moth bean* were statistically at par in both the years but significantly greater than the values observed with grasses (*sewan* grass 0.78 and 0.96 t/ha and *Cenchrus* grass 0.52 and 0.73 t/ha). It was also observed that *sewan* grass recorded significantly higher value of CEY over *anjan* grass. A higher yield of *sewan* grass was the function of higher values of growth parameters compared with *Cenchrus* grass.

***Economics*:** Working out of economic benefits in the terms of net returns and benefit: cost ratio indicated that none of the tree species had significant influence on any economic parameters in both the years. However, among tree species *Prosopis cineraria* plantation recorded numerically higher values of net returns (Rs. 8,450 and Rs. 19,949/ha) and B: C ratio (1.58 and 2.08) compared with other tree species (Table 4). It was mainly because of slight improvement in yields of crops and grasses in the plots of *Prosopis cineraria*, while cost of cultivation was same. Among crops and grasses, *cluster bean* recorded maximum values on economic benefits *viz*., net returns of Rs.15,066 and Rs. 18,620/ha, and B:C ratio of 1.99 and 2.12 during 2009 and 2010, respectively. This was followed by *moth bean* (net return of Rs. 13,332 and Rs. 18,521/ha, and B:C ratio 1.86 and 2.11). Between grasses, *sewan* had comparatively higher economic benefits than that of *Cenchrus.* The recorded values for net returns of Rs. 4,551 and 12,613/ha, and B:C ratio of 1.32 and 2.10 for different years, respectively in sewan grass when compared with *Cenchrus* (NR Rs. -714 and Rs. 7,174/ha, and BC ratio of 0.95 and 1.59). Grasses were found to be less remunerative than grain crops due to low price of produce in the market. However, utilization of produce under mixed farming system where animal is a component then the economic benefits differed and could be more beneficial than grain crops.

Table 2. Growth attributes of different crops and grasses at harvest

Treatment	Plant height (cm.)		No. of plants/m²		No. of tillers / tussock of grasses		Tussock diameter of grasses	
	2009	2010	2009	2010	2009	2010	2009	2010
(A) Tree species								
Prosopis cineraria	83.0	103.4	20.5	14.7	63.6	109.6	62.3	76.8
Ailanthus excels	81.1	100.4	18.7	15.4	59.1	108.5	59.6	75.5
Tecomella undulate	80.1	101.9	19.9	16.4	62.8	109.2	62.0	76.9
SEM	0.90	1.24	0.73	0.61	2.66	0.94	1.86	2.86
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS
(B) Crops and grasses								
Cyamopsis tetragonoloba	84.0	125.4	27.6	23.0	-	-	-	-
Vigna aconitifolia	39.2	42.7	26.9	17.4	-	-	-	-
Lasiurus sindicus	118.9	126.2	10.1	9.0	73.0	142.7	69.8	85.0
Cenchrus ciliaris	83.5	113.1	14.1	12.4	50.7	75.5	52.9	67.8
SEM	1.14	2.55	0.80	0.56	1.14	2.30	1.69	2.34
CD (P<0.05)	3.38	7.57	2.37	1.67	3.94	7.97	5.86	8.10

Table 3. Grain, straw, fodder and *cluster bean* equivalent yields of different crops and grasses

Treatment	Grain crops yield (kg/ha)				Grasses yield (t/ha)				CEY* (t/ha)	
	Grain		Straw		GFY		DMY			
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
A) Tree species										
Prosopis cineraria	719	837	1770	2280	10.96	15.39	4.13	5.47	0.92	1.16
Ailanthus excelsa	676	823	1800	2140	10.34	15.24	3.89	5.28	0.89	1.12
Tecomella undulata	716	817	18.2	2130	10.25	15.38	3.86	5.09	0.91	1.10
SEM	52	48.0	191.0	111	0.17	0.27	0.06	0.09	0.05	0.04
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B) Crops and grasses										
Cyamopsis tetragonoloba	818	915	1970	2470	-	-	-	-	1.21	1.41
Vigna aconitifolia	590	735	1630	1890	-	-	-	-	1.15	1.41
Lasiurus sindicus	-	-	-	-	12.07	16.74	4.68	6.02	0.78	0.96
Cenchrus ciliaris	-	-	-	-	8.97	13.93	3.25	4.54	0.52	0.73
SEM	28.0	23.0	129.0	48.0	0.21	0.51	0.08	0.13	0.03	0.03
CD (P<0.05)	97.0	81.0	NS	165.0	0.74	1.75	0.29	0.46	0.10	0.09

**Cluster bean* equivalent yield on the basis of mean data of grain, straw and dry fodder yields

Table 4. Economics and soil fertility status as influenced by treatment variables

Treatment	Economics								Soil fertility status			
	Cost of cultivation (Rs./ha)		Gross returns (Rs./ha)		Net returns (Rs./ha)		B : C ratio		Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
	2009	2010	2009	2010	2009	2010	2009	2010				
A) Tree species												
Prosopis cineraria	14,648	13,947	23,097	28,896	8,450	14,949	1.56	2.08	0.18	92.2	6.98	81.9
Ailanthus excelsa	14,648	13,947	22,199	28,112	7,551	14,165	1.49	2.02	0.17	91.1	7.03	82.7
Tecomella undulata	14,648	13,947	22,822	27,528	8,174	13,582	1.53	2.04	0.17	90.8	7.04	81.1
SEM	-	-	1,307.1	1,051.6	1,030.2	1,051.0	0.08	0.07	0.003	1.27	0.11	1.02
CD (P<0.05)	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
(B) Crops and grasses												
Cyamopsis tetragonoloba	15,240	16,630	30,306	35,250	15,066	18,620	1.99	2.12	0.19	98.6	7.17	84.4
Vigna aconitifolia	15,480	16,690	28,812	35,211	13,332	18,521	1.86	2.11	0.18	94.1	7.13	81.2
Lasiurus sindicus	14,160	11,458	18,711	24,071	4,551	12,613	1.32	2.10	0.16	85.3	6.83	79.9
Cenchrus ciliaris	13,710	11,008	12,995	18,182	-714	7,174	0.95	1.59	0.17	87.5	6.94	82.2
SEM	-	-	845.9	1037.4	734.9	1,034.5	0.05	0.06	0.003	2.42	0.16	2.17
CD (P<0.05)	-	-	2,513.5	3,082.6	2,183.6	3,073.9	0.16	0.19	0.009	7.20	NS	NS
Initial	-	-	-	-	-	-	-	-	0.13	74.6	6.35	73.7

***Soil fertility status*:** Soil samples analyzed at the initial stage and at the end of experimentation for organic carbon (OC) and available nutrients status of soil. revealed that all the attributes *viz*., OC, N, P and K were substantially improved as compared to initial level (Table 4). Although, differences in all soil attributes due to different tree species were non-significant but, crops and grasses had their significant effect on organic carbon and nitrogen content of soil. Organic carbon content recorded under *cluster bean* was significantly higher over *moth bean* and grasses, while nitrogen content under *cluster bean* treatment was at par with *moth bean, but it* was significantly higher over both grass species. Although, maximum values of available P and K contents of soil were observed with cluster bean treatments but differences could not reach to the level of significance. Both the grain crops, being legumes, accumulated higher contents of organic carbon and available N, possibly due to greater leaf litter fall on soil specially in *cluster bean,* which resulted higher contents of nutrients in soil. Yadav *et al.* (2007) and Ram *et al.* (2007) were also reported increase in values of organic carbon and available plant nutrients under MPTs based silvipastoral system.

Conclusion

It was concluded that for getting higher and remunerative productivity in cultivable wasteland of arid tropics in of north-western India, grain crop of *cluster bean* or *moth bean* could be grown in association of multipurpose tree species (*Prosopis cineraria*, *Ailanthus excelsa* and *Tecomella undulata*) as agri-silviculture model without any adverse effect on growth performance of tree species. However, in exigency of fodder for livestock production, *sewan* grass was the potential perennial grass species for growing under silvipastoral system.

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