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Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols

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ABSTRACT

The effect of a permanent plot long-term field experiment of integrated nutrient management of farmyard manure, green manure and composted rice straw with inorganic fertilizers on sustainable productivity and soil properties in rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system was studied after 16 years of cropping cycles on Inceptisols. The experiment is in progress since 1991 at Indira Gandhi Krishi Vishwavidyalaya, Raipur. Over 16 years of the study period, highest rice and wheat yield was obtained when 50% of N was supplied through green manure in conjunction with 50% of NPK through inorganic fertilizers (50% recommended dose of fertilizer+ 50% N-green manure). Significant residual effect of green manure was also observed on the following wheat crop, 50% recommended dose of fertilizer + 50% N (green manure) also maintained the sustainability of the system. The sustainable yield index of rice and wheat was registered to 0.78 and 0.44 and 0.84 and 0.45 in the treatment of 100% recommended dose of fertilizer to both the crops and 50% recommended dose of fertilizer+ 50% N (green manure) in rice and 100% recommended dose of fertilizer in wheat as compared to 0.30, 0.19 and 0.64 and 0.33 in the control and farmer's practice, respectively. *In-situ* application of green manure along with 50% of recommended dose of fertilizer is the most favourable treatment to have highest available N (255 kg/ha) in surface soil. The results show that available P content of soil increased significantly with farmyard manure, composted rice straw and green manure in conjunction with 50% recommended dose of fertilizer over initial value and control. Continuous use of fertilizers and intensive cropping had resulted in lowering the available K status of soil indicating the need of application of K to meet the crop requirement. While *p*H and EC were almost remained constant irrespective of the treatments.

Key words: Composted rice straw, Green manure, Integrated nutrient supply, Rice–wheat system, Sustainable yield index

In Chhattisgarh rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.), system is emerging as a popular cropping system with an area of more than 2 lakh ha in medium to heavy textured soils under irrigated and partially irrigated condition. But its productivity is very low ranging from 3.5 to 4.5 tonnes/ha as compared to other states and national average. The main reasons for low system productivity even in irrigated area are the inadequate application and unbalanced fertilizers to these fertility exhaustive crops (Sharma *et al*. 2003) but consequently declined the soil organic carbon and soil health, in general (Yadav *et al*. 2005). Besides, frequently occurred dry spells during rainy season and short winters due to rise in temperature have adverse effects on productivity of rice–wheat system. The interactive advantages of combining organic and inorganic sources of nutrients in integrated nutrient management have proved superior to the use of each component separately (Palaniappan and Annadurai 2007). Judicious use of organic manures, such as farmyard manure, green manuring and rice straw along with chemical fertilizers improves soil physical, chemical and biological properties and enhance productivity in both the seasons. It is essential to identify such practices which bring more sustainability to the production system, besides improving the productivity of the system and soil health.

MATERIALS AND METHODS

A long-term field experiment on integrated nutrient management in rice–wheat system was conducted from 1991–92 to 2006–07 at permanent plots in Indira Gandhi Krishi Vishwavidyalaya, Raipur. The climate is sub-humid and the mean annual rainfall of the area is 1 200 mm. The soil belongs to the order Inceptisols and neutral in soil reaction. Twelve treatments consisting of combinations of

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chemical fertilizers and organic sources of nutrients in rice and only chemical fertilizers at different levels in wheat were tested in randomized block design replicated thrice with a plot size of 12.0 m × 7.2 m. Bunds of 50 cm height were made between replications and individual plots to check the outflow of nutrients and reduce the border effect. 'Kranti' rice during rainy season and 'HI 1077' wheat was grown during winter season for first 10 years and 'Mahamaya' rice and 'GW 273' wheat was taken for rest of the years. The experiment was conducted under assured irrigation facilities and need-based irrigations were applied to rice and wheat as per recommended practice.

The recommended doses of fertilizers were 80: 60: 40 and 100: 50: 30 (N: P_2O_5: K_2O kg/ha) for rice and wheat, respectively. The N, P and K were supplied through urea, single superphosphate and muriate of potash, respectively. Nitrogen was supplemented to the respective treatment either through *in-situ* green manure, farmyard manure or rice straw residue so that 100% recommended N dose could be available to the rice crop. The average N content of green manure (*Sesbania aculeata*), farmyard manure and rice-straw residue on oven dry basis was ranged between 2.4 to 2.6, 0.5 to 0.6 and 0.3 to 0.4%, respectively. *Sesbania* (45 days old) was incorporated 1 to 2 days before transplanting of rice. Green manure was grown in respective permanent plots well before rice transplanting as per recommended seed rate, ie 40 kg/ha. The content of nitrogen in green manure was determined by taking random sample of dry weight collected from 1 m^2 area at 45 days after sowing. It varies from 2.4 to 2.6% and on an average 1.6 tonnes/ha dry weight of green manure supplies 40 kg N. On the basis of nitrogen content in 1 m^2 area, the remaining part of N-requirement of a particular treatment was supplemented through green manure and to supplement 50% N, the remaining is added through green manure grown aside.

Soil samples were analyzed for different parameters by following standard procedures for organic carbon, available nitrogen (alkaline permanganate method), available phosphorus and available potassium (ammonium acetate extract). Sustainability yield index (SYI) was calculated as per the formula suggested by Wanjari *et al*. (2004) for different treatments taking yield as dependent variable of respective crop. Mean yield of respective crop under each treatment (Yt) and standard deviation (S) over years were calculated using the yield data of respective crop from 1991 to 2007 for arriving at SYI using the equation SYI = (Yt–S)/Ymax, where Yt is sustainability index of treatment over a period of n years and Ymax is the maximum yields of respective crop. Due to yearly variation in price of crops, the total productivity in terms of rice equivalent yield and total net returns of ending year, ie 2006–07 was only presented in the study considering with Rs 6 500/tonne and Rs 11 000/tonne as farm gate prices for rice and wheat, respectively.

RESULTS AND DISCUSSION

Grain yield of rice and wheat

The results of 16 years long-term permanent experiment on the integrated nutrient management in rice–wheat cropping system showed that the different treatment combinations had marked differences in the productivity of rice and wheat. Green manuring or adding of rice residues or farmyard manure offer the twin benefits of soil quality and fertility enhancement while meeting a part of nutrient need of crops, not only sustain the higher yields of crop but also cut the expensive fertilizers on the other hand. Among the different sources of nitrogen substitution, highest yield of rice (6.08 tonnes/ha) and wheat (2.92 tonnes/ha) were obtained with the treatments in which 50% of N was substituted through green manure during rainy season (Table 1). The pooled grain yield of rice and wheat also showed that the increase in application of inorganic fertilizers, except at 75% level significantly increased the grain yield of both the crops. Application of optimal and sub-optimal recommended dose of fertilizers in both the crops had marked effect on the productivity of rice and wheat. Addition of 50% or 25% green manure N with 50 or 75% recommended dose of fertilizer (RDF) gave almost equal yield of both the crops to that of 100% RDF treatment. The rice and wheat grain yield among the integrated nutrient use treatments of green manure or farmyard manure or rice straw residue were also similar. The inorganic fertilizers treatments (50% dose of fertilizer) were similar to that of farmers practice. The integrated nutrient management treatments were higher to farmer's practice with respect to rice and wheat yield, while the lowest yield of rice and wheat (2.01 and 1.03 tonnes/ha) was recorded with no manures and fertilizers, ie control. These findings indicated that integrated use of chemical fertilizers with farmyard manure or green manure or rice straw residue facilitates to curtail the use of chemical fertilizers up to 50% and is a better alternative to use of full dose of recommended fertilizers (Gupta *et al*. 2006).

Total productivity and net returns

The highest total productivity (12.72 tonnes/ha) was obtained with 50% RDF + 50% N through green manure, followed by 100% of RDF (12.10 tonnes/ha) while, the lowest total productivity was obtained with control (3.03 tonnes/ha) in 2006–07. Among all the treatments, highest net returns (Rs 55 631/ha) was recorded with 50% of RDF + 50% N through green manure, followed by 75% of RDF (Rs 53 862/ha). Further, the result revealed that the comparable total net returns (Rs 51 176/ha) obtained from rice and wheat crops with 100% RDF to both crops.

Sustainability of crop yield

Sustainability yield Index (SYI) was highest (0.84 and 0.80) with 50% RDF+50% N through green manure and 75% RDF+25% N through GM (0.80), followed by 75%

Table 1 Effect of long-term integrated nutrient management on yield and sustainable yield index (SYI) of rice and wheat (pooled over 16 years, 1991–2006)

Treatments		Productivity (tonnes/ha) and economics (2006–07)				Productivity and sustainable yield index data base					
Rice	Wheat	Rice yield	Wheat yield	TP in terms of RAY	Total NR (Rs/ha)	Rice yield (tonnes/ha)	Per cent increase over control	SYI of rice	Wheat yield (tonnes/ha)	Increase over control (%)	SYI of wheat
No fertilizer, no manure (control)	No fertilizer, no manure (control)	2.01	0.60	3.03	-5820	2.21 (2.62)*		0.30	1.03 (3.00)*		0.19
50% RDF	50% RDF	4.13	2.62	8.57	29 606	4.40 (6.15)	100	0.57	1.98 (6.20)	92	0.31
50% RDF	100% RDF	4.98	3.25	10.49	41 560	4.70 (6.78)	113	0.61	2.47 (7.80)	139	0.39
75% RDF	75% RDF	5.03	3.26	10.56	41 982	5.73 (4.53)	160	0.71	2.38 (8.00)	131	0.36
100% RDF	100% RDF	6.08	3.55	12.10	51 176	5.85 (6.44)	165	0.78	2.73 (8.50)	164	0.44
50% RDF+50% N (FYM)	100% RDF	5.82	3.54	11.81	46 458	5.85 (6.40)	165	0.74	2.75 (8.60)	167	0.43
75% RDF+25% N (FYM)	75% RDF	5.61	3.35	11.28	45 906	5.57 (4.19)	152	0.76	2.62 (9.50)	154	0.34
50% RDF+50% N (RS)	100% RDF	5.18	3.63	11.33	39 704	5.36 (4.82)	143	0.73	2.70 (8.30)	162	0.42
75% RDF+25% N (RS)	75% RDF	5.45	3.32	11.06	41 626	5.52 (5.37)	150	0.74	2.67 (9.10)	159	0.41
50% RDF+50% N (GM)	100% RDF	6.34	3.77	12.72	55 631	6.08 (4.75)	176	0.84	2.92 (9.30)	183	0.45
75% RDF+25% N (GM)	75% RDF	6.17	3.72	12.46	53 862	5.93 (4.96)	169	0.80	2.76 (10.10)	168	0.41
Farmers' practice 50:30:20 NPK kg/ha	Farmers' practice										
	60:40:20 NPK kg/ha	4.36	2.77	9.06	32,537	4.76 (4.55)	116	0.64	2.27 (8.30)	120	0.33
LSD (P = 0.05)		0.11	0.09			0.77			0.26		

RDF, Recommended dose of fertilizer; FYM, farmyard manure; RR, composted rice -straw residue; GM, green manure, Price Rs/tonne: Rice 6 500, Wheat 11 000; REY, rice equivalent yield (tonnes/ha); * Figures in the parentheses are SD of mean

RDF+25% N through farmyard manure (0.76). The treatment having only100% RDF in rice also registered a comparable SYI (0.78). Comparatively lower values of SYI among the treatments having only inorganic fertilizers than the integrated use of both inorganic+organic inputs suggests that combined use of both inorganic and organic manures brings more sustainability of yield on long-term basis (Table 1). Higher values of SYI of rice under integrated nutrient management were also reported by Behera *et al*. (2007). The SYI of wheat was higher in different treatment combinations over control also observed in rice (Table 1). The sustainability in yield was increased with graded levels of fertilizers. Among organic sources applied in rice, highest residual effect was noticed by green manure (0.45), followed by farmyard manure (0.43) and rice-straw residue (0.42). This shows that application of green manure provided minimum guaranteed sustainable yield of wheat in that particular environment. The farmer's practice of nutrient management had reasonably lesser SYI of rice and wheat (0.64 and 0.33) than the others, but it was noticeably higher than the SYI of the control treatment (0.30 and 0.19, respectively). It was further noticed that sustainability of rice is more than wheat in this zone as indicated by higher SYI in all the treatments in rice compared to wheat.

Soil properties

Soil pH and EC: The *p*H ranged from 7.21 to 7.52 at the harvest of wheat under different manurial treatments. The *p*H slightly declined in all the treatments containing green manure/farmyard manure/rice-straw residue except in T_5 which had received only inorganic fertilizers. The water soluble salts expressed as electrical conductivity decreased with the application of organic manures. The plots which had received farmyard manure, recorded more decrease in electrical conductivity (15%) over highest value recorded at 100% RDF than others which is obviously due to decomposition of organic matter in soil.

Organic carbon and available N

Organic carbon content of surface soil increased significantly with incorporation of green manure/farmyard manure/rice-straw residue in conjunction with fertilizer. The levels of application of inorganic fertilizers increased the organic carbon content in soil. Among the inorganic fertilizer treatments, only 100% RDF was found competent to those which have received integrated nutrient management practices and improved the organic carbon content even more than 50% or 75% N through rice-straw residue. However, application of 75 and 100% RDF failed to influence organic carbon over other application rates. Application of farmyard manure (50% RDF+50% N through farmyard manure –100% RDF and 75% RDF+25%N through FYM –75% RDF) in wheat, composted rice-straw residue (50%RDF+50%N

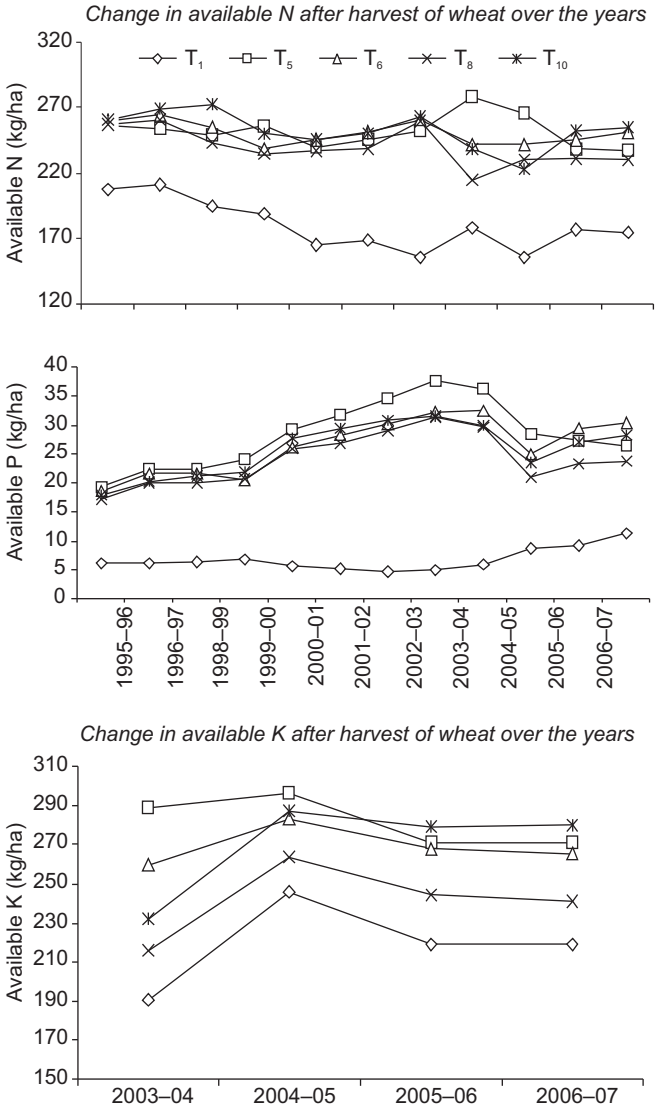

Fig 1 Change in available nutrient status of selected treatments after harvest of wheat

through rice-straw residue–100% and 75%RDF+25%N through rice-straw residue –75%) RDF and green manure (50%RDF+50% N through green manure–100%RDF) and 75%RDF +25%N through green manure–75% RDF in wheat significantly improved the organic carbon over initial status. Exclusion/omission of inorganic fertilizers from system (control plots) lowered the organic carbon (0.48%) even it was remained lesser than the initial values (0.51%) as compared to all the other treatments. Improvement in organic carbon status in farmyard manure/rice-straw residue/green manure treated plots after a continuous 31 cropping cycles was also reported by Sharma *et al*. (2007).

Available N content of surface soil varied significantly with application of farmyard manure/rice-straw residue/green manure in combination with fertilizers over initial status. The highest available nitrogen in surface soil (255 kg/ha) was recorded with *in situ* application of green manure for 50% N supplementation, followed by 50% N (farmyard manure) (251 kg/ha) along with inorganic fertilizers. Increase in available nitrogen with green manure and farmyard manure application might be attributed to the direct addition of nitrogen through farmyard manure and green manure to the available pool of the soil. The favourable soil conditions under farmyard manure and green manure addition might have helped in the mineralization of soil N leading to build-up of higher available N. Among the inorganic fertilizer treatments, 100% RDF have maintained the available N level of soil. It was slightly improved (237 kg/ha) from the initial values of 234 kg/ha. While, other sub-optimal doses as well as farmer's practice did not maintain the N level at the end of 16 crop cycles (Table 1, Fig 1).

Available P

Available P content of the soil was increased with incorporation of farmyard manure/rice-straw residue/green manure in combination with chemical fertilizer over initial status and was almost three times higher (30.3 kg/ha) in surface soils under 50% RDF+50% N (farmyard manure) in rice and 100% RDF in wheat. Application of half and full dose of fertilizer did not influence the available phosphorus status of soil. It is an established fact that 25 to 30% of applied phosphorus only is used by crops and rest remains in soil. The increased available P content of soil might be due to release of organic acids during decomposition which in turn helped in releasing phosphorus. Increase in available P with farmyard manure application might also be due to solubilization of the native P in the soil through release of various organic acids. This is more pronounced at the higher moisture level under irrigated conditions (Tiwari 2003). Organic manures enhanced the labile P in soil through complexation of cations like $Ca^{2+}$and Mg^{2+} when it is applied in combination with inorganic fertilizer.

Available K

The available K content of surface soil in rice–wheat crop rotation differed significantly due to various levels of organic in combination with inorganic sources of nutrients. However, continuous use of fertilizers and intensive cropping had resulted in lowering the available potassium status of soil indicating the need to apply the potassium to meet the crop requirement. Singh *et al*. (2006) also reported the same findings. The decrease was synchronous with lowering the dose of fertilizer and manures applied and maximum decrease was observed in control (219 kg/ha) as compared to 100% RDF (271 kg/ha). Interestingly, green manure in conjunction with fertilizer could only maintain the available potassium to that of initial status. farmyard manure or rice-straw residue incorporation to meet 50% N + 50% RDF recorded the higher available K over graded dose of fertilizers and control. Increase in available potassium due to green manure

Table 2 Soil physico-chemical properties under integrated nutrient management in rice-wheat cropping system

	Treatments		*p*H	EC (dS/m)	OC (%)	Available nutrient (kg/ha)		
	Rice	Wheat				N	P	K
	Initial status				0.51	234	11.5	280
T_1	No fertilizer, no manure (control)		7.35	0.20	0.48	175	11.2	219
T_2	50% RDF	50% RDF	7.43	0.22	0.57	206	20.5	231
T_3	50% RDF	100% RDF	7.41	0.21	0.59	213	21.7	240
T_4	75% RDF	75% RDF	7.35	0.23	0.57	217	24.3	225
T_5	100% RDF	100% RDF	7.52	0.23	0.64	237	26.5	271
T_6	50% RDF +50% N (FYM)	100% RDF	7.33	0.20	0.69	251	30.3	265
T_7	75% RDF +25% N (FYM)	75% RDF	7.37	0.20	0.66	231	27.7	251
T_8	50% RDF + 50% N (RR)	100% RDF	7.21	0.21	0.61	230	23.9	241
T_9	75% RDF +25% N (RR)	75% RDF	7.24	0.18	0.61	226	21.3	239
T_{10}	50% RDF + 50% N (GM)	100% RDF	7.35	0.22	0.71	255	28.3	280
T_{11}	75% RDF + 25% N (GM)	75% RDF	7.33	0.21	0.68	247	24.6	273
T_{12}	Farmers' practice	Farmers' practice	7.35	0.18	0.59	212	22.0	257
	50:30:20	60:40:20						
	NPK kg/ha	NPK kg/ha						
	LSD (P = 0.05)		0.17	NS	0.06	18	4.9	11

application may be attributed to the direct addition of potassium to the available pool of the soil. The beneficial effect of green manure and farmyard manure on available potassium may be ascribed to the reduction of potassium fixation and release of potassium due to interaction of organic matter with clay, besides the direct potassium addition to the potassium pool of the soil. But, the increase in K level was not as much as expected in the integrated nutrient treatments. Moreover, the available K content in the soil could not rise in rice straw residue incorporation over control and graded inorganic fertilizer treatments as in green manure/farmyard manure. This could be attributed to more K removal than small addition in rice and wheat (Kumar *et al*. 2008).

It may be concluded that integrated nutrient management coupled with organic manures, green manures and fertilizers enhanced the productivity of rice–wheat cropping system and fertility of Inceptisols. The study disapproved the apprehension that the use of chemical fertilizers over the years may impair the soil fertility on long-term basis. Even application of nutrient (NPK), if applied in recommended dose could sustain the productivity and soil fertility of the system.

REFERENCES

Behera B, Maruthi Sankar G R, Mohanty S K, Pal A K, Ravindra Chari G, SubbaReddy G and Ramakrishna Y S. 2007. Sustainable fertilizer practices for upland rice (*Oryza sativa*) from permanent manurial trials under subhumid alfisols. *Indian Journal of Agronomy* **52**(2): 96–101.

Kumar Balvinder, Gupta R K and Bhandari A L. 2008. Soil fertility changes after long-term application of organic manures and crop residues under rice–wheat system. *Journal of the Indian Society of Soil Science* **56**(1): 80–85.

Gupta Vikas, Sharma R S and Vishwakarma S K. 2006. Long-term effects of integrated nutrient management on yield sustainability and soil fertility of rice (*Oryza sativa*)–wheat (Triticum aestivum) cropping system. *Indian Journal of Agronomy* **51**(3): 160–4.

Palaniappan S P and Annadurai K. 2007. *Organic Farming: Theory and Practices*, pp 169. Scientific Publishers, Jodhpur.

Sharma M P, Bali P and Gupta J P. 2003. Long-term effect of chemical fertilizers on rice-wheat productivity and fertility of an Inceptisols. *Annals of Agricultural Research* **24**(1): 91–94.

Sharma M, Mishra B and Singh R. 2007. Long-term effects of fertilizers and manures on physical and chemical properties of a Mollisol. *Journal of the Indian Society of Soil Science* **55**(4): 523–4.

Singh G, Singh O P Singh R G, Mehta R K, Kumar V and Singh R P. 2006. Effect of integrated nutrient management on yield and nutrient uptake of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in lowlands of eastern Uttar Pradesh. *Indian Journal of Agronomy* **51**(2): 85–8.

Tiwari K N. 2003. *Fundamental of Soil Science*, pp 362. Indian Society of Soil Science, IARI, New Delhi.

Yadav M P, Aslam Mohd and Kushwaha S P. 2005. Effect of integrated nutrient management on rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in central plains of Uttar Pradesh. *Indian Journal of Agronomy* **50**(2): 89–93.

Wanjari R H, Singh M V and Ghosh P K. 2004. Sustainable yield index: An approach to evaluate the sustainability of long-term intensive cropping systems in India. *Journal of Sustainable Agriculture*, *USA* **24**(4): 39–56.