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Effect of row ratio and fertility levels on productivity, economics and nutrient uptake in maize *(Zea mays)* + soybean *(Glycine max)* intercropping system

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ABSTRACT

A field experiment was conducted during the rainy seasons of 2003 and 2004 at Udaipur, to study the effect of row ratios and fertility levels on maize *(Zea mays* L.) + soybean [*Glycine max* (L.) Merr.] inercropping system in south Rajasthan. The highest maize-equivalent yield was observed with 2:2 maize + soybean intercropping sown at 30 at 30 cm distance with each other. Application of 75% recommended dose of fertilizer (RDF) to maize (90 kg N/ha and 40 kg P/ha) and 50% to soybean (60 kg N/ha and 40 kg P/ha) significantly increased their respective yields, maize-equivalent yield, net returns and benefit : cost ratios over 50% RDF in maize and no fertilizer in soybean. The nutrient uptake by maize was highest with 1:1 ratio, while by soybean it was with 3:3 ratios. Increasing levels of fertility to maize and soybean up to 100% recommended dose increased the total nutrient uptake significantly over 75 and 50% in the both crops in intercropping system.

Key words : Maize+soybean inercropping, Row ratio, Fertility levels, Maize equivalent yield, Nutrient uptake.

The role of intercropping in maize is very important, as 85% area under maize in Rajasthan is dependent upon monsoon where erratic rainfall and prolonged break in monsoon frequently causes total failure of maize crop. Soybean is considered as an ideal crop for intercropping with maize owing to its comparative tolerance for shade and drought, efficient light utilization and less competitiveness for soil moisture (Wright *et al.,* 1988).

For successful and profitable intercropping system, there must be proper row ratio of component crop in order to avoid limitation of reduced plant population of base crop under traditional intercropping system (Pandey *et al.,* 1999). The beneficial effects of a suitable row ratio in cereal–legume intercropping system may be assessed by the overall productivity of the system (Marshall and Willey, 1983). Further soybean, being efficient utilizer of nitrogen, responds to N application despite being a leguminous crop (Jat and Gaur, 2000). The nutrient requirement of soybean may be different than that of sole maize (Sharma and Choubey, 1991). As the optimum row ratio and fertilizer schedule for obtaining potential yield from maize + soybean intercropping in south Rajasthan has not been worked out, the present study was carried out during the rainy seasons of 2003 and 2004.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Farm, Rajasthan College of Agriculture, Udaipur, during rainy seasons of 2003 and 2004. The soil was clay loam, alkaline and calcareous. The soil was medium in available nitrogen (265.5 kg/ha), medium in phosphorus (16.9 kg/ha) and high in potassium (377.4 kg/ha), with pH 8.9. The experiment was laid out in factorial randomized block design with 3 replications having 29 treatment combinations of 3 row ratios of maize + soybean (1:1, 2:2 and 3:3), 3 fertility levels for maize (100,75 and 50% recommended dose of fertilizer, RDF) and 3 fertility levels for soybean (100, 50% RDF and no-fertilizer) and with 2 absolute sole controls of maize and soybean. The recommended dose of nitrogen and phosphorus for maize was 90 kg N and 40 kg P_2O_5/ha. For component soybean, it was 60 kg N/ha 40 kg P_2O_5/ha. Maize cv. 'Ganga Safed 2' and soybean cv. 'JS 335' were sown in rows spaced 30 cm apart for intercropping and sole soybean and 60 cm for sole maize. Soybean was introduced while maintaining the population of sole maize in all the 3 row ratios. Sowing was done on 4 July in 2003 and 5 July in 2004. Before sowing, the seeds of soybean were inoculated with *Bradyrhizobium japonicum.* Thinning was done 15 and 25 days after sow-

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ing in both crops to keep the plant-to-plant spacing of 5 cm in soybean and 22 cm in maize. Nitrogen and phosphorus as per treatment to all the cropping sysems were given through urea and diammonium phosphate (DAP) respectively. One-third nitrogen along with full dose of phosphorus was applied as basal and remaining dose of N in 2 splits at knee-high stage (45 days after sowing) and tasselling stage in maize. In soybean, total nitrogen and phosphorus were applied at sowing as basal. The different crops were harvested at their physiological maturity.

RESULTS AND DISCUSSION

Maize yield

The maize grain yield was significantly affected by row ratios (Table 1). The highest grain yield of maize was recorded with 1:1 row ratio and was at par with 2:2 row ratio. Both these ratios were found significantly superior to 3:3 row ratio. On pooled data basis, 16.2 and 12.9% increase in grain yield was observed with 1:1 and 2:2 row ratio, respectively, over 3:3 row ratio. The increase is ascribed to the vigorous and enhanced plant growth of maize in 1:1 and 2:2 ratio over 3:3 row ratio as a result of reduced inter-row specific competition for solar radiation and plant nutrient. Singh and Singh (2001) and reported such effects of inter-row arrangement on yield of maize under maize + legume inercropping system.

Further, the grain yield of maize increased significantly up to 75% of recommended dose of fertility during both the years, however, in pooled mean it increased up to 100% RDF. Application of 100% RDF to maize increased the mean grain yield by 75% over 50% RDF. Significant increase in grain yield of maize with increasing levels of fertilizer dose could be attributed to increased dry-matter accumulation and dry-matter partitioning and indirectly higher nutrient uptake by crop at increasing fertility levels. The results are in close conformity with the findings of Kumar and Singh (1992), who reported an increase in-grain yield of maize as a result of an adequate supply of plant nutrient to both the crops in intercropping system.

Grain yield of maize was significantly affected by different fertility levels applied to soybean (Table 1). The 100 and 50% RDF applied to soybean increased the maize grain yield by 16.0 and 12%, respectively, over no-fertilizer application to intercrop soybean. Increased maize grain yield owing to increased fertilization to soybean might have been the function of increased nitrogen fixation by soybean benefiting the maize crop. Jat and Gaur (2000) also observed the beneficial effect of soybean intercropping with maize on yield under adequate fertilization to intercrop.

Table 1. Effect of row ratios and fertility levels on maize, soybean and maize-equivalent yield

Treatment	Maize grain (q/ha)			Soybean seed (q/ha)			Maize-equivalent yield (q/ha)		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
Intercropping ratio									
Maize + soybean (1:1)	45.71	43.17	44.44	6.66	5.39	6.03	63.16	58.81	60.98
Maize + soybean (2:2)	44.46	41.96	43.21	8.00	6.37	7.19	65.45	60.44	62.94
Maize + soybean (3:3)	39.71	36.76	38.24	8.30	6.60	7.45	61.48	55.93	58.70
CD (P=0.05)	2.02	2.22	1.48	0.48	0.43	0.32	2.87	2.59	1.9
Fertility levels (maize)									
100% RDF	46.59	43.57	45.08	8.17	6.53	7.35	68.02	62.53	65.27
75% RDF	44.93	42.14	43.54	7.81	6.23	7.02	65.41	60.22	62.81
50% RDF	38.35	36.17	37.26	6.98	5.60	6.29	56.67	52.44	54.55
CD (P=0.05)	2.01	2.22	1.48	0.48	0.43	0.32	2.87	2.59	1.91
Fertility levels (soybean)									
100% RDF	45.89	43.16	44.53	8.21	6.48	7.35	67.44	61.96	64.70
50% RDF	44.16	41.83	43.00	7.82	6.29	7.06	64.68	60.10	62.39
No fertilizer	39.82	36.89	38.36	6.92	5.59	6.26	57.98	53.13	55.55
CD (P=0.05)	2.01	2.22	1.48	0.48	0.43	0.32	2.87	2.59	1.91
Sole vs rest									
Sole maize	53.85	49.20	51.53				53.85	49.20	51.52
Intercropped maize	43.29	40.63	41.96				63.36	58.40	60.88
CD (P=0.05)	6.06	6.65	4.44				8.60	7.78	5.74
Sole soybean				18.90	16.43	17.67	49.57	47.7	48.63
Intercropped soybean				1.65	6.12	6.89	63.36	58.4	60.88
CD (P=0.05)				1.43	1.48	0.88	8.60	7.78	5.74

RDF, Recommended dose of fertilizer

Soybean yield

The seed yield of soybean was remarkably affected by intercropping row ratios (Table 1). The highest seed yield of soybean was recorded with 3:3 row ratio which was at par with 2:2 ratio. Both these ratios were significantly superior over 1:1 ratio. On pooled yield basis, 23.5 and 19.2% increase in seed yield of soybean was recorded with 3:3 and 2:2 ratio, respectively, over 1:1 ratio. Significantly increased seed yield of soybean in 3:3 ratio seems to be the cumulative effect of increased growth, nutrient uptake and dry-matter accumulation as a result of minimum shading effect of maize under these row ratios of maize + soybean. Mondal *et al.* (1998) also observed the highest soybean yield with 3 rows of soybean in paired row of maize.

The seed yield of soybean was significantly affected by various fertility levels applied to main crop. On pooled data basis, 11.6 and 16.8% increase in seed yield was observed with 75 and 100% RDF to the main crop, respectively, over 50% RDF. Further, the increasing levels of fertility in intercrop soybean significantly increased seed yield of soybean. On pooled data basis, 12.7 and 17.4% increase in soybean seed yield was recorded with 50 and 100% RDF, respectively, over no-fertilizer application. Marked improvement in yield of soybean owing to increasing levels of fertilizer in main and intercrop could be attributed to overall improvement in plant growth and yield attributes as a result of greater availability of plant nutrient, photosynhates and metabolites from the source. Kapila (1998) also reported increased seed yield with concomitant improvement in yield attributes and plant growth as a result of adequate supply of plant nutrients to both the crop in intercropping system.

Maize-equivalent yield

The highest mean maize-equivalent yield (MEY) was recorded under 2:2 row ratio, being 3.2 and 7.2% higher over 1:1 and 3:3 row ratio respectively. An improvement in maize-equivalent yield in 2:2 inter-row ratio of maize + soybean was mainly owing to production of higher yield of both the crops. Shivay *et al.* (2001) also recorded the maximum maize-equivalent yield with maize + soybean (45/90) paired planting. Significant increase in MEY because of increased levels of fertility to main and intercrop appears to be the result of higher productivity of both maize and soybean with increasing levels of fertilizers. Jat and Gaur (2000) also reported similar finding.

Further, the highest maize-equivalent yield was observed in 100% RDF to main crop maize which was at par with 75% RDF. Both these levels were significantly

Table 2. Effect of row ratios and fertility levels on net return and benefit : cost in maize + soybean

Treatment	Net return (Rs/ha)			Benefit : cost ratio		
	2003	2004	Pooled	2003	2004	Pooled
Intercropping ratio						
Maize + soybean (1:1)	40,128	35,788	37,958	3.56	3.10	3.33
Maize + soybean (2:2)	41,457	36,836	39,147	3.68	3.19	3.43
Maize + soybean (3:3)	38,262	33,223	35,742	3.39	2.88	0.12
CD (P=0.05)	1,861	1,807	1,381	0.17	0.18	0.12
Fertility levels (maize)						
100% RDF	43,061	38,089	40,575	3.70	3.20	3.45
75% RDF	41,559	36,673	39,116	3.69	3.18	3.43
50% RDF	35,226	31,085	33,156	3.24	2.79	3.01
CD (P=0.05)	1,861	1,807	1,381	0.17	0.18	0.12
Fertility levels (soybean)						
100% RDF	42,478	37,556	40,017	3.57	3.09	3.33
50% RDF	41,057	36,547	38,802	3.64	3.17	3.40
No fertilizer	36,312	31,745	34,029	3.42	2.91	3.16
CD (P=0.05)	1,861	1,807	1,381	0.17	0.18	0.12
Sole vs rest						
Sole maize	34,882	30,999	32,40	3.53	3.06	3.29
Intercropped maize	36,949	35,282	36,116	3.54	3.06	3.30
CD (P=0.05)	5,584	6,242	44,52	0.50	0.54	0.36
Sole soybean	25,156	23,738	24,447	2.61	2.40	2.50
Intercropped soybean	39,949	35,282	37,616	3.54	3.06	3.30
CD (P=0.05)	5,584	6,242	44,52	0.50	0.54	0.36

superior to 50% RDF; however, in pooled data maize-equivalent yield increased significantly up to 100% RDF. Compared to 50% RDF, application of 75 and 100% RDF to maize increased mean MEY by 15.1 and 19.6% respectively. Application of fertilizer to component soybean also affected the MEY favourably as compared to no-fertilizer, i.e., 50 and 100% RDF to soybean increased the MEY by 12.3 and 16.4% respectively.

Economics

The net returns and benefit : cost (B:C) ratios were significantly affected by various treatments. Highest net returns and B:C ratio were recorded under 2:2 row ratio (Table 2). On pooled data basis, 3.1 and 9.5% increase in net returns and 3.0 and 9.5% increase in B:C ratio at 2:2 ratio was observed over 1:1 and 3:3 ratio respectively. An improvement in economic indices in 2:2 inter-row system was mainly because of higher yield of maize and soybean under study. Pandey *et al.* (1999) also reported higher net returns with paired raw planting of maize and soybean in intercropping system.

Further, the net returns and B:C ratio were significantly increased up to 75% RDF to maize during both the years and pooled B:C ratio; however, pooled net return increased up to 100% RDF. On pooled data basis, 17.9 and 22.3% higher net returns and 13.9 and 14.5% higher B:C ratio were recorded with 75 and 100% RDF, respectively, over 50% RDF to maize.

Pooled net returns and B:C ratio also significantly increased by up to 50% RDF levels to intercrops. On pooled data basis, 14.0 and 17.5% increase in net returns and 7.5 and 5.3% increase in B:C ratio were observed with 50 and 100% RDF, respectively, compared to no-fertilizer application to intercrop soybean. Significant increase in net returns and B:C ratio owing to increasing levels of fertilizers to main and intercrop appear to be the result of increased productivity of both maize and soybean with increasing levels of fertilizer. Jat and Gaur (2000) also recorded maximum net returns with maize and soybean intercropping with recommended dose of fertilizers.

Nutrient uptake by maize

The total N uptake by maize was significantly higher under 1:1 ratio, being 16.5 and 11.4% higher over 3:3 and 2:2 ratio respectively (Table 3). However, the maximum total uptake of P and K by maize was recorded under 1:1 ratio and it was at par with 2:2 ratio. Both these ratios were, significantly superior over 3:3 row ratio for nutrient uptake. The magnitude of increase were 19.5, 16.1 and 13.7, 11.1% higher under 1:1 and 2:2 ratio, respectively, over 3:3 ratio.

Further, the NP uptake by maize significantly increased up to 100% RDF to maize, which was 18.0 19.5 and 23.7, 25.2% higher under 75 and 100% RDF, respectively, over 50% RDF to maize. However, K uptake by

Table 3. Effect of row ratios and fertility levels on N, P and K uptake of maize and soybean (pooled data) in maize + soybean intercroping

Treatment	Uptake of maize (kg/ha)			Uptake of soybean (kg/ha)		
	N	P	K	N	P	K
Intercropping ratio						
Maize + soybean (1:1)	116.43	25.37	121.83	52.96	5.52	28.55
Maize + soybean (2:2)	112.85	24.64	118.94	64.24	6.66	33.04
Maize + soybean (3:3)	99.92	21.22	106.99	67.45	6.97	34.62
CD (P=0.05)	3.49	0.81	4.92	3.62	0.25	1.39
Fertility levels (maize)						
100% RDF	119.16	25.96	123.19	67.20	6.95	34.62
75% RDF	113.73	24.78	119.14	63.39	6.57	32.85
50% RDF	96.31	20.72	105.44	54.06	5.63	28.74
CD (P=0.05)	3.49	0.81	4.92	3.62	0.25	1.39
Fertility levels (soybean)						
100% RDF	118.22	25.72	123.51	67.37	6.98	34.65
50% RDF	112.67	24.63	118.55	63.71	6.61	33.03
No fertilizer	98.31	21.12	105.70	53.62	5.56	28.54
CD (P=0.05)	3.49	0.81	4.92	3.62	0.25	1.39
Sole vs rest						
Sole maize	134.24	29.63	136.98			
Intercropped maize	109.73	23.82	15.92			
CD (P=0.05)	10.07	2.42	9.41			
Sole soybean				168.14	17.35	84.98
Intercropped soybean				61.55	6.39	32.07
CD (P=0.05)				10.83	0.73	4.17

maize significantly increased up to 75% RDF. The total NPK uptake by maize was highest with 100% RDF to soybean, though the nutrient uptake significantly increased up to 100% RDF to intercrop which was 14.6 and 20.7, 16.6 and 21.7, 12.1 and 16.8% higher under 50 and 100% RDF, respectively, over no-fertilizer application to intercrop.

Soybean

The total N, P and K uptake by soybean was significantly affected by row ratios and fertility levels during both the years. The highest uptake of NPK by soybean was recorded under 3:3 row ratio and it was statistically at par with 2:2 ratio but significantly higher by 27.3 and 21.2, 26.2 and 20.6% over 1:1 row ratio respectively. The NPK uptake by soybean crop was significantly higher up to 100% RDF and it was 17.2 and 24.2, 16.6 and 23.4, 14.3 and 20.4% higher under 75 and 100% RDF levels, respectively, over 50% RDF to maize.

Further, the total NPK uptake by soybean crop was significantly increased by up to 100% RDF compared to no-fertilizer. Application of 50 and 100% RDF to soybean increased the uptake of N by 18.8 and 25.5%, P uptake by 18.0 and 25.5% and K uptake by 15.7 and 21.4% respectively. Significant increase in NPK uptake by maize and soybean with increasing levels of fertility to main and intercrop seems primarily due to increased dry-matter production and secondly due to increased N, P and K contents of plants due to greater availability of these nutrients in the root zone and absorption by the crops. The results are substantiated by the findings of Shivay and Singh (2000).

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