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Production potential and economics of multi-cut forage sorghum (*Sorghum sudanense*) 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, Bihar to assess the production potential and economics of intercropping of forage sorghum (*Sorghum sudanense* Stapf) with cowpea [*Vigna unguiculata* (L.) Walp.], clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] and ricebean [*Vigna* umbellata (Thumb) ohwi and ohashi] under four row proportions, *viz.* 1:1, 1:2, 2:1 and 2:2. Green and dry fodder yield of both the component crops were substantially reduced under intercropping system compared with their sole crop yield. Pooled analysis of 2 years showed that intercropping of sorghum and cowpea with a row ratio of 2:2 recorded significantly higher total green fodder (59.6 t/ha), dry matter (14.88 t/ha) and crude protein yield (1.45 t/ha), as well as net returns (RS.28,570/ ha) and benefit: cost ratio (2.76) in comparison to the other treatments except sorghum + ricebean planted in the row ratio of 2:2. The association of sorghum and cowpea in row ratio 2:2 also showed the highest land equivalent ratio (1.45), price equivalent ratio (1.50), relative crowding coefficient (7.60) and lowest value of competitive ratio (1.29), followed by sorghum + ricebean in 2:2 row ratio. Among the component crops, sorghum was more competitive and aggressive than legume intercrops. However, maximum aggressivity index (0.53) and competitive ratio (3.42) were obtained with sorghum, when grown in association with clusterbean in row ratio 1: 2. Thus, intercropping of fodder sorghum with cowpea or ricebean both in 2:2 row ratio may be adopted for higher productivity, better quality and profitability during summer season.

Keywords : Competition functions, Crude protein yield, Economics, Forage yield, Intercropping, Land-equivalent ratio, Legumes, Sorghum.

Introduction

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 leaving 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 efficiency and providing stability to production (Venna *et al*., 2005), which also enriches the soil fertility (Bezbaruah and Thakuria, 1996). Sorghum is an ideal fodder crop, possessing quick growing and high-yielding ability during summer season. Intercropping of legumes in sorghum was found more productive and remunerative (Sharma *et al.,* 2008a) compared to their sole crops. The type of intercrop and spatial arrangement in intercropping has 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 forage sorghum and legumes in an intercropping system. The information on intercropping of forage sorghum with legumes is not adequate for summer season in this region. Therefore, this study was undertaken to assess the production potential, economics and quality of different intercropping systems of sorghum with legumes at different row proportions during summer season.

Materials and Methods

The field experiment was conducted during the summer season of 2007 and 2008 at Bihar Agricultural College Farm, Sabour, Bihar. The soil was sandy loam in texture

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having pH 7.1, low in initial organic C (0.40%) and available N (178.0 kg/ha), but medium in available P (13.4 kg/ha) and K (176.4 kg/ha). The treatments consisted of sole crops of sorghum (*Sorghum sudanense* Stapf), cowpea [*Vigna unguiculata* (L.) Walp.], clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] and ricebean [*Vigna umbellata* (Thumb) ohwi and ohashi], and 12 intercropping systems of sorghum with each of cowpea, ricebean and clusterbean in row ratios of 1:1,1:2, 2:1 and 2:2 (Table 1). Sixteen treatments 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 sorghun *cv* 'SSG-59-3' and forage legumes *viz.* cowpea *cv* 'Bundel Lobia -1', clusterbean *cv* 'Bundel Guar-I' and ricebean *cv* 'Bidhan-I' were sown at 25 cm apart in different row ratios as per treatments on 7th and 10th April 2007 and 2008, respectively. The seed rates for sorghum, cowpea, clusterbean and ricebean were 40, 35, 35 and 30 kg/ha, respectively in sole crops and as per area row proportions of component crops under different intercropping systems. The recommended fertilizer doses of 80 kg N+ 40 kg P_2O_5 + 20 kg K_2O/ha in sorghum and 20 kg N + 50 kg P_2O_5/ha in legume crops were applied in the form of urea, diammonium phosphate and muriate of potash, respectively as per area occupied by the component crops under different intercropping systems. Fertilizers @ 20 kg N and full doses of P and K were applied at sowing and the remaining 60 kg N/ha pf sorghum were top-dressed in three equal splits at crop stage of 4 weeks and after first and second cuts. Besides pre-sowing irrigation, two additional irrigations at 20 days interval were applied to the crops. Total three cuts were taken for green forage during both years. The first cut was taken at 55 days after sowing, the second after 40- 45 days of first cut and third at 50% flowering stage. The plant samples were oven dried and the dry matter and crude protein yield of the component crops were calculated. The economics of different crops and crop combinations were calculated on the basis of prevailing market price of green fodder and inputs. Different crop competition indices and yield advantages were computed as described by Willey (1979). The soil for pH, organic carbon, and available N, P and K and plant samples for dry matter production and crude protein contents were analyzed by following the standard laboratory procedures (AOAC, 1995). Price-equivalent ratio (PER) was calculated as:

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

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 yield

Green and dry fodder yield were significantly affected by different intercropping systems in both the years (Table 1). Green and dry fodder yield of sorghum in the intercropping was higher wherever the legumes yield were lower and *vice versa*. Sorghum in association with clusterbean gave comparatively higher yield than those in association with cowpea and ricebean. Variation in sorghum yield due to its association with different legumes might have been due to variation in their green-fodder yield.

The fodder yield of both the component crops were substantially reduced in intercropping system as compared to their sole stands. The reduction in green fodder yield (8.0%) and dry matter yield (7.6%) of sorghum was lowest when grown in association with clusterbean in 2:1 ratio. Among the legume intercrops, cowpea in row ratio of 1:2 showed the minimum reduction in green and dry matter yield (30.1%) in comparison with ricebean and clusterbean might be due to better competitive ability of cowpea than of rice bean and clusterbean with sorghum in intercropping system. The reduction in green and dry fodder yield of sorghum 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 sorghum under 2:1 row proportion gave lower fodder yield than other row proportions might be due to intense competitive effect because of greater population pressure on lesser population of legume intercrops.

This reduction in fodder yields of sorghum and legumes crops was compensated by contribution of both in total fodder yield of the intercropping system. The maximum contribution of cowpea in total green fodder and dry matter yield were 32.1 and 25.2% under intercropping of sorghum in the row ratio 1:2, followed by sorghum+cowpea intercropping in 2:2 row ratio. Pooled analysis of 2 years showed that the total green fodder yield (59.6 t/ha) and dry matter yield (14.88 t/ha) were the highest under sorghum+cowpea in 2:2 row ratio and significantly superior to the other intercropping system except

Table 1: Green fodder yield, dry matter yields (t/ha) and land equivalent ratio as influenced by sorghum – based intercropping systems

Treatments	Green fodder yield (t/ha)									Mean dry matter yield			Land equivalent ratio		
	2007			2008			Mean								
	S	I.C.	Total	S	I.C.	Total	S	I.C.	Total	S	I.C.	Total	2007	2008	Mean
Sorghum (S) sole	52.5	-	52.5	54.4	-	54.4	53.5	-	53.5	14.24	-	14.24	-	-	-
Cowpea sole	-	25.8	25.8	0.0	23.4	23.4	0.0	24.6	24.6	0.00	4.75	4.75	-	-	-
Clusterbean sole	-	19.5	19.5	0.0	17.8	17.8	0.0	18.7	18.7	0.00	3.83	3.83	-	-	-
Ricebean sole	-	23.2	23.2	0.0	21.6	21.6	0.0	22.4	22.4	0.00	4.45	4.45	-	-	-
S + Cowpea (1:1)	39.5	14.8	54.3	42.4	13.6	56.0	41.0	14.2	55.2	11.00	2.74	13.74	1.33	1.36	1.34
S + Cowpea (1:2)	35.6	17.5	53.1	37.1	16.8	53.9	36.4	17.2	53.6	9.76	3.29	13.05	1.36	1.40	1.38
S + Cowpea (2:1)	46.7	7.7	54.4	47.1	6.8	53.9	46.9	7.3	54.2	12.55	1.40	13.94	1.19	1.16	1.17
S + Cowpea (2:2)	43.2	16.2	59.4	44.9	14.8	59.7	44.1	15.5	59.6	11.83	3.05	14.88	1.45	1.46	1.45
S + Clusterbean (1:1)	45.3	8.6	53.9	45.8	6.8	52.6	45.6	7.7	53.3	12.18	1.56	13.74	1.30	1.22	1.26
S + Clusterbean (1:2)	41.5	9.5	51.0	41.0	8.7	49.7	41.3	9.1	50.4	11.03	1.85	12.88	1.28	1.24	1.26
S + Clusterbean (2:1)	48.6	5.8	54.4	49.8	4.4	54.2	49.2	5.1	54.3	13.16	1.04	14.20	1.22	1.16	1.19
S + Clusterbean (2:2)	45.8	8.9	54.7	46.2	7.4	53.6	46.0	8.2	54.2	12.30	1.63	13.93	1.33	1.26	1.30
S + Ricebean (1:1)	41.7	12.5	54.2	43.6	11.3	54.9	42.7	11.9	54.6	11.45	2.36	13.81	1.33	1.32	1.33
S + Ricebean (1:2)	38.5	15.5	54.0	38.3	14.8	53.1	38.4	15.2	53.6	10.31	3.01	13.32	1.40	1.39	1.40
S + Ricebean (2:1)	46.2	6.8	53.0	47.4	6.2	53.6	46.8	6.5	53.3	12.52	1.29	13.81	1.17	1.16	1.16
S + Ricebean (2:2)	43.5	14.2	57.7	44.8	13.2	58.0	44.2	13.7	57.9	11.85	2.73	14.58	1.44	1.43	1.44
SEm (±)	-	-	1.13	-	-	1.09	-	-	0.92	-	-	0.21	-	-	-
CD (P=0.05)	-	-	3.25	-	-	3.10	-	-	2.64	-	-	0.65	-	-	-

S= Sorghum; I.C.= Intercrops

sorghum + ricebean planted in the ratio of 2:2. The increase in total green fodder and dry matter yield with sorghum+cowpea in 2:2 row proportion was 11.4 and 4.3 per cent, respectively compared with sole sorghum. Higher fodder yield under the row ratio of 2:2 of sorghum and cowpea or ricebean might be owing to efficient utilization of space, light interception and nutrients along with the contribution of legume fodder to the cereal. Kumar *et al.* (2005) also reported highest fodder yield with row ratio of 2:2 in maize+cowpea intercropping system.

All intercropping systems recorded LER (Land equivalent ratio) values more than 1, which showed efficient utilization of land under intercropping of sorghum and legumes compared with sole cropping (Table 1). Among intercropping systems, sorghum and clusterbean sown at row proportion of 2:1 recorded minimum value of LER, mainly due to the lowest yield of clusterbean recorded with this system. However, sorghum with cowpea, followed by sorghum with ricebean in 2:2 row proportion showed the greater biological efficiency of the system, having LER values 1.45 and 1.44, respectively. These LER values show that to produce combined mixture yield by growing sole stand would require 45 and 44 % more land, respectively. Higher LER values with 2:2 row ratio of sorghum with cowpea and ricebean 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 characteristics, *viz*. nutrient requirements, root systems and canopy structures. Higher LER value was also reported by Sharma *et al*. (2008 b) at row ratio of 2:2 in maize + cowpea intercropping.

Crude protein yield

The influence of intercropping of sorghum with cowpea, ricebean and clusterbean was clearly evident in total crude protein yield of the system (Table 2). The highest total crude protein yield (1.45 t/ha) was recorded with sorghum + cowpea (2:2), which showed statistical parity with sorghum + ricebean (2:2) intercropping and these intercropping systems proved significantly superior to the rest of the systems. Intercropping of sorghum + cowpea in the row ratio of 2:2 gave 35.5 arid 62.9 % higher crude protein yield than sole stands of sorghum and cowpea, respectively. It was closely followed by intercropping of sorghum + rice bean in row ratio of 2:2. The difference in crude protein yield in all the treatments was noticed mainly due to variation in dry matter yield of sorghum and cowpea or ricebean. It was noted that the intercropping system with more number of legume rows recorded higher crude protein yield but under such treatment reduced area under sorghum brought out lower crude protein yield. However, the total crude protein yield in intercropping system was the reflection of contribution from both the component crops. The contribution of cowpea and ricebean in total crude protein yield was 45.9 and 42.4% under

Table 2 : Crude protein yield (t/ha), economics (Rs./ha), price equivalent ratio and competition functions as influened by sorghum – based intercropping systems (mean of 2 years)

Treatment	Crude protein yield			Net returns (Rs/ha)	Benefit cost ratio	Price equi-valent ratio	Competitive ratio		Relatyive crowding coefficient			Aggresivity	
	S	I.C.	Total				S	I.C.	S	I.C.	Product	S	I.C.
Sorghum (S) sole	1.07	-	1.07	21,630	2.19	-	-	-	-	-	-	-	-
Cowpea sole	-	0.98	0.89	9,503	0.94	-	-	-	-	-	-	-	-
Clusterbean sole	-	0.66	0.66	5,469	0.58	-	-	-	-	-	-	-	-
Ricebean sole	-	0.82	0.82	7,893	0.79	-	-	-	-	-	-	-	-
S + Cowpea (1:1)	0.82	0.52	1.34	25,738	2.45	1.39	1.34	0.75	3.30	1.24	4.10	0.19	-0.19
S + Cowpea (1:2)	0.73	0.62	1.35	25,296	2.45	1.37	1.93	0.52	4.34	1.01	4.38	0.33	-0.33
S + Cowpea (2:1)	0.93	0.26	1.29	23,647	2.31	1.31	1.49	0.67	3.58	0.84	3.01	0.14	-0.14
S + Cowpea (2:2)	0.88	0.57	1.45	28,570	2.76	1.50	1.29	0.78	4.66	1.63	7.60	0.19	-0.19
S + Clusterbean (1:1)	0.91	0.27	1.18	23,655	2.38	1.43	2.24	0.45	6.55	0.62	4.06	0.44	-0.44
S + Clusterbean (1:2)	0.82	0.32	1.14	22,279	2.26	1.36	3.42	0.29	7.82	0.42	3.28	0.53	-0.53
S + Clusterbean (2:1)	0.98	0.18	1.16	23,552	2.30	1.43	1.90	0.53	5.79	0.63	3.65	0.19	-0.19
S + Clusterbean (2:2)	0.92	0.29	1.21	24,219	2.46	1.45	2.13	0.47	6.72	0.67	4.50	0.42	-0.42
S + Ricebean (1:1)	0.85	0.44	1.29	24,983	2.45	1.40	1.56	0.64	4.16	1.01	4.20	0.27	-0.27
S + Ricebean (1:2)	0.77	0.56	1.33	25,025	2.41	1.41	2.19	0.46	5.35	0.89	4.76	0.38	-0.38
S + Ricebean (2:1)	0.93	0.24	1.17	23,019	2.29	1.33	1.45	0.69	3.52	0.88	3.10	0.15	-0.15
S + Ricebean (2:2)	0.88	0.51	1.39	27,258	2.64	1.48	1.43	0.70	4.85	1.31	6.36	0.21	-0.21
SEm (±)	-	-	0.02	549	0.05	-	-	-	-	-	-	-	-
CD (P=0.05)	-	-	0.06	1,564	0.15	-	-	-	-	-	-	-	-

S= Sorghum; I.C.= Intercrops; Selling price of green fodder (Rs./tonne): Sorghum = Rs. 600; Legumes = Rs. 800

intercropping of sorghum in the row ratio 1:2. Higher contribution through cowpea and ricebean with row ratio 1:2 to crude protein yield was mainly because of higher area allocation for legume component of the system. The minimum crude protein yield was recorded with sole clusterbean. Sharma (2008) in pearl millet + clusterbean at 2:2 ratio and Singh *et al.* (2005) in sorghum + cowpea also reported higher crude protein yield under intercropping systems of cereals and legumes.

Economics

Intercropping of sorghum with legumes at different row ratio registered higher values of price-equivalent ratio (PER) than their sole stands (Table 2). Intercropping of sorghum and cowpea in 2:2 row ratio gave the highest PER value (1.50), followed by sorghum + ricebean in 2:2 row proportion. Mean data of 2 years showed that among intercropping systems the differences in PER values ranged from 1.4% to 14.5% with minimum 1.4% from sorghum + rice bean at 2:2 row ratio to maximum 14.5% from sorghum + cowpea at 2:1 row ratio. The difference in PER might be due to the combined effect of fodder yield and higher price of fodders. The increased value of PER indicates the high remunerativeness of the intercropping system.

Intercropping of sorghum with cowpea, ricebean and clusterbean at different row ratio gave significantly higher net returns and benefit: cost (B:C) ratio than their sole stands (Table 2). There was 3.0 to 32.0% increase in net returns compared with sole sorghum under all the intercropping situations. The intercropping of sorghum with cowpea in 2:2 ratio gave the highest net returns (Rs.28,570/ ha) and benefit: cost ratio (2.76), followed by sorghum + ricebean in row proportion 2:2 (Rs.27,258/ha and 2.64, respectively). The net returns and B:C ratio with the treatment 2:2 row ratio of sorghum with cowpea and ricebean were the results of higher fodder yield and almost similar cost of cultivation compared with other intercropping systems, as the treatments differed mainly in row arrangements. Among the intercropping systems, sorghum in association with clusterbean gave comparatively lower net returns and B:C ratio than those in association with cowpea and ricebean. However, sorghum and clusterbean grown in 1:2 row ratio recorded the lowest profitability. The minimum values of net returns and B:C ratio under this intercropping system might be due to lower production of fodder by component crops. Sharma *et al.* (2008b) in maize and cowpea; Sharma (2008) in pearl millet + clusterbean both in 2:2 ratio also reported higher values of gross return, net return and B:C ratio.

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 (7.60) in the row ratio 2:2 of sorghum + cowpea, followed by that of sorghum + ricebean (6.36) grown in 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 component to the cereal component, which could be able to produce higher quantity of fodder and resulted in higher RCC value of the system. Sharma *et al.* (2008b) also reported higher value of RCC in maize + cowpea at a row ratio 2:2. The association of (sorghum with clustebean showed lower values of RCC, mainly due to low yield of clusterbean. Fodder sorghum 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 and aggressivity factors (Table 2). However, sorghum was more competitive and aggressive when grown in association with cluster bean in row ratio 1:2, having higher values of both aggressivity and competitive ratio. 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 sorghum and recorded higher value of aggressivity index. Verma *et al.* (2005) also reported highest value of aggresivity with 1:2 row ratio of pigeonpea + sorghum. Intercropping of sorghum with cowpea in 2:2 row ratio was least competitive with lower value of competitive ratio (1.29). However, minimum aggressivity value (0.14) was recorded with sorghum + cowpea, followed by sorghum + ricebean both in 2:1 row ratio. Intercropping of sorghum with cowpea and rice bean in row ratio 2:1 might have decreased the competition between both the component crops and lowered the power of dominance of sorghum and thus recorded lower value of aggressivity. Sharma *et al.* (2008b) also reported lower aggressively value with row ratio of 2:1 in maize + cowpea intercropping system.

It may be concluded that intercropping of fodder sorghum with cowpea or ricebean both in 2:2 row ratio were the most productive and remunerative intercropping systems for summer season.

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