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Effect of vegetable intercropping on productivity, economics and energetics of maize (*Zea mays*)

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ABSTRACT

A field experiment was conducted during the rainy seasons of 1996 and 1997 to study the productivity, economics and energetics of maize (*Zea mays* L.) intercropped with runner bean (*Phaseolus vulgaris* L.), cowpea [*Vigna unguiculata* (L.) Walp]. and clusterbean. [*Cyamopsis tetragonoloba* (L.) Taub.] under upland rainfed situation of South-Eastern Ghat Zone of Orissa. An intercropping maize with runner bean at 2:2 row ratio realized the maximum maize-equivalent yield (63.69 q/ha), production efficiency (217.5%), land-equivalent ratio (1.35), net returns (Rs 12,677/ha), monetary advantage index (6,604.4), return/rupee spent, relative net returns (1.91 and 1.26 over maize and runner bean respectively), energy output (174.81 x 1,000 MJ/ha), energy output : input ratio (12.26) and energy-use efficency (446.7 and 927.2 kg/1,000 MJ for main and total produce respectively) and appeared to be most productive and economically and energetically viable system, followed by maize + cowpea at 1:1 row ratio. This system increased the total production in terms of maize-equivalent yield by 114.5% and net profit by Rs 10,711/ha over normally sown sole maize.

Key words: Maize, Vegetable intereropping, Productivity, Economics, Energetics

Maize, runner bean, cowpea and clusterbean are the major rainy-season crop under upland, rainfed conditions of South-Eastern Ghat Zone of Orissa. But the productivity and profit realized from them are very low due to low soil fertility and heavy investment on wooden stakes used for trailing runner bean and cowpea. Taking advantage of wider row spacing in maize vegetables like runner bean, cowpea and clusterbean can be grown within the available interspace (Patra *et al.*, 1999). Maize stems can also be utilized for trailing runner bean and cowpea in substitute to wooden stakes. It is also established that legumes in association with maize have beneficial effect on its N economy and grain yield (Francis *et al.*, 1970; Nair *et*

al., 1979). Therefore, the present experiment was undertaken to study the production potential, economics and energetics of maize intercropped with runner bean, cowpea and clusterbean.

MATERIALS AND METHODS

The experiment was conducted during the rainy seasons of 1996–97 at Kalimela, Orissa. The soil was well drained, sandy-loam (Ultisol). The soil had pH 5.7, organic carbon 0.48%, total N 0.047% available P 23.7 kg/ha and exchangeable K 135.1 kg/ha. The experiment consisting of 14 treatments was laid out in randomized block design, replicated thrice. The treatments were 5 sole stands of each maize, runner bean, clusterbean and cowpea and intercrop association of uniform and paired-row maize with each of the intercrop as per plan lay out (Table 1). Maize was sown at 60 cm aprt in uniform rows and 45 cm apart in paired rows, leaving 90 cm between 2 paired rows. In both the planting systems plant-to-plant distance of 25 cm with in a row was maintained. The crops were sown on 4 June 1996 and 7 June 1997. Farmyard manure was incorporated into the soil @ 5 tonnes/ha 15 days before sowing. Sole and intercropped maize was supplied with 40 kg N, 17.47 kg P and 16.6 kg K/ha at the time of sowing and 40 kg N/ha was top-dressed at 5 weeks after sowing. Each of the sole crop of runnerbean, cowpea and clusterbean was supplied with 20 kg N, 17.47 kg P and 8.3 kg K/ha at the time of sowing. But only 50% of the above doses were applied under intercropping. The equivalent energy values as specified by Mittal *et al.* (1985) were used for calculating energy input and output. Competition functions like land-equivalent ratio (LER), relative crowding co-efficient (RCC), competition ratio (CR), aggressivity (A) and monetary advantage index (MA) were computed as suggested by Willey (1979). Relative net returns were calculated as per Jain and Rao (1980).

RESULTS AND DISCUSSION

Maize-grain yield

The sole maize crop gave significantly higher grain yield (7.40%) than paired row-sown sole maize, owing to 10.8% reduction in plant population in the latter system (Table 1). The grain yield of intercropped maize at all the proportions was reduced significantly (10.1 – 16.6%) compared with sole maize. This reduction might be attributed to significant lowering of plant population and grains/cob (12.4%–21.2%). The reduction in maize grain yield varied with the kind of intercrops and their proportions of sowing. Maize grain yield was lowered by 15.6% when intercropped with clusterbean, followed by 14.9% with runner bean and 13.4% with cowpea compared with sole maize. Among the intercropping systems, maize with runner bean at 2 :2 row ratio could recover maximum of its sole crop yields (89.9%), followed by cowpea at 1:1 row ratio (87.8%) probaby owing to maximum number of grains/cob. But maize with clusterbean at 2 :2 row ratio could reeover only 83.3% of its sole crop yield possibly owing to the lowest number of grains/cob (423.2). Both kinds of intercrops and their proportions of sowing had no significant influence on the grain size (100-grain

Table 1. Effect of cropping systems on yield, yield attributes of maize, runner bean, cowpea and clusterbean (pooled data of 2 years)

Treatment	Plant height (cm)	Grains/ cob	100-grain weight (g)	Maize grain yield (q/ha)	Intercrop* yield (q/ha)	Maize-equivalent yield (q/ha)	Production efficiency (%)
Maize sole (R)	232.6	537.6	25.0	29.28		29.28	100
Maize sole (P)	234.6	489.9	27.0	27.11		27.11	92.6
Runner bean sole					66.11	29.25	99.9
Clusterbean sole					39.00	29.25	99.9
Cowpea sole					103.54	77.66	265.3
Maize + runnerbean (1 : 1)	228.4	435.0	26.0	24.61	26.08	57.21	195.4
Maize + clusterbean (1 : 1)	223.3	437.7	27.0	24.74	5.68	29.00	99.1
Maize + cowpea (1 : 1)	220.6	471.2	25.0	25.71	31.16	49.08	167.6
Maize + runnerbean (2 : 1)	229.9	428.5	26.0	24.43	26.07	57.01	194.4
Maize + clusterbean (2 : 1)	232.6	439.6	26.0	25.00	5.00	28.75	98.2
Maize + cowpea (2 : 1)	230.6	465.1	26.0	25.42	28.58	46.85	160.0
Maize + runnerbean (2 : 2)	212.2	470.5	26.0	26.33	29.88	63.69	217.5
Maize + clusterbean (2 : 2)	205.2	423.2	27.0	24.39	6.20	29.03	99.2
Maize + cowpea (2 : 2)	214.8	455.9	26.0	24.95	26.65	44.94	153.5
CD (P = 0.05)	15.9	37.9	NS	1.54		1.97	

*Green pod yield; NS, not significant; R, regular rows; P, paired rows

Table 2. Effect of cropping systems on competition functions of maize, runner bean, clusterbean and cowpea (pooled data of 2 years)

Treatment	Land equivalent ratio	Competition ratio	Relative crowding coefficient			Aggressivity		Monetary advantage index	Relative net return	
			K_1	K_2	K	AMI	AIM		Maize	Intercrop
Maize + runner bean (1:1)	0.23	1 : 0.22	5.26	0.65	3.43	0.45	– 0.45	4,279	1.65	1.17
Maize + cluster bean (1:1)	1.00	1 : 0.03	5.44	0.17	0.93	0.75	– 0.75		0.81	0.55
Maize + cowpea (1:1)	1.18	1 : 0.12	6.64	0.43	2.86	0.68	– 0.68	2,837.2	1.51	1.10
Maize + runner bean (2:1)	1.22	1 : 0.23	2.52	1.30	3.28	0.27	– 0.27	4,105.1	1.79	1.22
Maize + clusterbean (2:1)	0.98	1 : 0.02	2.92	0.29	0.86	0.30	– 0.30		0.88	0.61
Maize + cowpea (2:1)	1.15	1 : 010	3.30	0.76	2.52	0.15	– 0.15	2,444.4	1.47	0.49
Maize + runner bean (2:2)	1.35	1 : 0.25	8.96	0.82	7.39	0.22	– 0.22	6,604.4	1.91	1.26
Maize + clusterbean (2:2)	0.99	1 : 0.04	5.00	0.19	0.95	0.34	0.34		0.84	0.88
Maize + cowpea (2:2)	1.11	1 : 0.10	5.77	0.35	2.02	0.30	– 0.30	1,781.3	1.37	1.05

K_1, Coefficient of maize; K_2, coefficient of intercrops; K, $K_1 \times K_2$ (relative crowding coefficient); AMI, aggressivity of maize over intercrops; AIM, aggressivity of intercrops on maize

weight) of maize. This indicated that adverse effect of intercropping commenced at an early period of growth affecting development and floral initiation and consequently reduced grains/cob and grain yield of maize. Maize grain yield was not affected due to signficant reduction of its height with runner bean at 2:2 row ratio.

Intercrop yield

All the intercrops recorded less yield than their respective sole crops (Table 1). The reduction was the maximum with clusterbean (85.9%), followed by cowpea (71.9%) and the minimum with runner bean (58.4%). As regards to proportions of sowing, minimum reduction in intercrop yield was recorded at 2:2 proportion (71.0%) and maximum at 2:1 proportion (73.4%), possibly due to 33.5 and 66.7% reduction in plant population of intercrops in the former and latter systems, respectively, compared with their respective sole crop population. But both shading effect and 25.2% reduction in intercrop population compared to pure cultures reduced the yield of intercrops at 1:1 row ratio (72.0%). However, runner bean at 2:2, cowpea at 1:1 and clusterbean at 2 :2 row ratio with maize recovered maximum of their sole crop yields (45.2, 30.1 and 15.9% respectively) among all the intercropping treatments.

Maize-equivalent yield

An intercropping of maize either with runner bean or cowpea at different row proportions increased the total production of the systems by 94.7–117.5% and 53.5–67.6%, respectively, in terms of maize-equivalent yield over sole maize. But maize

intercropped with clusterbean at all the row ratios recorded significantly less maize-equivalent yield than sole maize. On the contrary, all the intercropping systems at different row proportions failed to overcome respective moncultures of runner bean, cowpea and clusterbean for total production on maize-equivalent basis. However, among the intercropping systems, maize + runner bean at 2:2 row ratio recorded the maximum maize-equivalent yield which was 117.5% higher than that of maize sown in regular rows. This increase might be due to spatial complementary action and additional contribution from runnerbean to the extent of 58.7% towards total maize-equivalent yield of the system. This system was closely followed by maize + cowpea at 1:1 row ratio on the above aspects.

Competition functions

Maize with co-efficient values greater than unity, higher values of competitive ratio and positive values of aggressivity found to be most dominant component in all the intercropping systems at all the proportions (Table 2). However, maize + runner bean at 2:2 and maize + cowpea at 1:1 row ratio appeared more advantageous with higher RCC (K) values. They also provided greater yield advantage than maize + clusterbean system at all the proportions. Further, runner bean and cowpea at the same row ratios with maize showed lower competitive ratios with higher expected yields and complement maize to a greater extent. Francis *et al.* (1978) also observed greater yield advantage due to maize and bean association. Maize + runner bean at 2 : 2 row ratio recorded the highest land-equivalent ratio (LER) (1.35), followed by maize + cowpea at 1:1 row ratio (1.18) and established their superiority to the respective monocultures of component crops with 35 and 18% more land-use efficiency. Maize + clusterbean showed the minimum land-use efficiency at all the proportions of sowing.

Economics

Intercropping of runner bean and cowpea with maize at different row ratios gave significantly higher net returns, utilizing more cost than normally sown sole maize, but higher profit was realized utilizing less cost than sole runnerbean and cowpea (Table 3). Involvement of higher cost on sole runner bean and cowpea might be due to investment of Rs 18,519 more towards the cost of 74,074 number of stakes/ha for trailing each of them. Maize + clusterbean on the other hand, not only utilized more cost but also suffered a definite loss due to less economic yield of clusterbean at different row ratios than pure cultures of respective component crops. However, among all the intercropping systems maize + runner bean at 2:2 row ratio appeared to be more remunerative with the highest net return (Rs. 12,677/ha), monetary advantage index (Rs. 6,604), return/rupee spent (Rs 2) and relative net returns (1.91 and 1.26 compared with sole maize and runner bean respectively), followed by maize + cowpea at 1:1 row ratio. This system increased the net profit by Rs 10,711/ha over normally sown sole maize. Utilizing less cost (Rs 16,222/ha) it also realized more net profit

Table 3. Effect of cropping systems on economics and energetics of maize, runner bean, clusterbean and cowpea (pooled data of 2 years)

Treatment	Cultivation cost (Rs/ha)	Net return (Rs/ha)	Return/ rupee spent (Rs)	Energy input (1,000 MJ/ha)	Energy output (1,000 MJ/ha)	Energy output: input	Energy-use efficiency (kg/1,000 MJ)	
							Main	Total
Maize sole (R)	9,744	1,966	1.20	12.86	151.44	11.78	227.6	696.0
Maize sole (P)	9,175	1,669	1.19	12.58	144.85	11.51	215.5	679.2
Runner bean sole	29,019	4,036	1.14	336.20	26.80	0.08	24.5	28.0
Clusterbean sole	6,625	5,075	1.77	7.20	21.80	3.03	408.9	576.1
Cowpea sole	26,126	4,396	1.19	336.00	34.72	0.10	23.1	26.2
Maize + runner bean (1:1)	13,305	9,579	1.72	14.43	147.43	10.22	396.5	745.2
Maize + clusterbean (1:1)	11,834	–234	0.98	14.26	149.97	10.52	203.4	618.1
Maize + cowpea (1:1)	11,727	7,800	1.66	14.20	170.74	12.02	345.6	862.0
Maize + runner bean (2:1)	11,643	11,162	1.96	14.00	139.86	10.00	407.2	810.7
Maize + clusterbean (2:1)	10,929	570	1.05	13.92	141.76	10.18	206.5	609.0
Maize + cowpea (2:1)	11,239	7,502	1.67	14.04	146.92	10.46	333.7	798.7
Maize + runner bean (2 :2)	12,797	12,677	2.00	14.26	174.81	12.26	446.6	927.2
Maize + clusterbean (2:2)	11,483	130	1.01	14.12	146.29	10.36	205.6	651.4
Maize + cowpea (2:2)	11,640	6,335	1.54	14.14	138.78	9.81	317.8	752.9
CD (P = 0.05)		784			26.61			

Market price (Rs/q): Maize grain, 400 ; runner bean green pod, 500; cowpea and clusterbean green pod, 300
Price of each wooden stake, Re 0.25

(Rs 8,841) than sole runner bean.

Energy relationship

Intercropping system gave 8.9–14.7% higher energy output, utilizing only 8.2–12.2% higher energy than normally sown sole maize (Table 3). Mohapatra and Pradhan (1993) also reported 15.5% higher energy use under maize-based intercropping systems than pure culture of maize. While maximum energy was utilized in sole runner bean, followed by sole cowpea due to use of 74,074 number of wooden stakes/ha for trailing them, minimum energy was realized from them among all the cropping systems. This indicated inefficient use of energy and dispropor- tionate energy output with unit input in both the crops. But in combination with maize at different row proportions each of them saved energy to the extent of 321.92 × 1,000 MJ/ha and gave significantly higher energy output over their sole plan- tings with higher energy-use efficiency and energy output : input ratio. However, among the intercropping systems, maize + runner bean at 2 : 2 row ratio remain at par with normally sown sole maize produced the highest energy output (174.81 × 1,000 MJ/ha), followed by maize + cowpea at 1:1 row ratio. But this system utilized energy most efficiently for main (446.6 kg/1,000 MJ), and total produce (927.2 kg/1,000 MJ) with higher energy output : input ratio (12.26) than pure cultures of maize in the present study.

It was concluded that intercropping of compatible crops like runner bean with maize at 2:2 paired rows and 1 row of cowpea between 2 regular rows of maize may be practised for higher production, profit and for saving of energy.

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