Indian Journal of Agronomy 53(1): 51–56 (March 2008)

Fodder productivity and economics of multi-cut pearlmillet (*Pennisetum glaucum*) intercropped with clusterbean (*Cyamopsis tetragonoloba*)

K.C. SHARMA*

Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner, Rajasthan 334 006

Received: February 2008

ABSTRACT

A field experiment was conducted during summer seasons of 2006 and 2007 at Bikaner, Rajasthan to find out the effect of sole, mixed and intercropping in different row ratios (1:1, 1:2, 2:2 3:2 and 3:3) of pearlmillet [*Pennisetum glaucum* (L.) R.Br. emend. Stuntz] and clusterbean (*Cyamopsis tetragonoloba* (L.) Taub] on fodder productivity and its economics. Green and dry fodder yields of both the component crops, viz. pearlmillet and clusterbean, were substantially reduced under intercropping system compared with their sole crop yields. Pooled analysis of 2 years showed that intercropping of pearlmillet and clusterbean with a row ratio of 2:2 recorded the maximum values of growth parameters, viz. height and number of plants or tillers per unit area, green fodder (59.7 t/ha), dry matter (13.18 t/ha), crude protein (1.27 t/ha), land-equivalent ratio (1.35), price-equivalent ratio (1.44), net returns (Rs 47,300/ha) and benefit : cost ratio (3.27) than other intercropping row ratios, mixed cropping and sole stands of pearlmillet and clusterbeen. However, maximum aggressivity index (0.66) and relative crowding co-efficient (12.37) were obtained with mixed seed sowing of pearlmillet and clusterbean. Thus intercropping system of multi-cut fodder pearmillet and clusterbeen in a row ratio of 2:2 may be adopted for higher productivity, better quality and profitability in hot arid conditions.

Key words: Clusterbean, Competition functions, Crude protein yield, Economics, Fodder yield, Intercropping, Pearlmillet

Fodder requirement of livestock in hot arid zone of Rajasthan is generally met through low-quality crop residues and degraded pastures, which are not enough for the maintenance of animal health and productivity. In recent past, after introduction of Indira Gandhi canal project, successful digging of borewells in the area and increased population of ruminants in the region, farmers have started growing green fodders in different seasons of the year for their animals as well as for business purpose. Multi-cut fodder pearlmillet [*Pennisetum glaucum* (L.) R.Br. emend. Stuntz.] which is popularly known as *bajri*, is largely sown as a summer fodder crop in the region. But, being an exhaustive crop, it puts heavy demand on the soil for nutrients and moisture, as a result the farmers are not able to realize its full production potential. Fertilizer application is not only a costly affair but allocation of fertilizers to fodder crops is also very less and further the fertilizers are almost in short supply during the cropping season. Therefore, a need is being felt to search alternative cheaper technology to increase the fodder productivity and quality. Intercropping of cereals with legumes is an effective approach for boosting production and quality of forage crops (Rao and Willey, 1980), which also enriches the soil fertility (Bezbaruah and Thakuria, 1996). Pearlmillet and clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] are the potential fodder crops, which can provide good nutrition to livestock with higher fodder yields and improved fodder quality, when grown in association. Further, it may also be beneficial for improving the fertility status of the soil. Intercropping of clusterbean in pearlmillet was found more productive and remunerative than pearlmillet + cowpea or greengram (Ram *et al.*, 2005). But the information on row proportions of multi-cut fodder pearlmillet and clusterbean in intercropping system in hot arid region is not available. Therefore, the present investigation was undertaken.

***Corresponding author** (Email: kc_64sharma@yahoo.com)

MATERIALS AND METHODS

The field experiment was laid out for 2 years during summer seasons of 2006 and 2007 at the research farm of Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner. The soil was sandy, low in organic C (0.23%), available N (133.7 kg/ha), and available P (8.76 kg/ha) and medium in available K (134.4 kg/ha), with pH 8.38 and electrical conductivity 0.57 dS/m. There were eight treatments consisting of pearmillet sole, clusterbean sole, pearlmillet and clusterbean intercropping in row ratios of 1:1, 1:2, 2:2, 3:2, 3:3 and mixed seeding of pearlmillet and clusterbean in the same row. These were evaluated in randomized block design with four replications. For mixed sowing, 50% seed rate of each component crop was sown in the same row. But in other treatments the seed rate was calculated on the basis of row ratios and the area covered by the component crops. Fodder pearlmillet and clusterbean crops were sown 30 cm apart rows with a seed rate of 10 and 35 kg/ha respectively. The pearlmillet cv 'Rajko' and clusterbean cv 'Bundel Guar1' were sown during summer on 7 and 10 April in the first and second years respectively. The recommended fertilizer doses (90 kg N, 17.6 kg P and 33.2 kg K/ha for pearlmillet, and 20 kg N, 26.4 kg P and 33.2 kg K/ha for clusterbean) were applied as per area occupied by the component crops under different treatments. In addition, a uniform dose of dry sheep manure @ 5 t/ ha was also applied to each plot. Fertilizers @ 20 kg N and full doses of P, K and sheep manure were applied at sowing and the remaining 70 kg N/ha of pearmillet was top-dressed in three splits, viz. 20 kg N/ha at crop stage of 4 weeks and 25 kg N/ha each after the first and second cuts. The crop was raised under irrigated conditions with recommended agronomic practices. Total three cuts were taken each year, with the first cut at 55 days after sowing and the subsequent cuts at 35-40 days intervals. The growth data, viz. number of tillers or plants/unit area and height and green-fodder yield were recorded at each cut. The plant samples were collected from each plot for dry-matter contents and estimation of nitrogen for crude-protein yield. Chemical analysis for the estimation of N was done by Kjeldahl method. The economics was calculated on the basis of prevailing market prices of different inputs and output. Different crop-competition indices and yield advantages were computed as described by Willey (1979) and Cheema *et al.* (1993). Price-equivalent ratio (PER) was calculated as:

$$PER = \frac{(Y_{ab} \times Y_{ap}) + (Y_{ba} \times Y_{bp})}{\frac{1}{2}(Y_{aa} \times Y_{ap} + Y_{bb} \times Y_{bp})}$$

where Y_{aa}, yield of component crop 'a' as sole crop; Y_{bb}, yield of component crop 'b' as sole crop; Y_{ab}, yield of component crop 'a' as intercrop in combination with 'b'; Y_{ba}, yield of component crop 'b' as intercrop in combination with 'b'; Y_{ap}, market price of component crop 'a' produce; and Y_{bp}, market price of component crop 'b' produce.

RESULTS AND DISCUSSION

Green- and dry-fodder yields

Number of plants/tillers/m^2 and height of plants at different cut stages of both the component crops showed that intercropping of pearlmillet and clusterbean in 2:2 row ratio recorded the highest values of above both the traits of both component crops except at third cut stage of clusterbean, where the plant height was highest with the 1:1 row ratio (Table 1). The maximum number of plants/m^2 was recorded with sole clusterbean and this was followed by the row ratio of 1:1 of pearlmillet and clusterbean. Higher values of growth parameters with 2:2 and 1:1 intercropping systems might be due to better utilization of resources and competition between both the component crops for solar radiation, resulting in increased height of plants/tillers compared with sole stands. However, the plants/tillers of both the component crops were thinner in intercropping plots compared with those in sole stands.

Green and dry fodder yields were significantly affected by different intercropping row ratios in both the years (Table 2). The fodder yields of both the components crops were substantially reduced in intercropping system compared with their sole stands. This reduction in green- and dry-fodder yields of pearlmillet was minimum with 3:2 ratio intercropping (5.14 and 5.27%) in 2006 and in mixed sowing during 2007 (6.88 and 8.28%). It was followed by mixed sowing and 2:2 ratio intercropping. In clusterbean the minimum reduction was observed with 1:2 ratio intercropping in both the years (45.3 and 46.1% in green fodder and 45.7 and 48.6% in dry-matter yields in 2006 and 2007 respectively). The reduction in green and dry fodder yields of pearlmillet and clusterbean was mainly because of reduction in area under crops in the intercropping system. The reduction in pearlmillet yields was not to the similar extent as area reduced under different row ratios of intercropping system, which showed positive effect of legume component to the associated crop of pearlmillet by fixation of atmospheric nitrogen and providing better conditions of root growth. This reduction in fodder yields of pearlmillet under different intercropping systems of pearlmillet and clusterbean was compensated by contribution of both in total fodder yields of the intercropping system. The highest total green and dry fodder yields were recorded with 2:2 ratio intercropping of pearlmillet and clusterbean in both the years, followed by mixed sowing. These yields were significantly higher than intercropping in row ratios of 1:2, 3:3 and sole clusterbean in the first year and row ratios of 1:2, 3:2, 3:3 and clusterbean sole during the second year, but statistically on a par with rest of the treatments. Higher fodder yields under the row ratio of 2:2 of pearlmillet and clusterbean was due to increased values of growth parameters, viz. plant height and tiller number unit area. This might be owing to the efficient utilization of space, light interception and nutrients along with the contribution of legume to the cereal component of the system. Balyan and Seth (1991) also reported higher total productivity of pearlmillet + clusterbean intercropping. Chatterjee and Mandal (1992) also opined that paired row planting is advantageous for resource utilization, increasing productivity and water use efficiency of crops. Kumar *et al.* (2005) also reported highest fodder yield with row ratio of 2:2 in maize + cowpea intercropping system.

All the intercropping systems including mixed sowing recorded LER (land equivalent ratio) values more than 1, which showed efficient utilization of land under intercropping of pearlmillet and clusterbean compared with sole cropping (Table 2). The highest values of LER were obtained with 2:2 row ratio of pearlmillet and clusterbean, followed by 1:1 row ratio. Among intercropping systems, pearlmillet and clusterbean sown at row proportion 3:2 recorded minimum value of LER, mainly due to the lowest yield of clusterbean recorded with this system. Increased value of LER indicates greater biological efficiency of the system. On mean basis, the difference in LER values in different intercropping systems, varied from 3.85 to 18.40%. Higher LER value with 2:2 row ratio of pearlmillet and clusterbean indicating better adaptability of the intercropping system and it might be due to better utilization of natural resources, viz. space, light etc. as well as applied inputs by the component crops having different characterstics, viz. nutrient requirements, root systems and canopy structures. Higher LER was also reported by Adhikari *et al.* (2005) at a row ratio of 2:2 in maize + groundnut intercropping system.

Crude-protein yield

Nitrogen content in the dry fodder of both the component crops under different treatments did not show any special trend and recorded almost similar values, but N content varied at different cuts and recorded maximum at the first cut stage and decreased gradually in the second and third cuts of both the crops (Table 3). The difference in crude-protein yields recorded under different treatments of the intercropping system was found significant. Among the intercropping systems, maximum contribution of clusterbean to crude protein yield was in 1:2 ratio intercropping 36.1 and 36.4% in 2006 and 2007 respectively, followed by row ratio of 3:3 (31.5%) in 2006 and row ratio 2:2 (26.2%) in the 2007 year. Maximum crude protein yield through clusterbean with row ratio 1:2 was mainly because of higher area allocation for legume component of the system. The highest total crude protein yield was recorded with the treatment 2:2 row ratio of pearlmillet and clusterbean, followed by their 1:1 row ratio and mixed sowing treatment. The total crude protein yield recorded with row ratio 2:2 indicated increase of 19.4 and 67.5% in the first year and 21.1 and 88.1% in the second year over sole stands of pearlmillet and clusterbean, respectively. The increase in crude protein yield was mainly because of variation in the dry matter accumulation of both the component crops. It was noted that more number of clusterbean rows in pearlmillet and clusterbean intercropping system recorded higher yields of crude protein by clusterbean, but under such treatment reduced area under pearlmillet brought out lower crude-protein yields of total intercropping system. The difference in crude protein yields between intercropping row ratio 1:1 and mixed seed sowing as well as among row ratios 3:2, 1:2 of pearlmillet and clusterbean and sole pearlmillet were statistically not significant. The minimum crude protein yield was obtained

Table 1. Growth parameters as influenced by treatment variables (mean data of two years)

Treatment	Height of plants or tillers (cm)						No. of plants or tillers/m^2					
	Pearlmillet			Clusterbean			Pearlmillet			Clusterbean		
	I cut	II cut	III cut	I cut	II cut	III cut	I cut	II cut	III cut	I cut	II cut	III cut
Pearlmillet (Pm) sole	144.7	123.6	126.3				487.3	432.7	407.3			
Clusterbean (Cb) sole				73.7	36.8	49.7				65.3	61.0	34.0
Pm + Cb (1:1)	150.3	125.9	129.6	80.2	40.6	56.7	512.0	462.0	416.7	68.7	65.3	31.0
Pm + Cb (1:2)	133.9	116.0	125.7	68.1	37.6	47.3	463.7	415.7	387.3	47.7	47.0	24.7
Pm + Cb (2:2)	156.7	128.8	133.6	83.7	41.8	55.2	522.3	471.0	437.7	76.0	74.7	29.7
Pm + Cb (3:2)	145.5	115.2	121.7	59.7	33.6	48.3	485.3	445.3	379.3	51.3	45.7	20.7
Pm + Cb (3:3)	148.4	121.6	124.4	77.6	36.4	46.2	492.3	429.0	410.0	72.7	48.7	22.3
Pm + Cb (mix)	144.3	122.9	130.1	82.1	42.4	54.9	468.7	432.3	384.3	44.3	22.3	10.3
SEm±	4.4	3.9	2.1	3.0	1.7	3.2	13.4	12.8	13.9	6.6	5.8	4.2
CD (P=0.05)	9.2	8.2	4.5	6.3	3.7	6.7	28.1	26.8	29.2	13.9	12.1	8.7

*Number of plants/tiller counted per running m and converted to per m^2

Table 2. Green fodder, dry matter and land-equivalent ratio as influenced by treatment variables

Treatment	Green-fodder yield (t/ha)							Dry-fodder yield (t/ha)							Land-equivalent ratio		
	2006			2007			Pooled	2006			2007			Pooled	2006	2007	Mean
	Pm	Cb	Total	Pm	Cb	Total		Pm	Cb	Total	Pm	Cb	Total				
Pearlmillet (Pm) sole	58.4		58.4	56.7		56.7	57.5	13.29		13.29	12.32		12.32	12.80			
Clusterbean (Cb) sole		19.0	19.0		17.8	17.8	18.4		4.35	4.35		3.70	3.70	4.02			
Pm + Cb (1:1)	53.2	6.5	59.7	48.2	7.4	55.6	57.7	12.06	1.48	13.54	9.72	1.48	11.20	12.37	1.26	1.27	1.27
Pm + Cb (1:2)	38.4	10.4	48.8	33.6	9.6	43.2	46.0	9.46	2.36	11.82	7.19	1.90	9.09	10.45	1.22	1.13	1.17
Pm + Cb (2:2)	52.2	7.9	60.1	50.1	9.1	59.2	59.7	11.89	1.78	13.67	10.90	1.80	12.70	13.18	1.32	1.39	1.35
Pm + Cb (3:2)	55.4	4.5	59.9	46.7	4.9	51.6	55.7	12.59	1.01	13.60	9.85	0.99	10.48	12.22	1.18	1.10	1.14
Pm + Cb (3:3)	40.9	8.6	49.5	42.8	7.3	50.2	49.8	9.14	1.91	11.05	9.29	1.48	10.77	10.90	1.15	1.16	1.16
Pm + Cb (mix)	53.6	5.6	59.2	52.8	4.3	57.1	58.1	12.17	1.27	13.44	11.30	0.88	12.18	12.80	1.22	1.17	1.19
SEm±			2.3			2.1	2.2			0.54			0.47	0.51			
CD (P=0.05)			4.9			4.4	4.3			1.13			0.99	1.00			

Table 3. Nitrogen content and crude protein yield as influenced by treatment variables

Treatment	N content in pearlmillet at different cuts (%)						N content in clusterbean at different cuts (%)						Crude protein yield (t/ha)						
	2006			2007			2006			2007			2006			2007			Pooled
	Ist	IInd	IIIrd	Ist	IInd	IIIrd	Ist	IInd	IIIrd	Ist	IInd	IIIrd	Pm	Cb	Total	Pm	Cb	Total	
Pearlmillet (Pm) sole	1.67	1.22	1.14	1.77	1.31	1.11							1.08		1.08	1.04		1.04	1.06
Clusterbean (Cb) sole							3.22	2.81	2.60	3.29	2.80	2.58		0.77	0.77		0.67	0.67	0.72
Pm + Cb (1:1)	1.69	1.23	1.21	1.80	1.41	1.12	3.19	2.82	2.53	3.31	2.72	2.46	0.98	0.26	1.24	0.83	0.27	1.10	1.17
Pm + Cb (1:2)	1.71	1.24	1.20	1.82	1.39	1.19	3.23	2.71	2.57	3.28	2.79	2.34	0.76	0.43	1.19	0.61	0.35	0.96	1.07
Pm + Cb (2:2)	1.78	1.33	1.22	1.84	1.41	1.21	3.24	2.90	2.60	3.31	2.89	2.44	0.97	0.32	1.29	0.93	0.33	1.26	1.27
Pm + Cb (3:2)	1.72	1.31	1.16	1.81	1.33	1.21	3.33	2.81	2.52	3.25	2.88	2.39	1.01	0.18	1.19	0.84	0.18	1.02	1.11
Pm + Cb (3:3)	1.70	1.32	1.21	1.80	1.36	1.21	3.29	2.77	2.50	3.29	2.69	2.48	0.74	0.34	1.08	0.79	0.27	1.06	1.07
Pm + Cb (mix)	1.71	1.34	1.22	1.83	1.38	1.23	3.21	2.81	2.51	3.35	2.79	2.39	0.99	0.23	1.22	0.96	0.16	1.12	1.17
SEm±															0.05			0.04	0.05
CD (P=0.05)															0.10			0.08	0.09

with sole clusterbean. Kumar *et al.* (2005) in maize + cowpea at 2:2 row ratio and Singh *et al.* (2005) in sorghum + cowpea also reported higher crude protein yields under intercropping systems of cereals and legumes + sorghum at a row ratio 1:2.

Competition functions

The mixed sowing of pearlmillet and clusterbean recorded higher value of aggressivity in both the years than other treatments (Table 4). This was followed by intercropping of pearlmillet and clusterbean at a row ratio 1:1, and minimum aggressivity value was recorded with row ratio 3:3. The sowing of mixed seed of pearlmillet and clusterbean in the same row might have increased the competition between the plants of component crops and thereby resulted in the increase in dominance power of pearmillet and recorded higher value of aggressivity index. But large ratio, i.e. 3 rows each of pearlmillet and clusterbean in row ratio 3:3, might have decreased the competition between both the component crops and lowered the power of dominance of pearlmillet and thus recorded lower values of aggressivity Verma *et al.* (2005) also reported highest value of aggressivity with 1:2 row ratio of pigeonpea + sorghum.

The intercropping systems including mixed sowing recorded more than 1 value of relative crowding coefficient (RCC) in both the years. The highest value of RCC was recorded with mixed sowing of pearlmillet and clusterbean, followed by intercropping at 3:2 row ratio in the first year and at 2:2 row ratio during the second year. Intercropping of pearlmillet and clusterbean at a row ratio 3:3 gave the lowest value of RCC. The higher values of RCC with the mixed sowing, and intercropping in 3:3 and 2:2 ratio showed better land utilization efficiency by the component crops. It might be due to the beneficial symbiotic effect of legume component to the cereal component, which could be able to produce higher quantity of fodder and resulted in higher RCC value of the system. Verma *et al.* (2005) also reported higher value of RCC in pigeonpea + sorghum at a row ratio 1:2.

Economics

Pearlmillet and clusterbean intercropping system at each row ratio as well as in mixed sowing recorded higher values of price equivalent ratio (PER) than sole cropping of both the component crops (Table 4). Intercropping of pearlmillet and clusterbean in 2 : 2 row ratio gave the highest values of PER in both the years, followed by their 1:1 row ratio. Mean data of 2 years showed that among intercropping systems the differences in PER values ranged from 5.11 to 21.0% with minimum 5.11% from row ratio 1:1 to maximum 21.0% from the row ratio 1:2 compared with that of row ratio 2:2. The difference in PER might be owing to the combined effect of fodder yields and selling price of fodders. The higher price of legume fodder than that of the cereal resulted in higher values of PER. The increased value of PER indicates the high remunerativeness of the intercropping system.

Almost all the intercropping systems had higher net returns and benefit : cost (B:C) ratios than sole crops of pearlmillet and clusterbean, except treatment pearlmillet + clusterbean in a row ratio 1:2 and 3:3 where the values of net returns and B:C ratios were lower than that of sole pearlmillet (Table 4). Among the intercropping systems, intercropping of pearlmillet and clusterbean at a row ratio 2:2 recorded the highest, net returns and B : C ratio, followed by row ratio 1:1 and mixed sowing. The minimum net returns and B : C ratio were recorded with the sole clusterbean. The net returns and B : C ratio with the treatment 2:2 row ratio of pearlmillet and clusterbean were the results of higher fodder yields and almost similar cost of cultivation compared with other intercropping systems, as the treatments differed mainly in row arrangements. The minimum values of net returns and B : C ratio in sole clusterbean may be ascribed to lower quantity of fodder produced by clusterbean and comparatively higher cost of cultivation due to the costly seed material. Kumar *et al.*

Table 4. Competition functions and economics as influenced by treatment variables

Treatment	Aggressivity		Relative crowding coefficient		Price equivalent ratio		Cost of cultivation ($x10^3$ Rs/ha)	Net returns ($x10^3$ Rs/ha)	Benefit : cost ratio
	2006	2007	2006	2007	2006	2007			
Pearlmillet (Pm) sole							20.6	36.9	2.79
Clusterbean (Cb) sole							21.1	15.7	1.74
Pm + Cb (1:1)	0.57	0.43	10.23	5.67	1.38	1.36	20.8	43.8	3.10
Pm + Cb (1:2)	0.38	0.32	3.84	3.74	1.23	1.14	20.9	35.1	2.68
Pm + Cb (2:2)	0.25	0.19	8.42	7.59	1.41	1.48	20.8	47.3	3.27
Pm + Cb (3:2)	0.20	0.14	12.31	3.11	1.33	1.22	20.8	39.6	2.90
Pm + Cb (3:3)	0.08	0.11	2.34	3.08	1.21	1.24	20.8	36.9	2.77
Pm + Cb (mix)	0.63	0.69	12.46	13.54	1.34	1.33	20.8	42.3	3.03

*Rates of green fodders: Rs 1 and Rs 2/kg pearlmillet and clusterbean respectively; labour wages, Rs 107/manday

(2005) in maize + cowpea in 2:2 row ratio and Singh *et al.* (2005) in sorghum + cowpea also reported higher values of gross returns, net returns and B : C ratio.

It may be concluded that intercropping of multicut fodder pearlmillet and clusterbean at a row ratio 2:2 was the most productive and remunerative intercropping system in irrigated conditions of hot arid region of Rajasthan.

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