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Influence of different nutrient management practices on productivity, profitability and nutrient dynamics in basmati rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping systems in western Indo-Gangetic Plains of India

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ABSTRACT

A field investigation was carried out at ICAR-Indian Institute of Farming Systems Research, Modipuram during 2013–15 to devise the best nutrient management strategy in basmati (*Oryza sativa* L.)– wheat (*Triticum aestivum* L. emend Fiori and Paol) cropping system. Investigation used six nutrient management practices, viz. 100% organic; 75% organic + innovative practices; 50% organic + 50% inorganic; 75% organic + 25% inorganic; state recommendation and 100% inorganic. Grain yield and nutrient uptake of basmati rice and wheat were found at par under organic (100% organic and 75% organic + innovative practices) and integrated nutrient management practices (50% organic + 50% inorganic and 75% organic + 25% inorganic), however it was significantly higher compared to 100% inorganic nutrient management. Organic nutrient management, i.e.100% organic and 75% organic + innovative practices resulted in 42.4 and 37.7% higher grain yield in case of basmati rice and 29.3 and 39.7% higher yield in case of wheat, respectively over 100% inorganic; besides being superior in terms of soil available N, P, K and organic carbon. Additional net returns to the tune of ₹ 53.2 × 10^3/ha and ₹ 59.7 × 10^3/ha from basmati rice-wheat cropping system was recorded under 100% organic and 75% organic + innovative practices, respectively over 100% inorganic. Nutrient management through 75% organic + innovative practices in basmati rice–wheat cropping system resulted in ₹ 6.5 × 10^3/ha additional returns over 100% organic nutrient management and it also scored highest in terms of nitrogen use efficiency of both basmati rice (48.5 kg/kg N) and wheat (38.1 kg/kg N). A significantly higher residual soil fertility in terms of available N, P, K and organic carbon in soil as compared to 100% inorganic nutrient management was also observed.

Key words: Basmati rice-wheat cropping system, Indo-Gangetic Plains, Nutrient uptake, Organic nutrient management, Productivity

Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend Fiori and Paol) cropping sequence (RWCS) is the world's largest agricultural production system occupying around 12.3 Mha in India with 85% area falling in Indo-Gangetic plains (IGPs). As a result of several decades of continuous cropping under conventional practices, the RWCS have shown evidences of soil nutrient depletion and imbalances, low nutrient use efficiency, a general reduction in soil organic matter, and stagnating yields (Gupta *et al*. 2003).

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In RWCS, soil anaerobic–aerobic cycles during rice and wheat, respectively combined with the often high soil pH and permeability result in high losses of fertilizer nitrogen (N) during both rice and wheat cultivation (Singh *et al*. 2002) which culminates into low crop productivity and nutrient use efficiency. Yield decline in rice–wheat sequence was observed highest when N requirement is met only through chemical fertilizers in case of non-basmati rice however, basmati rice responded well to organic production system (Ravisankar *et al*. 2015). Main reasons for low and declining crop response to fertilizers are continued and excessive use of N-fertilizers, intensive rice–wheat cropping sequence, injudicious use of fertilizers and inadequate use of organic manures. Besides, the alternate anaerobic–aerobic cycles result in differential availability of P for rice and wheat (Singh *et al*. 2000).

Prevailing state recommendations on fertilizers are based on crop response over large area, ignoring variations in soil fertility leading to inefficient use of added nutrients. Hence, diagnostic surveys in the IGPs revealed that farmers often apply greater than recommended rates of fertilizer N and P, but ignore the sufficient application of other limiting nutrients to the RWCS (Singh *et al*. 2013).

As the success of any cropping system depends upon the appropriate management of resources including balanced use of manures and fertilizers (Dasog *et al.* 2011), adopting integrated nutrient management practices (organic manures with fertilizers) and certified organic agriculture (organic manures and biofertilizers) can reduce reliance on chemical inputs as well as make agriculture environmentally and economically sound. The main objective of this study was to compare growth, productivity, economics, nutrient uptake, soil fertility and nutrient use efficiencies for the basmati rice-wheat cropping sequence and to explore the possibility of reducing the quantity of organic manure under different combination of organic-inorganic nutrient inputs.

MATERIALS AND METHODS

A field experiment was conducted during 2013–14 and 2014–15 at Research Farm of ICAR-IIFSR, Modipuram, Meerut (UP) (29.4' N latitude, 77.5' E longitude and 230 m AMSL). It falls under the North-western plain agro-climatic zone. Climate of Meerut is classified as semi-arid sub-tropical and experienced a rainfall of 1012.2 mm and 460.5 mm during cropping seasons 2013–14 and 2014–15, respectively. The soil at site was typic Ustochrept deep sandy loam and slightly saline in nature (pH 8.2). The experimental site was already maintained since 2004–05 as part of long term Network Project on Organic Farming and the data being presented are from the ninth and tenth cropping cycle.

The treatments included six nutrient management practices, viz. 100% organic (T_1); 75% organic + innovative practices (T_2); 50% organic + 50% inorganic (T_3), 75% organic + 25% inorganic (T_4), state recommendation (T_5) and 100% inorganic (T_6). The experiment was carried out in randomized complete block design with four replications. Before randomization, the plots maintained under 100% organic management were split into T_1 and T_2, plots maintained under integrated nutrient management split into T_3 and T_4 while plots maintained under 100% inorganic management were split into T_5 and T_6. The state recommendations of nutrient management for basmati rice and wheat were 120:60:60 kg/ha N:P:K + 10.0 t/ha FYM and 150:60:40 kg/ha N:P:K + 4.0 t/ha FYM, respectively. In different treatments the recommended quantity of nutrients were supplied through FYM and vermicompost (VC) as organic source of nutrients and urea, DAP and MOP were used as inorganic sources of NPK. In treatment T_2 25% of recommended N was substituted and *Azotobacter*, PSB, *Trichoderma* and neemcake were applied as innovative practices. In both the crops *Azotobacter*, PSB and *Trichoderma* were applied as seed and seedling treatment, while neemcake (@ 250 kg/ha) was incorporated in soil at final land preparation. The manure in organic (T_1 and T_2) and integrated nutrient management (T_3 and T_4) were applied based on recommended fertilizer N equivalent (Table 1). The equivalent quantity of the manures was calculated based on the nutrient content in different manures.

Cropping sequence followed for experimentation was *Sesbania* green manure (summer) - basmati rice (*Kharif*)- wheat (*Rabi*). For raising *Sesbania* 20 kg seeds/ha were broadcasted in the field around 60 days before rice transplanting. In rice and wheat, standard crop management practices were followed in both the crops. The 25 days old seedling of rice cv. Pusa Basmati-6 were transplanted in first week of July by keeping planting geometry of 20 × 15 cm and harvested in second week of November during both the years. After harvesting of rice, wheat was sown on the same layout superimposing the same treatments. Wheat cv. HI 8498 was sown in third week of November in rows 20 cm apart using 100 kg seed/ha and harvested in second week of April. In rice, 12 irrigations including puddling were applied while in wheat a total of seven irrigations were applied including pre-sowing irrigation. In both the crops weed control was done twice manually.

As a component of cropping system *Sesbania* green manure was applied in all the treatments. *In situ* grown *Sesbania* green manure was incorporated in the soil at

Table 1 Application of nutrient source as per treatments

Nutrient management practice	Treatment	Basmati rice	Wheat
Organic	T1- 100% organic	FYM @ 10.9 t/ha+ VC @ 4.9 t/ha	FYM @ 13.6 t/ha+ VC @ 6.1 t/ha
	T2- 75% organic + innovative practices	FYM @ 8.2 t/ha+ VC @ 3.7 t/ha + *Azotobacter*, PSB, *Trichoderma* & Neemcake @ 250 kg/ha	FYM @ 10.2 t/ha+ VC @ 4.6 t/ha + *Azotobacter*, PSB, *Trichoderma* & Neemcake @ 250 kg/ha
Integrated	T3- 50% organic + 50% inorganic	FYM @ 5.5 t/ha + VC @ 2.5 t/ha + Urea @ 130 kg/ha	FYM @ 6.8 t/ha + VC @ 3.1 t/ha + Urea @ 163.0 kg/ha
	T4- 75% organic + 25% inorganic	FYM @ 8.2 t/ha+ VC @ 3.7 t/ha + Urea @ 65 kg/ha	FYM @ 10.2 t/ha+ VC @ 4.6 t/ha+ Urea @ 82 kg/ha
Inorganic	T5- State recommendation	FYM @ 10.0 t/ha+ Urea @ 210 kg/ha+ DAP @130 kg/ha+ MoP @100 kg/ha	FYM @ 4.0 t/ha+ Urea @ 275 kg/ha+ DAP @130 kg/ha+ MoP @67 kg/ha
	T6- 100% inorganic	Urea @ 210 kg/ha+ DAP @ 130 kg/ha+ MoP @100 kg/ha	Urea @ 275 kg/ha+ DAP @130 kg/ha+ MoP @ 67 kg/ha

least 20 days before sowing. The FYM was incorporated in soil at final land preparation and the vermicompost was applied at first irrigation. In both the crops one third dose of fertilizer N and full dose of P and K were applied as basal dose at sowing; while remaining N was top-dressed in two equal splits, i.e. 25 and 55 DAT in rice, and 25 and 60 DAS in wheat.

The observations on growth attributes, yield attributes and yields of the crops were recorded through standard procedures. Plant samples (grain and straw) were collected at harvest and analyzed for NPK content. Soil samples (0–15 cm depth) were collected from plots of different treatments after completion of each cropping cycle and analyzed for available N, P, K and soil organic carbon (SOC) content in soil following standard laboratory procedures. For economic analysis, minimum support price (MSP) of basmati rice and wheat grain fixed by the government was used for calculation of returns. The prices for basmati rice and wheat straw were the prevailing price in locale. For organic produce of basmati rice and wheat (T_1 and T_2) 20% premium price was assumed over and above the MSP. System productivity was estimated in terms of Basmati Rice Equivalent Yield (BREY) as per the formulae; BREY = Yx (Px / Pr), where; Yx is the yield of wheat (t/ha), Px is the price of wheat (₹/t), and Pr is the price of basmati rice. The equations used to quantify the effect of different nutrient management practices on the Nitrogen Use Efficiency (NUE), Partial Factor Productivity of NPK (PFP_{NPK}) and Nutrient Efficiency Ratio (NER) in basmati rice and wheat are given here.

$$\text{NUE} = \frac{\text{Grain yield (kg/ha)}}{\text{Quantity of N applied (kg/ha)}}$$

$$\text{PFP}_{\text{NPK}} = \frac{\text{Grain yield (kg/ha)}}{\text{Quantity of NPK applied (kg/ha)}}$$

$$\text{NER} = \frac{\text{Total biomass (kg/ha)}}{\text{Quantity of utilized N (N Uptake) (gk/ha)}}$$

The data pertaining to growth and yield attributes, yields, nutrient uptake, and soil fertility parameter were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test for RCBD using the SPSS software package (SPSS v.16, Armonk NY). To separate treatment means within each measured parameter, Tukey's Honest Significant Difference (HSD) post hoc test was performed at P = 0.05.

RESULTS AND DISCUSSION

Growth and yield attributes

Data pertaining to growth and yield attributes of basmati rice and wheat (Table 2) revealed that crop growth in terms of dry matter accumulation (DMA) at harvest couldn't differ significantly under different nutrient management practices; however the highest and lowest values of DMA of basmati rice (897.8 and 780.7 g/m^2) and wheat (988.0 and 835.1 g/m^2) were recorded under T_4 and T_6, respectively. The treatment T_4 being at par to T_5, T_3, T_2 and T_1 recorded significantly higher yield attributes, viz. tillers/m^2 (237.7), panicles/m^2 (224.8) and grains/panicle (112.5) in basmati rice and effective tillers/m^2 (246.2) and grains/spike (50.6) in wheat over T_6. The 1000-seed weight in both basmati rice and wheat did not differ significantly under different treatments. The addition of organic manure significantly influenced the beneficial microorganisms to colonize in rhizosphere and stimulate plant growth by providing necessary nutrients besides synthesizing some plant hormones (Venkatasalam *et al*. 2012); which may be the reason for increase in growth and yield attributes in treatments supplied with organic manures. As contrary to the trend in basmati rice, the DMA and yield attributes of wheat in T_2 (75% organic + IP) were noted high over T_1 (100% organic) and T_3 (50% organic + 50% inorganic). This may be due to easy availability of N and P due to beneficial role of biofertilizers and K because of less leaching in aerobic conditions of *rabi* season in T_2.

Productivity

The grain and biological yields of basmati rice and wheat exhibited significant variation due to different nutrient management practices (Table 3). Application of N in 75% organic + 25% inorganic form (T_4) recorded the highest grain yield of basmati rice (4.73 t/ha) and wheat (4.44 t/ha)

Table 2 Growth and yield attributes of basmati rice and wheat under different nutrient management practices (average of two years)

Treatment	Basmati rice					Wheat			
	Dry mater (g/m^2) at harvest	Tillers/m^2	Panicles/m^2	Grains/pancle	1000-grain weight (g)	Dry matter (g/m^2) at harvest	Effective tillers/m^2	Grains/spike	1000-grain weight (g)
100% organic (T1)	886NS	231b	214b	106bc	23.4NS	970NS	239b	47.5ab	43.0NS
75% organic + IP (T2)	882NS	226b	211b	103bc	23.4NS	984NS	244b	50.6b	44.0NS
50% organic + 50% inorgaic (T3)	895NS	237b	219b	109bc	23.8NS	975NS	243b	47.5ab	43.7NS
75% organic + 25% inorgaic (T4)	898NS	238b	225b	112c	24.1NS	988NS	246b	50.6b	44.5NS
State recommendation (T5)	822NS	207ab	197ab	97.2ab	22.6NS	896NS	218ab	45.4ab	44.4NS
100% inorganic (T6)	781NS	190a	188a	86.4a	21.0NS	835NS	203a	40.7a	43.8NS

Means followed by similar lowercase letter within a column are not significantly different (at P<0.05) according to Tukey's HSD test.

Table 3 Yields of basmati rice and wheat and Basmati Rice Equivalent Yield (BREY) under different nutrient management practices (average of two years)

Treatment	Basmati rice			Wheat			BREY (t/ha)
	Grain yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)	
100% organic (T_1)	4.50c	11.5b	39.1NS	3.97bc	10.1b	39.5NS	7.14bc
75% organic + IP (T_2)	4.35bc	11.4b	38.2NS	4.29c	10.6b	40.5NS	7.19bc
50% organic + 50% inorganic (T_3)	4.61c	12.0b	38.4NS	4.09bc	10.4b	39.3NS	7.32c
75% organic + 25% inorganic (T_4)	4.73c	12.1b	39.4NS	4.44c	10.9b	41.3NS	7.71c
State recommendation (T_5)	3.69ab	9.60ab	38.6NS	3.48ab	9.20ab	38.0NS	6.00ab
100% inorganic (T_6)	3.16a	8.50a	37.0NS	3.07a	8.20a	37.5NS	5.07a

Means followed by similar lowercase letter within a column are not significantly different (at $P<0.05$) according to Tukey's HSD test.

and found statistically at par with T_3, T_2 and T_1. Similar trends were observed in biological yield of both the crops. The lowest grain yield (3.16 and 3.07 t/ha) and biological yield (8.50 and 8.20 t/ha) of both basmati rice and wheat, respectively were recorded in T_6 (100% inorganic treatment). Both in terms of grain and biological yield organic (T_1 and T_2), integrated (T_3 and T_4); state recommendation and inorganic nutrient management practices (T_5 and T_6) were found at par to each other. These trends are in consonance with earlier reports of Bhattacharyya *et al.* (2010). However, harvest index of both the crops was not influenced significantly due to different nutrient management practices. Higher productivity in the T_4 -T_1 plots compared with T_5 and T_6 could be associated with advantages of organic inputs in enhancing soil microbial activities, supply of micronutrients and reduced losses of nutrients (Gopinath *et al.* 2008) and improved physical and chemical properties of the soil. Due to higher growth and yield attributes, yields of wheat in T_2 (75% organic + IP) and T_1 (100% organic) were higher as contrary to the trends in basmati rice. The enhanced performance of T_2 in wheat might be due to faster and quick release of nutrients in available form from decomposition of soil organic matter and applied manures besides enhanced P availability owing to PSB under aerobic conditions as contrast to the anaerobic edaphic condition in basmati rice.

Productivity of basmati rice-wheat cropping system in terms of BREY was recorded significantly higher in the integrated nutrient management practices like T_3 (7. 32 t/ha) and T_4 (7.71 t/ha) followed by organic nutrient management practices like T_1 (7.14 t/ha) and T_2 (7.19 t/ha) over inorganic nutrient management (T_6) (5.07 t/ha) and state recommendation (T_5) (6.00 t/ha) (Table 3). Due to higher yield of wheat in T_2 as compared to T_1 the system productivity also followed the same trend. The buildup of soil fertility in terms of available N, P, K and SOC in organic and integrated nutrient management practices as compared to inorganic management might have resulted in better nutrient uptake by the crops resulting in higher growth and yield attributes and higher yield and system productivity (BREY).

Nutrient uptake

The N, P and K uptake by both basmati rice and wheat; and BRWCS varied significantly under different nutrient management practices (Table 4). Organic (T_1 and T_2) and integrated nutrient management practices (T_3 and T_4) recorded significantly higher uptake of N, P and K by the basmati rice and wheat crops as compared to inorganic nutrient management (T_6). Integrated nutrient management practices, i.e. T_3 in basmati rice and T_4 in wheat and BRWCS being at par with organic nutrient management (T_1 and T_2) recorded significantly higher uptake of N over T_6. Further, both in basmati rice and wheat, T_4 being at par with T_3 recorded significantly higher P uptake over T_6. However, T_1 and T_5 could not make significant differences over T_6. Similarly in terms of K uptake, T_4 being at par with T_1, T_2 and T_3 found to be significantly superior over T_6 and T_5

Table 4 NPK uptake (kg/ha) of basmati rice, wheat and BRWCS under different nutrient management practices (average of two years)

Treatment	N			P			K		
	Basmati rice	Wheat	BRWCS	Basmati rice	Wheat	BRWCS	Basmati rice	Wheat	BRWCS
100% organic (T_1)	97.3^{bc}	82.7^{bc}	180^{b}	17.7^{abc}	18.0^{abc}	35.7^{b}	98.5^{ab}	114^{bc}	212^{bc}
75% organic + IP (T_2)	101^{c}	90.0^{c}	191^{bc}	18.6^{bc}	19.5^{bc}	38.1^{bc}	95.5^{ab}	111^{b}	207^{abc}
50% organic + 50% inorganic (T_3)	111^{c}	87.6^{c}	198^{c}	20.4^{cd}	21.6^{bc}	42.0^{cd}	102^{ab}	118^{bc}	220^{bc}
75% organic + 25% inorganic (T_4)	108^{c}	92.8^{c}	201^{c}	22.5^{d}	22.5^{c}	45.1^{d}	106^{b}	125^{c}	231^{c}
State recommendation (T_5)	86.8^{ab}	75.2^{ab}	162^{a}	16.8^{ab}	17.0^{ab}	33.7^{ab}	94.4^{ab}	98.0^{a}	192^{ab}
100% inorganic (T_6)	79.9^{a}	69.5^{a}	149^{a}	15.6^{a}	14.0^{a}	29.6^{a}	90.8^{a}	88.3^{a}	179^{a}

Means followed by similar lowercase letter within a column are not significantly different (at $P<0.05$) according to Tukey's HSD test.

in basmati rice, wheat and RWCS. The higher uptake of nutrients under integrated nutrient management (T_3 and T_4) was ascribed to continuous supply of nutrients throughout the crop growth period as the nutrients from inorganic sources were readily available to the crop in the early stages besides the slow and continuous release of nutrients from the organic source made available at later stages of the crop growth. Higher uptake of N, P and K under organic-inorganic nutrient combination was also reported by Devi *et al.* (2011) in wheat.

Moreover, among organic nutrient management practices T_2 recorded higher N and P uptake over T_1. It might have been due to the beneficial role of biofertilizers in N fixation, P solublization and mobilization of more amounts of nutrients in readily available form in the soil. Increased nutrient availability in the soil resulted in higher uptake of the nutrients by plants which enhance the vegetative growth which ultimately increased nutrients uptake due to higher total biomass (Jat *et al*. 2012). Due to higher biomass accumulation, T_5 recorded higher NPK uptake over T_6 but it was found statistically non-significant.

Soil fertility status

Due to different nutrient management practices over two years, perceptible changes in soil fertility in terms of available N, P, K and SOC was observed as compared to the initial status before start of experimentation (Table 5). The available N, P, K and SOC showed build up in soil under both organic and integrated nutrient management practices (T_1–T_4). However, the available N, P, K and SOC content were decreased in soil under inorganic nutrient management (T_6) during study period. At the end of second year of the study, the available N, P, K and SOC were significantly higher in organic nutrient management practices (T_1 and T_2) compared to inorganic nutrient management (T_6); it was at par with integrated nutrient management practices (T_3 and T_4). Continuous application of manure increases the level of N, P, K, in the soil over the years (Ginting *et al.* 2003) thus creating a reservoir of nutrients in soil. Application of organic manures like FYM, VC and green manure and their subsequent mineralization under high enzymatic activities in the soil might have enhanced the transformation of nutrients to available form. Role of FYM, VC and green manure in improving N, P and K availability in soil was also reported earlier by Singh *et al.* (2008).

Results further revealed that T_2 with application of 75% of nutrients through organic sources along with bio-fertilizer strains was observed statistically at par with 100% organic nutrient management (T_1) in terms of available NPK and SOC status of soil. Similar results were also confirmed by Singh *et al.* (2015). Similarly, the integrated nutrient management in T_4 (75% organic + 25% inorganic) was also found at par with T_3 (50% organic+50% inorganic) in terms of soil fertility parameters. This improvement in soil fertility was attributed to addition of FYM and VC which stimulated the growth and activity of microorganisms and thus increases the nutrients availability in the soil.

Table 5 Soil fertility status under different nutrient management practices at the end of experiment (average of two years)

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	SOC (%)
100% organic (T_1)	253c	24.5c	285b	0.721c
75% organic + IP (T_2)	255c	25.0c	282b	0.712c
50% organic + 50% inorganic (T_3)	205b	19.0b	270b	0.622b
75% organic + 25% inorganic (T_4)	202b	17.8b	267b	0.608b
State recommendation (T_5)	151a	17.3b	178a	0.430a
100% inorganic (T_6)	145a	13.8a	172a	0.374a

Means followed by similar lowercase letter within a column are not significantly different (at P<0.05) according to Tukey's HSD test.

Nitrogen Use Efficiency (NUE), Partial Factor Productivity (PFPNPK) and Nitrogen Efficiency Ratio (NER)

Results revealed that NUE, PFP_{NPK} and NER of the crops varied markedly under different nutrient management practices with the same level of N application. The values of these efficiency indices were recorded substantially higher under organic (T_1 and T_2) and integrated (T_3 and T_4) as compared to inorganic nutrient management (T_6) and this may be attributed to application of organic manures for longer time, i.e. previous 8 years. Application of 75% organic + innovative practices (T_2) recorded the highest NUE for both basmati rice and wheat and PFP_{NPK} of wheat than the 100% organic (T_1) and 100% inorganic nutrient management (T_6). However, the T_3 recorded the highest PFP_{NPK} of basmati rice while T_1 followed by T_6 recorded the maximum NER (N) of basmati rice-wheat system. Adoption of efficient NPK management practices is responsible for higher partial factor productivity (Yadav 2003). The 100% inorganic nutrient management (T_6) followed by state recommendation (T_5) registered the lowest values of NUE, PFP_{NPK} and NER. This is due to nutrient imbalance, decline in indigenous nutrient supply, subsoil compaction and reduced root volume under continuous application of inorganic fertilizers in T_6 which is also indicated by the soil fertility status under the treatment. Moreover, decomposition of organic manures like FYM and VC might have supplied plant nutrients in available form directly to plants and also created favourable soil environment by increasing the nutrients and water-holding capacity of soil for longer time, which resulted in better growth, yield attributes and ultimately grain yields and biomass production of crops.

Economics

Economic analysis reveals that the net returns and B:C ratio of basmati rice, wheat and BRWCS differed noticeably in different nutrient management options (Table 6) and that was directly related to the price of the crop produce and cost incurred on nutrient inputs under different treatments. Variable cost was involved with source of nutrient input

Table 6 Economics of basmati rice, wheat and BRWCS under different nutrient management practices (average of two years)

Treatment	Basmati rice			Wheat			BRWCS*				
	Variable cost (10^3 × ₹/ha)	Net returns (10^3 × ₹/ha)	B:C ratio	Variable cost (10^3 × ₹/ha)	Net returns (10^3 × ₹/ha)	B:C ratio	Variable cost (10^3 × ₹/ha)	Net returns (10^3 × ₹/ha)	B:C ratio	Additional cost over T_6 (10^3 × ₹/ha)	Additional returns over T_6 (10^3 × ₹/ha)
100% organic (T_1)	19.9	99.3$	2.26	24.7	35.5$	0.76	50.9	135$	1.49	33.1	53.2$
75% organic + IP (T_2)	17.9	96.5$	2.30	21.5	44.9$	1.03	45.7	141$	1.65	27.9	59.7$
50% organic + 50% inorganic (T_3)	12.7	93.5	2.56	15.3	37.6	1.01	34.2	131	1.78	16.4	49.5
75% organic + 25% inorganic (T_4)	16.4	93.9	2.33	20.0	38.1	0.91	42.6	132	1.60	24.8	50.4
State recommendation (T_5)	9.00	71.3	2.17	7.40	34.5	1.18	22.7	106	1.70	4.90	24.1
100% inorganic (T6)	5.50	58.2	1.98	6.00	23.5	0.84	17.8	81.7	1.43		

*Cost of *Sesbania* green manuring (₹ 6200/ha) was included in total cost of cropping sequence. $Premium price (20% higher over prevailing market price) was added in organically produced basmati rice and wheat yield.

in different treatments. Data shows that in terms of net returns organic farming (T_1 and T_2) led to higher economic gains as compared to inorganic and integrated nutrient management (T_3–T_6). The highest net returns of basmati rice (₹ 99.3 × 10^3/ha) were recorded in T_1 followed by T_2 while, the highest net returns of wheat (₹ 44.9 × 10^3/ha) and BRWCS (₹ 141.4 × 10^3/ha) were recorded in T_2. Due to higher yields and inclusion of premium price, additional returns under organic nutrient management practices like T_1 and T_2 were higher to the tune of ₹ 53.2 × 10^3/ha and ₹ 59.7 × 10^3/ha, respectively as compared to T_6. These findings pointed towards the scope for financial security under organic nutrient management system in long term. Similar observations were also noted by Malika *et al.* (2015). Considering the B : C ratio, treatment T_3 ranked first in basmati rice (2.56) and BRWCS (1.78); however the B:C ratio of wheat (1.18) was recorded highest under T_5. It was due to less requirement of organic manure at 50% substitution through inorganic fertilizers in T_3 and less variable cost of production than T_1, T_2 and T_4 (Table 6).

We conclude from our results that the supply of nutrients either through organic sources or in combination with inorganic sources in basmati rice-wheat cropping system gave at par yield. However, yield of Basmati-rice cropping systems (BRCS) with 20% higher price over prevailing market price, i.e. Basmati Rice Equivalent Yield (BREY) was quite higher over 100% inorganic nutrient management system. It was also noticed that, in organic cultivation of basmati rice–wheat cropping system, through application of bio-fertilizers 25% quantity of organic manures can be reduced without affecting the crop yields besides giving additional net returns of ₹ 6500/ha as compared to application of 100% manure equivalent to recommended dose of fertilizers.

REFERENCES

Bhattacharyya R, Kundu S, Prakash V and Gupta H S. 2008. Sustainability under combined application of mineral and organic fertilizers in a soybean-wheat system of the Indian Himalayas. *European Journal of Agronomy* **28**: 33–46.

Dasog V G S, Babalad H B, Hebsur N S, Gali S K, Patil S G and Alangawadi A R. 2011. Influence of nutrient management practices on crop response and economics in different cropping systems in vertisol. *Karnataka Journal of Agricultural Sciences* **24**(4): 455–60.

Devi K N, Singh M S, Singh N G and Athokpam H S. 2011. Effect of integrated nutrient management on growth and yield of wheat *(Triticum aestivum* L.) *Journal of Crop and Weed* **7**(2): 23–7.

Ginting D, Kessavalou A, Eghball B and Doran J W. 2003. Greenhouse gas emissions and soil indicators four years after manure compost application. *Journal of Environmental Quality* **32**: 23–32.

Gopinath K A, Saha R, Mina B L, Pande H, Kundu S and Gupta H S. 2008. Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Nutrient Cycling in Agroecosystems* **82**: 51–60.

Gupta R K, Naresh R K, Hobbs P R, Jiaguo Z and Ladha J K. 2003. Sustainability of post-green revolution agriculture: the rice–wheat cropping systems of the Indo-Gangetic Plains and China, *Improving the productivity and sustainability of Rice–Wheat systems: Issues and Impact,* pp. 1–25. Ladha J K, Hill J E, Duxbury J M, Gupta R K and Buresh R J (Eds.). ASA Special Publication No. 65. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison,Wisconsin, USA.

Jat N K, Kumar A, Meena S R, Rana D S, Meena B P and Rana K S. 2012. Influence of integrated nutrient management on the productivity, quality and soil health of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **57**(4): 327–32.

Malika M, Islam Md. R, Karim R, Huda A and Jahiruddin M. 2015. Organic and inorganic fertilizers influence the nutrient use efficiency and yield of a rice variety BINA dhan 7. *Academic Research Journal of Agricultural Science and Research* **3**(7): 192–200.

Ravisankar N, Kumar V, Shamim M and Dutta D. 2015. Network Project on Organic Farming. Annual Report 2014-15, ICAR-Indian Institute of Farming Systems Research, Modipuram, pp. 1–150.

Singh A B, Saha J K and Gosh P K. 2008. Effect of nutrient management practices on soybean (*Glycine max*)-chickpea (*Cicer arietinum*) cropping systems for improving seed yield, quality and soil biological health under rain fed condition. *Indian Journal of Agricultural Sciences* **78**(6): 485–9.

Singh B, Singh Y, Ladha J K, Bronson K F, Balasubramanian V, Singh J and Khind C S. 2002. Chlorophyll meter and leaf color chart-based nitrogen management for rice and wheat in north eastern India. *Agronomy Journal* **94**: 821–9.

Singh M, Beura K, Pradhan A K and Kumar N. 2015. Conjunctive organic and mineral fertilization-its role in nutrient uptake and yield of soybean under mollisol. *Ecoscan* **10**(3): 1275–9.

Singh V K, Dwivedi B S, Buresh R J, Jat M L, Majumdar K, Gangwar B, Govil V and Singh S K. 2013. Potassium fertilization in rice–wheat system on farmer's fields in India: crop performance and soil nutrients. *Agronomy Journal* **105**: 471–81.

Singh Y, Dobermann A, Singh B, Bronson K F and Khind C S. 2000. Optimal phosphorus management strategies for rice–wheat cropping on loamy sand. *Soil Science Society of America Journal* **64**: 1413–22.

Venkatasalam E P, Singh S and Sharma S. 2012. Effect of organic manures on yield and yield attributing characters of potato. *Potato Journal* **39**(1): 84–7.

Yadav R L. 2003. Assessing on-farm efficiency and economics of fertilizer N, P and K in rice–wheat systems in India. *Field Crops Research* **81**: 39–51.