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Productivity and economics of rice (*Oryza sativa*)-based cropping sequences

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ABSTRACT

A field experiment was conducted during 1987–90 to find out the most suitable rice (*Oryza sativa* L.)-based cropping sequence on sandy-loam soil of north-eastern ghat zone of Orissa under irrigated medium-land situation. Amongst different rice-based cropping sequences, rice–potato (*Solanum tuberosum* L.)– cowpea [*Vigna unguiculata* (L.) Walp.] recorded the highest yield on rice-equivalent basis with maximum production efficiency. Their sequence also achieved the highest energy output with maximum energy input : output ratio. Rice–garden pea (*Pisum sativum* L. sensu lato)–cowpea sequence secured the highest net return and cost : benefit ratio and was on a par with rice–potato–cowpea system. Inclusion of cowpea as summer crop in rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–cowpea and rice–mustard [*Brassica junecea* (L.) Czernj. & Cosson]–cowpea sequences not only inhanced the production of rainy and winter crops of both the sequences but also increased the total production on rice-equivalent basis by 2.5 and 2.8 tonnes/ha, net return by Rs 6,065 and Rs 6,871/ha and energy output by 9.32 MJ × 10^3/ha over rice–wheat–okra (*Hibiscus esculentus* L.) and rice–mustard–okra systems respectively. However, rice–cabbage [*Brassica oleracea* L. convar. *capitata.* (L.) Alef. var. *capitata* L.]–okra was found superior to rice–cabbage–cowpea with respect to rice-equivalent yield (2.6 tonnes/ha), net return (Rs 4,062/ha) and energy output (7.87 MJ × 10^3 /ha) due to poor performance of cowpea as compared to okra after cabbage.

Rice (*Oryza sativa* L.) is a principal crop of the zone grown extensively during the rainy season under irrigated medium-land condition of north-eastern ghat zone of Orissa. Wheat (*Triticum aestivum* L. emend. Fiori & Paol.), mustard [*Brassica juncea* (L.) Czernj. & Cosson], potato (*Solanum tuberosum* L.), garden pea (*Pisum sativum* L. sensu lato) and cabbage [*B. oleracea* L. convar. *capitata* (L.) Alef. var. *capitata* L.] are the major winter-season crops. But their relative suitability and economics when grown after rice has not yet been investigated, for which low returns often been realized from winter-season crops and rice grown after them. Further, land remains fallow in summer season after harvest of winter crops despite availability of irrigation water. Short-duration cowpea [*Vigna unguiculata* (L.) Walp.] and okra (*Hibiscus esculentus* L.) could very well be introduced in rice-based cropping systems in summer for maximum net return, harvesting higher solar energy and restoring soil fertility (Soni

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and Kaur, 1984). Since a meagre information is available on the relative suitability of different winter and summer crops after rice, their economics and energetics under multiple-cropping systems, an experiment was conducted on these aspects.

MATERIALS AND METHODS

The study was conducted at Ghumusar Udayagiri during 1987–90 on sandy-loam soil (typic haplustulf), acidic in nature (pH 5.8), low in organic carbon (0.48%) and poor in total N (0.047%), medium in available P (18.6 kg/ha) and low in exchangeable K (125 kg/ha). The experiment consisting of 10 cropping sequences had a single crop of rice ('IR 36') during the rainy season, 5 crops, viz. 'Sonalika' wheat, 'Pusa Bold' Indian mustard, 'Kufri Sindhuri' potato, 'Bonevillae' garden pea and 'Pusa Drum Head' cabbage, during the winter season; and 2 crops, viz. 'SEB 2' cowpea and 'Parveni Kranti' okra, during the summer season, was laid out in randomized block design and replicated thrice. Rice seedlings of 25 days old were transplanted in the second fortnight of July and the crop was harvested in the second fortnight of October respectively during the 3 years. All the winter-season crops were sown after rice during the second week of November in all the years. During the 3 years wheat was harvested between 7 and 15 March, mustard between 28 February and 12 March, potato between 21 and 28 February, garden pea between 17 and 27 February and cabbage between 15 and 20 March. Cowpea and okra were sown between 10 and 20 March after wheat, mustard, potato and garden pea and between 20 and 27 March after cabbage. Crops were raised with recommended package of practices. The total rainfall received during the cropping period was 1,067, 1,255 and 1,256 mm during 1987–88, 1988–89 and 1989–90 respectively. The intensification of time was measured by calculating land-use efficiency values by taking total duration of crops in individual cropping sequence divided by 365 days, and production efficiency values were calculated by taking total production in a sequence divided by total duration of crops in that sequence (Tomar and Tiwari, 1990). The cost of rice seed (Rs 3/kg), wheat (Rs 4/kg), mustard (Rs 12/kg), potato (Rs 4/kg), garden pea (Rs 25/kg), cabbage (Rs 300/kg), cowpea (Rs 40/kg), okra (Rs 25/kg), farmyard manure (Rs 80/tonne), N (Rs 4.86/kg), P (Rs 5.70/kg), K (Rs 2.10/kg), bullock labour (Rs 30/day), man-hour (Rs 25/day), woman-hour (Rs 25/day), quinolphos (Rs 210/litre), methyl demeton (Rs 130/litre), Nuvacron (Rs 220/litre), Demicron (Rs 310/litre) and carbendazim (Rs 220/kg) was multiplied with the total quantity and number used in each crop in a sequence and then added to calculate the cost of cultivation of each cropping sequence. Comparison among cropping sequences were worked out by converting the yield of all the crops into rice equivalents on price basis. Energy values for main produce obtained from different cropping sequences was computed as per the specification recommended by Mittal *et al.* (1985).

RESULTS AND DISCUSSION

Crop yield

In general, no significant difference was observed in the average yield of rice obtained from different cropping sequences in all the years (Table 1). However, maximum yield of rice was secured in rice–garden pea–cowpea sequence and the minimum in rice--garden pea--okra

Table 1. Rice-equivalent yield (tonnes/ha) of different crops in rice-based cropping sequences (average of 3 years)

Cropping sequence	Rice-equivalent yield of crops			
	Kharif	*Rabi*	*Summer*	Total
Rice–wheat–cowpea	3.8	3.4	6.4	13.6
Rice–wheat–okra	3.5	3.2	4.4	11.1
Rice–mustard–cowpea	3.9	2.2	6.9	13.0
Rice–mustard–okra	3.7	1.9	4.6	10.2
Rice–potato–cowpea	3.8	11.3	5.0	20.2
Rice–potato–okra	4.0	10.1	4.2	18.3
Rice–garden pea–cowpea	4.1	8.5	4.7	17.3
Rice–garden pea–okra	3.3	7.3	5.0	15.6
Rice–cabbage–cowpea	3.1	6.9	2.6	12.9
Rice–cabbage–okra	3.7	7.3	4.5	15.5
CD (P = 0.05)	NS	3.91	1.8	3.2

Price (Rs/tonne): rice grain 2,000, rice straw 200, wheat grain 2,400, wheat straw 200, mustard grain 7,000, potato tuber 1,000, cowpea green pod 3,000, cabbage 800, garden pea 3,000, okra 3,000

sequence. Winter crops like wheat, mustard, potato and garden pea gave higher yield after rice in the sequences having cowpea as summer crop, whereas cabbage obtained maximum yield after rice in the sequences having okra as a summer crop. Gradual reduction in yield of wheat in different years after transplanted rice in the sequences having okra as compared with cowpea during summer might be attributed to impaired soil structure developed out of continuous puddling of soil for rice and non-replenishment of soil by okra after wheat. Singh *et al.* (1984) also reported lower yield of wheat after puddled transplanted rice in the sequences having non-legume crops and attributed yield decrease to impaired soil structure after rice. Among the winter crops, potato recorded significantly the highest rice-equivalent yield in the rice–potato–cowpea sequence, despite its lowest price (Rs 1,000/tonnes) next to cabbage. The lowest rice-equivalent yield was obtained from mustard in rice–mustard–okra sequence, though it fetched the highest market price of Rs 7,000/tonne.

Between the 2 summer crops, cowpea achieved significantly the highest rice-equivalent yield (6.9 tonnes/ha) after mustard and remained on a par with that after wheat (6.4 tonnes/ha). But cowpea after cabbage accomplished significantly lower rice-equivalent yield (2.6 tonnes/ha). This might be attributed to the differences in the rooting depth of wheat and mustard as compared to cabbage which could have favoured cowpea in terms of nutrient availability. Sharma (1987) also reported higher yield of legume like greengram after wheat due to difference in rooting habit of both the crops. However the rooting habit of cabbage compared with cowpea is although dissimilar, the first crop being a heavy feeder exhausts the soil nutrients affecting the optimum growth and yield of the succeeding crop. Okra gave higher yield on rice-equivalent basis after garden pea and minimum after potato, though no significant

Table 2. Economics, energetics and other parameters of rice-based cropping sequences

Cropping sequence	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	Cost : benefit ratio	Land-use efficiency (%)	Production* efficiency (mg/day/ha)	Total man-days/ha	Energy input (MJ ×10³/ha)	Energy** output (MJ ×10³/ha)	Energy input : output ratio
Rice–wheat–cowpea	15,156	12,510	1.83	95.9	38.86	417	36.4	105.57	2.90
Rice–wheat–okra	16,221	6,445	1.40	91.2	33.33	505	44.5	96.65	2.17
Rice–mustard–cowpea	13,431	13,098	1.98	94.8	37.57	405	31.9	81.82	2.56
Rice–mustard–okra	14,496	6,227	1.43	90.1	31.00	493	40.0	73.53	1.84
Rice–potato–cowpea	22,318	18,265	1.82	91.8	60.00	603	50.6	188.58	3.73
Rice–potato–okra	23,383	13,772	1.59	87.1	57.55	691	58.7	177.63	3.03
Rice–garden pea–cowpea	15,405	19,643	2.27	91.0	52.11	405	30.6	76.91	2.51
Rice–garden pea–okra	16,470	16,119	1.93	86.3	49.52	493	38.7	64.09	1.66
Rice–cabbage–cowpea	16,158	10,132	1.63	95.6	36.96	548	39.7	74.06	1.87
Rice–cabbage–okra	17,223	14,194	1.82	93.4	45.45	636	47.8	81.93	1.71
CD ($P = 0.05$)		2,316.6			6.25			5.89	

*Calculated on rice-equivalent basis, **Energy output for main produce only differences were observed. Tomar and Tiwari (1990) also reported beneficial effect of legumes on succeeding non-legumes.

Yield of cropping sequences

Among the rice-based cropping sequences (Table 1) rice–potato–cowpea proved more productive, with significantly highest rice-equivalent yield and remained on a par with rice–potato–okra and rice–garden pea–cowpea. This might be due to inclusion of high-yielding crops like potato in the first 2 sequences and garden pea in the last one which contributed 56.2, 55.2 and 49.1% towards rice-equivalent yield of respective crop sequences. The lowest rice-equivalent yield was obtained from rice–mustard–okra despite the presence of high-priced crop like mustard. It was due to low yield that realized from mustard which contributed minimum towards the rice-equivalent yield in the sequence. The findings confirm the results of Yadav and Newaj (1990). Inclusion of cowpea as summer crop in different sequences obtained 1.7–2.8 tonnes/ha more rice-equivalent yield than okra. Okra obtained 1.9 tonnes/ha more rice-equivalent yield than cowpea in rice–cabbage–cowpea sequence because of better performance of okra than cowpea after cabbage.

Cost of cultivation

Maximum cost was incurred in rice–potato–okra, followed by rice– potato–cowpea sequence. Both the crop sequences involved potato crop, on which the highest cost (Rs 12,000/ha) was involved (Table 2). The lowest cost was incurred in rice–mustard–cowpea sequence because of minimum cost invested in raising mustard. This was in agreement with the findings of Deka *et al.* (1984).

Net return

Crop sequences having cowpea as summer crop secured significantly higher net return than the sequences having okra except in rice–cabbage–cowpea system. Rao and Willey (1980) concluded that multiple-cropping systems with legume offer special advantage to farmers and reduce the probability of low income. Rice–garden pea–cowpea system obtained significantly the highest net return and cost : benefit ratio, followed by rice–potato–cowpea. The findings confirm the results of Gupta and Rai (1990). The lowest economic yield from mustard showed the lowest net return and cost : benefit ratio for rice–mustard–okra system, though it fetched highest market price. Both the Rice–wheat–cowpea and rice–mustard–cowpea rotations gave significantly more net returns than rice–wheat–okra and rice–mustard–okra systems, due to better performance of cowpea compared with okra after wheat and mustard. Though comparable net returns obtained from rice and cabbage in both the rice–cabbage–cowpea and rice–cabbage–okra sequences, the latter sequence gave significantly more net return than the former due to poor performance of cowpea than that of okra after cabbage.

Land-use efficiency, production efficiency and labour employment

Rice–wheat–cowpea sequence (Table 2) showed the highest land-use efficiency, whereas rice–garden pea–okra secured the lowest. The production efficiency of rice–potato–cowpea was maximum, whereas that of rice–mustard–okra was minimum. Rice–potato–okra engaged maximum labourers (691 man-days/ha/year), which might be due to maximum labour engagement in potato (298 man-days/ha) and okra (88 man-days/ha) more than cowpea. But in rice–mustard–okra and rice–garden pea–cowpea minimum numbers of labourers were engaged (405 man-days/ha/year for each sequence).

Energy relationship

The maximum energy was utilized under rice–potato–okra system due to involvement of 2 high-energy use crops like potato (28.22 MJ × 10^3/ha) and okra (15.66 MJ × 10^3/ha), whereas rice–garden pea–cowpea utilized minimum energy due to inclusion of 2 low-energy-use crop like garden pea (8.26 MJ × 10^3/ha) and cowpea (7.55 MJ × 10^3/ha). Pal *et al.* (1985) also reported higher energy use by non-legume vegetables than legume vegetables. Rice–potato–cowpea yielded significantly highest energy output with maximum energy input : output ratio. The highest economic yield of potato in rice–potato–cowpea yielded significantly highest energy output with maximum energy input : output ratio. The highest economic yield of potato in rice--potato--cowpea sequence might be attributed for such prospective. Rice--garden pea--okra recorded the lowest energy output and energy input : output ratio due to minimum energy production by the component crops like rice (44.98 MJ × 10^3/ha) and garden pea (9.31 MJ × 10^3/ha). Rice–wheat–cowpea and rice–mustard–cowpea sequences have an edge over the rice--wheat--okra and rice--mustard--okra systems for energy output and energy input : output ratio and so also rice--cabbage--okra over rice--cabbage–cowpea with for energy output.

It was concluded that rice--garden pea–cowpea and rice–potato–cowpea may be used for the zone under irrigated medium-land condition. Wheat and mustard if grown after rice should be succeeded by a legume vegetable like cowpea, whereas cabbage after rice may be succeeded by okra instead of cowpea for higher yield and profit.

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