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Productivity and nutrient uptake of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system under different bio-sources and nitrogen levels

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ABSTRACT

A field experiment was conducted during 2006-07 and 2007-08 at New Delhi to assess the growth, yield and nutrient uptake behavior of maize (*Zea mays* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping system under different bio-sources and nitrogen levels. Application of vermicompost (VC) equivalent of 60 kg N/ha, being at par with farmyard manure (FYM) equivalent of 60 kg N/ha recorded taller plants with more leaf area index (LAI) and grains/cob, resulting in 22.7 and 23.8% enhancement in grain yield of maize over control in 2006 and 2007, respectively. The residual fertility of FYM resulted in higher plant height, LAI effective tillers/meter row length and grains/spikelet of wheat over the VC and control. Grain yield of wheat with residual of FYM increased to the tune of 21.2 and 24.1% over the control; and corresponding increase over the VC application was 9.1 and 10.3% in first and second year, respectively. Similar response in respect of biological yield and N, P, K and Zn uptake to organic sources was also found. Increasing N doses had beneficial effect on growth and yield attributes of both the crops resulting in 21.5, 38.9 and 48.9% increase in grain yield of maize; and 30.0, 47.7 and 61.2% increase in grain yield of wheat due to application of 40, 80 and 120 kg N/ha over the control, respectively. The biological yields of maize and wheat and nutrients uptake by cropping systems also improved with increasing nitrogen levels. The net returns/ha from maize–wheat cropping sequence was maximum with the application of FYM. Increasing N doses showed the increasing pattern of net returns up to 120 kg N/ha. Expected N balance remained positive with organic sources and N levels. The data on gain or loss of N in soil indicated that N content in soil showed the positive trend with *Azotobacter*, FYM and 80 and 120 kg N/ha.

Key words : Maize–wheat cropping system, Nutrient management, Nutrient uptake, Organic sources, Productivity

Maize and wheat are major crops of irrigated areas in northern parts of the country. Both the crops contribute 37% in food grain production (FAI, 2008). Being the exhaustive crops, maize and wheat require huge amount of nutrients particularly N for producing more yields. The experimental results at various places indicated that both maize and wheat respond well up to the N levels varying from 80 to 120 kg/ha (Raja, 2001 and Vadivel *et al.,* 2001). The continuous application of higher amount of chemical fertilizers leads to deteriorated soil heath with reduced organic matter and multiple nutrient deficiencies. As the consequence, it put a big question for sustaining the productivity of maize–wheat system. Integrated nutrient management, which includes potential sources of nutrients like chemical fertilizers, bulky organic manures and biofertilizers, could help in mitigating these problems to some extent (Dhaliwal *et al.,* 2007). The information on N management through organic and inorganic sources in individual crop of maize and wheat are available. But little information is available on system based integrated nutrient management practices. Thus the present study was under taken to study the effect of N levels with different bio-sources on growth, yield, returns and N balance in maize–wheat cropping system.

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MATERIALS AND METHODS

A field experiment on maize–wheat cropping system was carried out at the research farm of Division of Agronomy, Indian Agricultural Research Institute New Delhi during of 2006-2007 and 2007-08. The sandy loam soil of the experimental field had 0.37 and 0.38% organic carbon, 155.5 and 160.4 kg/ha available N, 162.1, and 166.3 kg/ha available K and 9.7 and 10.1 kg/ha available P with pH 7.3 and 7.2 during 2006-07 and 2007-08, respectively. Six combinations of organic sources [control, farmyard manure (FYM) and vermicompost (VC)] with and without *Azotobacter* application in main-plots and four N fertilizer treatments (0, 40, 80 and 120 kg N/ha) in the sub-plots were tested in three times replicated split plot design. The nutrient contents in FYM and VC were 0.49-0.51% N, 0.23-0.28% P and 0.51-0.53 % K; and 1.61-1.63% N, 0.68-0.72% P and 0.83-0.85% K, respectively. The VC and FYM were applied equivalent to 60 kg N/ha 10 days prior to sowing and the seed of maize was inoculated with *Azotobacter* before sowing as per treatments. N as per treatments was applied in three splits to both maize and wheat. 'Ganga safed 2' maize and 'HD 2824' wheat were planted on 10 and 5 July; and 29 and 23 November; and harvested on 14 and 12 October; and 10 and 4 April in 2006-07 and 2007-08, respectively. Other management practices were adopted as per recommendations of the crop under irrigated conditions. Growth parameters measured as per standard procedure at harvest stage of both the crops and nutrient uptake was worked out by multiplying the yield with nutrient content and dividing by 100. The economics was computed by using the prevalent prices of inputs and outputs. N balance was also worked out by using the data on input, uptake and residual soil content of nitrogen.

RESULTS AND DISCUSSION

Growth and yield attributes of maize

VC and FYM being at par recorded the taller plants with maximum leaf area index (LAI) compared to control during both the years (Table 1). Higher grains/cob was noticed with VC application than control and FYM. Similarly, FYM application also resulted in more grains/cob, than control during each year. VC, a rich source of macro and micro nutrients and growth hormones does not only supply essential nutrients to the soil but also improves the physico-chemical and biological properties of the soil (Sharma *et al*., 2005). Similar to VC, FYM also contains different macro and micro nutrients and also helps in improving the soil physico-chemical and biological conditions (Rawat and Pareek, 2003). The improved physico-chemical properties and availability of nutrients at a slow rate for longer time with the use of organic sources might be responsible for better growth of maize plants with FYM and VC application. The effect of organic sources on growth and yield attributes is thus quite comparable to that obtained by Jayaprakash *et al*. (2004). However, there was not significant effect of *Azotobacter* application on the growth and yield attributes during both the years (Table1).

Taller plants with higher leaf area index were recorded with each increasing N level up to 120 kg N/ha (Table 1). This improvement in crop growth might be because of the increased availability and uptake of N at higher N levels. Yadav *et al*. (2002) also reported the similar observations. Increasing levels of N from 0 to 40, 40 to 80 and 80 to 120 kg N/ha markedly improved the number of grains per cob and test weight during both the years (Table 1). The sink capacity of the plant is dependent mainly on vegetative growth and vigorous vegetative growth increased LAI with the application of higher doses of N; consequently supply of photosynthates for the formation of yield components was also enhanced. However, number of cobs per

Table 1. Effect of bio-fertilizer, organic sources and nitrogen levels on growth and yield attributes and yields of maize

Treatment	Plant height (cm)		LAI		Number of cobs (thousand/ha)		Number of grains/cob		Test weight (g)		Grain yield (t/ha)		Biological yield (t/ha)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Bio-fertilizer														
Control	176.4	175.1	3.64	3.50	64.30	64.17	301.11	273.08	219.7	216.9	4.03	3.87	9.74	9.40
Azotobacter	180.4	179.1	3.73	3.60	64.79	64.38	323.49	287.12	226.9	224.4	4.20	4.06	10.10	9.77
SEm±	3.00	3.01	0.06	0.08	1.24	1.88	7.35	4.89	4.26	3.98	0.09	0.09	0.15	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Organic Source														
Control	166.7	165.7	3.47	3.25	63.89	64.16	261.59	233.61	213.7	210.0	3.65	3.49	8.96	8.53
FYM	180.8	178.9	3.77	3.68	64.75	64.14	322.56	289.51	224.6	223.0	4.20	4.10	10.11	9.86
VC	187.5	186.7	3.82	3.73	65.00	64.51	352.76	317.18	231.5	229.0	4.48	4.32	10.69	10.36
SEm±	3.68	3.69	0.08	0.10	1.51	2.30	9.01	5.99	5.22	4.87	0.11	0.12	0.18	0.17
CD (P=0.05)	11.59	11.61	0.24	0.32	NS	NS	28.37	18.87	NS	NS	0.33	0.36	0.57	0.52
Nitrogen (kg/ha)														
0	152.0	151.5	3.02	2.90	63.50	63.42	202.13	198.69	205.4	203.3	3.28	3.07	8.19	7.71
40	173.4	171.5	3.52	3.38	64.47	64.15	288.13	254.10	221.5	219.9	3.93	3.78	9.53	9.14
80	187.5	186.7	3.92	3.75	65.07	64.75	347.75	309.14	230.1	226.0	4.46	4.35	10.58	10.35
120	200.6	198.8	4.27	4.17	65.15	64.77	411.20	358.48	236.1	233.5	4.78	4.67	11.38	11.13
SEm±	4.42	4.17	0.10	0.10	1.54	1.77	13.50	9.42	5.60	5.73	0.11	0.10	0.19	0.15
CD (P=0.05)	12.67	11.97	0.30	0.29	NS	NS	38.72	27.02	16.05	16.42	0.31	0.29	0.53	0.42

ha remained similar due to application of *Azotobacter* and different treatments of organic sources and N levels during 2006 and 2007.

Grain and biological yield of maize

Azotobacter application could not influence the grain and biological yields of maize during both the years, While, organic sources and N levels have significant effect on the grain and biological yields of maize during each years (Table 1). Application of VC resulted in significantly higher grain yield to the tune of 22.7 and 23.8% compared to control in first and second year, respectively. FYM also gave 15.1 and 17.5% significantly higher grain yield over control, but these values were statistically equal to that of VC in 2006 and 2007, respectively. Similarly, VC and FYM, being at par recorded 16.8 and 11.3%; and 19.6 and 13.8% higher biological yield than control in 2006 and 2007, respectively. The considerable improvement in grain yield due to application of organic sources might be attributed to the fact that organic sources of nutrients had the positive effect on yield attributes and cumulative effect of yield attributes mainly responsible for higher productivity with the application of organic sources. The findings are in close conformity to those of Meena *et al.* (2007). VC, being at par with FYM noticed higher biological yield as compared to control, probably due to more gain in plant height and dry matter accumulation with organic sources supply (Table 1). Similar findings have also been reported by Jayaprakash *et al*. (2004).

In general, application of 40, 80 and 120 kg N/ha resulted in 19.8, 36.0 and 45.7; and 23.1, 41.7 and 52.1% increase in grain yield; and 14.1, 24.6 and 34.4; and 14.8, 28.7 and 38.3% increase in biological yield over control during 2006 and 2007, respectively. The enhancements in grain and biological yield with each increase N levels were of significant level (Table 1). The beneficial effect of N application on growth and yield attributes and than their cumulative effect are responsible for enhancing productivity at higher N levels. The results are in close conformity with those of Jayaprakash *et al*. (2004).

The grain yield of maize varied significantly due to integrated effect of N levels and organic sources during both the years (Table 2). The highest grain yield was obtained with the combined use of 120 kg N/ha with VC, which were significantly higher than all the remaining combinations of organic sources and N levels. The application of FYM and 120 kg N/ha was the second best treatment combinations. But when reduced dose of N 80 or 40 kg N/ha were applied with either FYM or VC they remained statistically equal to 120 kg and 80 kg N/ha without organic sources during each year, respectively (Table 2), which is attributed to the fact that with the organic sources help in saving the inorganic N (Meena *et al*., 2007).

Table 2. Interaction effect of organic sources and nitrogen levels on grain yield (t/ha) of maize

Treatment	Organic sources					
	2006			2007		
Nitrogen (kg/ha)	Control	FYM	VC	Control	FYM	VC
0	2.72	3.39	3.63	2.54	3.29	3.49
40	3.42	4.04	4.25	3.36	3.94	4.14
80	4.06	4.55	4.7.8	3.86	4.42	4.67
120	4.42	4.81	5.07	4.20	4.75	4.97
SEm±		0.17			0.16	
CD(P=0.05)		0.48			0.47	

Growth and yield parameters of wheat

The application of both FYM and VC enhanced the growth in terms of plant height and LAI over control during both the years. The highest value of plant height and LAI was recorded on the residual fertility of FYM, which were significantly more than control and VC (Table 3). The FYM and VC might have released the sufficient amounts of nutrients by mineralization at a constant level which resulted in higher amount of residual contents of available nutrients and better environment for increased uptake of nutrients and consequently better crop growth (Khandwal and Bhardwaj, 2002). Similarly, with the application of FYM the number of effective tillers/meter row length and number of grains/ spikelet remained maximum, which were significantly higher over VC and control treatments. VC also showed the superiority over control in respect of all the yield attributes in each year. Higher values of yield attributes on the residual fertility of FYM compared to control and VC; and on residual fertility of VC as compared to control might be resultant of increased growth due to higher amount of available nutrients with these treatments. Similar observations were also reported by Singh and Agarwal (2001). However, test weight could not be differed due to varying organic sources (Table 3)

All the growth (plant height and LAI) and yield attributing parameters (effective tillers/meter row length, number of grains/ spikelet and test weight) of wheat improved significantly with each successive increase in N level up to 120 kg N/ha during both the years (Table 3). Supply of adequate quantity of N might have enhanced the availability and uptake of N due to its quick release and mineralization, which in turn may enhance the growth and developmental processes. The findings are in corroboration with those reported by and Choudhary *et al*. (2007). However, plant height and LAI and all the yield attributes did not show variation due to application of *Azotobacter* (Table 3). Similar observations were also reported by Kumpawat and Rathore (2003).

Grain and biological yield of wheat

In general, *Azotobacter* application improved grain and biological yield to the tune of 4.2 and 3.9; and 3.5 and 3.6% over control during first and second year, respectively, but these enhancements in grain and biological yields were not of significance level (Table 3). Different organic sources and N levels affected the both grain and biological yields significantly during each year. Application of FYM recorded 21.2 and 24.1% higher grain and 18.2 and 19.0% higher biological yield over control. Similar, FYM also resulted in 9.1 and 10.3% higher grain and 8.3 and 7.8% higher biological yield as compared to VC application in first and second year, respectively. Statistically also FYM was superior over VC by recording more grain and biological yields during each year. In similar, VC also out yielded the control treatment during both the years (Table 3). Increase in grain yield was due to favorable effect of organic sources on yield attributes besides their positive and significant association with grain yield during both the years. The findings are in close conformity of Kumpawat and Rathore (2003). Higher biological yield on the residual fertility of FYM and VC than control was due to more gain in plant height and dry matter accumulation with organic sources supply. Similarly findings have also been reported by Sharma *et al.* (2007).

In general, % increase of 29.2, 47.8 and 61.3; and 30.8, 47.6 and 61.2 percent in grain yield and 19.3, 37.2 and 47.4; and 18.3, 34.0 and 44.0 in biological yield due to application of 40, 80 and 120 kg N/ha was recorded over control in 2006-07 and 2007-08, respectively. Statistically also, each successive enhancement in N levels from 0 to 120 kg N/ha increased the both grain and biological yields during both the years (Table 3). The favorable effect of high doses of N on yield attributes and their cumulative effect on grain yield were mainly responsible for higher productivity. The results are in close conformity with that of Tulasa *et al*. (2002). The higher plant height and dry matter accumulation at higher N level are responsible for more biological yield over lower N level. The findings are closely with that of Kumpawat and Rathore (2003).

System productivity

Application of *Azotobacter* could not influence the system productivity in terms of maize grain equivalents yield during each year (Table 3). In general, FYM and VC had 18.3 and 15.4% and 21.1 and 17.4% increase in maize equivalents yield than control in 2006-07 and 2007-08, respectively. The highest system productivity

Table 3. Residual effect of bio-fertilizer and organic sources and direct effect of nitrogen levels on growth and yield attributes; and yields of wheat and system productivity

Treatment	Plant height (cm)		LAI		Effective tillers/ meter row length		Number of grains/spikelet		Test weight (g)		Grain yield (t/ha)		Biological yield (t/ha)		System productivity (t/ha)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2006-07	2007-08
Bio-fertilizer																
Control	80.4	79.8	2.52	2.34	66.4	65.9	2.63	2.12	40.4	39.0	3.74	3.61	8.85	8.48	9.21	8.89
Azotobacter	83.8	83.0	2.60	2.38	67.9	66.3	2.74	2.23	42.0	40.9	3.90	3.75	9.09	8.80	9.59	9.27
SEm±	1.39	1.50	0.05	0.04	1.21	1.16	0.05	0.05	0.70	0.71	0.09	0.08	0.08	0.12	0.19	0.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Organic Source																
Control	76.0	75.2	2.35	2.17	61.5	61.0	2.39	1.87	39.8	38.3	3.45	3.28	8.18	7.80	8.45	8.05
FYM	88.3	87.4	2.77	2.58	72.6	71.4	2.97	2.47	42.4	41.3	4.18	4.07	9.76	9.45	10.00	9.75
VC	82.1	81.5	2.56	2.33	67.3	65.9	2.71	2.19	41.4	40.2	3.83	3.69	8.98	8.68	9.75	9.45
SEm±	1.71	1.84	0.06	0.05	1.48	1.42	0.06	0.06	0.86	0.87	0.11	0.10	0.10	0.14	0.23	0.21
CD (P=0.05)	5.37	5.78	0.19	0.15	4.67	4.46	0.18	0.18	NS	NS	0.33	0.31	0.32	0.45	0.72	0.68
Nitrogen (kg/ha)																
0	68.3	69.4	1.65	1.47	56.7	55.8	2.22	1.75	34.4	33.0	2.84	2.73	6.93	6.72	7.19	6.89
40	79.4	78.7	2.37	2.15	64.5	63.8	2.56	2.08	39.9	38.3	3.67	3.57	8.55	8.30	9.00	8.77
80	87.4	85.7	2.91	2.75	71.3	70.1	2.86	2.36	43.7	42.4	4.20	4.03	9.80	9.38	10.29	9.90
120	93.3	91.7	3.32	3.07	76.2	74.7	3.10	2.52	46.7	46.2	4.58	4.40	10.61	10.16	11.12	10.75
SEm±	2.01	2.01	0.06	0.06	1.66	1.57	0.06	0.05	1.00	0.96	0.09	0.10	0.17	0.16	0.17	0.018
CD (P=0.05)	5.77	5.77	0.17	0.17	4.75	4.49	0.18	0.15	2.86	2.76	0.26	0.28	0.49	0.45	0.50	0.53

was found with FYM over control. VC also had more system productivity compared to control, but the differences in system productivity yield between FYM and VC was not significant during both the years. In general, % increase of 25.2, 43.1 and 54.7; and 27.4, 43.7 and 56.1 in system productivity yield was recorded due to application of 40, 80 and 120 kg N/ha over 0 kg N/ha in 2006 and 2007, respectively (Table 3). There was marked improvement in system productivity yield due to each increase in N level up to 120 kg N/ha. The higher system productivity with the application of organic sources and higher N level was attributed to the higher yield grain yield of maize and wheat at these treatments. The findings are in the close conformity of the results of Meena *et al*. (2007).

Nutrient uptake

Nitrogen, phosphorus, potassium and zinc uptake by maize–wheat cropping system differed significantly due to varying organic sources and N levels, but these were not influenced by the application of *Azotobacter* during both the years (Table 4). The uptake of nitrogen and potassium by maize–wheat cropping system was the highest with FYM during both the years while phosphorus uptake during first year and zinc uptake during both the years remained the maximum with VC application. But nitrogen, phosphorus and potassium uptakes during both the years and zinc uptake during first year could not differ statistically between FYM and VC, while both of these sources remained higher over control. The more uptake of nutrient might be due to better root establishment, resulting in higher absorption of nutrient to feed and sustain in increased growth lead to higher grain and straw yield. The nutrient uptake is the function of yield and nutrient concentration and yield is more deciding factor for higher nutrient uptake. Similar observations were resulted by Rawat and Pareek (2003).

Differences in N, phosphorus and potassium uptake by maize–wheat cropping system were obtained to be influenced significantly by various N levels. With each successive increase in N level from 0 to 120 kg N/ha, the uptake of N, P and K increased significantly during both the years (Table 4). The results are in consonance with those of Kumpawat and Rathore (2003) and Vedivel *et al*. (2001)

Nitrogen balance

N addition to the soil through fertilizers was the highest with 120 kg N/ha and similar quantity of N was available with both the organic sources (FYM and VC). Among the two organic sources FYM resulted in more N uptake as compared to VC and control. In similar increasing N levels improved the N uptake by the maize–wheat cropping system and maximum value was recorded at 120 kg N/ha was (Table 5). *Azotobacter* application also enhanced the N availability and N uptake. Based on the initial N of the soil and addition and depletion of the N, the expected N balance was negative with *Azotobacter* in first year and remained positive with organic sources and N levels. In general, the expected balance of N was more with the application of 120 kg N/ha during both the year. The data on gain or loss of N in soil indicated that N content in soil showed the positive trend with *Azotobacter*, FYM and 80 and 120 kg N/ha during both the years; and VC during

Table 4. Residual effect of bio-fertilizer and organic sources and direct effect of nitrogen levels on nutrient uptake by maize–wheat sequence

Treatment	Nitrogen uptake (kg/ha)		Phosphorus uptake (kg/ha)		Potassium uptake (kg/ha)		Zinc uptake (g/ha)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Bio-fertilizer								
Control	178.81	171.39	46.87	44.19	197.52	189.78	1042.78	954.44
Azotobacter	189.68	182.30	49.30	46.21	207.45	200.73	1076.11	998.61
SEm±	3.93	4.25	0.94	1.02	3.94	3.12	13.42	15.98
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Organic Source								
Control	151.82	144.94	40.28	37.26	176.13	165.84	830.42	752.92
FYM	202.68	195.33	51.57	49.34	217.81	213.10	1155.00	1055.83
VC	198.23	190.27	52.41	49.01	213.52	206.83	1192.92	1120.83
SEm±	4.82	5.20	1.15	1.25	4.82	3.82	16.43	19.57
CD (P=0.05)	15.18	16.38	3.61	3.93	15.18	12.03	51.76	61.66
Nitrogen dose (kg/ha)								
0	122.31	116.72	31.42	29.49	149.96	144.22	527.22	480.56
40	168.05	161.16	43.55	41.03	189.03	181.59	907.78	844.44
80	207.91	200.17	54.47	50.97	222.46	214.34	1260.00	1155.56
120	238.69	229.34	62.89	59.32	248.50	240.88	1542.78	1425.56
SEm±	4.37	3.52	1.40	1.08	5.50	4.98	30.00	15.27
CD (P=0.05)	12.54	10.10	4.02	3.11	15.78	14.30	86.07	43.80

second year. The higher gain in N was noticed with the application of *Azotobacter* and FYM; and increasing trend in N gain was noticed with each higher N levels during each year (Table 5). This could be ascribed to the application of FYM, VC, *Azotobacter* and N and variations in the addition and uptake of N by the crops. These findings supported those of Kumar (2008).

Economics

The cost of cultivation (₹11,720 and 11,781/ha) and net returns (₹18,689 and 21,023/ha) from maize was higher with VC as compared to FYM. However, FYM resulted in the higher values of net returns (₹30,157 and 34,989/ha) in wheat (Table 6). The data on system economics indicated that VC followed by FYM had the higher value of cost of cultivation than control, because of higher prices of VC compared to FYM. However, the net returns from the system remained higher with FYM (₹47,341 and 54,666/ha) than VC due more productivity of wheat on residual fertility of FYM than VC. Higher system productivity with VC

Table 5. Nitrogen balance sheet as influenced by bio-fertilizer, organic source and nitrogen levels on maize–wheat sequence

Treatment	Total available nitrogen (Initial + added through fertilizers) kg/ha		Total nitrogen harvest (kg/ha)		Expected nitrogen balance after last harvest (kg/ha)		Available nitrogen in soil after harvest (kg/ha)		Net loss or gain in nitrogen content in soil (kg/ha)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Bio-fertilizer										
Control	160.3	158.3	174.5	165.5	-14.2	-7.2	154.4	158.8	–0.5	0.5
Azotobacter	180.3	178.3	186.7	178.3	-6.4	0.0	158.0	163.6	3.3	5.3
Organic Source										
Control	160.3	158.3	152.6	140.7	7.7	17.6	151.5	156.5	–8.8	–1.8
FYM	220.3	218.3	200.1	191.2	20.2	27.1	161.1	165.0	+0.8	+6.7
VC	220.3	218.3	196.5	186.3	23.8	32.0	155.9	162.2	–4.4	3.9
Nitrogen dose (kg/ha)										
0	160.3	158.3	121.7	113.7	38.6	44.6	134.9	139.4	–25.4	–18.9
40	200.3	198.3	167.3	158.5	33.0	39.8	150.5	155.9	–9.8	–2.4
80	240.3	238.3	206.8	197.1	33.5	41.2	164.0	168.8	3.7	10.5
120	280.3	278.3	238.9	227.5	41.4	50.8	175.4	180.8	15.1	22.5

Table 6. Residual effect of bio-fertilizer and organic sources and direct effect of nitrogen levels on economics of maize–wheat and system economics

Treatment	Maize				Wheat				Maize – wheat system			
	Cost of cultivation (× 10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		Cost of cultivation (× 10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		Cost of cultivation (× 10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)	
	2006	2007	2006	2007	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Bio-fertilizer												
Control	11.1	11.2	16.3	18.4	10.96	11.1	25.9	29.9	22.1	22.2	42.2	48.3
Azotobacter	11.1	11.2	17.4	19.9	10.96	11.1	27.4	31.5	22.1	22.2	44.8	51.1
SEm±	-	-	0.49	0.57	-	-	0.67	0.79	-	-	1.0	1.21
CD (P=0.05)	-	-	NS	NS	-	-	NS	NS	-	-	NS	NS
Organic Source												
Control	10.2	10.3	14.8	16.4	10.96	11.1	23.1	26.2	21.1	21.3	37.9	42.6
FYM	11.4	11.5	17.2	19.7	10.96	11.1	30.2	34.9	22.3	22.5	47.3	54.6
VC	11.7	11.8	18.7	21.0	10.96	11.1	26.7	30.8	22.6	22.8	45.4	51.8
SEm±	-	-	0.61	0.70	-	-	0.82	0.97	-	-	1.22	1.4
CD (P=0.05)	-	-	1.93	2.21	-	-	2.5	3.07	-	-	3.86	4.6
Nitrogen dose (kg/ha)												
0	10.3	10.4	12.3	13.3	10.2	10.3	18.0	20.9	20.5	20.6	30.2	34.2
40	10.9	11.0	15.9	17.8	10.8	10.9	25.2	29.5	21.7	21.9	41.1	47.2
80	11.4	11.4	18.8	21.5	11.2	11.3	30.0	34.2	22.6	22.7	48.8	55.7
120	11.8	11.9	20.6	23.5	11.6	11.7	33.2	38.0	23.4	23.6	53.8	61.5
SEm±	-	-	0.5	0.6	-	-	0.8	1.0	-	-	1.1	1.3
CD (P=0.05)	-	-	1.7	1.7	-	-	2.3	2.8	-	-	3.2	3.8

application attributed to the higher returns. The results are in close conformity with that of and Verma *et al*. (2003). *Azotobacter* application could not register the significant enhancement net returns over control during both the years (Table 6). Net returns from maize, wheat and cropping system were differed significantly due to different N doses. Each successive increment in N levels from 0 to 120 kg N/ha improved the values of net returns from maize and wheat during both the years and cost of cultivation was also showed the increasing trend with each increase in N level (Table 6). Regarding the net returns of cropping system, it varied from ₹30,296 to ₹53,874/ha and ₹34,259 to ₹61,574/ha during first and second year, respectively. Statistically also, increasing N levels from 0 to 120 kg N/ha enhanced the net returns during both the years. Similar results are also reported by Kumar (2008).

Among the organic sources, maize recorded highest yield and returns with VC application, while wheat yield and system productivity and returns were the highest with FYM application. Application of 120 kg N/ha was found to have highest yield and returns from maize and wheat. Application of organics was found to save 40 kg N/ha through inorganic.

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