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PRODUCTIVITY OF DIFFERENT FODDER CROPS SEQUENCES GROWN IN ASSOCIATION OF BER (*ZIZYPHUS MAURITIANA* LAMK.) PLANTATION UNDER AGRI-HORTICULTURE SYSTEM IN HOT ARID REGION OF WESTERN INDIA

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SUMMARY

The field experiment was conducted during 2008-11 to find out the most productive and remunerative fodder crops sequence in association of ber (*Zizyphus mauritiana* Lamk.) plantation in hot arid ecosystem of western India. Results indicated that among fodder cropping sequences, pearlmillet (*Pennisetum glaucum*)+clusterbean (*Cyamopsis tetragonoloba*)-lucerne (*Medicago sativa*) sequence recorded maximum values of green fodder (96.5 and 92.9 t/ha), dry matter (19.5 and 21.3 t/ha) and crude protein (2.87 and 3.05 t/ha) yields in both the years, and overall net returns of (Rs. 97.6 thousands/ha) and B : C ratio (2.43). These fodder yields were significantly higher over rest of the sequences in both the years except green fodder and dry matter yield of pearlmillet sole-lucerne in first year and dry matter yields alone of pearlmillet+clusterbean-oats (*Avena sativa*) in both the years. Growth data on ber plantation showed that none of the fodder cropping sequences had its significant effect on ber growth attributes viz., plant height, collar girth and canopy diameter except collar girth at 15 months stage, where differences in collar girth were significant and trees in the plots under pearlmillet+clusterbean-oats recoded maximum value of 21.7 cm, which was at par with pearlmillet+clusterbean-lucerne, sorghum (*Sorghum bicolor*)+cowpea-oats, sorghum+cowpea (*Vigna unguiculata*)-lucerne, sorghum sole-oats, clusterbean sole-lucerne and ber sole, and significantly higher over rest of the sequences. Differences due to fodder cropping sequence in ber tree productivity viz., fruits, dry leaves fodder and dry wood yields were also non-significant. Hence, it can be concluded that growing of pearlmillet+clusterbean-lucerne in association of ber plantation holds promise to provide higher and remunerative productivity in hot arid ecosystem of western India.

Key words : Agri-horticulture, ber, fodder crops sequences, fodder yield, economics

Like other parts of the country, animal husbandry being an integral part of agriculture plays an important role in livelihood security and economic sustenance in hot arid region of western India also. This region is not only gifted with best inherent quality breeds of different animal species along with a good animal strength but after improvement in irrigated conditions due to introduction of Indira Gandhi Canal Project and successful digging of tube wells, population of milch animals like crossbred cows and buffaloes is increasing day by day, but their productivity is very low due to poor quality and limited quantity of fodders. As per practical experience of the region, farmers have started growing of fodder crops in both the seasons by sparing some piece of their lands under fodder production, but it is insufficient in bridging the gap between demand and supply of fodder for ever increased animal population of the region. Farmers are not ready to put their lands solely under fodder crops due to poor economic returns. Therefore, there is a need to develop some fodder based alternate land use systems which can provide employment, food and sustainable family income. Aonla,

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ber, bael, lasoda, pilu, etc. are the main fruit tree species which can be grown in arid ecosystem in association of field crops under agri-horticulture system (Awasthi and Pareek, 2011). Among fruit trees, ber (*Zizyphus mauritiana* Lamk.) is most suitable fruit tree and it is normally widely spaced and its interspaces have scope of growing fodder crops. Moreover, due to annual pruning of ber trees, they can be trained for above ground spreading for growing of fodder crops in both the seasons. Most of the studies conducted so far are based on rainfed conditions by taking grain crops in interspaces and information on fodder crops based agri-horticulture under irrigated situations is meagre. Hence, present investigation was undertaken to find out the most suitable fodder crops sequence in association of ber plantation in agri-horticulture system in hot arid ecosystem of western India.

MATERIALS AND METHODS

The field experiment was conducted during 2008-11 at Agricultural Research Farm, Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner (Rajasthan). The soil of experimental field was sandy with low organic carbon (0.43%), available nitrogen (238.4 kg/ha), phosphorus (14.5 kg P_2O_5/ha) and potassium (280.3 kg K_2O/ha) along with pH value of 7.85 and EC 0.56 dS/m. The experiment consisted of 13 treatments, one ber sole ($T_{ber\ sole}$) and 12 fodder cropping sequences viz., sorghum (*Sorghum bicolor*) sole-oat (*Avena sativa*) (T_1), sorghum sole-lucerne (*Medicago sativa*) (T_2), pearlmillet (*Pennisetum glaucum*) sole-oat (T_3), pearlmillet sole-lucerne (T_4), clusterbean (*Cyamopsis tetragonoloba*) sole-oat (T_5), clusterbean sole-lucerne (T_6), cowpea (*Vigna unguiculata*) sole-oat (T_7), cowpea sole-lucerne (T_8), sorghum+cowpea-oat (T_9), sorghum+cowpea-lucerne (T_{10}), pearlmillet+clusterbean-oat (T_{11}) and pearlmillet+clusterbean-lucerne (T_{12}). Trial was laid out in randomized block design with three replications. During **kharif,** gross plot size was 24 x 32 m and adjusted 12 ber plants in each plot. Each plot was divided into two equal size plots for growing **rabi** season crops. Almost one and a half months old budded saplings of ber varieties *'seb'* and '*gola*' in equal proportion were planted at a distance of 8 x 8 m in last week of August, 2008 in the pits (45 cm diameter and 0.90 m deep) dug out by tractor drawn auger (digger) in the month of June, 2008. The pits were filled by fairly mixed 1 : 4 ratio of sheep manure up to 15 cm below the ground level. In very first year all efforts were made to get healthy plantation and any casualty was immediately replaced to maintain full tree population and growing of fodder crops was started from **kharif** season of next year i. e. 2009-10. While the varieties of fodder crops viz., 'HC-308' of sorghum, 'UPC 5286' of cowpea, 'RBC-2' of pearlmillet, 'BG-1' of clusterbean, 'Kent' variety of oat and 'T-9' of lucerne were used. During **kharif,** crops were sown on 6th and 3rd of July and **rabi** crops on 25th and 28th of October in first and second years, respectively. All recommended agronomic package of practices of different crops were followed to raise healthy crop and trial was undertaken under irrigated conditions. Growth data of ber viz., tree height, collar girth and tree canopy were observed at 3, 6, 9, 15 and 24 months after plantation. Green fodder crops were harvested at green stage and 1 kg of plant samples of each plot and each crop was collected for the estimation of dry matter and crude protein. Ber productivity viz., dry leaves fodder and dry wood yield was taken at the time of pruning in April 2010 and fresh fruits yield at ber fruit maturity as and when matured during **rabi** season of 2010-11. Statistical analysis was done as per standard method. Prevalent prices of all inputs and outputs were considered for working out the economics.

RESULTS AND DISCUSSION

Seasonal Green Fodder and Dry Matter Yields

Data on green fodder and dry matter yields of **kharif** season revealed that pearlmillet grown sole or in intercropping system with clusterbean recorded highest fodder yields with statistical parity in both the years, and these yields were significantly superior to rest of the fodder crops (Table 1). It was also noted that cereals viz., sorghum and pearlmillet alone as well as in intercropping with legumes also recorded significantly higher green fodder and dry matter yields over legumes. While in case of **rabi** season crops, lucerne significantly outyielded oat in all the cropping sequences in both the years, and green and dry matter yields among oat to oat and lucerne to lucerne during **rabi** season in all the sequences were statistically at par except when crops were preceded by sorghum. Where, oat and lucerne yields were significantly inferior to other highest yielders. It might be due to allelopathic effect of sorghum grown as preceded crop on succeeded crops viz., oat and

TABLE 1
Season-wise green and dry fodder yields (t/ha) under different treatments

Treatment	Green fodder yield				Dry matter yield			
	2009-10		2010-11		2009-10		2010-11	
	Kharif	**Rabi**	**Kharif**	**Rabi**	**Kharif**	**Rabi**	**Kharif**	**Rabi**
T_1	34.7	36.3	28.1	31.5	7.27	8.44	7.42	7.43
T_2		45.6		44.5		8.93		9.14
T_3	39.6	40.4	40.5	36.7	8.29	9.44	10.22	8.52
T_4		56.3		45.6		10.84		8.99
T_5	20.1	43.8	17.9	38.6	3.97	10.84	4.05	8.96
T_6		58.0		46.4		10.04		9.26
T_7	15.4	40.0	16.9	39.7	2.97	9.04	3.88	9.25
T_8		56.0		50.8		11.01		10.07
T_9	32.1	40.0	31.4	39.2	6.64	9.35	7.33	9.64
	(4.0)	(0.76)	(3.3)	(0.60)				
T_{10}		54.2		50.4		10.47		10.05
T_{11}	39.0	41.8	42.7	40.1	8.37	9.61	11.23	9.74
	(5.2)	(0.99)	(6.1)	(0.93)				
T_{12}		57.5		50.2		11.10		10.2
S. Em±	0.90	2.63	1.90	2.09	0.19	0.56	0.34	0.42
C. D. (P=0.05)	2.84	7.72	5.99	6.14	0.61	1.65	1.07	1.24

Treatment details are given in Materials and Methods. Figures in parentheses are yields of legume components.

lucerne. Higher productivity of pearlmillet and clusterbean with ber plantation was also reported by Awasthi and Pareek (2008). Gupta (1994) also found better compatibility of ber with crops. Kumar *et al.* (2005) reported that ber did not significantly affect the pasture yields.

Annual Green and Dry Matter Yields

Data recorded on sum up fodder yields of both the seasons showed that green fodder and dry matter yields recorded with pearlmillet+clusterbean-lucerne were statistically at par with pearlmillet sole-lucerne except dry matter yield in second year, where dry matter yields were at par with pearlmillet+clusterbean-oat and pearlmillet+clusterbean-lucerne, but these yields were significantly higher over rest of the sequences (Table 2). Mean yield data of two years also indicated the highest green fodder and dry matter yields recorded with pearlmillet+clusterbean-lucerne were at par with pearlmillet-lucerne in green fodder and with pearlmillet+clusterbean-oat in dry matter yields. Higher green fodder in previous sequence may be due to more green fodder productivity of crops of sequence viz., pearlmillet, clusterbean and lucerne of the sequence, while comparatively greater dry matter content (%) of oat fodder might be the reason of higher dry matter yield in pearlmillet+clusterbean-oat sequence.

Crude Protein Yield

Like fodder yields, crude protein (CP) production recorded with pearlmillet+clusterbean-lucerne in both the years as well as on mean data basis as given in Table 2 was significantly higher over all the other sequences except pearlmillet+clusterbean-oat and clusterbean sole-lucerne in first year, where differences in CP yields were non-significant. Higher protein yield in above sequences might be the combined effect of higher fodder yields and inclusion of CP rich legumes as intercrop as well as sequential crop.

Growth Attributes of Ber Plantation

Data presented in Table 3 on growth attributes indicated that ber saplings showed continuous improvements at all the growth stages in all the growth parameters viz., plant height, collar girth and canopy diameter. Higher percentage of improvement in all the growth attributes up to 15 months and lower percentage

TABLE 2
Annual fodder and crude protein yields (t/ha) under different treatments

Treatment	Green fodder yield			Dry matter yield			Crude protein yield		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
T_1	71.1	60.2	65.6	15.7	14.8	15.2	1.25	1.18	1.22
T_2	80.3	72.7	76.5	16.2	16.5	16.3	2.27	2.38	2.32
T_3	80.1	77.3	78.7	17.7	18.7	18.2	1.39	1.49	1.44
T_4	95.9	86.2	91.0	19.1	18.9	19.0	2.79	2.52	2.65
T_5	63.9	56.5	60.2	14.0	13.0	13.5	1.45	1.48	1.46
T_6	78.2	64.3	71.2	15.2	13.3	14.2	2.78	2.64	2.70
T_7	55.4	56.6	56.0	12.0	13.0	12.5	1.28	1.57	1.42
T_8	71.4	67.7	69.5	14.0	14.0	14.0	2.73	2.73	2.73
T_9	72.1	70.7	71.3	16.0	16.6	16.2	1.36	1.45	1.40
T_{10}	86.3	81.9	84.1	17.1	17.4	17.2	2.62	2.59	2.60
T_{11}	80.8	82.8	81.8	17.9	21.5	19.2	1.48	1.79	1.63
T_{12}	96.5	92.9	94.6	19.5	21.3	20.3	2.87	3.05	2.96
S. Em±	2.70	2.50	1.76	0.55	0.54	0.41	0.06	0.08	0.04
C. D. (P=0.05)	7.92	7.33	5.18	1.60	1.59	1.22	0.21	0.24	0.13

TABLE 3
Mean value of growth attributes of ber trees at different intervals

Growth attributes (in cm)	Observations after plantation				
	3 months (Nov., 08)	6 months (Feb., 09)	12 months (Nov., 09)	15 months (Feb., 10)	24 months (Sep., 10)
Plant height	49.5±15.6	56.3±12.4	112.0±26.1	247.5±10.6	250.0±23.0
Imp. (%)	-	13.7	98.9	121.0	1.01
Collar girth	2.38±0.25	4.16±0.64	7.21±2.08	17.4±2.15	23.0±2.72
Imp. (%)	-	74.8	73.3	141.3	32.2
Canopy dia.	21.1±28.4	43.8±10.7	104.2±21.6	225.8±12.8	338.6±39.2
Imp. (%)	-	107.6	137.9	116.7	49.9

improvement at 24 months was mainly because of pruning of ber plantation done during April, 2010 for getting commercial ber production and also might be due to maximum use of plants energy into development of profuse tillers and leaves before flowering and fruiting stage. Analysis of ber growth attributes observed at 15 and 24 months stages before pruning for getting commercial ber fruits production and after almost maximum growth just before initiation of flowering, respectively, revealed that none of fodder crop or cropping sequences significantly decreased the ber growth, except collar girth at 15 months stage, where differences in collar girth were significant (Table 4). At this stage, maximum value of collar girth was observed in the plantation under the treatment of pearlmillet+clusterbean-oats, which being at par with pearlmillet+clusterbean-lucerne, sorghum+cowpea-oat, sorghum+cowpea-lucerne and ber sole was significantly higher over rest of the cropping sequences. Overall, it was also noted that growing of cereals in association of ber plantation was found more favourable for ber growth than legumes. It might be due to competition for sunlight between long stature cereal crops and ber plantation, resulted in improved growth attributes and contrary to this, legume crops might not have posed any competition for sunlight as well as plant nutrients, hence, ber plantation showed its normal growth and recorded comparatively lower values of growth attributes.

Ber Productivity

Fresh ber fruit yields during **rabi** season of 2010-11, and dry leaf fodder and dry wood yields recorded in pruning in April, 2010 under different

TABLE 4
Growth attributes of ber trees under different treatments

Treatment	At 15 months			At 24 months		
	Tree height (cm)	Collar girth (cm)	Canopy diameter (cm)	Tree height (cm)	Collar girth (cm)	Canopy diameter (cm)
$T_{ber\ sole}$	236.0	18.7	213.3	269.0	24.3	371.4
T_1	241.3	17.7	208.7	210.7	25.7	371.2
T_2	237.0	16.3	210.3			
T_3	249.3	16.3	226.0	252.0	22.7	307.6
T_4	253.0	16.2	240.7			
T_5	254.0	16.7	217.7	229.3	21.0	307.6
T_6	255.0	17.7	220.0			
T_7	233.7	15.3	216.3	274.3	24.0	326.7
T_8	236.3	16.7	223.0			
T_9	250.3	19.3	241.3	249.0	18.0	292.7
T_{10}	242.7	18.7	234.7			
T_{11}	265.7	21.7	237.7	266.0	25.3	392.7
T_{12}	263.3	20.3	246.0			
S. Em±	15.99	1.36	11.74	20.75	4.20	62.61
C. D. (P=0.05)	NS	3.97	NS	NS	NS	NS

NS–Not Significant.

treatments as detailed in Table 5 indicated that none of the fodder cropping sequences exerted significant effect on any yield parameter. Maximum ber fruit (2.59 t/ha) and dry wood (1.75 t/ha) yields recorded with fodder cropping sequence pearlmillet+clusterbean-lucerne were 11.6 and 16.7 per cent higher over lowest yielders viz., cowpea sole-oat and pearlmillet sole-lucerne sequences, respectively. Whereas, maximum dry leaves productivity (692.6 kg/ha) was observed with ber plantation planted under clusterbean sole-oat sequence and it was 23.1 per cent greater than lowest yielder sequence i. e. sorghum sole-oat sequence. Differences in all yield parameters due to different fodder cropping sequences were lower than above among themselves. The average fruit yield of ber was found higher under clusterbean cropping over sole ber plantation by Singh *et al.* (2011). Ram and Kumar (2011) also reported that dry leafy fodder and dry wood production of ber were not significantly affected by different pasture grasses.

TABLE 5
Productivity of ber trees in third year of plantation under different treatments

Treatment	Fruit yield (t/ha)	Dry wood yield (t/ha)	Dry leaf fodder yield (kg/ha)
$T_{ber\ sole}$	2.46	1.58	666.7
T_1	2.33	1.51	562.5
T_2	2.38	1.60	598.9
T_3	2.35	1.54	588.6
T_4	2.46	1.50	635.5
T_5	2.39	1.60	692.6
T_6	2.46	1.68	630.1
T_7	2.32	1.65	614.5
T_8	2.43	1.64	666.7
T_9	2.38	1.71	604.2
T_{10}	2.44	1.69	677.0
T_{11}	2.35	1.54	583.3
T_{12}	2.59	1.75	672.0
S. Em±	0.11	0.08	42.1
C. D. (P=0.05)	NS	NS	NS

Economics

Economic evaluation in terms of net returns and benefit : cost ratio showed that growing of all the fodder crops/cropping sequences with ber plantation was found beneficial and higher net returns and B : C ratios than recorded with sole ber plantation (net returns 13.6 thousand/ha and B : C ratio 1.49) except B : C ratio in sorghum sole-oat, where B : C ratio noted was slightly lower (1.46) than sole ber plantation (Table 6). It was mainly because of comparatively lower improvement in fodder yields compared with increase in cost of cultivation. Among fodder cropping sequences, pearlmillet+clusterbean-lucerne sequence registered higher net returns (Rs. 165.6 thousands/ha) and B : C

TABLE 6
Economics of agri-horticulture system

Treatment	Cost of cultivation (x 10^3 Rs./ha)	Gross returns (x 10^3 Rs./ha)	Net returns (x 10^3 Rs./ha)	Benefit : cost ratio
$T_{ber\ sole}$	27.7	41.3	13.6	1.49
T_1	65.6	96.2	30.6	1.46
T_2	67.0	130.8	63.8	1.95
T_3	62.6	118.5	55.9	1.89
T_4	66.7	158.2	91.4	2.37
T_5	65.9	110.0	44.1	1.67
T_6	67.3	148.2	80.9	2.20
T_7	66.2	103.2	37.0	1.56
T_8	67.6	141.3	73.7	2.09
T_9	65.9	107.4	41.4	1.63
T_{10}	67.3	147.5	80.1	2.19
T_{11}	66.7	123.8	57.2	1.86
T_{12}	68.0	165.6	97.6	2.43

ratio (2.43) followed by clusterbean sole-lucerne (158.2 thousands/ha and 2.37) and minimum values were observed with sole ber plantation. Higher values of economic returns and B : C ratios with above sequences were mainly because of combined effect of higher fodder productively as compared to costs involved and had no effect on productivity of ber plantation. It was also noted that at the tune of fodder productivity lucerne crop as succeeded crop recorded higher values of net returns and B : C ratios in all the cropping sequences as compared to oat crop.

CONCLUSION

Based on above study, it was concluded that growing of pearlmillet+clusterbean-lucerne fodder sequence with ber plantation under agri-horticulture system was found mutually complementary, productive and remunerative alternate land use system in hyper arid ecosystem of western India.

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