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Research Paper

Intensification and diversification in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system for sustainability

ALOK KUMAR, H.P. TRIPATHI AND R.A. YADAV

N.D. University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh 224 229

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ABSTRACT

A field experiment was conducted at Faizabad during 2005-10 to find out the feasibility of intensification and diversification in traditional rice (*Oryza sativa* L.)-wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping system. Hybrid rice-potato (*Solanum tuberosum* L.)-greengram (*Vigna radiata* L. Wilczek) sequence was found most efficient with respect to production (22.1 t/ha/year), systems profitability (391.6 ₹/ha/day), monetary returns (₹125.3×10^3/ha/year) and energy production (54.2 × 10^6 kcal.) followed by hybrid rice-mustard [*Brassica juncea* (L.) Czernj & Cosson]-blackgram (*Vigna mungo* L.) and basmati rice-lentil (*Lens culinic* Medik)-green fodder (maize (*Zea mays* L.) + cowpea [*Vigna unguiculata* (L.) Walp]. Intensification through inclusion of oilseeds and pulses crops increased the energy output and nutrient use efficiency. The sequences included leguminous crops (grains/fodder) improved the availability of NPK and organic C of the soil besides intensifying the system for higher productivity and profitability.

Key words : Diversification, Rice-based cropping system, Soil fertility, Sustainability.

The importance of highly intensive crop sequences is well recognized to meet out the growing food demands of ever-increasing population. Oilseeds and pulses including vegetables are receiving more attention owing to higher prices due to increased demand. Inclusion of these crops in sequence was found more beneficial than cereals alone (Kumar *et al.*, 2008). An intensive cropping system which is not only highly productive and profitable but also stable over time and maintains soil fertility, is of great importance in present conditions.

Rice-wheat is the most important crop sequence in India, occupying 60-70% of the total cultivated area in eastern Uttar Pradesh. Wide adoption of this system is mainly due to stable production and less labour requirement (Kumar *et al.*, 2001). But continuous adoption of the sequence has led to the problem of specific weeds, reduced soil fertility in specific root zone with special reference to micro-nutrients and infestation of similar kind of pests, which ultimately resulted in declining the efficiency and productivity of the system (Katyal, 2003; Kumar and Yadav, 2005). It is difficult to replace the rice by any other crop in rainy (*kharif*) season due to soil and climatic conditions of the area. Hence, the only option left is to replace wheat in winter (*rabi*) season along with different rice varieties for intensification and diversification of traditional rice-wheat system. Therefore, an experiment was conducted to find out the feasibility of intensification and diversification of existing rice-wheat system for sustainability in long run.

Corresponding author Email: alok1957@rediffmail.com

MATERIALS AND METHODS

A field experiment was conducted at Masodha, Faizabad during five consecutive years from 2005-06 to 2009-10. The climate of the experimental site was sub-humid sub-tropical with hot summers and fairly cool winters. The soil of the experimental field was silt loam in texture (52.9% silt 22.3% clay) and taxonomically classified as Typic Ustochrept. The soil was low in available N (142 kg/ha) and medium in organic carbon (0.54%), available P (18.6 kg/ha) and available K (136 kg/ha) with pH 7.3. Eight treatments comprised two crop sequences with inbred rice variety 'Sarjoo 52', viz. rice-wheat (conventional) and rice-wheat-green manuring of *Sesbania aculeata* (GM), three crop sequences with hybrid rice variety 'PHB 71' *viz.* rice-wheat-GM, rice-potato-greengram, rice-mustard-blackgram and three crop sequences with basmati rice 'Pusa basmati' *viz.* rice-wheat-GM, rice-berseem (fodder and seed both), rice-lentil-maize + cowpea (green fodder). These 8 treatments (crop sequences) were tested in randomized block design with four replications.

The varieties taken were: inbred rice 'Sarjoo 52', hybrid rice 'PHB 71', basmati rice 'Pusa basmati' , wheat 'PBW-343', potato 'K. Ashoka', greengram 'NDM-1', blackgram 'NDU-1', berseem 'Vardan' and lentil 'NDL-1'. All the crops including rice (transplanted) were grown under irrigated conditions with recommended package of practices. The recommended doses of NPK were applied through urea, diammonium phosphate and muriate of potash, respectively. The soil samples (0-15 cm) collected at the end of fifth cycle, and were analyzed for organic carbon and available N, P and K by following standard procedures. The economics and rice-equivalent yield were computed at prevailing market rates during 2009-10 (Table 1) of different commodities. The land use efficiency was worked out by dividing total duration of crops in individual crop sequence by 365 (days). The production efficiency was worked out by dividing total production of a sequence by total duration of crops in that sequence (Tomar and Tiwari, 1990). Stability indices were computed for the sequences on the basis of rice-grain-equivalent yield (Singh *et al.*, 1990).

RESULTS AND DISCUSSION

Yield and economics

Maximum rice grain-equivalent yield of 22.1 t/ha/year was recorded with hybrid rice-potato-greengram sequence, which showed 110%, 70%, 96%, 51% and 50% increase over inbred rice-wheat, hybrid rice-wheat- green manuring of *Sesbania aculeata* (GM), basmati rice-berseem, basmati rice-lentil-green fodder (maize + cowpea) and hybrid rice-mustard-blackgram sequences, respectively (Table 1).

The rice-wheat-fallow/GM systems with different rice varieties were found most sustainable (SI=0.92-0.95) followed by basmati rice-lentil-green fodder of cowpea + maize (SI=0.89). Hybrid rice-mustard-blackgram and hybrid rice-potato-greengram were also found quite stable (SI=0.87 and 0.84). Basmati rice-berseem (GF + seed) sequence showed minimum stability (SI=0.81). Kumar *et al.* (2001) also reported that rice-wheat sequence was most stable system in eastern Uttar Pradesh conditions.

The medium duration hybrid rice 'PHB-71' followed by potato-greengram crop sequence proved to be most remunerative with the net profit ₹ 125.3×10^3/ha/annum (Table 1) followed by scented rice Pusa basmati-lentil-maize + cowpea (green fodder) which provided ₹93.3×10^3/ha/annum as net returns. The other good sequences were hybrid rice 'PHB-71'-mustard-black gram and rice (hybrid)-wheat-green manuring which gave higher net returns of ₹32.3×10^3 and ₹16.9×10^3/ha/year, respectively over traditional inbred rice-wheat sequence (₹56.9×10^3/ha/year). Kharub *et al*. (2003) also reported that inclusion of pulse crops in rice-based crop sequences improved the productivity and net returns.

The highest benefit : cost ratio of 2.06 was found in rice (Pusa basmati)-lentil-maize + cowpea (green fodder) followed by rice 'PHB-71'–mustard–black gram (1.77) against B:C ratio of 1.49 available with rice 'PHB 71'–potato-greengram which gave highest net return (Table 2). The lowest B: C ratio of 1.27 was found in rice (Sarjoo-52)-wheat-green manuring (*Sesbania aculeata)* sequence.

Efficiency indices

Hybrid rice-potato-greengram and hybrid rice-mustard-blackgram sequences gave 60.4 and 40.3 kg/ha/day higher production efficiency compared with 28.77 kg/ha/day in traditional rice-wheat sequence (Table 2). The maximum

Table 1. Yield and economics of various rice-based crop sequences (mean data of 5 years)

Treatment	Yield (t/ha)			Inbred rice yield equivalent (t/ha/year)	Cost of cultivation (× 10^3 ₹/ha/year)	Net returns (× 10^3 ₹/ha/year)	B:C ratio	Sustainability index
	Kharif	*Rabi*	*Zaid*					
Inbred rice-wheat-fallow	5.3	4.3	-	10.5	42.8	57.0	1.33	0.93
Inbred rice-wheat-GM	5.7	4.6	-	11.3	47.3	60.2	1.27	0.95
Hybrid rice-wheat-GM	7.5	4.5	-	13.0	49.2	73.9	1.50	0.94
Hybrid rice-potato-greengram	7.6	25.3	1.06	22.1	84.2	125.3	1.49	0.84
Hybrid rice-mustard-blackgram	7.4	1.8	0.96	14.7	50.4	89.2	1.77	0.87
Basmati rice-wheat- GM	4.4	4.5	-	12.4	46.6	71.4	1.53	0.92
Basmati rice-berseem (GF+seed)	4.3	55.3	0.16	11.2	38.5	68.3	1.77	0.81
Basmati rice-lentil-GF (maize+cowpea)	4.2	1.8	39.9	14.6	45.3	93.3	2.06	0.89

Sale price (₹/kg)-Coarse-rice-9.50, Basmati-rice 15.00, Wheat-grain-11.50, Greengram- 35.00, Blackgram-35.00, Lentil-30.00, Mustard-20.00, Potato 4.00, Berseem/maize + cowpea green fodder 0.50 and Berseem seed-90.00.

GM – green manuring of *Sesbania aculeata*, GF- green fodder

of land use efficiency (90.41%) was found in basmati rice-lentil-maize + cowpea (green fodder) sequence closely followed by hybrid rice-potato-greengram (87.67%) due to intensification of the systems.

Basmati rice-berseem (seed + fodder) sequence was found most efficient in terms of apparent nutrient use efficiency (37.47 kg/ha/kg nutrient) followed by hybrid rice-potato-greengram (35.01 kg/ha/kg). The highest energy production of 54.2×10^6 kcal was recorded with hybrid rice-potato-greengram closely followed by hybrid rice-wheat-green manuring (41.6×10^6 kcal) against lowest values of 14.8×10^6 kcal found with basmati rice-berseem (fodder & seed). Synonymous to production efficiency and energy production, the highest system profitability of ₹391.6/ha/day was also found with hybrid rice-potato-greengram sequence followed by ₹ 283.3/ha/day in hybrid rice- mustard-blackgram against lowest values of ₹191.2/ha/day found in rice (Sarjoo 52) – wheat-green manuring of *Sesbania aculeata* (Table 2).

Soil fertility

Changes in the organic C and availability of major nutrients during the years (Table 3) revealed that there was increase in organic carbon and availability of nutrients *viz.* NPK in soil after competition of 5th cycle. The increase was more pronounced in rice-potato-greengram followed by rice-mustard-blackgram. The minimum increase was noticed in existing cropping system of rice-wheat. The systems, having leguminous crops or green manuring of *Sesbania*, showed more build up in organic carbon and nutrients availability. Sharma *et al.* (2004) also observed that sequence including leguminous crops improved the soil fertility.

These results clearly indicated that in *kharif* season, basmati rice or hybrid rice are more remunerative and productive than inbred rice. In *rabi* season replacement of wheat with mustard or potato is better option for higher profitability and energy production. The inclusion of pulse crops (grain/fodder) or green manuring of *Sesbania* during summer season improved soil fertility besides intensifying the system for higher productivity and sustainability.

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Table 2. Efficiency of various rice based crop sequences (mean data of 5 years)

Treatment	Production efficiency kg/ha/day	Land use efficiency (%)	Apparent nutrient use efficiency (kg/ha/kg nutrient)	Energy production ($\times 10^6$ k cal.)	System profitability (₹/ha/day)
Inbred rice-wheat-fallow	28.8	73.97	22.8	33.2	211
Inbred rice-wheat-GM	31.0	73.97	24.6	35.8	191
Hybrid rice-wheat-GM	35.5	73.97	26.4	41.6	235
Hybrid rice-potato-greengram	60.4	87.67	35.0	54.2	392
Hybrid rice-mustard-blackgram	40.3	86.30	31.3	38.6	283
Basmati rice-wheat-GM	34.0	77.26	27.0	30.9	218
Basmati rice-berseem (GF+seed)	30.8	85.20	37.5	14.8	219
Basmati rice-lentil-GF (maize+cowpea)	40.0	90.41	32.4	20.9	283

K cal. (per 100 gm) rice-346, wheat-346, potato-97, greengram-334, blackgram-347, lentil-343, mustard-541.

Table 3. Changes in soil-fertility parameters after fifth cycle as influenced by different rice-based crop sequences

Treatment	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Inbred rice-wheat-fallow	0.54	153	21.6	148
Inbred rice-wheat-GM	0.60	164	22.8	154
Hybrid rice-wheat-GM	0.58	160	23.4	161
Hybrid rice-potato-greengram	0.61	166	22.7	159
Hybrid rice-mustard-blackgram	0.63	162	23.2	164
Basmati rice-wheat-GM	0.59	167	22.7	156
Basmati rice-berseem (GF+seed)	0.64	170	23.3	160
Basmati rice- lentil-GF (maize+cowpea)	0.58	159	21.6	155
Initial soil-test values	0.51	142	18.0	136

GM – green manuring of *Sesbania aculeata*, GF- green fodder

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