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Forage production potential of different silvi-pastoral systems under arid conditions of Rajasthan

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ABSTRACT

A field experiment was conducted at Jodhpur during 2005 and 2006 to assess the production potential of different silvi-pastoral systems involving two grasses, viz. buffel grass (*Cenchrus ciliaris* L.) and sewan (*Lasiurus sindicus* Henr.) and fodder *sem* (*Lablab purpureus* L.) as legume in association with *Colophospermum mopane* Kirk ex Benth.; and *Hardwickia binata* Roxb trees with and without N application. The results revealed that average plant height and survival percentage of *C. mopane* were higher than of *H. binata*. Further, the growth of *C. mopane* varied significantly due to cropping systems. Fodder production was influenced by the cropping system and was maximum in *L. sindicus* (4.54 and 2.07 t/ha green and dry yields) and lowest in *C. ciliaris* + *L. purpureus* system (3.04 and 1.48 t/ha green and dry yields). Mean data showed that dry-fodder yield was on par with that in *L. sindicus, C. ciliaris* and *L. sindicus* + *L. purpureus* systems but protein yield was higher in *L. sindicus* + *L. purpureus* and *C. ciliaris* + *L. purpureus* systems compared with that in sole strips of respective grasses. Application of 40 kg N/ha increased the dry-fodder yield by 16.4% and crude-protein yield by 22.3% over the control. Thus the productivity and quality of fodder can be increased by strip cropping of *C. ciliaris* or *L. sindicus* with *L. purpureus* in association with *C. mopane* or *H. binata* under silivi-pastoral system in arid zone.

Key words : *Cenchrus ciliaris, Colophospermum mopane, Hardwickia binata, Lablab purpureus, Lasiurus sindicus*, Silvi-pastoral system, Strip cropping

Livestock play an important role in the livelihood of the farmers of the Indian hot arid zone, but the availability of fodder is limited due to low and erratic rainfall along with poor soil condition in the zone. Further, the arid ecosystem is highly fragile and soil degradation is one of the major problems. Dhir (1995) estimated that nearly two-third of these lands are in a state of severe degradation or already desertified. In the arid zone of Rajasthan about one-third areas are wastelands, of which 50% are grazing lands and 45% are sandy wastes (Balak-Ram *et al.*, 2003). The productivity from these grazing lands is only 300-400 kg/ha. Lack of proper selection of cropping system and agronomic practices lead to low productivity of these lands. Under such a situation silvi-pastoral system with suitable species of trees and grasses help in increasing the land productivity and also maintain environmental potentialities. Planting the trees either on the field boundary or in rows in association with grasses provides valuable leaf fodder during scarcity or lean period (Gill, 2003). Moreover, deep root system of trees binds the soil, reduces erosion and extracts moisture from deeper strata of the soil (Ahuja, 1984). Perennial grasses besides providing fodder to the livestock also prevent soil erosion and ameliorate the soil health. Further, the integration of legume and application of nitrogen also improves the productivity and quality of fodder. Therefore the present study was undertaken to evaluate the production potential of different silvi-pastoral systems having perennial grasses, viz. *Cenchrus ciliaris* L. and *Lasiurus sindicus* Henr.; pasture legume, viz. *Lablab purpureus* L.; and trees, such as *Colophospermum mopane* Kirk ex Benth. and *Hardwickia binata* Roxb. under arid climate.

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MATERIALS AND METHODS

A field experiment was conducted during two years from 2005 to 2006 under rainfed condition at Central Arid Zone Research Institute, Jodhpur. The climate of the region is typically hot arid, characterized by low rainfall (100-500 mm/year), high temperature (40-46°C) and high wind velocity (20-40 km/hr). The rainfall is largely monsoon-driven, which comes between June and September. Monsoon rains account for 95% of the total rainfall with high coefficient of variation (40-60%) and erratic distribution. Total rainfall received during 2005 and 2006 was 283.0 and 270.4 mm respectively in 20 rainy days each year. The soil was loamy sand, having pH 8.3 and organic

C 0.18%. The available N, P and K were 140, 12.3 and 191 kg/ha, respectively.

The treatments consisted of two tree species (*Colophospermum mopane* and *Hardwickia binata)*, four cropping systems (*Cenchrus ciliaris*, *Lasiurus sindicus*, *Cenchrus ciliaris* + *Lablab purpureus* and *Lasiurus sindicus* + *Lablab purpureus*) and two N levels (0 and 40 kg/ha). These treatments were tested in split-plot design with three replication, keeping the tree species in main plot and the cropping system and N levels in subplots. Grasses and legume were grown in strips between the rows of trees. Trees were planted in July 2001 at 9 x 5 m spacing, whereas grasses were established in rows at 60 cm spacing. The plot size was 18 x 10 m. The field remained fallow in 2001 and 2002, whereas in 2003 and 2004 the grasses and cowpea were grown between the interspaces of trees. *L. purpureus* was sown with the onset of monsoon in the first week of July during both the years in strips between the perennial strips of grasses at 60 cm row. Nitrogen was top-dressed in the form of urea in two equal splits, first at 20-25 days and second at 35-40 days of crop growth depending on the availability of rain. The pasture was manually weeded at 20-25 days after sowing (DAS). Grasses were harvested at the stage of 50-55 days by cutting at 10 cm above the ground level and *L. purpureus* was harvested at flowering stage.

Data on green-forage yield/plot were recorded, and 100 g sample was collected from each plot and kept in oven at 85°C temperature to constant weight for estimating dry-matter accumulation. Tree height and canopy spread was measured in October every year and the leaf-fodder and fuel-wood yields were recorded only during 2006. Plant samples were analysed for N content and crude protein. Soil samples were also collected periodically for estimation of water use and water-use efficiency from different systems.

RESULTS AND DISCUSSION

Growth performance

In June 2005 the survival of *C. mopane* and *H. binata* was 98 and 60% respectively. Similarly, both the tree species differed in plant height and canopy area. Branching and growth of *C. mopane* were higher than of *H. binata*. At 51 months stage the plant height and canopy area of *C. mopane* was 166 cm and 1.87 m^2/tree, whereas those of for *H. binata* were 106 cm and 0.42 m^2/tree respectively. Increment in height during 51 and 63 months was 30% for *C. mopane* and 19% for *H. binata,* indicating slower growth of the latter than of the former species. Further, cropping system also affected the height and canopy area of *C. mopane,* but trees such as *H. binata* were less affected by the cropping system. However, in 2006 the canopy area of *H. binata* was significantly influenced by the cropping system. The maximum height (239 cm) and canopy area (3.91 m^2/tree) of *C. mopane* were recorded with *L. sindicus* + *L. purpureus* cropping, followed by *C. ciliaris* + *L. purpureus* system, which were significantly higher than with sole strip of grasses (Table 1). Similarly, canopy area of *H. binata* was maximum (1.23 m^2/tree) under *L. sindicus* + *L. purpureus* strip-cropping system, followed by that of *C. ciliaris* + *L. purpureus* system. The better plant growth of trees in grass-legume strip cropping might be due to more tillage operations (two harrowing) required for field preparation and the beneficial effect of legume crop. Further, fast growth habit of grasses exerts greater competition for moisture during the early rainy season. Sole strip of grasses resulted in less moisture availability for tree plants. However, the growth of legume was slow at initial stages, exerting less competition for moisture. Sharma *et al.* (1998) also found that both the height and canopy area of *Acacia tortilis* and *Ziziphus rotundifolia* were lower when grown in association with *C. ciliaris* and *L. sindicus* than compared with tree alone. Plant height and canopy area of tree species were not influenced significantly by N application, but in 2006 the canopy area of *C. mopane* was significantly increased in the plots where 40 kg N/ha applied.

Growth performance of intercrops, i.e. grasses and legumes, did not vary due to cropping system and tree species (Table 2). Application of 40 kg N/ha significantly increased the plant height and number of tillers/m row length in grasses and branches/plant in *L. purpureus*. The better plant growth was due to the beneficial effect of N fertilization. Gill and Sharma (2005) also reported similar results.

Forage yield and quality

The forage yields of grasses and legume were not significantly influenced by *C. mopane* and *H. binata* (Table 2). The non-significant differences might be due to slower growth of trees at initial stage and wider spacing, indicating their less effect on total biomass production of pasture species. Kaushik and Kumar (2003) found that fodder yield of buffel grass and cowpea raised in interspace of *C. mopane* and *H. binata* did not show any significant variation compared with their sole cropping.

The green-and dry-forage yields of grasses and *Lablab purpareus* were significantly influenced by strip cropping and also varied with the year. Green-forage yield was maximum in *L. sindicus* in both the years, and it was significantly higher from the other cropping systems in 2005 but on a par with *C. ciliaris* in year 2006. Similarly, mean dry-forage yield was maximum in *L. sindicus* and on a par with that in sole strip of *C. ciliaris* and *L. sindicus* + *L. purpureus*. However, in 2006 dry-fodder yield of *C. ciliaris* was significantly higher compared with that of

Table 1. Effect of cropping system and N application on tree growth under silvi-pastoral systems

Treatment	*Colophospermum mopane*				*Hardwickia binata*			
	Plant height (cm)		Canopy area (m^2/tree)		Plant height (cm)		Canopy area (m^2/tree)	
	2005	2006	2005	2006	2005	2006	2005	2006
Cropping system								
C. ciliaris	160	206	1.36	2.53	105	129	0.37	0.76
L. sindicus	150	198	1.52	2.65	103	120	0.39	0.52
C. ciliaris + *L. purpureus*	169	222	2.50	3.45	104	118	0.45	0.80
L. sindicus + *L. purpureus*	183	239	2.10	3.91	110	134	0.48	1.23
SEm±	11	10	0.10	0.19	8	10	0.11	0.10
CD (P=0.05)	32	30	0.30	0.56	NS	NS	NS	0.30
N (kg/ha)								
0	158	211	1.79	2.88	100	122	0.41	0.85
40	173	221	1.96	3.39	111	129	0.43	0.81
SEm±	8	7	0.08	0.09	6	7	0.10	0.07
CD (P=0.05)	NS	NS	NS	0.40	NS	NS	NS	NS

Table 2. Effect of cropping system and N application on growth and yield of grasses and legume

Treatment	Growth parameters						Green-fodder yield (t/ha)			Dry-fodder yield (t/ha)		
	C. ciliaris		*L. sindicus*		*L. purpureus*		2005	2006	Mean	2005	2006	Mean
	Plant height (cm)	Tillers/ mrl	Plant height (cm)	Tillers/ mrl	Plant height (cm)	Branches/ plant						
Trees												
C. mopane	103.3	79.3	110.0	93.7	24.2	5.2	4.59	2.98	3.78	2.49	1.18	1.84
H. binata	111.5	81.8	106.5	94.3	28.5	5.5	4.31	3.06	3.68	2.50	1.16	1.83
SEm±	3.2	2.1	2.9	2.1	0.5	0.1	0.87	0.13	0.04	0.04	0.04	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cropping system												
C. ciliaris	105.6	78.5					3.89	3.26	3.57	2.37	1.46	1.91
L. sindicus			107.6	91.3			5.63	3.44	4.54	2.95	1.19	2.07
C. ciliaris + *L. purpureus*	108.5	82.6			26.3	5.3	3.57	2.51	3.04	1.93	1.02	1.48
L. sindicus + *L. purpureus*			109.9	96.7	25.8	5.4	4.71	2.86	3.79	2.73	1.00	1.87
SEm±	2.3	1.7	2.2	2.6	1.4	0.2	0.24	0.14	0.14	0.17	0.06	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.68	0.40	0.41	0.49	0.18	0.27
N (kg/ha)												
0	103.7	77.7	104.9	87.5	25.1	5.1	4.18	2.70	3.44	2.32	1.07	1.69
40	109.0	83.4	111.7	100.5	28.2	5.6	4.72	3.31	4.02	2.67	1.27	1.97
SEm±	2.3	1.7	2.2	2.6	1.4	0.2	0.17	0.10	0.10	0.12	0.04	0.06
CD (P=0.05)	NS	5.0	6.5	7.5	NS	0.5	0.48	0.28	0.29	0.35	0.12	0.19

other cropping systems. The variation in forage yield of strip cropping in different years was due to the variation and distribution of rainfall. During 2005 the rainfall was properly distributed in two peak growing months, i.e. 132.5 mm in July and 77.2 mm in August, whereas in July 2006 only 27 mm rain was received and in August 2006 it was 185 mm. Therefore during 2005, the moisture was available for a longer period and coincided with the growth stages of the grasses resulting in greater fodder production.

The inclusion of *L. purpureus* strip reduced the total biomass production because its growth and yield were less under the low-rainfall situation compared with those of the grass component. The protein yield was significantly higher in strip cropping of *L. sindicus* + *L. purpureus* compared with that in other cropping systems. The protein yield of *C. ciliaris* + *L. purpureus* was also significantly higher than of sole *C. ciliaris*. The higher protein yield might be due to the higher protein content of *Lablab* fodder (Table 3). The association of cereal and legume forages not only maintains similar level of herbage yield but also nearly doubles the crud-protein production (Menhi

Lal and Tripathi, 1987). Bhati (1997) also reported that strip cropping of grasses and rainy-season (*kharif*) legume is more acceptable than that of grass legume intercropping.

Dry matter accumulation of grasses and *Lablab purpureus* was increased significantly by application of 40 kg N/ha compared with that of the control, but the response of fertilizer was poor in 2006 due to improper distribution of rains. The mean data revealed 16.6% increase in dry-fodder yield of pasture species due to application of 40 kg N/ha in comparison with the control. Gill and Sharma (2005) observed an increasing trend in dry weight with N application in *C. ciliaris* and *L. sindicus.* The protein content of grasses and legume was not much affected by the cropping system but the application of 40 kg N/ha improved the protein content of *C. ciliaris*, *L. sindicus* and *Lablab* marginally compared with that of the control (Table 3). Similarly, the protein yield of pasture grasses and legume increased by 22.3% with application of 40 kg N/ha over the control. The higher protein yield was due to increase in protein content and better dry-matter accumulation on N application.

Leaf and fuel wood yield

The tree growth at the early stage was generally slower, hence lopping was not done up to the fifth year. However, in 2006 lopping of trees at 50% foliage gave 108 and 63 kg/ha leaf fodder from *C. mopane* and *H. binata* along with 435 and 151 kg/ha fuel wood respectively. The leaf- and fuel-wood yields were higher in *C. mopane* than in *H. binata* (Table 4). Further, these did vary significantly due to different cropping systems and N application. The leaf fodder from trees contributed 7% to total fodder productivity by the system in 2006. At the early stage of growth these tree species had no adverse effect on the fodder yield of grasses (Kaushik and Kumar, 2003); besides tree leaves and fuel wood were additional benefit.

Water use and water-use efficiency

Water use was not influenced by the cropping system, but water-use efficiency varied in different cropping systems. Application of 40 kg N/ha increased water-use (Figure 1) and water use efficiency (Figure 2) of grasses and lablab. Maximum water use efficiency (11.2 kg dry matter/ha/mm) was recorded in *L. sindicus* with 40 kg N/ha application, whereas it was minimum in lablab (3.9 kg dry matter/ha/mm) without N application. Further, the water use efficiency of *C. ciliaris* and *L. sindicus* was higher than that of lablab, but the difference between the pasture grass species was not conspicuous. The higher WUE may be attributed to appreciable increase in dry-matter production. Application of 40 kg N/ha increased the water-use efficiency by 19% over the control. Patidar *et al.* (2003) also reported similer results. The use of nitrogen resulted in greater production per unit of available water, thus increasing the water-use efficiency. This increase occurred due to stimulation of early growth under adequate fertility, which increased the leaf surface for photosynthesis and root development into deeper soil zones. The well-fertilized plants with vigorous, extensive root system absorbed

Table 3. Protein content and protein yield of grasses and legume as influenced by different cropping systems and N application

Treatment	Crude protein content (%)									Protein yield (kg/ha)		
	Cenchrus ciliaris			*Lasiurus sindicus*			*Lablab purpureus*			2005	2006	Mean
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean			
Trees												
C. mopane	7.84	7.11	7.48	8.33	7.84	8.09	18.90	20.83	19.87	242.1	97.1	169.6
H. binata	7.38	6.25	6.82	8.70	8.18	8.44	18.90	19.56	19.23	246.4	93.2	169.8
SEm±	1.12	1.32	1.14	1.31	1.30	1.00	1.84	1.62	1.34	5.4	4.30	4.20
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cropping system												
C. ciliaris	7.36	6.74	7.05							174.6	98.4	136.5
L. sindicus				8.55	7.91	8.23				252.2	94.6	173.4
C. ciliaris + *L. purpureus*	7.86	6.61	7.24				18.95	19.89	19.42	232.4	86.1	159.2
L. sindicus + *L. purpureus*				8.73	8.10	8.42	18.85	20.37	19.61	317.8	101.7	209.7
SEm±	1.2	1.34	1.16	1.22	1.12	1.11	1.80	1.82	1.43	11.3	6.4	7.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	32.0	NS	22.0
N (kg/ha)												
0	7.49	6.53	7.01	8.36	7.49	7.93	18.05	19.77	18.91	221.7	83.6	152.7
40	7.76	6.82	7.29	8.68	8.54	8.61	19.15	20.50	19.83	266.7	106.7	186.7
SEm±	1.2	1.34	1.16	1.22	1.12	1.11	1.80	1.82	1.43	8.0	4.5	5.5
CD (P= 0.05)	NS	NS	NS	NS	0.4	NS	NS	NS	NS	23.0	13.0	16.0

Table 4. Leaf-fodder and fuel-wood yields (kg/ha) of trees under different cropping systems in 2006

Cropping system	Leaf-fodder yield			Fuel wood yield		
	C. mopane	*H. binata*	Mean	*C. mopane*	*H. binata*	Mean
C. ciliaris	103	65	84	413	155	284
L. sindicus	99	60	79	396	144	270
C. ciliaris + *L. purpureus*	111	59	85	444	142	293
L. sindicus + *L. purpureus*	119	67	93	477	161	319
Mean	108	63	86	435	151	293
	Leaf-fodder yield			Fuel-wood yield		
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Trees (T)	9	29		35	105	
Cropping system (CS)	5	NS		17	NS	
T x CS	8	NS		24	NS	

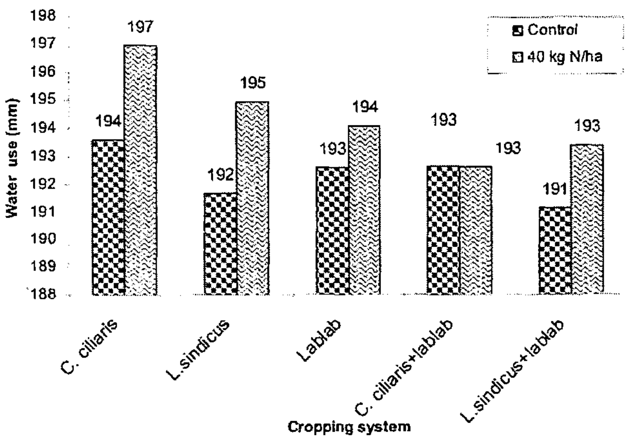

Figure 1. Water-use by pasture grasses and legume under different cropping system and fertility levels

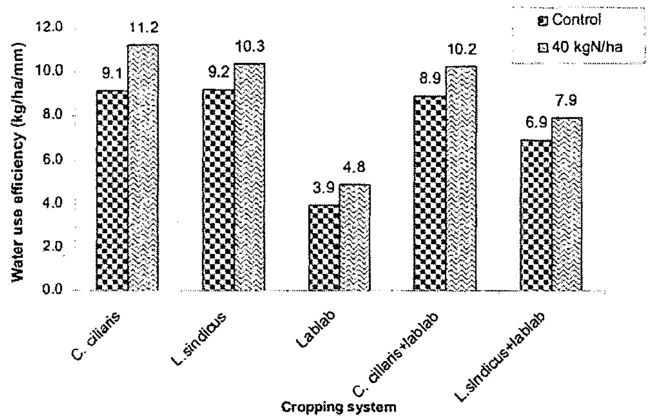

Figure 2. Water-use efficiency of grasses and legume under different cropping system and fertility levels

more water from higher tension level and from greater depth in the soil.

It was concluded that for getting higher productivity of quality fodder, stripping of grasses with legumes in association with *C. mopane* or *H. binata* can be adopted in a silivi-pastoral system under arid conditions. Application of 40 kg N/ha also improves the land and water productivity of the system.

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