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Fodder productivity and economics of pearlmillet (*Pennisetum typhoides*) with legumes intercropping under various row proportions

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ABSTRACT

A field experiment was conducted during the summer seasons of 2007 and 2008 at Sabour to assess the productivity and economics of intercropping of forage pearlmillet [*Pennisetum typhoides* (L.) R. Br. Emend & Stuntz.] with cowpea [*Vigna unguiculata* (L.) Walp.], clusterbean [*Cyamposis tetragonaloba* (L.) Taub.] and rice bean [*Vigna umbellata* (Thumb) ohwi and ohashi] under 4 row proportions, *viz.,* 1: 1, 1: 2, 2: 1 and 2: 2. Fodder yields of both the component crops were substantially reduced under intercropping system compared with their sole stands. Pooled analysis of 2 years showed that pearlmillet + cowpea (2: 2) recorded significantly higher total green (52.8 t/ha), dry fodder (13.24 t/ha), crude protein yield (1.36 t/ha), as well as net returns (Rs 24,060/ha) compared with the other treatments. The highest land-equivalent ratio (1.42), relative crowding coefficient (6.54) and lowest value of competitive ratio (1.29) also indicated superiority of pearlmillet + cowpea system. Among the component crops, pearlmillet was more competitive and aggressive to legume intercrops. However, maximum aggressivity index (0.55) and competitive ratio (3.42) were obtained with pearlmillet + clusterbean (1: 2). Thus, intercropping of pearlmillet and cowpea in 2: 2 row ratio may be adopted for higher fodder productivity, quality and profitability during summer.

Key words: Crude protein, Economics, Fodder crops, Intercropping, Legumes, *Pearlmillet*, Yield

Livestock play an important role in the rural economy of India by providing employment and supplementary family income, which contributes about 21% of the total agricultural income. Fodder requirement of livestock is generally met through poor-quality available crop residues, which are not enough for the maintenance of animal health and productivity. The feed and forage resources of the country are able to meet only 40% of the requirement with vast deficit of 64 and 16% in green and dry- fodder, respectively (Ram and Singh, 2003). Intercropping of cereals with legumes is an effective approach for boosting herbage yield, utilization of land efficiently and providing stability to production (Verma *et al*., 2005), which also enriches the soil fertility (Bezbaruah and Thakuria, 1996). Pearlmillet is an ideal fodder crop, possessing quick growing and high-yielding ability during summer. Intercropping of legumes in pearlmillet was found more productive and remunerative (Ram *et al*., 2005; Sharma, 2008) when compared with their sole crops. The types of intercrop and spatial arrangement in intercropping have important effects on the balance of competition between component crops and their productivity (Sarkar and Pal, 2004). Hence, to get the best results, a rational approach is required for agronomic information on appropriate row proportion of fodder pearlmillet and legumes in an intercropping system. Since pearlmillet is a new crop for this region and information on intercropping of pearlmillet with legumes is not available. Therefore, this study was undertaken to assess the productivity, economics and quality of different intercropping systems of pearlmillet with legumes at different row proportions during summer season.

MATERIALS AND METHODS

The field experiment was laid out for 2 years during summer seasons of 2007 and 2008 at Bihar Agricultural College Farm, Sabour, Bihar. The soil of experimental field was sandy loam in texture having pH 7.1, low in initial organic C (0.40%) and available N (178.0 kg/ha), medium in available P (13.4 kg/ha) and K (176.4 kg/ha). The treatments consisted of sole crops of pearlmillet [*Pennisetum glaucum* (L.) R. Br. Emend & Stuntz.], cowpea [*Vigna unguiculata* (L.) Walp.], clusterbean [*Cyamposis tetragonaloba* (L.) Taub.] and rice bean [*Vigna umbellata*

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(Thumb) ohwi and ohashi], and 12 intercropping systems of pearlmillet with each cowpea, rice bean and clusterbean in row ratios of 1: 1, 1: 2, 2: 1 and 2: 2 (Table 1). The treatments (16) were laid out in randomized block design with 3 replications. Seed rate for each intercropping system was calculated on the basis of ratio indicating the number of rows of each component crop. Fodder pearlmillet 'G.B. 1' and forage legumes *viz.*, cowpea 'Bundel Lobia 1', clusterbean 'Bundel *Guar* 1' and rice bean 'Bidhan 1' were sown at 25 cm apart in different row ratios as per treatments on 6th and 9th April in the 2007 and 2008, respectively. The seed rates for pearlmillet, cowpea, clusterbean and rice bean were 10, 35, 35 and 30 kg/ha, respectively. The recommended fertilizer doses of 90-17.2-16.6 kg N-P-K/ha in pearlmillet and 20-21.5 kg N-P/ha in legume crops were applied as urea, diammonium phosphate and muriate of potash, respectively as per area occupied by the component crops. Nitrogen @ 30 kg N along with full doses of P and K were applied at sowing and the remaining 60 kg N/ha of pearlmillet was top-dressed in 2 equal splits, at 4 weeks after sowing and after first cut. The crop was raised under irrigated conditions with recommended agronomic practices. Total 2 cuts were taken during both the years (Ist cut at 55 DAS and IInd at 40-45 days after first cut). The results of both the years were pooled and analyzed statistically. The plant samples were oven dried and the dry-matter and crude protein yields of the component crops were calculated by multiplying dry matter content to green fodder yield and nitrogen content to dry matter yield, respectively. The economics of different crops and crop combinations were calculated on the basis of prevailing market rates of green fodder and inputs. Different crop-competition indices and yield advantages were computed as described by Willey (1979).

RESULTS AND DISCUSSION

Green and dry-fodder yields

Plant height of both the component crops and number of tillers/ linear m of pearlmillet were higher at first cut stage compared with second cut stage (Table 1). Intercropping of pearlmillet and legumes in 2:2 row proportions recorded the highest values of plant height and number of tillers at both the cuttings, which however, were at par with pearlmillet and legumes grown either in 1:1 or 2:1 row proportions. Higher values of growth parameters with 2:2 row ratio might be due to better utilization of resources and less competetion between both the component crops for solar radiation, resulting in increased height of plant / tillers when compared with sole stands. However, the tillers of pearlmillet were thinner in intercropping plots compared both these in sole stands. Legumes grown in association with pearlmillet in 2:1 row ratio gave lower values of plant height due to more shading and competition effects.

Green fodder yields of both the component crops were higher at first cut compared with second cut might be due to efficient utilization of available resources. Green and dry fodder yield of pearlmillet in the intercropping was higher wherever the legumes yields were lower and *vice versa*. (Tables 2 and 3). The maximum mean green fodder (43.4 t/ha) and dry matter yields (11.6 t/ha) of pearlmillet

Table 1. Growth parameters of crops as influenced by pearlmillet- based intercropping systems (mean of 2 years**)**

Treatment	Plant height (cm)				No of tillers/ m row (Pm)	
	Pearlmillet		Intercrop		I cut	II cut
	I cut	II cut	I cut	II cut		
Pearlmillet (Pm) sole	147.4	98.8			118.0	93.2
Cowpea (Cp) sole			119.2	59.6		
Clusterbean (Cb) sole			74.2	39.4		
Rice bean (Rb) sole			112.8	51.2		
Pm + Cp (1:1)	153.2	105.6	123.6	64.2	133.0	104.4
Pm + Cp (1:2)	145.5	101.4	114.8	60.6	124.2	98.1
Pm + Cp (2:1)	155.4	107.6	111.6	62.4	119.8	94.8
Pm + Cp (2:2)	157.6	109.4	125.4	66.2	136.6	106.6
Pm + Cb (1:1)	151.8	107.2	77.2	44.4	135.2	105.4
Pm + Cb (1:2)	143.5	104.5	68.4	39.2	127.4	101.8
Pm + Cb (2:1)	152.4	109.5	66.2	41.6	122.5	95.8
Pm + Cb (2:2)	154.2	108.2	79.2	46.2	139.2	108.4
Pm + Rb (1:1)	152.6	106.2	116.2	55.4	134.4	105.4
Pm + Rb (1:2)	143.6	105.4	108.6	50.8	122.6	96.6
Pm + Rb (2:1)	155.4	105.8	106.4	51.5	116.8	93.4
Pm + Rb (2:2)	156.5	108.4	115.2	54.2	137.2	107.2
SEm ±	2.1	1.5	2.4	1.2	1.8	1.4
CD (P=0.05)	6.2	4.3	6.8	3.5	5.2	4.1

was obtained when grown in association with clusterbean in 2: 1 row ratio which, however was at par with cowpea and rice bean planted with pearlmillet in the same proportion and proved significantly superior to rest of the combinations. Among the legume intercrops, cowpea in 1:2 row ratio gave significantly higher green and dry matter yields than rice bean and clusterbean might be due to better competitive ability of cowpea when compared with rice bean and clusterbean with pearlmillet in intercropping system. The increase in green and dry fodder yields of pearlmillet and legumes intercropping were mainly because of higher plant population due to increase in area under crops in the intercropping system. In contrast, legumes grown in association with pearlmillet under 2: 1 row proportion gave lower fodder yields than other row proportions might be due to intense competitive effect because of greater population pressure of pearlmillet on lesser population of legume intercrops.

In general, fodder yields of the component crops, *viz.*, pearlmillet + cowpea, pearlmillet + ricebean and pearlmillet + clusterbean decreased comparison with their sole stands. This decrease was compensated by contribution of both in total intercrop yield. The total green fodder (52.6 t/ha) and dry matter yields (13.2 t/ha) were the highest under pearlmillet + cowpea in 2: 2 row ratio and significantly superior to the other intercropping systems except pearlmillet + ricebean planted in the ratio of 2: 2 which showed comparable dry fodder yield. The increase in total green fodder and dry matter yields with pearlmillet + cowpea in 2: 2 row proportion was 11.5 and 3.2 %, respectively compared with sole pearlmillet. Higher total green fodder and dry matter yields under the row ratio of 2:2 of pearlmillet and cowpea was due to increased values of growth parameters *viz.*, plant height and tiller number/unit area. This might be owing to efficient utilization of space and light interception along with nutrient contribution of leguminous fodder to the cereal. Kumar *et al*. (2005) also reported highest fodder yields with row ratio of 2: 2 in maize + cowpea intercropping system.

All intercropping systems recorded land equivalent ratio (LER) values more than 1 (Table 3). Among intercropping systems, pearlmillet with cowpea, followed by pearlmillet with rice bean in 2: 2 row proportion showed the greater biological efficiency of the system, having LER values 1.42 and 1.39, respectively. These LER values showed that to produce combined mixture yield by growing sole stand would require 42 and 39 % more land, respectively. Higher LER values with 2: 2 row ratio of pearlmillet with cowpea and rice bean indicate better adaptability of the intercropping system and it might be due to efficient utilization of natural resources *viz.*, space, light etc. as well as applied inputs by the component crops having different

Table 2. Green-fodder yield (t/ha) as influenced by pearlmillet- based intercropping systems

Treatment	2007						2008						Total green-fodder yield	
	Pearlmillet			Intercrops			Pearlmillet			Intercrops				
	I cut	II cut	Total	I cut	II cut	Total	I cut	II cut	Total	I cut	II cut	Total	2007	2008
Pearlmillet (Pm) sole	28.8	17.6	46.4				30.0	18.3	48.3				46.4	48.3
Cowpea (Cp) sole				16.8	7.8	24.6				16.0	6.8	22.8	24.6	22.8
Clusterbean (Cb) sole				15.0	4.5	19.5				14.4	3.9	18.3	19.5	18.3
Rice bean (Rb) sole				15.5	6.3	21.8				15.5	5.4	20.9	21.8	20.9
Pm + Cp (1:1)	20.5	13.0	33.5	9.5	4.3	13.8	22.6	13.8	36.4	8.6	3.8	12.4	47.3	48.8
Pm + Cp (1:2)	18.2	11.4	29.6	11.2	5.2	16.4	20.0	11.6	31.6	11.0	4.3	15.3	46.0	46.9
Pm + Cp (2:1)	25.3	15.5	40.8	5.4	2.3	7.7	26.5	15.8	42.3	4.8	1.5	6.3	48.5	48.6
Pm + Cp (2:2)	23.0	14.2	37.2	10.5	4.7	15.2	24.0	14.6	38.6	9.5	4.7	14.2	52.4	52.8
Pm + Cb (1:1)	24.2	15.0	39.2	6.0	1.6	7.6	26.2	15.4	41.6	5.5	1.3	6.8	46.8	48.4
Pm + Cb (1:2)	22.2	13.6	35.8	6.6	1.9	8.5	23.5	14.3	37.8	6.8	1.9	8.7	44.3	46.5
Pm + Cb (2:1)	26.3	16.0	42.3	3.7	1.0	4.7	27.9	16.7	44.6	3.5	0.9	4.4	47.0	49.0
Pm + Cb (2:2)	24.6	15.3	39.9	6.2	1.6	7.8	25.5	15.6	41.1	5.8	1.6	7.4	47.7	48.5
Pm + Rb (1:1)	22.2	13.6	35.8	8.0	3.2	11.2	23.8	14.6	38.4	7.5	2.8	10.3	47.0	48.7
Pm + Rb (1:2)	20.0	12.2	32.2	10.6	3.9	14.5	21.4	12.4	33.8	9.6	3.2	12.8	46.7	46.6
Pm + Rb (2:1)	25.0	15.3	40.3	5.5	1.7	7.2	26.6	16.0	42.6	4.5	1.3	5.8	47.5	48.4
Pm + Rb (2:2)	23.0	14.1	37.1	9.4	3.5	12.9	24.5	14.9	39.4	8.0	3.3	11.3	50.0	50.7
SEm ±	0.34	0.21	0.56	0.2	0.09	0.32	0.36	0.22	0.59	0.22	0.08	0.29	0.99	1.01
CD (P=0.05)	0.99	0.61	1.60	0.7	0.26	0.91	1.05	0.64	1.69	0.62	0.23	0.84	2.85	2.91

characteristics, *viz.*, nutrient requirements, root systems and canopy structures. Kumar *et al*. (2005) also reported higher LER value with maize and legumes intercropping.

Crude protein yield

Crude protein yield of both the component crops and total varied significantly (Table 3). The highest total crude protein yield (1.36 t/ha) was recorded with pearlmillet + cowpea (2:2), which showed statistical parity with pearlmillet + rice bean (2:2) intercropping and these intercropping systems proved significantly superior to the rest of the systems. The increase in crude protein yield (CPY) was mainly because of variation in dry matter accumulation of the component crops. Intercropping with more number of legume rows recorded higher CPY but under such treatment reduced area under pearlmillet lowered CPY. However, the total CPY in intercropping was the reflection of contribution from both the component crops. Higher contribution through cowpea with row ratio 1:2 to total CPY was mainly because of higher area allocation for legume component of the system. The difference in CPY between intercropping of pearlmillet and cowpea as well as pearl millet and rice bean both in row ratio of 1:1 and 1:2 were statistically not significant. The minimum CPY was recorded with sole clusterbean. Sharma (2008) in pearlmillet + clusterbean at 2:2 ratio and Singh *et al*. (2005) in sorghum + cowpea also reported higher CPY under intercropping of cereals and legumes.

Economics

Intercropping of pearlmillet with legumes at different row ratios registered the higher values of net returns (NR), and B:C ratio than their sole stands (Table 3). This advantage was due to the increased total yield of the forage from two components and higher sale price of the legume fodders.

The intercropping of pearlmillet with cowpea in 2: 2 row ratio gave the highest NR, and B:C ratio (2.31) over rest of the systems. This was ascribed to its higher fodder yields and almost similar cost of cultivation. Among the intercropping systems, pearlmillet in association with clusterbean gave comparatively lower NR and B:C ratio than those in association with cowpea and rice bean. However, pearlmillet and clusterbean grown in 1: 2 ratio recorded the lowest profitability. The minimum values of NR and B:C ratio under this intercropping system may be ascribed to lower quantity of fodder produced by component crops. Sharma *et al*. (2008) in maize and cowpea and Sharma (2008) in pearlmillet + clusterbean both in 2: 2 ratio also reported better economics.

Competition functions

Relative crowding coefficient (RCC) of the system was greater than one in all the treatments indicating yield advantage compared with their monocultures due to mutual cooperation. The product of RCC was however, the highest (6.54) in the row ratio 2: 2 of pearlmillet + cowpea, followed by that of pearlmillet + rice bean (5.51) grown in

Table 3. Dry-matter, crude- protein yields (t/ha), economics (x10^3Rs/ha), and land equivalent ratio as influenced by pearlmillet - based intercropping systems

Treatments	Mean dry matter yield			Crude protein yield			Cost of cultivation	Net returns	B : C ratio	Land equivalent ratio	
	Pm	IC	Total	Pm	IC	Total				2007	2008
Pearlmillet (Pm) sole	12.83		12.83	1.02		1.02	10.52	17.89	1.70	1.00	1.00
Cowpea (Cp) sole		4.57	4.57		0.86	0.86	10.36	8.60	0.83	1.00	1.00
Clusterbean (Cb) sole		3.84	3.84		0.67	0.67	9.63	5.49	0.57	1.00	1.00
Rice bean (Rb) sole		4.28	4.28		0.79	0.79	10.21	6.87	0.67	1.00	1.00
Pm + Cp (1:1)	9.47	2.53	12.00	0.77	0.48	1.25	10.44	21.01	2.01	1.28	1.30
Pm + Cp (1:2)	8.29	3.06	11.35	0.66	0.58	1.23	10.42	20.63	1.98	1.30	1.33
Pm + Cp (2:1)	11.26	1.35	12.61	0.89	0.25	1.14	10.47	20.06	1.92	1.19	1.15
Pm + Cp (2:2)	10.35	2.90	13.24	0.81	0.54	1.36	10.44	24.06	2.31	1.42	1.42
Pm + Cb (1:1)	10.90	1.45	12.35	0.86	0.25	1.11	10.08	19.92	1.98	1.23	1.23
Pm + Cb (1:2)	9.97	1.73	11.70	0.79	0.30	1.09	9.93	19.03	1.92	1.21	1.26
Pm + Cb (2:1)	11.60	0.91	12.51	0.92	0.16	1.08	10.23	19.47	1.90	1.15	1.16
Pm + Cb (2:2)	10.90	1.53	12.43	0.86	0.28	1.14	10.08	20.30	2.01	1.26	1.26
Pm + Rb (1:1)	10.05	2.15	12.21	0.79	0.40	1.19	10.37	20.49	1.98	1.29	1.29
Pm + Rb (1:2)	8.94	2.73	11.68	0.71	0.51	1.21	10.32	20.41	1.98	1.36	1.31
Pm + Rb (2:1)	11.17	1.30	12.47	0.88	0.24	1.12	10.42	19.65	1.89	1.20	1.16
Pm + Rb (2:2)	10.34	2.42	12.77	0.85	0.45	1.30	10.37	22.26	2.15	1.42	1.36
SEm ±	0.16	0.05	0.17	0.01	0.01	0.02		0.55	0.04		
CD (P=0.05)	0.44	0.15	0.48	0.03	0.03	0.06		1.56	0.12		

Selling price of green fodder (Rs/tonne): Pearlmillet, 600; Legumes, 800; IC; Inter crop

Table 4. Competition functions as influenced by pearlmillet-based intercropping systems (mean of 2 years)

Treatments	Competitive ratio		Relative crowding coefficient			Aggressivity
	Pm	IC	Pm	IC	Product	Pm
Pm + Cp (1:1)	1.34	0.75	2.82	1.24	3.50	0.19
Pm + Cp (1:2)	1.93	0.52	3.65	1.01	3.69	0.31
Pm + Cp (2:1)	1.49	0.67	3.58	0.84	3.01	0.14
Pm + Cp (2:2)	1.29	0.78	4.01	1.63	6.54	0.18
Pm + Cb (1:1)	2.24	0.45	5.81	0.62	3.60	0.47
Pm + Cb (1:2)	3.42	0.29	6.98	0.42	2.93	0.55
Pm + Cb (2:1)	1.90	0.53	5.53	0.63	3.49	0.22
Pm + Cb (2:2)	2.13	0.47	5.91	0.67	3.96	0.45
Pm + rb (1:1)	1.56	0.64	3.62	1.01	3.66	0.28
Pm + rb (1:2)	2.19	0.46	4.60	0.89	4.09	0.38
Pm + rb (2:1)	1.45	0.69	3.51	0.88	3.09	0.13
Pm + rb (2:2)	1.43	0.70	4.20	1.31	5.51	0.24

IC: Inter crop; Rb: Ricebean; Cb: Clusterbean; Pm: Pearlmillet; Cp: Cowpea

same proportion. Higher values of RCC with these intercropping systems showed better land utilization efficiency by the component crops. It might be due to the beneficial symbiotic effect of legume to the cereal component, which could be able to produce higher quantity of fodder and resulted in higher RCC value of the system.

Fodder pearlmillet in combination with legumes in the row ratio of 1: 2 was more competitive than all the intercropping systems, as this proportion had higher competitive ratios (CR) and aggressivity (A) indices (Table 4). However, pearlmillet was more competitive and aggressive when grown in association with clusterbean, having higher A and CR values. The increase in number of rows of legumes might have increased the competition between the plants of component crops and thereby resulted in the increase in dominance power of pearlmillet and recorded higher A value. Verma *et al*. (2005) also reported highest value of aggresivity with 1: 2 row ratio of pigeonpea + sorghum. Pearlmillet grown in association with cowpea in 2:2 row ratio was found least competitive with lower value of CR (1.29). However, minimum A value (0.13) was recorded with pearlmillet + rice bean, followed by pearlmillet + cowpea both in 2: 1 row ratio. Intercropping of pearlmillet with rice bean or cowpea in row ratio 2: 1 might have decreased the competition between both the component crops and lowered the power of dominance of pearlmillet and thus recorded lower A value. Sharma *et al*. (2008) also reported higher relative crowding coefficient values and lower A values with row ratio of 2:2 and 2: 1 in maize + cowpea, respectively.

It was concluded that intercropping of fodder pearlmillet with cowpea in 2: 2 row ratio is a biologically and economically sustainable intercropping system for irrigated conditions of Bihar.

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