Journal of the Indian Society of Soil Science, Vol. 66, No. 3, pp 287-294 (2018)
DOI: 10.5958/0974-0228.2018.00035.X

Conjoint Application of Organic and Inorganic Sources of Nutrients on Yield, Nutrient Uptake and Soil Fertility under Rice (*Oryza sativa*)–Wheat (*Triticum aestivum*) System

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A field experiment was conducted for three years on a sandy loam soil at Varanasi, Uttar Pradesh to study the direct effect of three sources of organic manures *i.e.*, sewage sludge (SS), vermicompost (VC) and *Sesbania* green manure (GM) in combination with 75% of recommended fertilizers (RDF). Other treatments were: absolute control, 100% RDF + SZnB and customized fertilizer (CF) under rice-wheat system. Grain yield of rice in RDF + SZnB and CF was statistically at par with RDF (4.47 t ha^{-1}). Supplementing 25% N through SS resulted in a significant decrease in grain yield of rice over RDF. However, grain yield of rice was at par with RDF when 25% N was supplemented through VC or GM. In following wheat, grain yield was similar under all the treatments except for absolute control (without fertilizers), which produced significantly lower yields. Application of VC or GM at 25% of recommended N could sustain the yield of rice-wheat system along with 75% RDF. Total removal of N, P, K, S, Zn and B was higher by rice than wheat, indicating its nutrients exhaustive nature. Soil pH and EC did not change significantly with the application of organic and inorganic sources of nutrients. Organic carbon content in soil increased significantly by supplementing fertilizers with organic sources. Differential pattern of nutrient build-up was recorded in the post-harvest soil samples. In post-rice soil, N, K and S did not show significant build-up while P and Zn contents increased significantly. Application of S, Zn and B significantly increased their contents in soil over RDF. In post wheat harvest soil, application of CF showed a significant increase in P content. Application of organics over three years resulted in a significant increase of Zn over 100% RDF.

Key words: Organic and inorganic sources of nutrients, yields, uptake, soil fertility, rice–wheat system

Sustainable agriculture is dependent on sound nutrient management practices. Intensive cultivation and imbalanced fertilizer use have lead to multiple nutrient deficiencies in Indian soils. As a result, yields of various crops have reached a plateau or are on the decline. Several nutrient management options have been practiced by the farmers, however, the best one is an integration of organic and inorganic sources. It is widely recognized that neither use of organic manures alone nor chemical fertilizers can achieve the yield sustainability under the modern intensive farming (Kumar *et al*. 2014). Therefore, it is necessary to use organic manures in conjunction with fertilizers to meet nutrient requirement and obtain optimum yields.

Green revolution technologies in the mid-1960s led to emergence of rice (*Oriza sativa*)-wheat (*Triticum aestivum*) (RW) as the major production system covering an area of about 10 million hectares (Mha) in the Indo-Gangetic Plains (IGP) of India (Yadvinder-Singh and Sidhu 2014). A significant increase in productivity of this system has been achieved due to introduction of high yielding and disease resistant crop varieties, increased use of fertilizers, better irrigation facilities, better farm machinery and implements, *etc*. The RW cropping system is highly nutrient exhaustive and removes annually more than 650 kg ha^{-1} of N, P and K in

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addition to 0.5-1.0 kg Zn ha^{-1}, 2-3 kg Fe ha^{-1} and 3.0-3.5 kg Mn ha^{-1} (Shah *et al.* 2011). The RW system, as a result of several decades of continuous cropping showed stagnation in yields which is mainly due to soil nutrient depletion and imbalances, low nutrient use efficiency and reduction in soil organic matter (Gupta *et al.* 2003).

Organic amendments such as sewage sludge (SS) and vermicompost (VC) invariably contain all essential plant nutrients, which are released into the soil solution upon their decomposition by microorganisms. Green manuring (GM), using *Sesbania* before transplanting of rice has been advocated to improve yields and to partially meet N requirement of rice (Singh 1984). Residual effect of GM plus 100% recommended dose of NPK (100% RDF) significantly increased the yield of wheat over 100% RDF. Sen and Bandyopadhyay (2001) reported that application of fertilizers supplemented through organic manure produced significantly higher yield of rice than fertilizers alone. Customized fertilizers (CFs) are also becoming the need of the hour for application of these nutrients in balanced quantity to enhance the yield and soil fertility status under RW cropping system. Customized fertilizers have been included in the Fertilizer Control Order (FCO 2018), as a new category of fertilizers that are area/soil/crop specific. Customized fertilizers are ready-to-use granulated multinutrient fertilizers, formulated on sound scientific plant nutrition principles integrated with soil information, extensive laboratory studies and evaluated through field research. Keeping the above fact in view, this study was initiated to study the effect of supplementation of fertilizers with different organics on yield and fertility of soil under RW system.

Materials and Methods

The field experiment was conducted for three consecutive years at the Agricultural Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh during the rainy (*kharif*) and winter (*rabi*) season of 2012 to 2015. Initial soil samples were taken from 15 different places from the experimental field using a 5 cm diameter auger. Soil samples were mixed thoroughly, air-dried in the shade, crushed to pass through a 2-mm sieve and stored in polythene bag for analysis. The SS sample was collected from Bhagwanpur sewage treatment plant and VC and GM were obtained from Agriculture Research Farm, BHU. The farm lies in the northern Gangetic alluvial plain (25°18' N, 83°03' E at 129 m above the mean sea level). Varanasi falls in a semi-arid to sub-humid climate with moisture deficit index between 20-40. The normal period for onset of monsoon in this region is the 3rd week of June which lasts up to end of September or sometimes extends up to the 1st week of October. Showers of rain are often experienced during winter season. The annual rainfall of this region is about 1100 mm. Generally, the maximum and the minimum temperature ranged between 20-42 °C and 9-28 °C, respectively. May and June are the hottest months with maximum temperature ranging from 39 to 42 °C. The cold period lies between November and January with minimum temperature varying from 90-10 °C. The mean relative humidity is about 68% which rise to 82% during wet season and goes down to 30% during dry season.

Soil of the experimental field was sandy loam in texture (54.7% sand and 25.3% clay).The initial soil properties were: pH (8.18), electrical conductivity (0.18 dS m^{-1}), organic carbon (4.7 g kg^{-1}), available N (138.5 kg ha^{-1}), P (23.5 kg ha^{-1}), K (139.1 kg ha^{-1}) and S (20.7 mg kg^{-1}). The DTPA-extractable Zn and hot $CaCl_2$-extractable B levels in soil were 0.5 and 0.6 mg kg^{-1}, respectively. The chemical compositions with respect to N, P K, S, B and Zn content of the organic sources (SS, VC and GM) used to supplement the fertilizers are presented in table 1.

The experiment was laid out in a randomized block design with 8.0 m × 3.2 m net plot size having three replications. The treatment details for rice and wheat are presented in table 2. The same sequence of treatments was followed for three years. The N, P, K, S, Zn and B were applied through urea, diammonium phosphate (DAP), muriate of potash (MOP), gypsum, zinc sulphate and borax, respectively. Half dose of N and full dose of P and K were applied as basal while remaining N was applied in 2 equal splits at 30 and 60 days after transplanting/ sowing (DAT/DAS) in both rice and wheat. The quantities of SS, VC and GM were calculated on the basis of their N content and incorporated in plots on dry-weight basis 10 days prior to transplanting/sowing. Twenty-five-day old-

Table 1. Nutrient composition of organic sources (dry weight basis) (3 years mean data)

Nutrient	Sewage sludge	Vermicompost	*Sesbania*
N (%)	1.33	1.45	2.29
P (%)	0.21	0.46	0.30
K (%)	0.14	0.55	0.84
S (%)	0.44	0.39	0.36
B (mg kg^{-1})	2.10	1.32	1.38

Table 2 . Treatment details of the field experiment

Treatment symbols	Rice (HUR 105)	Wheat (Malviya 234)
T_1	Control (without fertilizers)	Control (without fertilizers)
T_2	RDF * (N:P_2O_5:K_2O@120-60-60 kg ha^{-1})	RDF - NPK (N:P_2O_5:K_2O@120-60-60 kg ha^{-1})
T_3	RDF + S: Zn: B @ 40:05:1.5 kg ha^{-1}	RDF
T_4	Customized Fertilizer [11 : 32 : 13 : 0.9 : 0.24 (N : P_2O_5 : K_2O : Zn : B)]	Customized Fertilizer* [10 : 18 : 25 : 3.0 : 0.5 (N : P_2O_5 : K_2O : S:Zn)]
T_5	75% RDF + 25% N through sewage sludge (SS)	RDF
T_6	75% RDF + 25% N through vermicompost (VC)	RDF
T_7	75% RDF + 25% N through *Sesbania* (GM)	RDF

RDF*= Recommended dose of fertilizers

seedlings of rice were transplanted manually at a distance of 20 cm from row to row and 15 cm from plant to plant while wheat was shown at a distance of 22.5 cm from row to row.

Chemical analyses

Grain and straw samples of rice and wheat were collected at maturity and washed in detergent solution (0.2% liquid), 0.1 *N* HCl solution and deionized water in sequence and dried at 70 °C till the constant weight. Straw, grain, VC, GM and SS samples were digested in di-acid mixture (HNO_3:$HClO_4$:: 3:1, v/v), and analyzed for P and K. Total N was determined in samples digested in H_2SO_4 (Tandon 2001). The content of Zn in the di-acid digest was determined using atomic absorption spectrophotometer (UNICAM – 969).The soil samples were collected after the harvest of rice and wheat crop. The post-harvest soil samples were analyzed for pH in 1:2.5 soil: water suspension; organic carbon (Walkley and Black 1934); available N (Subbiah and Asija 1956); $NaHCO_3$ extractable-P (Olsen *et al*. 1954), ammonium acetate extractable K (Hanway and Heidel 1952) and 0.15% $CaCl_2$ extractable S by developing turbidity using $BaSO_4$ (Chesnin and Yien 1951) and DTPA extractable Zn (Lindsay and Norwell 1978) by atomic absorption spectrophotometer following the procedure outlined in Sparks (1996). The soil samples were analyzed for available B by extracting with hot 0.02*M* $CaCl_2$ (Aitken *et al*. 1987) as it does not alter the amount of B extracted and gives a clear and colourless extract. Boron content in the soil extract and plant digest was determined by spectrophotometer using Azomethine-H (John *et al*. 1975).

Statistical Analysis

Data of three years of study were pooled and subjected to one-way analysis of variance (ANOVA) using SPSS version 16 software. Duncan's multiple range test (DMRT) was performed to test the significance of difference between the treatments.

Results and Discussion

Grain and straw yield of rice and wheat

Pooled analysis of three years yield data (Table 3) showed that grain yield of rice significantly increased in T_3 (100% RDF with S_{40}, Zn_5 and $B_{1.5}$) over T_2 (RDF). The grain yield of rice was at par by supplementing 25% RDF with SS (T_5), VC (T_6) and GM (T_7) while grain yield in T_6 and T_7 was statically similar to that of RDF (T_2). It was significantly lower in T_5. Thus, 25% RDF can be supplemented with VC and GM to sustain the grain yield of rice. It may be attributed to the availability of nutrients from organic as well as from native reserve of the soil due to the acidification and increased microbial activity. There was 45 per cent decrease in grain yield of rice grown without fertilizer (T_1) over RDF (T_2). The maximum grain yield (Table 3) of rice was recorded with under T_3 which was 3.9 per cent higher over RDF (T_2). Applications of 75% RDF + 25% N through GM (T_7) yielded at par with 75% RDF + 25% N through VC (T_6) and significantly lower than CF (T_4) in rice. Singh *et al.* (2001a) reported that integrated application of organic manures with inorganic fertilizer gave significantly higher grain yield of rice.

Grain yield in succeeding wheat crop was statistically at par in all the treatments except T_1 (control) in which no fertilizers were applied (Table 3). The results from our study suggest that when wheat received RDF, no significant residual effect of organic sources applied to previous rice was observed in wheat. It has also been reported that long-term sustainability in productivity of an intensive rice–wheat cropping system could be only achieved

Table 3. Effect of organic and inorganic sources of nutrients on yield and total (grain+straw) uptake of N, P, K, S, Zn and B by rice and wheat (3 years mean data)

Treatment	Yield (t ha^{-1})		Macronutrient uptake (kg ha^{-1})				Micronutrient uptake (g ha^{-1})	
	Grain	Straw	N	P	K	S	Zn	B
Rice								
T_1	2.46±0.09 a	3.45±0.02 a	38.6±1.54 a	14.5±0.62 a	49.2±3.35 a	19.5±1.57 a	128±1.87 a	160±14.9 a
T_2	4.47±0.06 cd	6.14±0.12 c	75.2±3.80 b	31.0±1.79 b	117±3.40 bcd	32.2±7.61 a	295±20.2 c	300±20.7 b
T_3	4.58±0.05 d	6.56±0.13 d	79.2±5.15 b	35.0±0.76 b	106±0.58 b	44.0±2.13 b	301±6.33 c	334±28.3 b
T_4	4.55±0.07 d	6.21±0.11 cd	75.6±8.31 b	31.3±2.65 b	121±4.07 cd	38.2±6.01 b	295±10.1 c	317±15.6 b
T_5	4.06±0.11 b	6.47±0.17 cd	73.7±4.27 b	29.0±2.49 b	128±7.59 d	42.1±6.61 b	283±17.7 bc	327±15.4 b
T_6	4.22±0.10 bc	5.72±0.13 b	70.8±3.31 b	29.0±2.07 b	110±0.32 bc	38.0±0.61 b	243±10.6 b	294±22.6 b
T_7	4.23±0.10 bc	5.71±0.06 b	70.9±3.25 b	29.2±1.58 b	109±2.24 b	41.4±5.25 b	271±15.0 bc	278±10.0 b
Wheat								
T_1	0.85±0.04 a	1.21±0.01 a	8.41±0.13 a	1.49±0.06 a	23.5±0.72 a	4.10±0.26 a	81.4±3.05 a	59.0±6.57 a
T_2	3.20±0.03 b	4.38±0.07 b	32.0±0.51 b	4.57±0.32 b	85.8±3.21 b	9.62±1.26 b	292±5.33 b	187±13.4 b
T_3	3.37±0.11 b	4.65±0.16 b	35.0±1.65 bc	4.84±0.12 b	87.8±1.02 b	9.79±0.61 b	307±15.5 b	203±14.6 b
T_4	3.37±0.14 b	4.57±0.19 b	32.7±1.36 b	4.53±0.21 b	91.4±2.38 b	9.54±0.91 b	310±6.22 b	192±26.9 b
T_5	3.35±0.10 b	4.48±0.03 b	32.7±0.78 b	4.81±0.21 b	86.0±2.29 b	9.14±0.66 b	299±18.1 b	216±22.9 b
T_6	3.26±0.08 b	4.38±0.08 b	37.6±0.77 cd	4.57±0.06 b	84.5±0.95 b	9.11±0.57 b	282±4.61 b	195±20.3 b
T_7	3.24±0.07 b	4.39±0.08 b	38.8±0.08 d	4.53±0.11 b	82.8±5.67 b	10.2±0.58 b	296±13.2 b	216±30.6 b

For the same parameter, different letters indicate statistically significant differences ($P<0.05$). For treatment details, see Table 2.

through the integration of inorganic and organic sources of nutrients (Singh *et al*. 2001b; Sekhon *et al.* 2011).

The maximum straw yield (Table 3) of rice was in T_3 (6.56 t ha^{-1}) followed by in T_5 *i.e.* 75% RDF + 25% N through SS (6.47 t ha^{-1}) with a respective increase of 6.84 and 5.37 per cent over RDF (3.45 t ha^{-1}). In wheat (Table 3), it was the maximum in T_3 (4.65 t ha^{-1}) followed by T_4 (4.57 t ha^{-1}) resulting an increase of 6.16 and 4.33 per cent over RDF (4.38 t ha^{-1}). In rice, straw yield was at par in T_3, T_4 and T_5. Straw yield of rice significantly decreased in T_6 and T_7 and at par with T_4 and T_5 as compared with RDF (T_2). It might be due to less availability of nutrients in T_6 and T_7 as 25% less RDF was applied. Higher straw yield in T_3 might be due to adequate supply of the macro and micro nutrients. Gour *et al.* (2015) also reported highest grain and straw yields under treatment RDF along with S, Zn and B in rice.

Nutrient uptake

The total nutrients uptake of N, P and K varied from 38.6 to 79.2, 14.5 to 35.0 and 49.2 to 128 kg ha^{-1} in rice, and 8.41 to 38.8, 1.4 to 4.84 and 23.5 to 91.4 kg ha^{-1}, respectively in wheat crop (Table 3). In rice, N and P uptake in grain and straw was statistically at par in all treatments except T_1 (without fertilizers). Application of RDF + SZnB (T_3) in rice, resulted in respective increase of 6.26, 15.0, 16.2 and 14.0 per cent in N, P, S and B uptake in grain over RDF (T_2). Similar findings were also reported by Singh *et al.* (2001a). The K uptake under T_3 and T_2 was at par both in rice grain and straw. The uptake of N, P and K in wheat grain varied from 4.84 to 25.6, 0.51 to 3.24 and 4.72 to 22.2 kg ha^{-1} while in straw from 3.58 to 13.26, 0.98 to 1.66 and 18.78 to 68.47 kg ha^{-1}. The highest N uptake in wheat grain was recorded in treatment T_7 (25.6 kg ha^{-1}) followed by T_6 (25.17 kg ha^{-1}) which increased by 16 and 14 per cent, respectively over T_2 (Table 3). The highest (38.8 kg ha^{-1}) uptake of N was recorded in T_7 which was 21.5 per cent higher over T_2 (RDF). The total P uptake of rice and wheat was statistically at par with T_2 in all the treatments except in T_1 (without fertilizer). Similar results were also reported by Bahadur *et al.* (2012).

The significantly higher total uptake of K in rice was found in treatment T_4 (121 kg ha^{-1}) and T_5 (128 kg ha^{-1}) which increased by 3.7 and 9.7 per cent, respectively over RDF (T_2). The uptake of K in grain of wheat increased significantly in T_4 (CF) and T_7 (GM) over T_2. The increased uptake of K by wheat may be ascribed to the release of K from the K bearing minerals by complexing agents and organic acids produced during decomposition of organic resources. Similar results were also observed by Mohapatra *et al.* (2008) in rice–potato (*Solanum tuberosum* L.) cropping system and Sawarkar *et al.* (2013) under soybean-wheat cropping sequence.

The total S uptake by rice (Table 3) significantly increased over RDF (T_2) in all the treatments except in T_1 (without fertilizers). The S uptake pattern in rice grain was not significant whereas in straw, it increased significantly over RDF (T_2) and without fertilizers (T_1). The S uptake by wheat in all the treatments did not show any significant increase either in grain or in straw when compared with RDF except T_1. Previously, Sharma *et al.* (2013) did not observe significant increase in S uptake under integrated nutrient management in wheat. The total uptake of Zn and B varied from 128 to 301 g ha^{-1} and 160 to 334 g ha^{-1} in rice, and 81 to 310 and 59 to 216 g ha^{-1} in wheat, respectively. It was noted that uptake of Zn in rice grain decreased significantly with the application of SS (T_5,) VC (T_6) or GM (T_7). The probable reason may be the formation of insoluble complex with native Zn which make it unavailable for plant absorption. There was no significant increase in total B uptake in rice and wheat (Table 4) with respect to RDF (T_2) except over rice grown without fertilizer application (T_1).

Soil properties

The pH and EC of the post-harvest soil under rice and wheat (Table 4) varied within a narrow range among different treatments and the differences were statistically not significant. After 3rd year in a continuous RW cropping, soil organic C (OC) was significantly greater in plots receiving 75% RDF + 25% N through VC (5.2 g kg^{-1}) followed by 75% RDF + 25% N through SS (5.3 g kg^{-1}) and CF (4.8 g kg^{-1}) which was 40, 41 and 35 per cent higher, respectively, over RDF in post-rice harvest soil. The soil OC (Table 4) content increased significantly from 2.5 g kg^{-1} in control (T_1) and attained a maximum of 5.3 g kg^{-1} in T_6 (75% RDF + 25% N through VC to rice). This could be ascribed to the contribution from annual use of VC for three years, and it was statistically at par with T_5 and T_7 *i.e.* 75% RDF + 25% N through SS and 75% RDF + 25% N through GM. The subsequent decomposition of these materials might have resulted in enhanced OC content of the soil. In rice, the OC content under plots that received fertilizers was higher than T_1. This also indicated that, substantial improvement in soil health can be expected by application of fertilizers. In post-harvest soil collected after the harvest of 3rd wheat crop, highest OC content was recorded in treatment 75% RDF + 25% N through VC *i.e.* T_6 (5.3 g kg^{-1}) which was statistically similar to T_5, and T_7. The lowest value of OC was recorded in T_1 (2.1 g kg^{-1}). The treatment T_3 (3.4 g kg^{-1}) and T_4 (3.6 g kg^{-1}) were at par with T_2 (3.1 g kg^{-1}). Gudadhe *et al.* (2015) also reported higher

Table 4. Soil fertility parameters after harvest of rice and wheat during terminal year

Treatment	Soil properties			Available nutrient status in soil					
	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})	Zn (mg kg^{-1})	B (mg kg^{-1})
Rice									
T_1	7.97±0.09a	0.35±0.18a	2.5±.04a	182±7.24a	45.2±3.02a	142±5.63a	9.35±0.65a	0.43±0.07a	1.19±0.05a
T_2	8.11±0.08a	0.52±0.10a	3.1±.01a	193±8.73a	56.8±3.88b	160±9.75a	10.4±0.65a	0.45±0.14a	1.29±0.05ab
T_3	8.16±0.17a	0.51±0.17a	3.4±.01a	206±12.1ab	62.9±6.68bc	187±12.8c	15.7±0.76b	0.75±0.08b	1.66±0.08c
T_4	7.76±0.29a	0.49±0.07a	4.7±.03b	207±17.6ab	71.1±1.43cd	197±6.54c	14.9±1.36b	0.74±0.6b	1.60±0.11c
T_5	7.63±0.26a	0.50±0.03a	5.2±.01b	218±1.05b	70.8±1.74cd	183±8.68bc	15.6±1.24b	0.65±0.09b	1.30±0.09b
T_6	7.77±0.23a	0.46±0.03a	5.3±.06b	202±6.76ab	77.0±0.96cd	182±5.50bc	14.4±1.96b	0.71±0.22b	1.33±0.04b
T_7	7.90±0.29a	0.63±0.05a	4.8±.03b	216±4.79b	77.5±2.74cd	193±6.40c	14.3±1.30b	0.64±0.14b	1.38±0.05b
Wheat									
T_1	7.99±0.12a	0.13±0.01a	2.1±0.01a	208±1.71a	48.8±1.62a	111±5.78a	9.3±0.94a	0.47±0.05a	0.95±0.06a
T_2	8.17±0.02a	0.15±0.01a	3.1±0.02b	219±3.95a	57.3±2.06b	120±1.32a	10.4±0.61a	0.65±0.03a	1.24±0.07b
T_3	8.17±0.10a	0.14±0.01a	3.4±0.01b	225±3.08ab	60.6±2.93b	121±3.55a	16.5±0.94b	1.01±0.11b	1.71±0.13c
T_4	8.20±0.16a	0.15±0.01a	3.6±0.02b	243±8.31b	71.1±1.84c	127±6.36ab	11.8±0.63bc	0.98±0.10b	1.61±0.04c
T_5	7.82±0.25a	0.16±0.01a	4.9±0.02c	245±6.30b	71.9±1.47c	145±5.39bc	12.7±0.85bc	0.96±0.14b	1.39±0.08b
T_6	8.08±0.03a	0.15±0.01a	5.3±0.03c	274±11.3c	72.0±3.54c	140±7.02bc	12.5±0.62bc	0.86±0.11b	1.38±0.04bb
T_7	8.23±0.08a	0.15±0.02a	5.1±0.04c	241±8.54b	72.7±1.90c	150±7.60bc	13.9±0.16d	0.95±0.05b	1.39±0.13b

For the same parameter, different letters indicate statistically significant differences (*$P<0.05$*). For treatment details, see Table 2.

levels of soil organic carbon under integrated treatments of organic and inorganic combinations.

Available macronutrients

At the harvest of 3rd wheat, fertility status of soil (Table 4) indicated that available soil N increased significantly over T_2 (RDF) in all the treatments (T_5, T_6 and T_7) in which 25% RDF was supplemented with organics (SS, VC and GM) on N equivalent basis. However, the increase among organic treatments was statistically similar. As regards to N content in post-wheat soil, a significant increase was visible in T_4 (CF), T_5 (75% RDF + 25% N through SS), T_6 (75% RDF + 25% N through VC) and T_7 (75% RDF + 25% N through GM) over T_2. This increase may be attributed to higher microbial activity in the INM treatments which favored the conversion of the organically bound N to inorganic form (Panwar 2008). Whereas increase in CF treatment may be attributed to higher root biomass due to high dose of P application. Increase in available N content of soil due to addition of organics was observed in rice (Singh *et al*. 2006).

The available P (Table 4) in soil after rice was either maintained or significantly improved (T_5,T_6 and T_7) due to addition of different organic sources over T_2 (61.3 kg ha^{-1}). In post wheat soil, P content significantly increased under treatment T_4 (71.1 kg ha^{-1}), T_5 (71.9 kg ha^{-1}), T_6 (72.1 kg ha^{-1}) and T_7 (72.7 kg ha^{-1}) over T_2 (57.3 kg ha^{-1}). Treatments T_4, T_5, T_6 and T_7 were statistically at par with each other. Organic manures, on decomposition, solubulize insoluble organic P fractions through release of various organic acids, thus resulting into a significant improvement in available P status of the soil. Maitra *et al*. (2008) also found similar improvement in soil available P status in a Typic Ustochrept of Uttar Pradesh due to integrated nutrient management in sunhemp.

The highest K (197 kg ha^{-1}) was recorded in CF (T_4) followed by 193 kg ha^{-1} in GM (T_7) plot which was 27 and 26 per cent higher over RDF (142 kg ha^{-1}) in post-rice soil (Table 4). In post-wheat soil, the K content ranged between 111 to 150 kg ha^{-1}. The highest K was recorded in treatment T_7 which received RDF along with residual effect of fertilizers and GM added to previous rice. Treatments T_1, T_2, T_3 and T_4 were statistically at par with each other. The increase in the available K content under integrated nutrient management might be due to reduction of K fixation and release of K from interaction of organic matter with clay besides addition of K to the available pool (Barik *et al*. 2008). Available S content in post-rice soil (Table 4) showed a significant change with the application of inorganics (T_3 and T_4) and organics (T_5, T_6 and T_7). It ranged between 9.25 mg kg^{-1} in T_1 (without fertilizers) to a maximum of 15.8 mg kg^{-1} in T_3 in post-rice soil. Similar trend was noticed in post-wheat soil.

Available micronutrients

There was a significant build-up of DTPA- Zn with the application of organic sources (T_5, T_6 and T_7) both in post-rice and post-wheat soil (Table 4) which was significantly higher than T_2. The highest available Zn was recorded in T_3 both in post-rice soil (0.75 mg kg^{-1}) and post-wheat soil (1.01 mg kg^{-1}) which was significantly superior to T_1 and T_2. The lowest value was recorded in T_2 (0.45 mg kg^{-1}) in post-rice soil. Similar, results were also reported in integrated use of fertilizers and organics increased the Zn content in Vertisol under soybean-wheat cropping system due to mobilization of native Zn through decomposition of residual biomass of both the crops (Thakur *et al*. 2011). In wheat, significantly higher DTPA-Zn content in soil was recorded in treatment T_3 (1.01 mg kg^{-1}) over T_1 and T_2. The hot $CaCl_2$-extractable B content varied between 1.19 to 1.66 and 0.95 to 1.71 mg kg^{-1} (Table 4) in post-rice and post-wheat soil, respectively. The maximum B content of 1.66 mg kg^{-1} was recorded in T_4 in post-rice soil whereas in post-wheat soil, the B content was maximum in T_3, whereas the minimum 1.19 and 0.95 mg kg^{-1} was recorded in treatment T_1 under post-rice and post-wheat soil, respectively. The organics treatments (T_5, T_6 and T_7) did not show any significant build up in available B content of soil.

Conclusions

Result of a 3 year study on RW system revealed that grain yield of rice with 75% RDF + 25% N through VC or GM was at par with RDF. Partial substitution of RDF with SS produced lower yield compared with the RDF. There was no residual effect of organic manures in the following wheat. It may be inferred that yield of RW system could be sustained by supplementing 25% RDF in rice with GM or VC. Organic sources improved soil fertility parameters.

Acknowledgments

The authors gratefully acknowledge the contribution of the M/S Sathguru Management Consultant, Hyderabad for providing financial assistance under USAID-AIP programme during the course of investigation.

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Received 30 December 2017; Accepted 30 August 2018