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Research Paper

Effect of integrated nutrient management on productivity and economics of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi)* seasons of 2013–14 and 2014–15 at Kanpur, Uttar Pradesh, to evaluate the effect of recommended dose of fertilizer (RDF), alone and in combination with 10 t/ha compost, 5 t/ha vermicompost and *Azotobacter* and phosphate-solubilizing bacteria (PSB) on growth, yield attributes, yields and economics of wheat (*Triticum aestivum* L.). Treatments were laid out in a 3 times replicated randomized block design. The soil of the experimental field was sandy loam, deficient in nitrogen and medium in phosphorus and potassium. Combined use of RDF + vermicompost @ 5 t/ha, RDF + compost @ 10 t/ha and RDF + vermicompost @ 5 t/ha + *Azotobacter* and PSB increased the tillers/m^2 by 30.6%, 27.6% and 26.8%, respectively, over RDF in wheat. Similarly, the combined use of RDF, compost or vermicompost and biofertilizers improved values of yield attributes, which reflected in higher grain yield of wheat. The highest grain yield of wheat was recorded with RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB in the first year, and with RDF + compost @ 10 t/ha + *Azotobacter* + PSB in second year, though both these treatments gave at par grain yield during both the years. Averaged across 2 years, treatments RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB and RDF + compost @ 10 t/ha + *Azotobacter* + PSB increased the grain yield by 21.5 and 20.1%, respectively over the RDF.

Key words : *Azotobacter*, Farmyard manure, Phosphate-solubilizing bacteria, Vermicompost, Wheat

Wheat is the world's most widely cultivated staple food crop after rice. The area under wheat increased from 12.8 million ha in 1966–67 to 30.2 million ha in 2015–16 (DAS, MoAC, 2016). In this period, production has also increased from 11.4 to 93.5 million tonnes and the productivity increased from 887 to 3,093 kg/ha (DAS, MoAC, 2016). However, there is not any noticeable improvement in the productivity of wheat during the last 10 years in the country. Thus, there is a need to further increase the production to fulfill the requirements of increasing population, maintenance of adequate buffer stock and to meet out the demand for processing industries (Choudhary *et al.*, 2017).

Wheat is generally grown in intensive cropping systems with higher use of inorganic plant nutrients, specially supplied through N : P : K fertilizers. The continuous use of chemical fertilizers alone adversely affects the soil health and long-term crop productivity. Thus, it becomes necessary to supply the nutrients to crop through combined use of chemical fertilizers, organic sources and biofertilizers to sustain the soil health and crop productivity. The integrated use of organic manures and inorganic fertilizers in different proportions has proved its worth in maintaining higher productivity, providing greater stability to crop production (Patel *et al.*, 2014) and sustaining the soil health (Weber *et al.,* 2007; Pullicinoa *et al.,* 2009). In view of the above facts, the present field study was carried out to evaluate the effect of recommended dose of fertilizer (RDF) alone and in combination with 10 t/ha compost, 5 t/ha vermicompost and *Azotobacter* and phosphate solubilizing bacteria (PSB) on growth, yield attributes, yields and economics of wheat.

MATERIALS AND METHODS

The experiment was conducted during the winter (*rabi*) seasons of 2013–14 and 2014–15 at Student Instructional Farm, Chandra Sekhar Azad University of Agriculture and Technology, Kanpur (25°28' to 26°58' N and 79°31' to 80°34' E). The experiment consisted of 5 treatments hav-

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ing integrated doses of nutrients, viz. RDF + compost @ 10 t/ha, RDF + vermicompost @ 5 t/ha, RDF + compost @ 10 t/ha + *Azotobacter* + PSB, RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB and RDF + *Azotobacter* + PSB compared with only RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) treatment, replicated 3 times. The experiment was laid out in a randomized block design. The soil of the experimental field was sandy loam in texture and had low levels of organic carbon (0.42%) and available nitrogen (165.0 kg/ha), and medium levels of available phosphorus (17.8 kg P/ha) and available potassium (165.0 kg K/ha), with a *p*H of 8.1. Recommended doses of P and K and vermicompost were applied as basal doses and *Azotobacter* was used as seed treatment before sowing of wheat. The required quantities of N, P and K were supplied through urea, diammonium phosphate and muriate of potash, respectively. Nitrogen, through urea, was applied in 3 equal splits at basal, tillering and flowering stages. However, the total quantity of vermicompost was applied before the last ploughing and mixed well in the soil. Wheat variety 'New Shekhar' (also known as 'K 1006'), maturing in 125–130 days, was used as a test variety. The crop was sown during the third week of November during both the years. This variety has been reported to contain 12.5 to 13.0% protein and is resistant to all kind of wheat rusts and smuts. The crop was irrigated by tubewell irrigation at critical growth stages, i.e. at crown-root initiation (CRI), tillering, late jointing, flowering, milk and dough grain. The climate during both the 2 crop seasons was close to normal. The intercultural operations, like weed management were done well in time in all plots judiciously during both the cropping seasons. All the recorded data from the experiment were statistically analyzed using the F-test as per the standard statistical procedure (Gomez and Gomez, 1984) and values of critical difference (CD) (P = 0.05) were used to determine the significance of difference between the treatment means.

RESULTS AND DISCUSSION

Growth parameters

Different growth parameters, like plant height, leaf-area index and number of tillers/plant were influenced significantly due to imposition of treatments over the control (Table 1). The combined use of organic manures (compost or vermicompost), fertilizers and biofertilizers was more useful than chemical fertilizers alone, particularly with respect to growth parameters in wheat. The tallest plants were recorded with treatment RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB during both the years. However, plant height with the former treatment was statistically similar to that with RDF + compost @ 10 t/ha, RDF + vermicompost @ 5 t/ha and RDF + compost @ 10 t/ha + *Azotobacter* + PSB. All the preceding treatments resulted in significantly taller plants than RDF i.e. 150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S and RDF + *Azotobacter* + PSB. A significant variation in values of leaf-area index (LAI) was also existed due to imposition of different fertilizer and manurial treatments. Statistically similar LAI values were recorded with RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB, RDF + compost @ 10 t/ha, RDF + vermicompost @ 5 t/ha and RDF + compost @ 10 t/ha + *Azotobacter* + PSB, which were significantly higher than RDF i.e. 150 : 60 : 40 : 20 : 20 kg/ha N:P:K:ZnS and RDF + *Azotobacter* + PSB treatments during both the years. In general, addition of compost or vermicompost along with biofertilizers effectively increased the LAI over the control (RDF of 150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) and RDF + *Azotobacter* + PSB. Application of biofertilizers along with RDF could not bring any significant improvement in LAI over RDF, indicating that the biofertilizers were much more effective when used with organic manures than when used with fertilizers (RDF) in increasing the LAI. The number of tillers/unit area was also influenced significantly by different treatments. It ranged from 400 to 574

Table 1. Effect of different nutrient sources on growth parameters of wheat

Treatment	Plant height at harvesting (cm)		Leaf-area index (90 DAS)		Tillers/m^2	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) (Control)	63.5	64.6	4.91	4.56	344	390
RDF + compost @ 10 t/ha	73.9	73.1	5.02	5.10	420	445
RDF + vermicompost @ 5 t/ha	73.9	73.9	5.67	5.07	574	385
RDF + compost @ 10 t/ha + *Azotobacter* + PSB	74.1	77.0	6.06	5.37	479	458
RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB	75.1	76.7	6.35	5.24	512	419
RDF + *Azotobacter* + PSB	67.7	68.3	5.13	4.60	400	369
SEm±	1.8	1.8	0.27	0.56	2.9	2.2
CD (P=0.05)	5.6	5.4	0.85	1.70	9.3	7.1

RDF, Recommended dose of fertilizer; DAS, days after sowing and 369 to 458 tillers/m^2 during 2013–14 and 2014–15 respectively. The lowest number of tillers/m^2 was produced by RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn: S), which was significantly lower to the values obtained by all the other nutrient sources. It thus indicated that combined use of organic manures (compost or vermicompost), fertilizers and biofertilizers was more useful than chemical fertilizers alone, particularly with respect to tillers/m^2 in wheat. Our findings confirm the results of Singh *et al.* (2013).

Yield attributes

The important yield attributes of wheat, viz. spikes/m^2, spike length (cm), filled grains/spike and 1,000-grain weight (g) were significantly influenced by different treatments during both the years (Table 2). The number of spikes/m^2 are very important yield attribute which contribute handsomely towards the grain yield. Nutrient source RDF + vermicompost @ 5 t/ha resulted in the highest number of spikes/m^2 in the first year and RDF + compost @ 10 t/ha + *Azotobacter* + PSB in the second year, which was significantly higher than that of all the other nutrient sources. Averaged over 2 years, nutrient sources RDF + vermicompost @ 5 t/ha and RDF + compost @ 10 t/ha + *Azotobacter* + PSB recorded 7.5 and 12.5% more spikes/m^2 over RDF. During both the years, however, nutrient source RDF + *Azotobacter* + PSB resulted in the lowest number of spikes/m^2, which was significantly lower than all the other nutrient sources. It indicates that use of biofertilizers was ineffective in increasing the number of spikes/m^2 when they were combined with chemical fertilizers alone (RDF + *Azotobacter* + PSB). However, addition of biofertilizers (*Azotobacter* + PSB) to RDF increased the spike length significantly over RDF alone, indicating the positive impact of biofertilizers. Nutrient sources RDF + compost @ 10 t/ha, RDF + vermicompost @ 5 t/ha, RDF + compost @ 10 t/ha + *Azotobacter* + PSB and RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB resulted in at par spike length during both the years. Similarly, nutrient sources RDF + compost @ 10 t/ha, RDF + vermicompost @ 5 t/ha, RDF + compost @ 10 t/ha + *Azotobacter* + PSB and RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB yielded at par number of filled grains, and all resulted in significantly higher number of filled grains over the RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S). The treatment of RDF and RDF + *Azotobacter* + PSB resulted in the at par 1,000-grain weight. However, other sources did not differ significantly in recording the 1,000-grain weight. Thus, it is evident that combined use of RDF, compost or vermicompost and biofertilizers favoured better plant growth parameters, which eventually reflected in improved values of yield attributes in our study. Our results confirm the findings of Rathor and Sharma (2010).

Yields

The nutrient sources significantly influenced the biological, grain and straw yields, and harvest index of wheat during both the years (Table 3). The lowest biological yields were recorded with nutrient source RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S), which was at par with RDF + *Azotobacter* + PSB in the first year, and significantly greater than RDF + *Azotobacter* + PSB in the second year. It indicates that the influence of combined application of biofertilizers and RDF on biological yield of wheat was inconsistent. However, combined application of RDF, compost or vermicompost and biofertilizers was a better choice for enhancing the biological yield of wheat. The highest grain yield of wheat was observed with RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB in the first year, and with RDF + compost @ 10 t/ha + *Azotobacter* + PSB in the second year, though both these treatments gave

Table 2. Effect of integrated nutrient management on yield attributes of wheat

Treatment	Spikes/m^2		Spike length (cm)		Filled grains/spike		1,000-grain weight (g)	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) (Control)	421	377	7.52	7.98	45.5	44.3	38.1	39.5
RDF + compost @ 10 t/ha	412	416	8.34	9.06	59.7	48.1	41.1	40.5
RDF + vermicompost @ 5 t/ha	508	350	8.25	9.08	58.1	50.5	41.7	40.5
RDF + compost @ 10 t/ha + *Azotobacter* + PSB	452	446	8.32	9.57	59.3	53.7	42.6	42.7
RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB	490	393	8.60	9.50	59.8	52.1	42.8	42.9
RDF + *Azotobacter* + PSB	354	325	7.76	8.46	52.5	47.6	39.2	40.2
SEm±	1.5	2.3	0.21	0.35	1.2	1.5	1.0	0.4
CD (P=0.05)	5.1	7.0	0.64	1.06	3.5	4.5	3.1	1.2

RDF, Recommended dose of fertilizer

at par grain yield during both the years. The lowest grain yield during both the years was recorded with RDF (150: 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S), which was significantly lower than all the other nutrient sources included RDF + *Azotobacter* + PSB. It indicates that addition of biofertilizers with RDF proved beneficial in increasing the grain yield of wheat over RDF alone. Furthermore, addition of organic manures, viz. compost and vermicompost, with RDF and biofertilizers was a better option for enhancing the grain yield of wheat. There was not much variation in straw yields under different treatments. Many nutrient sources had very close straw yields. Actually, the main difference existed in harvest index which caused significant changes in grain yield under different nutrient sources. The highest value of harvest index (%) was recorded with RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB in the first year (47.4%) and with RDF + compost @ 10 t/ha + *Azotobacter* + PSB in the second year (44.5%), both being significantly higher over RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) and RDF + *Azotobacter* + PSB. Overall, combined application of RDF, organic manures (compost or vermicompost) and biofertilizers helped wheat crop better in enhancing the grain yield and harvest index over sole application of chemical fertilizers (RDF). Shah and Ahmad (2006) and Ram and Mir (2006), and Singh *et al.* (2012) also reported similar findings.

The correlation analysis was performed to assess the relationship among growth parameters, yield attributes and grain yield of wheat. To test the strength of relationship between any 3 variables, the coefficients of correlation were computed. The computed values of correlation coefficients were compared with table value of correlation coefficients (r) at n-2 degrees of freedom. If the computed value of r was higher than the table value, then it was considered as significant. The data given in Table 4 indicate that grain yield of wheat was positively and strongly correlated with leaf-area index, spike length, filled grains/spike and 1,000-grain weight.

Economics

The least cost of cultivation was recorded with RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) during both the years (Table 5). It increased further when RDF was combined with organic manures and biofertilizers, as the cost of organic manures is generally higher than chemical fertilizers. The cost of cultivation was still higher when vermicompost was combined with RDF and biofertilizers over when compost was used with RDF and biofertilizers. Thus, the highest cost of cultivation was observed with

Table 3. Effect of integrated nutrient management on yields and harvest index of wheat

Treatment	Biological yield (t/ha)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) (Control)	8.87	8.04	3.62	3.45	5.25	4.59	40.9	42.9
RDF + compost @ 10 t/ha	9.15	8.41	4.16	3.64	5.00	4.77	45.5	43.3
RDF + vermicompost @ 5 t/ha	9.61	8.70	4.43	3.78	5.17	4.92	46.2	43.4
RDF + compost @ 10 t/ha + *Azotobacter* + PSB	9.73	9.10	4.53	4.05	5.19	5.05	46.6	44.5
RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB	9.84	8.74	4.67	3.81	5.17	4.93	47.4	43.6
RDF + *Azotobacter* + PSB	8.93	8.18	3.95	3.52	4.98	4.66	44.2	43.0
SEm±	0.14	0.04	0.08	0.02	0.23	0.28	0.1	0.1
CD (P=0.05)	0.43	0.11	0.24	0.06	0.68	0.82	0.4	0.3

RDF, Recommended dose of fertilizer

Table 4. Computation of correlation coefficients among different growth and yield attributes of wheat

Parameter	LAI		Spikes/m^2		Spike length (cm)		Filled grains/spike		1,000-grain weight (g)	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
Spikes/m^2	0.701	0.717	–	–	–	–	–	–	–	–
Spike length (cm)	0.762	0.971**	0.626	0.579	–	–	–	–	–	–
Filled grains/spike	0.652	0.900*	0.475	0.474	0.953**	0.952**	–	–	–	–
1,000-grain weight (g)	0.867*	0.839*	0.683	0.587	0.960**	0.885*	0.929**	0.904*	–	–
Grain yield (t/ha)	0.913*	0.921**	0.692	0.633	0.934**	0.909*	0.898**	0.959**	0.984**	0.853*

*Significant at 5% level of significance; **Significant at 1% level of significance

Table 5. Effect of integrated nutrient management on economics of wheat

Treatment	Cost of cultivation (× 10³ ₹/ha)		Gross income (× 10³ ₹/ha)		Net income (× 10³ ₹/ha)		Benefit: cost ratio	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
RDF (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) (Control)	45.9	46.4	63.1	69.9	17.1	23.5	1.37	1.50
RDF + compost @ 10 t/ha	50.9	51.4	70.3	73.6	19.4	22.2	1.38	1.43
RDF + vermicompost @ 5 t/ha	55.9	56.4	74.7	76.2	18.7	19.8	1.33	1.35
RDF + compost @ 10 t/ha + *Azotobacter* + PSB	51.1	51.8	76.1	80.9	25.0	29.1	1.49	1.56
RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB	56.1	56.8	78.0	76.8	22.0	20.0	1.39	1.35
RDF + *Azotobacter* + PSB	46.1	46.8	67.3	71.2	21.1	24.5	1.46	1.52

RDF, Recommended dose of fertilizer

RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB during both the years. The highest gross income was achieved with RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB in the first year, and with RDF + compost @ 10 t/ha + *Azotobacter* + PSB in the second year. However, the highest net income and benefit: cost ratio were obtained with RDF + compost @ 10 t/ha + *Azotobacter* + PSB. Use of RDF alone (150 : 60 : 40 : 20 : 20 kg/ha N : P : K : Zn : S) gave the least values of gross income and net income. However, the minimum benefit: cost ratio was recorded with RDF + vermicompost @ 5 t/ha. Even application of biofertilizers (*Azotobacter* + PSB) with RDF proved much better over RDF alone, particularly with respect to the gross income, net income and benefit: cost ratio. Das *et al.* (2000), Yadav and Kumar (2009) and Verma *et al.* (2014), also reported similar results.

It can be thus concluded that combined application of recommended dose of fertilizer (RDF) along with compost or vermicompost and biofertilizers (*Azotobacter* + phosphate-solubilizing bacteria (PSB) in wheat was a better option over RDF alone. Furthermore, considering the economics of different nutrient sources, application of RDF + compost @ 10 t/ha + *Azotobacter* + PSB was the best option for wheat cultivation.

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