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Bio-economic evaluation of rainfed maize (*Zea mays*)-based intercropping systems with blackgram (*Vigna mungo*) under different spatial arrangements*

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To stabilize crop production and to provide insurance mechanism against aberrant weather situations characterizing rainfed agriculture, intercropping could be a viable agronomic means of risk minimizing farmers' profit and subsistence-oriented, energy-efficient and sustainable venture (Faroda *et al.* 2007). Since maize (*Zea mays* L.) is a widely spaced crop, inter-row space could profitably be utilized for legumes in the interspaces. Maize–legume intercropping system, besides increasing productivity and profitability also improves soil health, conserves soil moisture and increases total out turn (Padhi and Panigrahi 2006, Ummed *et al*. 2008). Spatial arrangement and plant population in an intercropping system have important effects on the balance of competition between component crops and their overall productivity. Keeping these facts in view, the present investigation was planned to augment the possibility of increasing production potential of maize–blackgram (*Vigna mungo* L. Hepper) intercropping system in relation to different planting patterns under dry sub-humid rainfed conditions.

The field study was conducted during rainy (*kharif*) season during (2003–05) at the Research Farm of PAU Research Station for Kandi Area (RSKA) located at 31°6'5" N, 76°27'26" E and 355 meters above mean sea level on a well drained sandy loam soil under rainfed conditions. The climate was dry sub-humid with average annual rainfall of 1 130 mm, almost 80% of which is received from July to mid of September. The soil was classified as typical fluventiv ustochrept having 0.28% organic carbon, 202 kg/ha $KMnO_4$–N, 13 kg/ha Olsen P, 384 kg/ha NH_4OAC-K and *p*H 8.2. Nine treatments consisting of 3 sole cropping systems and 6 intercropping systems in different row proportions were tested in randomized block design replicated thrice. The planting pattern consisted of sole crop of maize at 50 cm (T_1), 60 cm (T_2), sole crop of blackgram (T_3), maize (50 cm) + 1 row of blackgram (T_4), maize (60 cm) + 1 row of blackgram (T_5), maize (75 cm) + 2 rows of blackgram (T_6), maize (90 cm) + 2 rows of blackgram (T_7), paired rows of maize (45/60 cm) + 1 row of blackgram (T_8) and paired rows of maize (60/45 cm) + 1 row of blackgram (T_9). 'Megha' maize and 'Mash 338' blackgram were sown on a well prepared field after the receipt of good amount of rainfall in the first fortnight of July. Maize was sown by dibbling method in rows as per treatments with plant-to-plant spacing of 22.5 cm. Blackgram was sown at inter-row spacing of 30 cm as per treatments and thinning was done 20 days after sowing to maintain proper intra-row space of 15 cm. Under monoculture cropping, maize crop received half nitrogen (40 kg N/ha as urea) and full P (40 kg P_2O_5/ha as single superphosphate) as basal and remaining half nitrogen (40 kg N/ha as urea) was top-dressed at knee-height stage. However, entire dose of 12 kg N as urea and 40 kg P_2O_5/ha as single superphosphate was drilled basally in blackgram. In case of intercropping systems, the required amounts of fertilizers (N and P) were applied depending on the row arrangements of component crops. Market prices prevailing during the crop season each year were used for computing maize equivalent yield. Competition functions like land equivalent ratio, competition ratio, relative crowding co-efficient, area-time equivalent ratio were calculated on pooled basis as per Willey (1979). Economics of various cropping systems was also worked out to find out the most feasible and remunerative cropping system under rainfed conditions. A total of 433.3, 541.4 and 490.2 mm rainfall in 20, 24 and 22 rainy days was received during the crop growing season in the respective years.

Growth, yield-attributing characters and yield of maize showed variation and decreasing trend in the intercropping systems depending on spatial arrangement of component crops (Table 1). Sole stand of maize either at 50 or 60 cm

*Short note

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(T_1 or T_2) recorded taller plants, higher number of grains/cob, 1 000-grain weight and grain yield over intercropped maize. This could be accredited to the absence of interspecific competition and limited distribution of habitat having more photosynthetic efficiency, better light interception, higher dry matter accumulation and translocation of manufactured food material from the source (vegetative parts) to sink (reproductive organ by the seed). In general, the yield reduction in the intercropping pattern for maize crop with blackgram in 1: 1 (T_4 or T_5) and 2: 1 (T_8 or T_9) row ratios was relatively lower as compared to its counterpart in 1: 2 orientations (T_6 or T_7). Reduction in yield of the main crop was the maximum (41.8–46.2%) when maize was widely spaced at 75/90 cm in comparison to its cultivation at 50/60 cm (21.8–27.1%). However, when paired row planting of maize was done, yield reduction to the tune of 29.0–29.8% was observed.

Monocultured production of blackgram (T_3) yielded higher than those of intercropped culture (Table 1). Magnitude of reduction in the yield attributes and yield of blackgram was variable due to intercropping with maize depending on the plant population and spatial arrangement of component crop. Such a reduction in yield components and yield might be linked with the shading and competition consequence of maize plants on associated legume crop. Two rows of blackgram grown in association with maize planted either at 75 or 90 cm apart (T_6 or T_7) recorded the least reduction in yield attributes and yield in comparison to sole blackgram (T_3).

All the intercropping systems showed superiority over sole cropping of maize or blackgram, as evident by maize equivalent yield (Table 1). The additional yield advantage due to intercropping and also the higher economic value of intercrop may be accredited to higher total productivity under intercropping systems, irrespective of row arrangements compared to sole cropping. The highest maize equivalent yield was recorded with intercropping pattern of maize (50 cm) with blackgram in 1: 1 row ratio (T_4), followed by maize (75 cm) with blackgram in 1: 2 row proportion (T_6). This could be attributed to balanced competition and complementary effect of both crops for better utilization of available resources. Similar beneficial effects of legumes intercropping in relation to higher system productivity and profitability have also been reported by Birbal Sahu (2006) and Rao *et al.* (2009).

Compared to the sole crop, intercropping of maize with blackgram, irrespective of spatial arrangements showed land equivalent ratio (LER) values greater than one, indicating higher total productivity of the system and yield advantage due to intercropping (Table 2). Intercropping pattern of maize (50 cm) with blackgram in 1 : 1 row ratio (T_4) recorded the maximum biological efficiency (1.34) of the system, followed by LER of 1.25 in case of maize (75 cm) + 2 rows of blackgram (T_6), reflecting their superiority among all the intercropping systems. Maize proved to be the dominant companion to blackgram, having higher values of competition ratio (CR) co-efficient than the associated blackgram in all the intercropping systems, irrespective of row ratios (Table 2). The relative crowding co-efficient indicated that it was advantageous and biologically sustainable to grow blackgram as intercrop with maize under rainfed conditions, which was further established by the product of crowding co-efficient K (Table 2), may be due to mutual co-operation. Similar results were reported by Sharma and Singh (2008). When the values of area time equivalent ratio (ATER) was considered to asses the yield advantage due to intercropping, it was found that all the intercropping systems except that with paired row planting of maize (T_8 or T_9) showed ATER values greater than unity indicating better land utilization efficiency under these systems.

Table 1 Growth, yield components and yield as influenced by maize-based intercropping system under different row ratios (pooled data of 3 years)

Cropping system	Maize				Blackgram					MEY	SYI	PE
	Plant height (cm)	Grains/ cob	1 000-grain wt (g)	Grain yield (kg/ha)	Plant height (cm)	Pods/ plant	Seeds/ pod	1 000-seed wt (g)	Seed yield (kg/ha)	(kg/ ha)		(kg/ha/ day)
Sole maize (50 cm) (T_1)	199	418	146.9	2366								
Sole maize (60 cm) (T_2)	195	408	146.7	2268						2 268	0.76	24.4
Sole blackgram (30 cm) (T_3)					40.7	23.2	6.4	39.9	835	2 885	0.87	31.0
Maize (50 cm) + blackgram (1: 1) (T_4)	202	383	142.0	1812	39.9	21.3	6.2	34.6	464	3 430	0.90	36.9
Maize (60 cm) + blackgram (1: 1) (T_5)	189	379	137.4	1688	36.9	20.3	5.9	35.2	417	3 142	0.83	33.8
Maize (75 cm) + blackgram (1: 2) (T_6)	195	371	144.5	1349	38.5	19.8	6.3	37.0	563	3 322	0.87	35.7
Maize (90 cm) + blackgram (1: 2) (T_7)	187	404	140.9	1246	39.7	22.8	6.4	38.0	515	3 049	0.85	32.8
Maize (paired 45/60 cm) + blackgram (2: 1) (T_8)	193	358	136.0	1644	37.7	17.7	6.3	34.2	259	2 544	0.85	27.4
Maize (paired 60/45 cm) + blackgram (2: 1) (T_9)	194	350	134.4	1627	39.2	18.3	6.2	34.8	255	2 510	0.90	27.0
CD (P=0.05)	NS	36	5.1	152	NS	2.7	NS	2.5	71	276		

MEY, Maize equivalent yield; SYI, sustainability yield index; PE, production efficiency

Table 2 Biological and economic parameters of maize-based intercropping system under different row ratios (pooled data of 3 years)

Intercropping system	LER	CR		RCC			ATER	MA ($\times 10^3$ Rs/ha)
		Maize	Intercrop	Maize (K_m)	Intercrop (K_i)	System ($K=K_m \times K_i$)		
Maize (50 cm) + blackgram (1: 1) (T_4)	1.34	1.39	0.72	3.59	1.25	4.49	1.23	5021
Maize (60 cm) + blackgram (1: 1) (T_5)	1.23	1.46	0.68	2.68	1.00	2.68	1.14	3386
Maize (75 cm) + blackgram (1: 2) (T_6)	1.25	1.73	0.58	2.79	1.03	2.87	1.12	3830
Maize (90 cm) + blackgram (1: 2) (T_7)	1.16	1.74	0.57	2.33	0.80	1.86	1.04	2428
Maize (paired 45/60 cm) + blackgram (2: 1) (T_8)	1.02	1.15	0.87	1.22	0.90	1.10	0.96	288
Maize (paired 60/45 cm) + blackgram (2: 1) (T_9)	1.01	1.13	0.89	1.18	0.88	1.04	0.95	144

LER, Land equivalent ratio; CR, competition ratio; RCC, relative crowding co-efficient; K, product of relative crowding co-efficient; ATER, area time equivalent ratio; MA, monetary advantage

Table 3 Soil nutrient status and economics of various treatments as influenced by maize-based intercropping system under different row ratios

Cropping system	Net returns ($\times 10^3$ Rs/ha)	Benefit: cost ratio	Income equivalent ratio (IER)	Nutrient uptake (kg/ha) by intercropping system			Available nutrient status (kg/ha) after harvest of crops		
				N	P	K	N	P	K
Sole maize (50 cm) (T_1)	4.21	1.45	1.00	138.3	17.8	183.1	137.8	12.2	277.7
Sole maize (60 cm) (T_2)	3.93	1.43	0.96	140.0	17.0	182.2	135.9	12.4	273.5
Sole blackgram (30 cm) (T_3)	6.55	1.61	1.20	69.7	8.4	73.4	168.9	11.3	320.2
Maize (50 cm) + blackgram (1: 1) (T_4)	8.54	1.78	1.52	184.9	21.3	242.2	147.8	11.3	283.1
Maize (60 cm) + blackgram (1: 1) (T_5)	6.06	1.50	1.27	182.4	21.2	242.5	146.5	11.2	279.8
Maize (75 cm) + blackgram (1: 2) (T_6)	6.13	1.48	1.32	179.9	20.4	225.2	155.3	10.7	290.1
Maize (90 cm) + blackgram (1: 2) (T_7)	5.22	1.46	1.21	180.3	20.5	224.4	152.6	10.6	289.5
Maize (paired 45/60 cm) + blackgram (2: 1) (T_8)	3.18	1.23	1.04	177.2	21.7	233.7	142.5	11.1	277.9
Maize (paired 60/45 cm) + blackgram (2: 1) (T_9)	3.23	1.22	1.03	177.7	21.7	234.0	143.9	11.0	281.0

Irrespective of the plating pattern, all the intercropping systems showed their superiority in terms of economic viability and sustainability over monoculture cropping of maize. The highest production efficiency (36.9 kg/ha/day), sustainability yield index (0.90), income equivalent ration (1.52), net returns (8.54×10^3 Rs/ha) and B : C ratio (1.64) was recorded with intercropping blackgram with maize (50 cm) in 1 : 1 row ratio (Table 3). The increase in the number of intercrop rows in between maize rows (T_6 or T_7) or higher the number of maize rows neighbouring blackgram row (T_8 or T_9), caused a decline in economic returns.

Sole maize removed comparatively higher amount of N (138.3 kg/ha), P (17.8 kg/ha) and K (183.1 kg/ha) which might be attributed to its inherent exhaustive nature and ability to produce higher total biomass production resulting in higher absorption of nutrients. The total K uptake was quite high in comparison to the uptake of N and P in all the treatments. Respective values of N, P and K uptake were also higher with sole blackgram compared with intercropped maize (Table 3). Total N, P and K uptake of the system was relatively higher than sole copping, irrespective of the row ratio. Intercropping of blackgram with maize increased the available soil N content and decreased both available P and K content at all the row ratios compared to initial and post harvest available N, P and K content after soil maize sown at 50 cm row spacing. These results are in conformity with the findings of Padhi and Panigrahi (2006).

Thus, it can be concluded that intercropping of blackgram with maize planted at 50 cm in 1 : 1 row proportion can be suggested as a productive, remunerative and biologically sustainable intercropping system under rainfed conditions.

SUMMARY

An experiment was conducted during 2003–05 to assess the production potential, biological and economic feasibility of intercropping maize with blackgram in different row proportions under rainfed conditions. Intercropping blackgram with maize, irrespective of row arrangements was found to be beneficial in increasing the system's total productivity and yield advantage to the tune of 9.3–48.0% under different intercropping systems compared to monocultures of both maize and blackgram. Among the intercropping systems, maize (50 cm) with blackgram in 1 : 1 row proportion was proved to be the most efficient, productive and remunerative as it gave the highest mean maize equivalent yield (3 430 kg/ha) and also accounted for

highest values for land equivalent ratio (1.34), relative crowding co-efficient (4.49), area-time equivalent ratio (1.23), income equivalent ratio (1.52), sustainability yield index (0.90), production efficiency (36.9 kg/ha/day), net returns (8.54×10^3 Rs/ha) and B: C ratio (1.78) compared to other intercropping systems, thus, can be suggested as a biological and economically sustainable intercropping system for higher productivity and profitability under rainfed conditions. Magnitude of reduction in yield of the base crop due to intercropping of blackgram was the highest (41.8–46.2%) when maize was widely planted either at 75 or 90 cm in 1: 2 row ratios as against the 21.8–27.1% for maize planted at 50/60 cm in 1: 1 row proportion. Paired row planting showed yield reduction to the extent of 29.0–29.8%.

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