Indian Journal of Agronomy 53(1):27–31 (March 2008)

Effect of crop diversification on productivity and profitability of rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system

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Received: December 2007

ABSTRACT

A field study with eight crop sequences was conducted at Karnal during 2001-06 to diversify or intensify the rice (*Oryza sativa* L.) - wheat (*Triticum aestivum*) cropping system and to select suitable cropping system based on productivity and profitability. Combined analysis of the data of 6 years showed that rice - vegetable pea - wheat - greengram sequence produced 27.91% higher wheat equivalent yield than rice - wheat system. Diversification or intensification of rice - wheat system, once in 3 years, improved the net returns when all the crops (except rice) were grown on raised-bed in a system approach. Inclusion of oilseed or pulses in rice - wheat system once in 3 years or intensification by growing vegetable pea in between rice and wheat or greengram after wheat showed higher net returns and sustainable value index (SVI) compared with rice - wheat system. Maximum SVI (0.92) and net returns (Rs 38.6 x 10^3 /ha/year) were recorded in rice - Indian mustard - greengram - rice – wheat – greengram - rice – wheat - greengram crop sequence. Benefit : cost ratio (1.74) and profitability (Rs 124/ha/day) were highest in pigeon pea - wheat - rice - wheat - rice - wheat crop sequence. Growing of berseem in the rotation reduced the weed population in the subsequent wheat cycle. After 6 years, rice - vegetable pea - wheat - greengram, rice - Indian mustard – greengram – rice – wheat – greengram - rice – wheat - greengram and pigeonpea – wheat - rice – wheat - rice - wheat showed 37.5, 25.0 and 20.0% increase, respectively in organic C content (0-15 cm) than continuous rice-wheat system.

Key words: Cropping system, Diversification, Intensification, Productivity, Profitability, Wheat-equivalent yield

In South Asia, rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop sequence is the largest agricultural production system, which occupies 13.5 million ha, including 10.3 million ha in India, extending from Indo-Gangetic plains to Himalayan foot-hills. Rice and wheat contribute 77.7% of the total foodgrain production in the country. In India 23 and 40% of total rice and wheat area, respectively is represented by rice - wheat system alone (Timsina and Connor, 2001), which requires contrasting edaphic conditions. Rice is generally transplanted in puddled soil and is given continuous submergence, whereas wheat is grown in upland well-drained soils having good tilth. Continuous adoption of this system declines the soil and crop productivity (Yadav *et al.*, 1998). In India, most of the oilseed and pulse crops are grown on flat land by broadcasting with flood irrigation or under continental monsoon type climate, resulting in low productivity. Generally, these crops are sensitive to water stagnation, experienced during rainy season or flood irrigation. To mitigate these problems there is a need to investigate innovative planting techniques for these crops, which could be helpful in diversification of rice - wheat system. In bed-planting technology, the crop is grown on top of bed and irrigation is applied in furrows. Additionally, these furrows can also be used for drainage when there is excess irrigation or rainfall. Study conducted by Connor *et al.* (2003) in farmers' participatory trial in India showed that bed planting gave higher grain yield in crops like maize (37.4%), blackgram (33.6), greengram (21.8%), green pea (14.5%), wheat (6.4 %), rice (6.2%), pigeonpea (46.7%) and gram (37.0%) compared with flat planting. We hypothesize that inclusion of oilseed, pulses or green vegetable could sustain the productivity. Besides adoption of proper input-management technologies, diversification or intensification of rice - wheat system through crops of diverse nature may be a good proposition to break the monotony of the system. Therefore, an effort was made to find out the effect of diversification or intensification on the productivity and profitability of rice - wheat system.

MATERIALS AND METHODS

A field experiment was conducted at Directorate of Wheat Research, Karnal for 6 years (2000-01 to 2005-06).

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The experimental soil was sandy clay-loam in texture (22% clay), low in organic C (0.37%) and available N (145 kg/ha), and medium in available P (17.2 kg/ha) and available K (155 kg/ha) content. The soil samples were analysed at the beginning of the experiment and after completion of six cropping cycles for organic C. Eight cropping sequences with three years duration were tried in randomized block design with four replications. These were: CS_1, rice - wheat for three years (control); CS_2, rice – berseem [*Trifolium alexandrinum* (L.) tuslen.] fodder – rice – wheat-rice – wheat; CS_3, sorghum [*Sorghum bicolor* (L.) Moench] – wheat-greengram [*Pheseolus radiatus* (L.) Wilczek] – rice – wheat – rice – wheat; CS_4, Rice – mustard [*Brassica juncea* (L.) Czernj & Cosson] – greengram – rice – wheat – greengram – rice – wheat - greengram; CS_5, soybean [*Glycine max* (L.) Merr.] - wheat-rice - wheat-rice - wheat; CS_6, rice - vegetable pea (*Pisum sativum* (L.) - wheat - greengram (3 years); CS_7, maize (*Zea mays* L.) – vegetable pea – wheat - rice – wheat – greengram - rice – wheat - greengram; CS_8, pigeonpea [*Cajanus cajan* (L.) Millsp.] – wheat - rice – wheat - rice - wheat. All the crops included in CS_3 to CS_8 were grown on beds except rice and sorghum. Rice variety 'IR 64' was transplanted in the first week of July and harvested in the last week of October in all the treatments. The other rainy-season crops, viz. soybean 'SL 295', pigeonpea 'UPAS 120', sorghum 'PC 9' and maize 'Naveen' were sown in last week of June, but harvested on different dates (soybean in the last week of October, pigeonpea in the middle of November, maize and sorghum in the last week of September). Vegetable pea 'Arkel' and Indian mustard 'Agrani' were sown in the last week of October and harvested in the first week of January and middle of March, respectively. Wheat variety 'PBW 343' was sown in the second week of November under normal-sown conditions, whereas 'Raj 3765' (late sown) in the first week of January immediately after harvest of catch crop vegetable pea. Greengram 'Narendra 1' was sown in mid-March after the harvest of Indian mustard and at the end of April after the harvest of wheat.

The number of rows differed according to the crops: 3 rows of wheat, two rows of vegetable pea, greengram, soybean and Indian mustard, and one row of maize and pigeonpea were grown on bed, whereas other crops were cultivated as per the recommended practice. In bed-planting system, the crops were grown on the top of 40 cm wide raised beds and irrigation was given in 30 cm wide furrows. Wheat after pigeonpea / maize / soybean / vegetable pea and greengram after Indian mustard / wheat was sown just by reshaping of the beds to reduce the tillage cost. Greengram and vegetable pea residues were incorporated into the soil after picking of pods. Recommended doses of N, P, and K were applied to different crops through urea, diammonium phosphate and muriate of potash, respectively. In the crops succeeded by green-manuring, 25% less N was applied. Irrigation was applied in furrows between two beds under bed planting, whereas flood irrigation was given under flat planting at critical stages of the crops. The need-based plant-protection measures were adopted in different crops. A quadrant (1 m^2) was marked (unweeded) in wheat crop and dry weight of weeds was recorded at 90 days after sowing (DAS).

The cost of cultivation was calculated by taking into account the prevailing prices of inputs. The minimum support prices were used for rice, wheat, maize, soybean, pigeonpea, greengram and Indian mustard, whereas market prices were taken into consideration for wheat straw, berseem and sorghum fodder and for green pea pod. The returns were calculated on yearly basis. Different crop sequences were compared by converting the yields of all the crops in a sequence into wheat-equivalent yield on price basis and then averaged. The intensification in temporal dimension was measured in terms of land-use efficiency, by taking total duration of crops in a crop sequence divided by 365 days. Production efficiency was calculated as equivalent wheat yield in a crop sequence divided by duration of crop sequence (Tomar and Tiwari, 1990). Sustainability value index (SVI) was calculated as per the procedure described by Singh *et al.* (1990).

RESULTS AND DISCUSSION

Crop productivity

Grain yield of rice varied from 5.91 to 9.12 t/ha (Table 1). The increase in rice yield due to incorporation of greengram residues ranged from 7.36 to 11.28%. Pod yield of vegetable pea ranged from 2.83 to 7.16 t/ha due to climatic variations. Green-pod yield of vegetable pea was 7.48 to 27.36% higher when the previous crop was maize compared with rice. Wheat yield under normal-sown conditions ranged from 3.78 to 6.52 t/ha, but it decreased to 2.19 to 3.72 t/ha under late-sown conditions. Summer greengram after Indian mustard produced 1.06 to 1.12 t/ha seed yield, whereas after wheat it was 0.49 to 0.73 t/ha. Indian mustard, pigeonpea and soybean planted on bed yielded 2.59 to 3.04 t/ha, 2.22 to 2.56 t/ha and 2.01-2.21 t/ha respectively, whereas maize yielded only 4.27 to 4.50 t/ha. Higher yield of oilseeds and pulses was due to absence of water stagnation on the crops when planted on beds. These findings support the observation of Connor *et al.* (2003).

Wheat-equivalent yield

Systems productivity and profitability played a vital role in determining the most useful and profitable crop se-

quence. The pooled analysis of the data of 6 years revealed that rice - vegetable pea - wheat - greengram (15.26 t/ha) and rice - Indian mustard – greengram – rice – wheat – greengram - rice – wheat - greengram (14.82 t/ha) crop sequences produced at par wheat-equivalent yield, which was significantly higher than of other crop sequences, and 27.91 and 24.22% greater than of rice - wheat system (Table 2). Higher wheat-equivalent yield in these crop sequences was due to intensification. In the former sequence vegetable pea was grown as pre-winter (*rabi*) crop and summer greengram as green-manure crop after late-sown wheat, whereas in the latter crop sequence greengram was taken as summer crop either after Indian mustard or after timely sown wheat. Singh *et al.* (2007) reported that growing of rice – wheat - greengram improved the system productivity by 39.1% than rice - wheat system. These findings are in agreement with those of Gangwar and Ram (2005). Maize – vegetable pea – wheat - rice – wheat – greengram - rice – wheat - greengram crop sequence also gave significantly higher wheat-equivalent yield (13.31 t/ha) than rice - wheat system. This was possible due to inclusion of greengram as the summer crop. The lowest wheat-equivalent yield was obtained from soybean – wheat - rice - wheat - rice - wheat crop sequence.

Land use and production efficiency

Maximum land-use efficiency was obtained in the rice - vegetable pea - wheat - greengram (96.4%), followed by rice - Indian mustard - greengram – rice – wheat – greengram - rice – wheat - greengram crop sequence (93.2%) (Table 2). This higher land-use efficiency was due to more number of crops in a calendar year, whereas lowest was recorded in rice - wheat system (69.6%). On the contrary, production efficiency was highest in rice - wheat crop sequence (46.95 kg/ha/day), followed by pigeonpea - wheat - rice – wheat - rice - wheat (46.31 kg/ha/day) and lowest in maize - vegetable pea – wheat - rice – wheat – greengram - rice – wheat - greengram (41.6 kg/ha/day).

Dry weight of weeds

Maximum dry weight of weeds (Table 2) was recorded in continuous rice - wheat (93.5 g/m^2), followed by soybean – wheat - rice – wheat - rice - wheat (93.3 g/m^2) crop sequences. On the contrary, minimum dry weight was recorded in rice - vegetable pea - wheat - greengram (29.7 g/m^2), followed by rice- berseem - rice – wheat - rice - wheat crop sequence (48.45 g/m^2). The lowest dry weight in the former crop sequence was due to inclusion of vegetable pea and very late sowing of wheat, which did not provide conducive environment for germination of weeds, particularly *Phalaris minor*. The latter crop sequence also reduced the dry weight of weeds in wheat crop due to repeated cutting of weeds along with berseem fodder in the previous year. This phenomenon probably exhausted the

Table 1. Average grain yield (t/ha) of various crops in different seasons

Cropping system	First cycle (3 years)				Second cycle (3 years)			
	Kharif	*Pre-rabi*	*Rabi*	*Zaid*	*Kharif*	*Pre-rabi*	*Rabi*	*Zaid*
Rice - wheat	6.77		5.01		6.05		4.11	
Rice - wheat	8.59		5.55		6.22		3.79	
Rice - wheat	7.55		5.46		7.29		4.17	
Rice - berseem	6.86		110.90		5.91		90.15	
Rice - wheat	8.30		5.89		7.06		4.31	
Rice - wheat	8.07		5.11		7.19		4.65	
Sorghum (fodder) - wheat - greengram	53.00		5.15	0.65	53.25		4.22	0.62
Rice - wheat	9.12		5.97		7.63		3.78	
Rice - wheat	8.37		5.26		7.19		4.63	
Rice-Indian mustard - greengram	6.79		3.04	1.06	6.72		2.59	1.12
Rice - wheat - greengram	8.99		6.52	0.73	7.71		4.22	0.61
Rice - wheat - greengram	8.71		6.03	0.53	7.29		4.89	0.59
Soybean - wheat	2.21		5.52		2.01		4.76	
Rice - wheat	9.12		5.61		7.02		4.23	
Rice - wheat	7.37		5.32		6.72		4.24	
Rice - vegetable pea - wheat - greengram	6.74	2.83	3.72		7 20	2.51	3.58	
Rice - vegetable pea - wheat - greengram	8.98	7.16	2.19		8.38	4.69	3.05	
Rice - vegetable pea - wheat - greengram	7.92	3.78	2.35		7.19	5.07	2.95	
Maize-vegetable pea - wheat	4.50	3.06	4.21		4.27	3.45	4.34	
Rice - wheat - greengram	8.59		5.79	0.54	6.81		3.87	0.49
Rice - wheat - greengram	7.48		5.21	0.52	7.71		4.16	0.56
Pigeonpea - wheat	2.56		5.35		2.22		4.68	
Rice - wheat	8.63		5.54		7.71		3.92	
Rice - wheat	7.81		5.21		7.39		4.63	

seed bank of *Phalaris minor*. These findings support the observations of Malik and Singh (1995), who reported that repeated cutting of berseem reduced *Phalaris minor* population in the subsequent wheat cycle.

Organic carbon

Continuous six years of growing rice - vegetable pea - wheat - greengram resulted in maximum organic C content (0.55% at 0-15 cm and 0.43% at 15-30 cm), followed by rice - Indian mustard - greengram – rice - wheat-greengram - rice – wheat - greengram crop sequence, which was significantly higher than other cropping systems under study (Table 2). Pigeonpea – wheat - rice – wheat - rice - wheat crop sequence also recorded significantly higher organic C content (0.48%) at 0-15 cm depth than rice - wheat system. Rice - vegetable pea - wheat - greengram, rice - Indian mustard – greengram – rice – wheat - greengram - rice – wheat - greengram and pigeonpea – wheat - rice – wheat - rice - wheat determined 37.5, 25.0 and 20.0% increase in organic C content than continuous rice - wheat system, respectively. These findings are in agreement with the observation of Chauhan *et al.* (2001).

Economics

The economic analysis of different crop sequences showed that net returns were maximum in rice - Indian mustard - greengram –rice – wheat – greengram - rice – wheat - greengram, which was significantly higher than in all other cropping sequences under study (Table 2). This was mainly due to inclusion of summer greengram and taking Indian mustard once in three years. Rice - vegetable pea - wheat - greengram crop sequence ranked second in net returns. These findings corroborate the observation of Chauhan *et al.* (2001) where vegetable pea was grown under flat planting condition. The crop sequence pigeonpea – wheat - rice – wheat - rice - wheat recorded the maximum benefit : cost ratio (1.74) and profitability (Rs 124/ha/day) due to inclusion of pigeonpea in first year. Gangwar and Ram (2005) also reported higher benefit : cost ratio (2.4) by this crop sequence compared with other crop sequences. The crop sequences rice - Indian mustard - greengram – rice – wheat - greengram - rice – wheat - greengram gave the second best benefit : cost ratio and profitability. Rice - Indian mustard - greengram – rice – wheat - greengram - rice – wheat - greengram, rice - veg etable pea - wheat - greengram, maize–vegetable pea – wheat - rice – wheat – greengram - rice – wheat - greengram and pigeonpea – wheat - rice – wheat - rice - wheat showed 0.92, 0.90, 0.81 and 0.73 sustainable value index respectively than rice - wheat system (0.68). Higher SVI value for different crop sequences pointed to long-

Table 2. Wheat-equivalent yield, land-use efficiency (LUE), production efficiency and economics under different cropping sequences

Cropping sequence	Wheat-equivalent yield (t/ha)							LUE (%)	Production efficiency (kg/ha/day)	Dry weight of weeds in wheat (g/m^2)	Organic C (%)		Net returns (x 10^3 Rs/ha)
	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	Pooled				0-15 cm	15-30 cm	
Rice - wheat - rice - wheat -rice - wheat	11.76	14.87	13.38	10.20	9.98	11.36	11.93	69.59	46.95	93.5	0.40	0.32	24.4
Rice – berseem - rice – wheat - rice - wheat	11.30	15.27	13.62	9.45	11.33	11.84	12.14	73.42	45.28	48.5	0.44	0.34	23.4
Sorghum (fodder) - wheat - greengram - rice – wheat - rice - wheat	11.04	15.52	13.84	8.95	11.19	11.82	12.06	76.16	43.39	86.4	0.47	0.35	23.6
Rice - Indian mustard - greengram - rice - wheat - greengram - rice – wheat - greengram	14.68	16.05	16.59	14.87	13.14	13.62	14.82	93.15	43.60	67.8	0.50	0.43	38.6
Soybean - wheat - rice – wheat - rice - wheat	9.81	15.22	13.05	8.67	11.19	10.95	11.48	72.88	43.17	93.3	0.44	0.34	27.1
Rice - vegetable pea - wheat - greengram													
Rice - vegetable pea - wheat - greengram													
Rice - vegetable pea - wheat - greengram	13.98	18.64	14.16	13.37	16.11	15.23	15.26	96.44	43.34	29.8	0.55	0.43	33.9
Maize - vegetable pea –wheat - rice – wheat-greengram - rice – wheat -greengram	12.62	14.96	15.15	12.46	11.66	13.02	13.31	87.67	41.60	68.6	0.43	0.35	33.4
Pigeonpea – wheat - rice – wheat - rice - wheat	11.94	14.74	13.13	10.39	11.43	12.00	12.27	72.60	46.31	59.4	0.48	0.34	32.8
SEm±	0.16	0.31	0.31	0.26	0.28	0.29	0.24			1.9	0.02	0.01	0.4
CD (P=0.05)	0.46	0.90	0.92	0.78	0.82	0.85	0.68			5.6	0.07	0.04	1.3

term profitability for the farmers (Singh *et al.*, 1990).

It may be concluded that rice - Indian mustard – greengram – rice – wheat – greengram - rice – wheat - greengram, rice – vegetable pea – wheat - greengram, maize–vegetable pea – wheat - rice – wheat -greengram - rice – wheat - greengram and pigeonpea – wheat - rice – wheat - rice - wheat recording higher net returns and sustainable value index may be recommended in place of rice - wheat system.

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