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Crop Diversification With Ricebean-Based Intercropping Systems For Maximising Productivity, Profitability and Energy Use Efficiency in Rainfed Upland

P K Roul, Rajashree Sahoo and S N Jen
Departhement of Agronomy,College of Agriculture, OUAT, Bhuneswar, Orissa-751 003

ABSTRACT

A field experiment was conducted at the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar during *kharif* seasons of 2007 and 2008 to study the performance of ricebean-based intercropping systems in rainfed upland. The soil was well drained loamy sand in texture with acidic reaction (pH - 5.6), low in available N (230.4 kg ha^{-1}), medium in available P (14.6 kg ha^{-1}) and K (164.2 kg ha^{-1}). The experiment comprised of 10 treatments laid out in a randomized block design with 3 replications. The treatments were ricebean (sole), maize (sole), arhar (sole), sorghum (sole), ricebean + maize (2:1), ricebean + maize (4:2), ricebean + arhar (2:1), ricebean + arhar (4:2), ricebean + sorghum (2:1), ricebean + sorghum (4:2). The growth parameters, yield attributes and yield of sole crop of ricebean were significantly higher than ricebean grown in association with maize/arhar/sorghum. Performance of ricebean in association with arhar at 4:2 row ratio was better compared to its association with other crops irrespective of row ratios. The rice bean yield under ricebean + arhar (4:2) was 23.6 % less than sole ricebean (11.52 q ha^{-1}). However, considering the intercropping system as a whole, ricebean + arhar (4:2) excelled all other treatments in terms of system productivity (19.15 q ricebean equivalent yield), land equivalent ratio (1.36), net return (Rs.20,037 ha^{-1}) and energy use efficiency (13.93 q/MJ x 10^{3}) . The productivity, net return and energy use efficiency under ricebean + arhar (4:2) were 66.2, 121.8 and 56.3% more than sole ricebean, respectively.

Key words : Intercropping system, Sole crop, System productivity, Row ratio.

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In view of serious problems posed by uplands in rainfed agriculture, our main focus should be to sustain production and productivity of rainfed uplands. Rice, the dominant crop in *kharif* season suffers from drought due to erratic monsoon behavior. Emphasizing upon the principal crops for enhancing production may not be possible, since productivity of such crops has reached a plateau. Moreover, Ricebean, a nontraditional pulse crop with adaptability to hot and humid climate and ability to tolerate drought, has a tremendous yield potential under rainfed upland situations of Orissa. Since, farmers can not afford to grow ricebean as a sole crop at the cost of rice and other upland *kharif* crops, there is need for intercropping of ricebean with existing upland *kharif* crops like maize, arhar and sorghum. The productivity of any intercropping systems greatly depends upon not only on the component crops but also on row proportions (Marshall and Willey, 1983). Hence the present investigation was carried out to study the effects of ricebean-based intercropping systems with different row proportions in rainfed upland.

MATERIAL AND METHODS

A field experiment was conducted at the Central Research Station, Orissa University ofAgriculture and Technology, Bhubaneswar (20^{o} 15' latitude and 85^{o} 52'E longitude and at analtitude of 25.9 m above MSL), to assess the performance of ricebean-based intercropping systems with varied row ratios in rainfed upland during *kharif* seasons of 2007 and 2008. The soil of the experimental field was loamy sand in texture, acidic in reaction (pH-5.6), low in organic carbon (0.4%) and available nitrogen (230.4 kg/ha), but medium in available P (14.6 kg/ha) and available K (164.2 kg/ha). The treatments comprised of sole crops of ricebean, maize, arhar, sorghum and intercropping systems of ricebean + maize (2:1) ricebean + maize (4:2), ricebean + arhar (2:1), ricebean + arhar (4:2), ricebean + sorghum (2:1), ricebean + sorghum (4:2). Ten such treatments were replicated thril in a randomized block design. The test varieties of ricebean, maize, arhar and sorghum were RBL 6, Vijaya, Asha (ICPL-87119) and CSH 9, respectively. The sole crop of ricebean was sown at a spacing of

Table 1. Effect of intercropping systems on yield attributes, seed yield, stover yield and harvest index of ricebean (pooled data of two years)

Particular	Cluster plant^{-1}	Pods cluster^{-1}	Pods plant^{-1}	Pod length (cm)	Seeds pod^{-1}	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (%)
Ricebean	14.97	2.28	34.13	7.64	6.73	11.52	37.27	23.38
Ricebean+ Maize(2:1)	9.12	2.26	20.61	7.02	5.14	7.20	27.18	20.94
Ricebean+ Maize (4:2)	10.06	2.57	25.85	7.16	5.71	7.50	27.56	21.39
Ricebean+ Arhar (2:1)	10.17	2.68	27.25	7.23	5.83	7.60	27.61	21.58
Ricebean+ Arhar (4: 2)	11.14	3.01	33.53	7.37	6.35	8.80	31.36	21.91
Ricebean+ Sorghum (2:1)	8.46	2.13	18.01	6.84	4.86	5.80	23.98	19.47
Ricebean+ Sorghum (4:2)	8.63	2.34	20.19	6.93	5.02	6.00	24.61	19.60
SEm (±)	0.34	0.08	0.87	0.19	0.17	0.26	0.78	0.68
CD (P = 0.05)	0.92	0.29	2.81	0.62	0.46	0.73	2.63	1.89

60 cm X 25 cm, whereas maize, arhar and sorghum were sown at spacing of 30 cm X 12.5 cm. The intercropping systems were based on replacement series principle. In all the intercropping systems the population of ricebean and the other component crop was 2/3rd and 1/3rd of normal population, respectively. The seed and fertilizer required for different intercropping systems were worked out based on plant population of component crops. The weather parameters during crop growing seasons were favorable for growth of all the crops under study. The crops could experience a temperature regime of 15 to 33.2°C and rainfall of 1128.4 to 1211.0 mm, suitable for the growing of the crops. The yield attributes and yield of ricebean were recorded. The intercropping system yield was computed by addition of ricebean yield with ricebean equivalent yield of the component crop. Ricebean equivalent yield (q ha^{-1})= [Yield of other crop produce (q ha^{-1}) x Price of that produce (Rs ha^{-1})]/ Price of ricebean (Rs q^{-1}). To judge the efficiency of intercropping systems, Land equivalent ratio (LER) of the component crops were calculated and the LER of intercropping system was calculated by using the formula:

$$LER = \frac{Y_{ia}}{Y_{sa}} + \frac{Y_{ib}}{Y_{sb}}$$

where Y_{ia} and Y_{ib} are the intercrop yields of component crops a and b, respectively. Y_{sa} and Y_{sb} are the sole crop yields of component crops a and b, respectively. Energy input was calculated from sowing to harvest pertaining to each treatment of the experiment. It was estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by Mahapatra and Pradhan (1993). The standard energy coefficient for seed and stover was multiplied with their respective yields and summed up to obtain the total energy output per each treatment. The Energy output input ratio was worked out by dividing the Energy output with the Energy input. Then the energy use efficiency was calculated as per the following formula:

Energy use efficiency

$$(q/MJ \times 10^3) = \frac{\text{Total production (q)}}{\text{Energy input } (MJ \times 10^3)}$$

The findings are as follows.

Table 2. Effect of ricebean based intercropping systems on grain yield, ricebean equivalent yield, land equivalent ratio (LER) and economics of production (pooled data of two years)

Particular	Ricebean yield (q ha^{-1})	Component crop yield (q ha^{-1})	Ricebean equivalent yield of systems (q ha^{-1})	LER	Cost of cultivation (Rs)	Gross Return (Rs)	Net return (Rs)	Return per Re. invested
Ricebean	11.52	-	11.52	1.0	7,772	16,806	9,034	2.16
Maize	-	30.58	15.8	1.0	8,578	23,710	15,132	2.76
Arhar	-	11.46	17.2	1.0	8,178	26,935	18,751	3.29
Sorghum	-	20.34	10.51	1.0	7,922	15,248	7,326	1.92
Ricebean+ Maize (2:1)	7.2	18.6	16.8	1.23	10,925	26,151	15,226	2.39
Ricebean+ Maize (4:2)	7.5	19.5	17.4	1.28	10,925	27,187	16,262	2.48
Ricebean+ Arhar (2:1)	7.6	6.4	17.2	1.21	10,102	27,350	17,258	2.70
Ricebean+ Arhar (4: 2)	8.8	6.9	19.15	1.36	10,102	30,139	20,037	2.98
Ricebean+ Sorghum (2:1)	5.8	10.5	11.2	1.02	10,051	17,612	7,561	1.75
Ricebean+ Sorghum (4:2)	6.0	11.0	11.7	1.06	10,051	18,226	8,175	1.81

Sale price (Rs/q) grain of ricebean, maize, sorghum and arhar are 1200.00, 620.00, 620.00 and 1800.00 respectively.

RESULTS AND DISCUSSION

Yield attributes of Ricebean

Number of clusters per plant (Table 1) was the highest (14.97) in sole ricebean, followed by ricebean+ arhar grown at 4:2 row ratio (11.14), but significantly lower number of clusters per plant was recorded from ricebean grown in combination with other crops. Ricebean + sorghum produced the lowest number of clusters per plant. Pods per cluster recorded under ricebean+ arhar (4:2) was 3.01, which was significantly more than sole crop of ricebean (2.28) as well as other intercropping systems. The number of pods per plant was noted to be significantly more in sole crop of ricebean (34.13), compared to all other sole crop treatments. Among intercropping systems, pods per plant was the highest in ricebean + arhar at 4:2 ratio (33.53), which was also significantly higher than ricebean grown under other intercropping systems. Ricebean+ sorghum produced the lowest number of pods per plant. Pod length of ricebean was significantly influenced by intercropping systems. The longest pods (7.64 cm) were observed in sole ricebean. But among intercropping systems, longer pods (7.37 cm) were observed in ricebean+ arhar (4:2) followed by ricebean+ arhar (2:1) ratio (7.23 cm). The smallest pods were observed with ricebean+ sorghum in intercropping systems. Number of seeds per pod was the highest (6.73) with sole ricebean. In case of inter cropping systems, maximum number of seeds per pod (6.35) was recorded in ricebean+ arhar (4:2), which was significantly different from rest of the intercropping systems. Ricebean+ sorghum produced the lowest number of seeds per pod.

Table 3. Effect of ricebean based intercropping systems on energetics of production (pooled data of two years)

Particular	Energy input ($MJ\ x10^3\ ha^{-1}$)	Energy output ($MJ\ x10^3\ ha^{-1}$)	Energy output input ratio	Energy use efficiency ($q/MJ\ x\ 10^3$)
Ricebean	5.47	54.20	9.90	8.91
Maize	10.00	104.32	10.43	8.99
Arhar	5.33	95.68	17.95	16.94
Sorghum	7.63	69.83	9.15	8.08
Ricebean+Maize (2:1)	11.32	112.66	9.95	8.88
Ricebean+Maize (4:2)	11.32	115.89	10.23	9.11
Ricebean+ Arhar (2:1)	7.55	104.45	13.83	12.96
Ricebean+Arhar (4: 2)	7.55	112.56	14.90	13.93
Ricebean+Sorghum (2:1)	9.93	95.69	9.63	6.80
Ricebean+Sorghum (4:2)	9.93	97.94	9.86	7.04

Seed yield, stover yield and harvest index of Ricebean

The seed yield of sole ricebean was 12.27 q ha^{-1}, which declined significantly when grown in various intercropping systems. This might be attributed to the fact that interspecific competition in intercropping was more than intraspecific competition of sole stand (Kumar *et al*., 2003). Moreover, 33.3 per cent reduction in plant population of ricebean under intercropping was the prime factor for yield reduction. Among the intercropping systems, highest yield(10.08q ha^{-1}) was observed in ricebean + arhar (4:2), significantly more than all other intercropping systems. However, ricebean + arhar (2:1), ricebean + maize at 2:1 and 4:2 row ratios were at par to each other. Ricebean+ sorghum at 2:1 and 4:2 row ratios were also comparable to each other. Ricebean + sorghum (2:1) produced the lowest seed yield (5.8 q ha^{-1}). Stover yield of ricebean varied significantly, with different sole and intercropping systems. The highest stover yield (40.21 q ha^{-1}) was obtained from sole ricebean, which was significantly more than other treatments. But among other intercropping systems, ricebean + arhar (4:2) produced significantly higher stover yield (35.92 q ha^{-1}). Ricebean+ sorghum produced the lowest stover yield. Harvest index of sole ricebean was 23.38 per cent indicating the highest partitioning of photosynthates for grain under the treatment. Significant reduction in harvest index was noticed under intercropping systems. Comparatively higher harvest index was computed under ricebean+ arhar at 4:2 row ratio (21.91 %). Ricebean+ sorghum had the lowest harvest index (19.47 and 19.60 %) irrespective of row ratios.

Intercropping system yield, economics and energetics

Considering the system productivity (Table 2), ricebean + arhar (4:2) produced the maximum ricebean equivalent yield (19.15 q ha^{-1}), whereas lowest equivalent yield was registered with sole sorghum. Land equivalent ratio was the highest in ricebean + arhar (4:2) intercropping system (1.36) followed by ricebean + maize at 4:2 row ratios (1.28). Ricebean + arhar (4:2) and ricebean + arhar (2:1) were most remunerative with highest net return of Rs.20,037 ha^{-1} and Rs.17,258 ha^{-1} and the return per rupee invested from these systems were 2.98 and 2.70, respectively. So also from energy point of view (Table 3), ricebean + maize irrespective of their row ratios utilized more energy (11.32 MJ x 10^3/ha) followed by sole maize, than other treatments. This might be due to higher energy input through seed and fertilizer. (Mahapatra and Pradhan, 1993). Ricebean + maize produced the highest energy output (115.89 MJ x 10^3/ha), but ricebean + arhar at 4:2 row ratio, recorded energy out put of 112.56 MJ x 10^3/ha. The energy use efficiency of this treatment was 13.93 q/MJ x 10^3, compared to energy out put of 54.20 MJ x 10^3/ha and energy use efficiency of 8.91 q/MJ x 10^3 for sole ricebean. The higher energy output under Ricebean + arhar (4:2) might be due to higher economic yield (Padhi and Panigrahi, 2006).

The productivity of sole ricebean declined under intercropping, but the system productivity, economic returns and energy use efficiency of ricebean + arhar grown at 4:2 row ratio was the highest. Thus the study clearly established the feasibility of growing ricebean based intercropping systems in rainfed upland situation for higher productivity, profitability and energy use efficiency.

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