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Diversification of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system for improving soil fertility and productivity

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ABSTRACT

A field experiment was conducted during 1996–97 to 1999–2000 at Karnal, to evaluate the effect of 6 rice (Oryza *sativa* L.)-based crop sequences on soil fertility and productivity. Maximum wheat-equivalent yield was recorded by inclusion of potato (*Solanum tuberosum* L.) (197.1–200.3 q/ha), followed by vegetable pea (*Pisum sativum* L.) (173.5–173.8 q/ha) between rice and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crops. These systems resulted in additional wheat-equivalent yield of 48–71 q/ha over the rice–wheat system. Continuous incorporation of *Sesbania aculeata* as green-manure increased organic carbon by 8.7%, available N by 12.1%, Olsen's P by 10.1% and available K by 5.0% in soil compared to rice–wheat sequence. Growing of vegetable pea and potato between rice and wheat also increased organic carbon by 8.9 and 17.1%, available N by 6.3 and 8.3% and available P by 6.3 and 19.0%, respectively, compared to rice–wheat system. Green-manuring with *Sesbania aculeata* added 97–109 kg N/ha and enhanced the wheat-equivalent yield in the rice–wheat system. Electrical conductivity and pH of soil decreased due to the inclusion of vegetable rice, potato and green-manure.

Key words : Diversification, Green-manuring, Productivity, Rice–wheat system, Soil fertility, Wheat equivalent yield

Rice–wheat system is the backbone of India's food security. This system occupies an area of 10.5 m ha in the Indo-Gangetic plains of India, out of which 4.0 million ha area in the north-western plains. There are reports of yield stagnation and decline in soil productivity (Yadav *et al.*, 1998), due to continuous adoption of this system. Rapid spread of rice–wheat system in the post-green Revolution era in this region caused an eclipse on sustainability of soil productivity (Rattan and Singh, 1997). In this context, low input-sustainable agriculture (Grubinger, 1992) and reduced chemical inputs (Kirchner *et al.*, 1993) concepts which focus on green-manuring, recycling crop residues and inclusion of legumes in rotation are important. The decline in crop yield could be minimized by introduction of green-manures in rice–wheat of diversification of this system (Chauhan, 2000). In the present scenario, adequate quantity of organic manures like farmyard manure and compost are difficult to obtain due to mechanization of agriculture, which has resulted in considerable decrease in farm animals.

Therfore, a need was felt to evaluate other organic sources like green-manure crop in the lean period (May/June) or by diversifying the rice–wheat system by introducing pea and potato between rice and wheat. Accordingly, different rice-based crop sequences were tried to investigate their effect on soil health and crop productivity.

MATERIALS AND METHODS

A field experiment was conducted at research farm of Directorate of Wheat Research, Karnal, for 4 years (1996–2001). The experimental soil was sandy clay loam in texture (22% clay), low in organic C (0.36%) and available N (139 kg/ha), medium in available P (17.6 kg/ha) and low in K (151 kg/ha) content. Electrical conductivity and pH were determined in 1:2 soil water suspension. Organic carbon was determined by Walkley and Black method, phosphorus by Olsen's method and nitrogen by alkaline potassium permanganate and potassium by ammonium acetate method after the harvest of wheat crop. Six rotation, viz. rice–wheat, rice–vegetable pea–wheat and rice–potato–wheat with and without green-manure (*Sesbania aculeata*), were tried in randomized block design with 3 replications in a net plot size of 60 m^2. Early rice and late wheat were grown wherever the vegetable pea/potato were grown between rice and wheat and otherwise rice and wheat were grown timely. The varieties and fertilizer applied to different crops are given in Table 1. Irrigation was applied on the basis of critical physiological stages of different crops. Recommended doses of fertilizers were applied to the crops, except in case of rice following green-manuring when 75% of recommended dose was applied. *Sesbania aculeata* was grown after wheat and incorporated into the soil at 55–60 days after sowing. The productivity of different crop sequences were compared by converting the yield of all crops into wheat equivalent on the basis of minimum support price or prevailing market price. Changes in soil-fertility status were monitored after harvest of wheat in each cycle.

RESULTS AND DISCUSSION

Crop productivity

There were no significant differences in yield of rice among different treatments. In spite of 25% less N application in rice where green-manuring was practised, similar yield of rice was recorded as with 100% NPK without green-manuring (Table 2). This showed that inclusion of green-manuring saved 25% N in rice–wheat system. Timely-sown wheat varieties gave higher yield under green-manuring than without green-manuring, but this was not true with late-sown wheat which preceded vegetable pea or potato.

Rice–wheat sequence gave significantly lower wheat-equivalent yield (122 q/ha) than other crop sequences. The wheat-equivalent yield was significantly higher where potato (197–200 q/ha) was taken between rice and wheat. The mean increase in wheat-equivalent yield was up to 76 q/ha (62%) over the rice–wheat system. This finding corroborates the observations of Govindakrishnan and Lal (1997), who reported that planting of potato in third week of October and harvesting in last week of December, followed by wheat enhanced wheat-equivalent yield of the system. Growing vegetable pea between rice and wheat also resulted significantly higher equivalent wheat yield (173 q/ha) than rice–wheat with green-manuring (125 q/ha) and rice–wheat without green-manuring (122 q/ha).

Table 1. Varieties and fertiliser doses (kg/ha) applied to different crops

Crops	Varieties	N	P	K
Rice, early	'Govind'	150	60	40
Rice, late	'Pusa 44'	150	60	40
Wheat, timely-sown	'PBW 343'	150	60	40
Wheat, late-sown	'RAJ 3765'	120	60	40
Vegetable pea	'Arkel'	20	60	40
Potato	'Kufri Bahar'	150	80	100

Nitrogen build up by incorporation of Sesbania aculeata

Sesbania aculeata produced 38.5 to 43.5 q/ha of dry matter in 55–60 days and added 97 to 109 kg N/ha under different treatments (Table 3). These observations are in agreement with Meelu *et al.* (1994). Paikaray *et al.* (2001) observed that integrated use of *Sesbania* green-manure saved 80 kg N/ha in rice–wheat system. The improvement in soil fertility and wheat-equivalent yield were noticed in green-manure related treatments compared to pure rice–wheat sequence due to the addition of biomass and nitrogen.

Table 3. Biomass and nitrogen addition through *Sesbania aculeata* in 50–55 days

Crop sequence	Fresh weight (q/ha)	Dry weight (q/ha)	N addition (kg/ha)
Rice–wheat–GM	283	43.6	109.0
Rice–wheat–GM	262	40.6	101.5
Rice–potato–wheat–GM	248	38.9	97.0

GM, Green-manure

Soil fertility

Growing of either vegetable pea or potato between rice and wheat or green-manuring after wheat or both enhanced the soil organic carbon content significantly compared to rice–wheat system, except in 1997 when the increase was marginal and non-significant (Table 4). An increase of 8.7, 8.9, and 17.1% in organic carbon was observed after 4 years of incorporation of *Sesbania aculeata* and growing of vegetale pea and potato between rice and wheat over the rice–wheat system respectively. In 1997, rice–pea–wheat and rice–potato–wheat with or without

Table 2. Crop productivity (q/ha) under different crop sequences (mean data of 4 years)

Crop sequence	Rice	Potato	Pea	Wheat	Total wheat-equivalent yield
Rice–wheat	62.74			54.24	122.23
Rice–wheat-green manure (GM)	64.02			56.48	125.42
Rice–pea–wheat	65.92		48.03	30.83	173.46
Rice–pea–wheat–GM	65.05		48.17	30.35	173.80
Rice–potato–wheat	66.04	183.50		30.64	197.11
Rice–potato–wheat–GM	65.28	189.75		30.98	200.35
CD (P=0.05)		5.38			

Table 4. Soil fertility status as influenced by different crop sequences

Crop sequence	1996–97	1997–98	1998–99	1999–2000
Organic carbon (%)				
Rice–wheat	0.356	0.342	0.385	0.392
Rice–wheat–GM	0.366	0.390	0.423	0.426
Rice–pea–wheat	0.379	0.419	0.429	0.427
Rice–pea–wheat–GM	0.389	0.410	0.424	0.441
Rice–potato–wheat	0.382	0.424	0.439	0.459
Rice-potato–wheat–GM	0.404	0.419	0.435	0.462
CD (P=0.05)	0.013	0.015	0.016	0.012
Available N (kg/ha)				
Rice–wheat	141.3	137.0	135.0	135.0
Rice–wheat–GM	142.0	145.0	150.3	151.4
Rice–pea–wheat	141.0	143.7	144.0	143.6
Rice–pea–wheat–GM	145.0	145.0	148.7	148.4
Rice–potato–wheat	150.0	148.3	145.7	146.3
Rice–potato–wheat–GM	148.7	150.7	156.3	157.6
CD (P=0.05)	NS	NS	9.1	10.9
Available P (kg/ha)				
Rice–wheat	17.8	18.1	18.4	18.9
Rice–wheat–GM	17.9	18.6	19.1	20.8
Rice–pea–wheat	17.9	18.5	19.0	20.1
Rice–pea–wheat–GM	18.2	18.4	19.1	20.3
Rice–potato–wheat	18.3	19.0	20.3	22.5
Rice–potato–wheat–GM	18.4	18.8	19.9	21.6
CD (P=0.05)	NS	NS	1.1	1.9
Available K (kg/ha)				
Rice–wheat	140.7	149.7	157.0	157.0
Rice–wheat–GM	148.0	151.0	156.0	157.0
Rice–pea–wheat	151.7	155.0	154.3	159.0
Rice–pea–wheat–GM	155.0	160.3	158.0	161.0
Rice–potato–wheat	151.3	160.0	160.0	164.3
Rice–potato–wheat–GM	158.0	159.7	166.7	170.2
CD (P=0.05)	NS	NS	NS	NS

Initial values of OC, available N, P, and K were 0.36%, 139 kg/ha, 17.6 kg/ha and 151 kg/ha respectively.
GM, Green-manure

green-manure recorded significantly higher organic carbon compared to rice–wheat system. The increase in available N and P in cropping sequences involving green-manuring, vegetable pea and potato in the rice–wheat system was marginal in 1997–98 and 1998–99 but a significant build up these nutrients under these systems was noticed in 1999–2000 and 2000–2001. Similarly, available N was significantly higher after 1999 in every cropping sequence compared to rice–wheat system. After 4 years, growing of green-manure after wheat and vegetable pea and potato between rice and wheat showed 12.1, 6.3, 8.3% increase in available N, respectively, compared to rice–wheat system. In the initial 2 years nitrogen and phosphorus were at par under different crop sequences. Available P increased by 10.1, 6.3 and 19.0% due to inclusion of green-manuring, vegetable pea and potato, respectively, compared to rice–wheat system. Available K was also increased but non-significantly in different cropping sequences compared to rice–wheat sequences. Interestingly, rice–pea–wheat and rice–potato–wheat rotation revealed similar increase in organic carbon, available N, P and K as rice–wheat–green-manuring sequences. Therefore, it could be envisaged that growing of vegetable pea or potato between rice and wheat, without green-manuring, were equally effective as rice–wheat–green-manuring in maintaining soil fertility. Mahapatra *et al.* (2002) reported beneficial effects of *Sesbania* green-manuring in rice–wheat system on soil organic carbon, available N and P. Similarly, Lal and Govindkrshnan (2000) also reported that 40 kg N was sufficient for growing wheat after potato. Although soil pH and electrical conductivity decreased due to inclusion of green-manure, pea and potato between the rice–wheat crop sequence compared to pure rice–wheat sequence but the differences were non-significant.

It was concluded that growing of vegetable pea or potato between rice and wheat system could be as beneficial as rice–wheat–green-manure sequence for enhancing soil fertility and crop productivity.

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