Indian Journal of Agronomy **53**(2): 97–101 (June 2008)

Productivity, profitability and nutrient balance as influenced by diversification of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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Received: January 2007

ABSTRACT

A field experiment was conducted during 2004-2005 and 2005-06 at Sabour, Bihar to diversify the existing rice (*Oryza sativa* L.) ñ wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system. Among the 14 rice-based cropping systems tested, rice-potato (*Solanum tuberosum* L.)ñonion (*Allium cepa* L.) + maize (*Zea mays* L.) relay cropping gave the highest mean rice-equivalent yield (30.66 t/ha/year), followed by rice-garlic (*Allium sativum* L.) - maize (30.35 t/ha/year) and rice-potato-onion (27.95 t/ha/year). The highest net returns of Rs 96,581/ha/year were realized from rice-garlic-maize, which were on a par with that of rice-potato-onion + maize relay cropping (Rs 92,837/ha/year). However, the benefit : cost ratio was highest (1.73) in rice-berseem [*Trifolium alexandrinum* (L.) Juslen.] ñ maize + cowpea [*Vigna unguiculata* (L.) Walp.], both grown for fodder. The highest water-use efficiency (37.01 kg rice-equivalent yield/ha/mm) was recorded with riceñgarlicñmaize system. The rice-potato-onion + maize relay cropping proved the most effective in producing highest calorific value (61,155 K calories/ha) and showed the maximum land-use efficiency (94.8%). The same cropping system removed the maximum quantity of N (371.6 kg/ha), P (110.4 kg/ha) and K (451.4 kg/ ha), followed by rice-berseem -maize + cowpea (F), having corresponding values 352.0, 88.2 and 361.0 kg/ ha/year. Heavy removal of NPK by rice-berseem-maize+cowpea (F) resulted in maximum negative balance of nitrogen (152.9 kg/ha), phosphorus (31.4 kg/ha) and potassium (304.6 kg/ha/year). Potassium balance was negative in all the cropping systems, indicating that K was the most removable nutrient by the crops, which results in mining of soil K and thus calls for adequate K fertilization.

Key words: Diversification, Energy equivalent, Nutrient balance, Productivity, Profitability, Rice-equivalent yield

Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is the most dominant cropping system in the alluvial plains of Bihar. The wide adoption of rice-wheat system is mainly due to its high productivity, stability and less risk. Though the system has sustained over the years, yield gradually stagnates (Nambiar and Abrol, 1992). This stagnation in productivity can be attributed mainly to monotony of the system as well as exhaustive nature of the cereal-cereal crop sequence. Besides, continuously following the same system has adverse effect on soil conditions, utilimately reducing the productivity of the system (Kumar and Yadav, 1993). Since rice is the staple food of this state, one can think of replacing wheat only. Further, inclusion of crops like oilseed, pulse and vegetable will improve the economic condition of the farmers owing to higher price and higher volume of their main and by-products. Kumpawat (2001) also reported beneficial effect of inclusion of pulses, oilseeds and vegetables in the system than cereals after cereals. In addition, the legumes have favourable impact on the soil fertility and help in increasing the yield of the succeeding rice crop (Kharub *et al.*, 2003). In view of these facts, the present experiment was carried out to find out the possibility of diversification in existing rice- wheat cropping system for sustainable productivity, profitability and their relative nutrient balance in the soil.

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MATERIALS AND METHODS

A field experiment was conducted during 2004-05 and 2005-06 at Bihar Agricultural College farm, Sabour, Bihar on sandy loam soil, having pH 8.1, organic C 0.47%, and the available N 155 kg/ha, P 11.6 kg/ha and K 101.3 kg/ ha. Fourteen rice-based cropping systems were evaluated for their production potential and economics, viz. S_1, rice-wheat; S_1, rice-wheat-*dhaincha* (*Sesbania aculeata*) as green-manure; (S_3), rice–wheat–greengram (*Phaseolus radiatus* L.), S_4, rice-wheat-maize; S_5, rice-maize+potato (intercropping); S_6, rice-potato-onion; S_7, rice-potato-onion+maize (relay cropping); S_8, rice-potato-sunflower (*Helianthus annuus* L.); S_9, rice-garlic-maize; S_{10}, rice-cabbage(*Brassica oleracea* L. var. capitata)–okra (*Abelmoschus esculentus* L.); S_{11}, rice-marigold (*Tagetus erecta L.*)-maize + greengram intercropping; S_{12}, rice-fenugreek(*Trigonella foenum graecum* L.) - maize; S_{13}, rice-sunflower-okra; and S_{14}, rice-berseem - maize + cowpea (both for fodder). A randomized block design was followed with three replications. Maize + potato, maize + greengram and maize + cowpea (F) were sown in 1:1, 1:1 and 2:2 row proportions ,whereas seeds of maize in onion + maize relay cropping were dibbled in 4:1 row proportion before 15 days of onion harvesting. Rice cv 'Sita', during rainy (*kharif*) season; wheat 'HP 1761', maize 'Devki', potato 'Kufri Ashoka', garlic 'Yumuna Safed', cabbage 'Pusa Mukta', marigold 'Pusa Narangi', fenugreek 'Rajendra Kranti', sunflower 'BSH-1', berseem 'Wardan' during winter (rabi) season; and greengram 'PS 16', maize 'Suwan', onion 'Nasik Red', okra 'Prabhani Kranti', sunflower 'BSH-1', maize (F) 'African Tall', cowpea (F) 'Pusa Komal' during summer season were raised under irrigated conditions with recommended packages of practices. Nitrogen, P and K were supplied through urea, single superphosphate and muriate of potash, respectively. *Sesbania aculeata* raised *in situ* after wheat was incorporated in the soil after 50-55 days. The N, P, K and the moisture content in *Sesbania* on dry-weight basis was 2.53, 0.7, 1.3 and 85%, respectively. Energy outputs of different crops in the cropping systems were calculated using the energy equivalents as reported by Panesar and Bhatnagar (1994). The total rainfall received during the crop period was 994 and 1353 mm in 2004-05 and 2005-06, respectively.

RESULTS AND DISCUSSION

System productivity

Sesbania aculeata produced 3.56 and 4.03 t/ha of dry matter in 50-55 days and added 90.12 and 102.0 kg N/ha during 2004-05 and 2005-06, respectively (Table 1). Kharub *et al.* (2003) reported addition of 97 to 109 kg N/ha on green manuring with *Sesbania aculeata.* Differences among treatments for grain yield of rice were non-significant in the first year (Table 1). But in the second year incorporation of *Sesbania aculeata as* green manure during summer season helped the succeeding rice to produce the highest grain yield (5.31 t/ha), which was significantly higher than of all other treatments except rice-wheat-greengram and rice-berseem-maize + cowpea grown for fodder. Similarly, a system that included fodder or legume crops in rice-wheat system showed improvement in grain yield of rice. Singh and Sharma (2002) also reported beneficial effect of legumes on the succeeding rice crop. The improvement in grain yield of rice under green- manuring and legume crops can be ascribed to fixation of the atmospheric nitrogen by these crops which might have improved the fertility status of the soil. Kharub *et al.* (2003) reported increase in organic C, available N, P and K contents due to incorporation of *Sesbania aculeata as* green manure in rice–wheat system.

The rice-equivalent yields of different systems showed that the maximum mean yield (30.66 t/ha) was obtained from rice-potato-onion + maize relay cropping system, closely followed by rice-garlic-onion (30.35 t/ha/) and rice-potato-onion (27.95 t/ha). The higher rice-equivalent yield in these cropping systems was owing to replacement of wheat with high-volume or high-priced vegetable crops like potato, onion and garlic. Choudhary *et al.* (2001) also reported greater productivity by replacing wheat in rice-wheat system with vegetables like radish and potato. Inclusion of oilseeds, vegetables, ornamental or fodder crops to diversify the existing rice-wheat system also helped in achieving higher rice-equivalent yield than with sequences having cereals and pulse crops. Inclusion of green manure crop of *Sesbania* in rice-wheat system could not significantly improve the productivity of rice-wheat system in spite of improved rice yield. The existing rice-wheat system recorded the lowest productivity (10.44 t/ha).

Land- and water-use efficiency

The land-use efficiency was highest in rice-potato-onion + maize (94.8 %), followed by rice-garlic-maize (93.2%) because these sequences utilized the land most efficiently (Table 2). The existing rice-wheat system was most inferior in respect of land use, as the land remained fallow for more than 2 months in a year. The variation in land-use efficiency was primarily due to the duration of winter and summer crops in the cropping systems.

Different cropping systems consumed varied quantities of irrigation water (Table 2). The total field water supply in the field was the highest (1060 mm/ha) with rice-potato-onion + maize relay cropping, followed by rice-cabbage-okra. The highest water supply in the field was perhaps due to substantially high water requirement of onion + maize and okra during summer season. However, the water- use efficiency was maximum (37.0 kg rice-equivalent yield/ha/mm) with rice-garlic- maize, followed by rice-maize + potato intercropping because of high production with less water use. The other cropping systems, viz. rice-potato-sunflower, rice-potato-onion + maize relay cropping, rice-potato-onion and rice- marigold-maize + greengram showed water-use efficiency ranging from 27.2-28.9 kg REY/ha/mm. The lowest water-use efficiency was recorded with rice-sunflower-okra system (16.58 kg rice-equivalent yield/ha/mm).

Energetics

The maximum energy output (61,155 K calories/ha/year) was found in rice-potato-onion + maize relay cropping system, followed by rice-maize+potato intercropping (57,996 K-calories/ha/year), rice-potato-sunflower and rice-potato-onion systems (Table 2). This indicates that these cropping systems have high value of high-quality produce. The cropping systems in which potato and onion crops were not included i.e. rice-wheat-maize gave the highest energy output (45,901 K-calories/ha/year), followed by rice-garlic-maize. The remaining cropping systems gave energy output ranging from 28,082 to 34,376 K calories/ha/year. Rice- cabbage- okra cropping system gave the lowest energy output.

Table 1. Effect of different rice-based cropping systems on yields (t/ha) of different crops

Cropping system	2004-2005			2005-2006			Rice- equivalent yield (t/ha)		
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	2004-05	2005-06	Mean
Rice-wheat	5.13	4.32		4.85	3.68		11.01	9.87	10.44
Rice-wheat-green manure	5.19	4.44	23.11*	5.31	3.88	26.15*	11.24	10.60	10.92
Rice-wheat-greengram	5.14	4.30	0.90	5.18	3.76	0.76	14.93	13.63	14.28
Rice-wheat-maize	5.04	4.44	4.35	4.82	3.52	4.47	15.04	13.70	14.37
Rice-maize +potato (I.C.)	4.97	8.18+ 15.00		4.83	7.52 + 14.24		21.38	20.24	20.81
Rice – potato-onion	5.17	23.76	15.85	4.81	21.67	19.39	26.69	27.21	27.95
Rice-potato-onion + maize**	4.98	24.15	15.26 +10.96	4.76	22.39	18.09+11.11	30.44	30.88	30.66
Rice-potato- sunflower	5.11	23.51	1.80	4.85	22.43	1.68	22.02	20.90	21.46
Rice-garlic-maize	5.08	9.73	4.61	4.84	7.01	4.37	34.05	26.65	30.35
Rice- cabbage- okra	5.12	22.33	11.50	4.82	27.30	11.52	21.64	23.17	22.41
Rice-marigold-maize+greengram (I.C.)	5.08	6.98	4.64+0.31	4.86	6.62	4.71+0.21	21.25	20.04	20.64
Rice-fenugreek-maize	5.18	1.87	4.76	4.88	1.65	4.66	16.31	15.12	15.71
Rice-sunflower-okra	5.19	2.19	10.73	4.87	1.89	10.75	17.79	16.98	17.47
Rice-berseem-maize+ cowpea (F)	5.11	48.86	27.07+10.62	5.23	52.46	29.79+9.32	16.91	17.70	17.31
SEm±	0.15			0.13			0.31	0.30	0.33
CD (P=0.05)	NS			0.36			0.96	0.87	1.02

*Green manure biomass added to soil; ** Maize grown for cob; I.C., Intercropping; F, Fodder

Table 2. Economics and efficiencies as influenced by different rice-based cropping systems (Mean data of two years)

Cropping system	Cost of cultivation (x 10^3 Rs/ha)	Net income (x 10^3 Rs/ha)	Benefit : cost ratio	Land use efficiency (%)	Water applied (mm)	Water use efficiency (kg REY/ ha-mm)	Total calories output (x 10^3 K calories)
Rice-wheat	31.5	37.1	1.18	65.5	520	20.07	31.14
Rice-wheat-green manure	35.5	39.3	1.11	78.9	580	18.82	31.99
Rice-wheat-greengram	39.8	48.1	1.20	87.7	640	22.23	34.38
Rice-wheat-maize	46.3	49.5	1.07	90.7	760	18.90	45.90
Rice-maize +potato (I.C.)	66.9	61.4	0.92	73.7	630	33.03	57.99
Rice – potato-onion	80.8	81.9	1.01	79.5	940	28.67	48.12
Rice-potato-onion + maize relay cropping	91.5	92.8	1.01	94.8	1,060	28.92	61.16
Rice-potato- sunflower	65.6	57.7	0.88	83.3	760	28.23	50.49
Rice-garlic-maize	63.2	96.6	1.53	93.2	820	37.01	44.66
Rice- cabbage- okra	67.1	69.5	1.04	88.8	1,000	22.40	28.08
Rice-marigold-maize + greengram (I.C.)	61.1	60.9	0.99	90.7	760	27.16	34.04
Rice-fenugreek-maize	44.6	50.7	1.14	93.2	700	22.40	34.37
Rice-sunflower-okra	52.2	47.4	0.91	88.5	940	16.58	34.04
Rice-berseem-maize+ cowpea (F)	36.9	63.9	1.73	85.5	700	24.70	31.04
SEm±		1.40					
CD (P=0.05)		4.22					

Sale price of produce (Rs/t)- Rice seed, 5,500; rice and wheat straw, 1,250;wheat seed, 7,500; potato tuber, 3,000; maize seed, 5,000; okra fruit, 4,000; sunflower seed,12,500; garlic bulb, 14,000; cabbage head, 2,000; marigold flower, 8,500; fenugreek seed, 20000; greengram seed, 24,000; onion bulb, 3,000; maize stone, 2,000; maize stover, 500; berseem and maize + cowpea green fodder, 750; maize cobs, 3,000

Economics

Economic analysis showed that the highest cost of cultivation (Rs 91,500 /ha) incurred on rice-potato-onion + maize relay cropping system, followed by rice-potato-onion (Rs 80,750 /ha) (Table 2). Inclusion of potato and onion in the system increased the cultivation cost, as they required heavy fertilization and labour. Inclusion of potato and garlic during winter season was instrumental in raising the net returns of the system. The highest net returns of Rs 96,581/ha was realized from rice- garlic- maize system which, however, were on a par with that of rice-potato-onion + maize (relay cropping) system (Rs 92,837/ha). These two cropping systems earned an additional income of Rs 59,442/ha and Rs 55,698/ha, respectively over the existing rice-wheat cropping system. The cropping systems in which potato and garlic did not find a place, gave the highest net returns of Rs 69,518/ha e.g. rice-cabbage-okra, followed by rice-berseem -maize + cowpea grown for fodder (Rs 63,868/ha). The highest B : C ratio (1.73) was obtained with rice-berseem-maize + cowpea grown for fodder, followed by rice-garlic-maize (1.52). The highest B : C ratio in the former system was mainly due to lower cost of production. The existing rice-wheat system had the lowest profitability (Rs 37,139/ha).

Nutrient removal and balance sheet

The highest removal of N was recorded in rice-potato-onion+maize relay cropping which, however, showed statistical parity with rice-berseem-maize+cowpea both grown for fodder and these cropping systems removed significantly higher N than that in all the other cropping systems (Table 3). The maximum removal of N may be attributed to greater biomass production of crops under these cropping systems. Sharma and Sharma (2002) also reported higher amount of nitrogen removal by rice-berseem system. The phosphorus and potassium uptake by different cropping systems in a year was 47.8-110.4 kg P/ha and 210.1-451.4 kg K/ha, respectively. Rice-potato-onion + maize relay cropping was found to be the most exhaustive cropping system, which resulted in highest P (210.1 kg/ha) and K uptake (451.4 kg/ha). Thus, higher P and K uptake might be due to the realization of higher yields (Table 1) from this cropping system. The lowest NPK uptake observed in rice-wheat system was mainly due to two crops in the system.

Budgeting of the nutrients added as fertilizer and of those removed by the crops showed a deficit of nitrogen in rice-berseem-maize+cowpea (F) and rice-fenugreek-okra cropping systems (Table 3). These results confirm those of Sharma and Sharma (2002). This deficit was mainly due to lesser quantity of N applied to the legume crops and higher N concentration in the plant as well as higher biomass production. However, the other cropping systems showed a positive balance of N. Rice-wheat-*Sesbania*, followed by rice-marigold-maize + greengram cropping system showed the maximum positive balance of N. Higher N balance in the former system was owing to addition of biomass and fixation of atmospheric nitrogen by the green manure crop.

The balance of P was positive in rice-wheat-greengram,

Table 3. Nutrient removal and balance sheet of nutrients in rice-based cropping system

Crop sequence	Total nutrients applied in 2 years (kg/ha)			Total nutrients removed (kg/ha)			Nutrient balance in soil (kg/ha)		
	N	P	K	N	P	K	N	P	K
Rice-wheat	440	86.0	99.6	365.0	95.6	420.2	+ 75.0	- 9.6	- 320.6
Rice-wheat-green manure	632	139.1	198.2	380.0	99.0	437.2	+ 252.1	+ 40.1	- 239.0
Rice-wheat-greengram	480	129.0	99.6	439.5	109.3	457.3	+ 40.5	+ 19.7	- 357.7
Rice-wheat-maize	640	137.6	166.0	525.7	145.4	551.4	+ 112.5	- 7.8	- 385.4
Rice-maize +potato (I.C.)	620	144.5	240.7	612.1	187.3	682.2	+ 7.9	- 42.8	- 441.5
Rice – potato-onion	700	180.6	332.0	596.2	194.8	770.1	+ 103.8	- 14.2	- 438.1
Rice-potato-onion + maize**relay cropping	800	206.4	365.2	743.3	220.8	902.8	+ 57.0	- 14.4	- 537.6
Rice-potato-sunflower	660	189.2	265.6	550.4	172.2	662.7	+ 109.6	+ 17.0	- 397.1
Rice-garlic-maize	640	197.8	232.4	475.0	144.3	538.9	+ 165.0	+ 53.5	- 306.5
Rice- cabbage- okra	640	154.8	265.6	549.5	179.0	611.9	+ 90.5	- 24.2	- 346.3
Rice-marigold-maize+ greengram (I.C.)	680	197.8	232.4	486.0	141.4	476.7	+ 194.0	+ 56.4	- 244.3
Rice-fenugreek-maize	480	137.6	166.0	501.8	125.1	445.4	- 21.8	+ 12.5	- 279.4
Rice-sunflower-okra	560	163.4	199.2	416.7	120.2	426.5	+ 143.3	+ 43.2	- 227.3
Rice-berseem-maize+ cowpea (F)	400	111.8	132.8	705.7	174.6	721.9	- 305.7	- 62.8	- 589.1
SEm±				14.3	3.5	15.6			
CD (P=0.05)				41.7	10.2	45.5			

*Green manure biomass added to soil; ** maize grown for cob; I.C., intercropping; F, fodder rice-potato-sunflower, rice-garlic-maize, rice-marigold-maize + greengram, rice-fenugreek-maize and rice-sunflower-okra cropping system, and it varied from 6.30 Kg/ha/year in rice- fenugreek-maize to 28.20 kg/ha/year in rice- marigold-maize + greengram cropping system. This shows that the P removed by the crops was less than that the applied to them. However, the other cropping systems showed a negative balance. The maximum deficit of P (31.40 kg/ha/year) was observed in rice-berseem-maize+cowpea (F) cropping system , indicating that the quantity of P applied to fodder crops was less than that removal from the soil. The results are in conformity with those of Sharma and Sharma (2002).

The highest gap between addition and removal was observed in potassium, which resulted in negative K balance in all the cropping systems. The maximum deficit of K (294.6 /ha/year) was observed under rice-berseem-maize+cowpea (F), followed by rice-potato-onion+maize relay cropping system (268.8 /ha/year). Sharma and Sharma (2002) reported the highest deficit of K in rice-berseem cropping system. The rice-wheat-maize, rice-potato-onion and rice-maize+potato intercropping resulted in 64.8, 117.5 and 120.9 kg/ha higher negative balance compared with rice-wheat cropping system. These results indicate an alarming situation for mining of nutrients, which requires a fresh look to revise them as per needs of the crops in the cropping system.

It was concluded that farmers with adequate resources can diversify the existing rice-wheat cropping system with rice-garlic-maize and rice-potato-onion + maize cropping systems for getting higher productivity and profitability.

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