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Research Paper

Integrated nutrient management in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during 2011–12 and 2012–13 at New Delhi, to evaluate the effect of integrated nutrient management on growth and yield attributes, yield and economics of maize (*Zea mays* L.)–wheat {*Triticum aestivum* (L.) emend. Fiori & Paol.} cropping system. The experiment was laid out in a randomized block design (RBD) during the first year of maize and in factorial randomized block design (FRBD) in successive crops with 3 replications, consisting of 5 different treatments in rainy and winter season each comprising 25 treatment combinations. The results revealed that 50% recommended dose of fertilizer (RDF-120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha) + 50% recommended dose of nitrogen (RDN-120 kg N/ha) through crop residue mixed farmyard manure resulted in significantly higher maize grain yield (4.24 t/ha) over the control (2.23 t/ha) during first year, but during the second year (5.25 t/ha) it was significantly higher than the control (3.07 t/ha) and 50% RDF + 25% RDN + biofertilizer (4.83 t/ha). Application of 100% RDF to maize recorded significantly maximum net profit (₹28.22 × 10^3, 42.74 × 10^3 ₹/ha), followed by 75% RDF + 25% RDN. However, benefit: cost (B:C) ratio of 1.33 and 1.60 were recorded significantly higher under the control over the other treatments followed by 100% RDF, during 2011 and 2012 respectively. In wheat crop, 100% RDF showed significantly higher growth and yield attributes over the control. The maximum wheat grain yield (4.97 t/ha) and net returns (66.96 × 10^3) were recorded with the application of 100% RDF through chemical fertilizers, whereas, maximum B: C ratio (2.76) was recorded in control.

Key words **:** Cropping system, Crop residue mixed farmyard manure, Economics, Farmyard manure, Fertilizer levels, Integrated nutrient management, Yield

Maize–wheat cropping system is one of the major cropping systems in India, covering around 1.8 million ha mainly in Indo-Gangetic Plains of India. Maize and wheat are the main source of world's food energy and also contain significant amounts of proteins, vitamins and minerals, which are essential nutrients for human health. Maize is the third most important foodgrain crop in India, considered as a most important option for diversifying agriculture in upland areas of India. Maize has high production potential compared to any other cereal crop. It is well known that maize is a heavy feeder of nutrients and being C4 plant type, it is a very efficient converter of solar energy into dry matter. Wheat, is another major important staple cereal, supplies the bulk of calories and nutrients in the diets of a large proportion of the world population (Water *et al.,* 2009; Chatzav *et al.,* 2010). Globally, India is the second largest wheat-producing country and contributes about 11.9% to the world wheat production from about 12% of world area (Singh *et al.,* 2010).

Continuous use of chemical fertilizers in intensive cropping system is leading to imbalance of nutrients in soil, which has an adverse effect on soil health and also on crop yields. But, use of organics alone does not result in spectacular increase in crop yields, due to their low nutrient status. Sustainable yield could be achieved only by applying appropriate combination of green manures or organic manures and chemical fertilizers (Verma and Bhagat, 1990; Obi and Ebo, 1995). Farmyard manure (FYM) is also considered as an important source of macro and micronutrients to increase crop yield. Due to higher prices of inorganic fertilizers, farmers in India could easily manage to prepare FYM in their farms and to apply them in fields. Manure contains all the plant nutrients

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needed for crop growth including trace elements. The availability or efficiency of manure utilization by a crop is determined by the method of its application, time to incorporate and the rate of manure decomposition by microorganisms in soil (Herbert, 1998).

Considering these above facts, adoption of integrated nutrient managements involving residue mixed farmyard manure, fertilizer levels in conjunction with biofertilizers to improve production, productivity, profitability and efficient utilization of nutrient are the need of the hour. Hence an attempt was made to assess the direct and cumulative effects of integrated nutrient management on maize and wheat in maize–wheat cropping system.

MATERIALS AND METHODS

The field experiment was conducted on a fixed site during the rainy and winter seasons of 2011–12 and 2012–13 at the Research Farm, Indian Agricultural Research Institute, New Delhi (28°38' N, 77°11' E, 228.6 m above mean sea-level), to study the effect of crop residue mixed farmyard manure and fertilizer combinations on growth parameters, yield attributes and yield of maize–wheat cropping system each in randomized block design during the first year of maize and in factorial randomised block design (FRBD) in successive crops with 3 replications. The soil of the experimental site was sandy clay loam, with bulk density of 1.6 g/cm, field capacity of 17.6% (w/w) and infiltration rate of 1.3 cm/hr. It had 0.39% organic carbon, 163.1 kg $KMnO_4$ oxidizable N/ha, 13.4 kg 0.5 N $NaHCO_3$ extractable P/ha, 235.1 kg 1.0 N NH_4OAC-exchangeable K/ha, 7.8 *p*H and 0.31 dS/m electreical conductivity at the start of the experiment. The field had an even topography and good drainage condition. The mean annual rainfall of Delhi is about 650 mm, of which nearly 80% is received during July–September and the rest during the period between October and May. The treatment consisted of 5 fertility levels in rainy season (*kharif*) maize, viz. T_1, control, T_2, 100% recommended dose of fertilizer (RDF); T_3, 75% RDF + 25% recommended dose of nitrogen (RDN); T_4, 50% RDF + 50% RDN; T_5, 50% RDF + 25% RDN + biofertilizer (BF); and 5 fertility treatments in the winter season (*rabi*), viz. T_1, control; T_2, 100% RDF; T_3, 75% RDF; T_4, 50% RDF + 25% RDN; T_5, 37.5% RDF + 37.5% RDN + biofertilizer (BF). The experiment was started with maize crop (*kharif*) and laid out in randomized block design (RBD) and the second crop of maize laid out in factorial randomized block design (FRBD). So, there was no pooled data of maize crop. Maize 'PEHM 2' was planted on 19 July and 13 July and harvested on 17 and 10 October during 2011–12 and 2012–13, respectively. After harvesting of maize wheat 'HD 2967' was planted on 12 and 17 November and harvested on 10 and 15 April during 2011–12 and 2012–13, respectively. The experiment was conducted to know the direct effect of different treatments on one crop and residual effect on succeeding crop. Recommended dose of nitrogen (RDN) were applied through crop residue mixed farmyard manure (CRFYM) and recommended dose of fertilizer (RDF) were applied through chemical fertilizers. One-third N for maize, half N for wheat and full dose of P and K through urea, diammonium phosphate and muriate of potash, respectively were applied at the time of sowing and the remaining N was applied in 2 split doses–30 days after sowing (DAS) and at tasseling stage–in maize and after first irrigation in wheat. Well-rotten crop residue mixed farmyard manure (CRFYM) @ 15 t/ha containing 0.45, 0.2, 0.45% N, P and K was applied as per the treatments at the time of sowing.

The biofertilizers, viz. *Azospirillum* for maize and *Azotobacter chroococcum* for wheat and phosphate-solubulizing bacteria (PSB), i.e. *Pseudomonas striata,* for both the crops were applied directly to soil in rows during sowing. Other management practices were adopted as per recommendation of the crop grown under irrigated conditions. In maize, 5 plants were selected randomly from the second row of the each plot for the measurements of plant height, dry matter accumulation and leaf-area index of maize and also for plant height of wheat. In wheat, 1 m^2 area was selected after leaving the first row of the each plot for the measurement of dry-matter accumulation and leaf area index. Leaf-area was measured by using leaf-area meter (1/2–MDL-1,000, LICOR Ltd, USA). Leaf area index was computed by dividing the leaf area to ground area. After harvesting, shelling/threshing, cleaning and drying, the grain yield was recorded. Straw/stover yield was obtained by subtracting grain yield from the total biomass yield. Net returns for both the crops were computed on the basis of grain and straw yield, their prevailing market prices and cost of cultivation. Benefit : cost ratio was computed by dividing the net returns by total cost of cultivation. Total productivity of the system in wheat-equivalent yield was calculated on the basis of support price for the main produce during 2011–12 and 2012–13 and prevailing market prices for the inputs. The data collected for different parameters were statistically analysed using the *F*-test as per the procedure given by Gomez and Gomez (1984) for randomized block design and factorial randomized block design. The results are presented at 5% level of significance (P= 0.05) for making comparison between treatments.

RESULTS AND DISCUSSION

Growth attributes of maize

Application of 50% recommended of fertilizer (RDF) through chemical fertilizers and 50% recommended dose of nitrogen (RDN) through crop residue mixed farmyard manure recorded the maximum growth attributes of maize (Table 1). The highest values of plant height, dry-matter accumulation and leaf-area index (LAI) during 2011 and 2012, respectively, were registered at 50% RDF + 50% RDN, which were significantly higher than the control. However, growth parameters of the maize were better during the second year than to first year owing to favourable weather condition and rapid mineralization of organic nutrients during the second year of the experiment. Verma (2011) reported that application of organic source of nitrogen (FYM followed by *Azospirillum*) positively influenced the plant height, LAI, dry-matter/plant and days to maturity and silking due to prolonged release of nutrients from FYM, which increase the efficiency of nutrients and provide favourable conditions for plant growth. The reason for maximum height, dry-matter and LAI of maize with of 50% RDF + 50% RDN might be due to fertilizer source that fulfilled the nutrient requirements at early growth stages, while CRFYM facilitated crop at later stages by providing continuous and uniform supply of nutrients coupled with high photosynthetic rates and excellent vegetative growth resulting in accumulation of dry matter into the plants. In maize, residual effect of applied nutrients to wheat was not significant with respect to all growth parameters. However, relatively higher residual effect of applied nutrients to wheat on maize was observed with 37.5% RDF + 37.5% RDN + BF, followed by 50% RDF + 25% RDN. The interaction effect of *kharif* and r*abi* treatments on growth attributes of maize were non-significant during both the years.

Yield and yield attributes of maize

Yield attributes like cob length, 1,000-grain weight and grains/cob were significantly increased with the application of different combinations of CRFYM and fertilizer over the control during both the years (Table 2). The maximum values of yield attributes were recorded owing to combined application of 50% RDF + 50% RDN followed by application of 75% RDF + 25% RDN and these were significantly higher than the control. Maximum cob lengths were recorded with 50% RDF + 50% RDN during both the years. These values were significantly higher than 100% RDF and the control. The significantly higher values of grains/cob and 1,000-grain weight were recorded with 50% RDF + 50% RDN over the control, but at par with the other treatments during both the years. Residual effects of applied treatments to wheat on yield attributes of maize were non-significant during the second year except grains/cob. Significantly higher grains/cob were recorded from 37.5% RDF + 37.5% RDN + BF over the control and it was at par with remaining treatments.

Grain and biological yields were significantly influenced by application of different nutrient treatments; however, harvest index did not differ significantly (Table 3).

Table 1. Effect of integrated nutrient management on growth attributes of maize and wheat (pooled data of 2 years)

Treatment	Maize						Wheat		
	Plant height (cm)		DMA (g/plant)		LAI		Plant height (cm)	DMA (g/m^2)	LAI
	2011	2012	2011	2012	2011	2012			
Treatment to maize									
Control	162.5	170.3	104.3	106.3	2.14	2.38	88.3	1054.7	3.07
100% RDF	180.7	186.4	123.4	147.1	2.26	3.00	90.1	1119.9	3.18
75% RDF + 25% RDN	182.6	188.8	129.0	153.4	2.33	3.03	90.3	1120.5	3.21
50% RDF + 50% RDN	183.6	191.6	134.7	158.8	2.40	3.12	90.6	1122.2	3.23
50% RDF + 25% RDN+BF	175.8	183.3	117.1	142.2	2.20	2.80	90.4	1121.5	3.22
SEm±	4.4	3.4	4.6	2.9	0.03	0.03	0.96	14.7	0.04
CD (P=0.05)	13.4	9.7	13.9	8.2	0.10	0.09	NS	41.8	0.11
Treatment to wheat									
Control		183.4		136.7		2.77	84.2	919.9	2.72
100% RDF		183.8		142.2		2.88	93.3	1218.6	3.54
75% RDF		183.7		140.7		2.85	89.4	1092.2	3.07
50% RDF + 25% RDN		184.5		142.8		2.90	90.9	1127.7	3.21
37.5% RDF + 37.5% RDN + BF	185.0		145.4		2.92	91.8	1180.2	3.36	
SEm±		3.4		2.9		0.03	0.96	14.7	0.04
CD (P=0.05)		NS		NS		0.09	2.73	41.8	0.11

Plant height at maturity, DMA; dry-matter accumulation at maturity, LAI; leaf-area index at 90 DAS in both maize and wheat; RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; BF, biofertilizer

Application of 50% RDF + 50% RDN to maize resulted in significantly higher grain yield than the control during the first year, but it was significantly higher than the control and 50% RDF + 25% RDN + BF during the second year. Biological yields and harvest index of maize were influenced significantly due to application of different treatments to maize during both the years. Significantly higher biological yields were recorded with 50% RDF + 50% RDN to maize than the control and 50% RDF + 25% RDN + BF during 2011 and 2012. Significantly higher harvest index was observed with 50% RDF + 50% RDN to maize over the control. However, the yields and harvest index recorded from remaining treatments were at par with each other during both the years. Application of 100% RDF resulted in statistically similar yield, as obtained from different combination of CRFYM and fertilizers. However, it was significantly higher than the control. Grain and biological yields of maize were significantly higher with the application of 37.5% RDF + 37.5% RDN + BF applied to wheat and grain yield was at par with 100% RDF and 50% RDF + 25% RDN, but significantly higher than that of the control and 75% RDF; and biological yields were significantly higher than the control and were at par with the remaining treatments.

Interaction effects of treatments applied to maize crop and treatments applied to previous wheat crop on grain and biological yield of maize were found significant (Table 5). Direct application of 50% RDF + 50% RDN to maize and application of 37.5% RDF + 37.5% RDN + BF to wheat proved the best combination and recorded significantly highest grain yield over interaction of 50% RDF + 25% RDN and control and also interaction of maize control with all the treatments of wheat. However, it was at par with rest of the treatment combinations (Table 5). This is in conformity with the result of Thavaprakaash *et al.* (2005). The variation in grain yield across the treatment may be traced to their favourable effects on the growth attributes, which further got translated to yield attributes and finally on grain yield. The integrated nutrient treatments might have resulted in sufficient amount of released nutrients by mineralization at a constant level and increased the nutrient uptake because of the better soil environment created owing to cumulative effect of organic sources combined with inorganic source of nutrients, which improved the plant growth and consequently enhanced the yield attributes and yield. The treatment which received the maximum amount of recommended dose of nitrogen through residue mixed FYM in preceding wheat crop had higher value of all the yield components than the treatments, which received 100% RDF through chemical

Table 2. Effect of integrated nutrient management on yield attributes of maize and wheat (pooled data of 2 years)

Treatment	Maize						Wheat		
	Cob length (cm)		Grains/cob		1,000-grain weight (g)		Effective tillers/m^2	Grains/ spike	1,000-grain weight (g)
	2011	2012	2011	2012	2011	2012			
Treatment to maize									
Control	10.7	12.1	266.7	275.3	206.7	222.7	332.6	44.5	38.1
100% RDF	12.6	14.1	414.0	417.5	232.0	240.1	356.2	46.5	38.3
75% RDF + 25% RDN	13.4	14.5	419.8	422.7	235.3	242.1	358.7	46.7	38.4
50% RDF + 50% RDN	13.4	14.8	421.8	426.7	237.2	245.0	363.2	47.2	38.7
50% RDF + 25% RDN+BF	12.2	13.4	413.1	412.7	230.2	237.2	360.6	47.0	38.1
SEm±	0.4	0.2	5.7	5.1	3.0	3.4	6.1	0.81	0.60
CD (P=0.05)	1.2	0.5	17.3	14.4	9.0	9.8	17.3	NS	NS
Treatment to wheat									
Control		13.5		376.3		233.9	300.7	40.4	37.2
100% RDF		13.8		387.9		238.7	385.6	50.4	39.8
75% RDF		13.7		386.3		236.2	350.4	45.6	37.6
50% RDF + 25% RDN		13.9		392.9		238.7	362.3	47.0	38.3
37.5% RDF + 37.5% RDN + BF	14.0		411.5		239.7	372.3	48.6	38.6	
SEm±		0.2		5.1		3.4	6.1	0.81	0.60
CD (P=0.05)		NS		14.4		NS	17.3	2.3	1.71
Interaction (kharif × rabi)									
SEm±		0.4		11.3		7.7	13.6	1.8	1.34
CD (P=0.05)		NS		32.2		NS	38.7	NS	NS

RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; BF, biofertilizer

Table 3. Effect of integrated nutrient management on yields (t/ha) and harvest index (%) of maize and wheat (pooled data of 2 years)

Treatment	Maize						Wheat		
	Grain yield		Biological yield		Harvest index (%)		Grain yield	Biological yield	Harvest index (%)
	2011	2012	2011	2012	2011	2012			
Treatment to maize									
Control	2.23	3.07	7.63	9.35	29.3	32.8	4.31	11.10	38.5
100% RDF	4.07	5.06	11.50	13.88	35.4	36.5	4.67	11.94	39.1
75% RDF + 25% RDN	4.14	5.16	11.67	14.14	35.5	36.5	4.69	11.98	39.1
50% RDF + 50% RDN	4.24	5.26	11.94	14.40	35.5	36.5	4.71	12.06	39.1
50% RDF + 25% RDN + BF	3.97	4.83	11.22	13.24	35.3	36.6	4.70	12.02	39.1
SEm±	0.11	0.08	0.21	0.19	0.8	0.5	0.11	0.18	0.64
CD (P=0.05)	0.34	0.21	0.65	0.55	2.4	1.5	0.31	0.52	NS
Treatment to wheat									
Control		4.35		11.98		36.0	3.92	10.28	37.9
100% RDF		4.72		13.20		35.6	4.97	12.62	39.4
75% RDF		4.66		13.06		35.5	4.63	11.88	39.0
50% RDF + 25% RDN		4.76		13.32		35.6	4.72	12.01	39.3
37.5% RDF + 37.5% RDN + BF	4.88		13.45		36.2	4.85	12.31	39.4	
SEm±		0.08		0.19		0.5	0.11	0.18	0.64
CD (P=0.05)		0.21		0.55		NS	0.31	0.52	NS
Interaction (kharif × rabi)									
SEm±		0.17		0.43		1.2	0.24	0.41	1.44
CD (P=0.05)		0.48		1.23		NS	0.68	1.17	NS

RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; BF, biofertilizer

Table 4. Economics and system productivity of maize and wheat as influenced by integrated nutrient management (pooled data of 2 years)

Treatment	Maize						Wheat			
	Cost of cultivation (× 10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		Benefit: cost ratio		Cost of cultivation (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	System productivity (MGEY)
	2011	2012	2011	2012	2011	2012				
Treatment to maize										
Control	18.24	18.67	24.17	29.92	1.33	1.60	27.94	55.89	1.98	6.80
100% RDF	26.57	34.31	28.22	42.74	1.06	1.25	27.94	62.60	2.31	8.43
75% RDF + 25% RDN	31.99	37.90	24.42	40.65	0.76	1.07	27.94	62.90	2.32	8.51
50% RDF + 50% RDN	36.94	41.03	19.56	39.05	0.53	0.95	27.94	63.46	2.35	8.62
50% RDF + 25% RDN + BF	30.51	34.60	23.85	39.02	0.78	1.13	27.94	63.22	2.34	8.32
SEm±			0.97	0.99	0.04	0.03		1.59	0.05	0.12
CD (P=0.05)			2.94	2.81	0.11	0.09		4.51	0.16	0.35
Treatment to wheat										
Control		33.30		33.08		0.97	20.45	56.48	2.76	7.29
100% RDF		33.30		39.15		1.24	29.09	66.96	2.33	8.51
75% RDF		33.30		38.22		1.20	27.04	62.90	2.34	8.14
50% RDF + 25% RDN		33.30		39.75		1.26	30.48	60.76	2.00	8.27
37.5% RDF + 37.5% RDN + BF		33.30		41.16		1.33	32.62	60.99	1.87	8.45
SEm±				0.99		0.03		1.59	0.05	0.12
CD (P=0.05)				2.81		0.09		4.51	0.16	0.35
Interaction (kharif × rabi)										
SEm±				2.21		0.07		3.55	0.12	0.27
CD (P=0.05)				6.29		0.19		10.09	0.35	0.77

*cost of cultivation and net returns (× 10^3 ₹/ha); RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; BF, biofertilizer
MGEY : Maize grain equivalent-yield

fertilizers. Chauhan (2010) reported that application of organic matter significantly increased 5.75% more grain yield with application of FYM @ 10 t/ha. Nanjappa *et al.* (2001) reported that combined application of 50 or 75% recommended dose of fertilizer with 12 t/ha FYM or 2.7 t/ha vermicompost caused higher productivity of maize compared with the application of either only inorganic fertilizer or organic sources.

Growth attributes of wheat

Plant height, dry-matter accumulation at maturity and leaf-area index 90 DAS were influenced significantly owing to different organic and inorganic nutrient combinations (Table 1). Among all the treatments, wheat responds better to 100% RDF than the other treatments. Among the organic and inorganic nutrient combinations, 37.5% RDF + 37.5% RDN + BF recorded significantly highest growth and growth attributes over the control. Significantly higher plant height, dry-matter (DM) and LAI (3.54) were recorded with 100% RDF, followed by 37.5% RDF + 37.5% RDN + BF. Plant height with the application of 75% RDF and 50% RDF + 25% RDN was found non-significant with each other but significantly higher than the control. Maximum values of these growth parameters were observed with 100% RDF because it supplied the highest amount of essential nutrients compared to the other treatments. Among the nutrient-applied treatments 75% RDF exhibited the lowest values of all the growth parameters, followed 50% RDF + 25% RDN. Residual effects of applied treatments to maize on plant height of wheat was found non-significant, but DM and LAI were significant. Residual effect of nutrients applied to maize on wheat was the highest with the application of 50% RDF + 50% RDN, followed by 50% RDF + 25% RDN + BF. Application of chemical fertilizers alone or with organic manure increased the plant height significantly owing to the stronger role of nutrients in cell division, cell expansion and enlargement which ultimately affect the vegetative growth of plant and ultimately higher dry-matter production. Nitrogen is the key element which affects the chlorophyll content in leaf of the plants. The increase translocation of N by biological supply results in more chlorophyll content. Potassium plays significant role in nutrient transportation in plants. The increase in chlorophyll content might be owing to synergistic effect of potassium over the other nutrients. Our results confirm those of Idris *et al.* (2001); Idris and Wisal (2001); Singh and Agarwal (2001); Iqbal *et al.* (2002); and Baque *et al*. (2006). Similar results were also obtained by Rehman *et al.* (2010).

Yield and yield attributes of wheat

The yield attributes, viz. effective tillers/m^2, grains/spike and 1,000-grain weight, of wheat were significantly higher than the control (Table 2). However, most of the yield attributes attained the maximum values when 100% RDF was applied, while minimum values were obtained with the application of 75% RDF. Significantly effective tillers/m^2, grains/spike and 1,000-grain weight were recorded with 100% RDF, followed by application of 37.5% RDF + 37.5% RDN + BF**.** The residual effect of applied nutrients in preceding maize crop on yield attributes of wheat were found non-significant except effective tillers/m^2. Significantly higher value of effective tillers/m^2 was recorded with the application of 50% RDF + 50% RDN to preceding maize.

Yield is the manifestation of various yield components. Significantly higher grain yields (4.97 t/ha) of wheat were recorded with the application of 100% RDF over the control and 75% RDF, and it remained statistically similar with remaining treatments (Table 3). Application of 37.5% RDF + 37.5% RDN + BF and 50% RDF + 25% RDN resulted in statistically similar yield as obtained from different combination of CRFYM and fertilizers. However, it was significantly higher than the control. Significantly

Table 5. Interaction effect of treatments applied to maize and wheat on grain yield (t/ha) of maize (2012)

Treatment to wheat (*rabi*)	Treatment to maize (*kharif*)					
	Control	100% RDF	75% RDF + 25% RDN	50% RDF + 50% RDN	50% RDF + 25% RDN + BF	Mean
Control	2.00	5.00	5.12	5.21	4.43	4.35
100% RDF	3.17	5.07	5.17	5.27	4.95	4.72
75% RDF	3.00	5.03	5.13	5.23	4.89	4.66
50% RDF + 25% RDN	3.33	5.09	5.17	5.28	4.94	4.76
37.5% RDF + 37.5% RDN + BF	3.83	5.09	5.19	5.30	4.97	4.88
Mean	3.07	5.06	5.16	5.26	4.83	
SEm±			0.17			
CD (P=0.05)			0.48			

RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; BF, biofertilizer

higher biological yield were recorded with the application of 100% RDF over rest of the treatments and it was at par with 37.5% RDF + 37.5% RDN + BF. However, harvest index did not differ significantly. Unfertilized control treatment recorded the lowest grain and biological yields. The lower yield of other organic nutrients including the control was due to their lower yield-attributing characters. Maximum residual effects were observed with the treatment that received the maximum amount of organic source. Application of 50% RDF + 50% RDN to maize crop recorded the maximum residual effects on yield and yield-attributing characters of wheat. This residual effect of organic nutrient source on succeeding crop may be owing to the presence of highly persistent materials which require long time for complete decomposition. Thus nutrients released from residue mixed farmyard manure for long period notably benefited the succeeding crop.

Interaction effects of treatments applied to preceding maize and succeeding wheat crop on grain yield of wheat were found significant (Table 5). Interaction of application of 50% RDF + 50% RDN to maize and application of 100% RDF to wheat recorded significantly highest grain yield over combination of wheat control with the control, 100% RDF and 75% RDF + 25% RDN of maize. These results are in agreement with Kumar and Singh (1997), who reported that the maximum wheat grain yield was obtained with the application of FYM combined with 50% recommended NPK, which resulted in a significantly higher yield than the application of 100% NPK.

System productivity

System productivity in terms of wheat seed-equivalent yield was significantly influenced due to different treatments (Table 4). In maize, highest system productivity was recorded under treatment 50% RDF + 50% RDN, followed by 75% RDF + 25% RDN, but in wheat the highest system productivity was recorded with 100% RDF followed by 37.5% RDF + 37.5% RDN + BF. Treatments applied with FYM showed better system productivity. It might be owing to direct and residual effect of FYM which becomes pronounced on the system productivity during crop cycle because of improvement in soil health parameters. Application of organic amendments ensure long - term sustainability of soil fertility by improving levels of soil organic carbon, availability of nutrients and soil microbial activities (Malero *et al.,* 2007; Bodake and Rana, 2009)

Economics

Adoption of any new technology for crop production by the farmer ultimately depends on the additional monitory returns they get by adopting the technology. The economics of maize and wheat in maize–wheat cropping system was significantly influenced due to different CRFYM and fertilizer combinations (Tables 4). Application of 100% RDF to maize recorded the minimum cost of cultivation and significantly maximum net profit, followed by 75% RDF + 25% RDN, but significantly benefit: cost ratio of 1.33 and 1.60 were recorded under the control over other treatments, followed by 100% RDF, during 2011 and 2012 respectively. The gross and net returns of maize were higher during 2012 than 2011. It might be because of more crop growth, yield and minimum support price during 2012. This confirms the findings of Kumar *et al.* (2007).

In case of wheat, higher cost of cultivation was observed with the treatment which received 37.5% RDF + 37.5% RDN + BF and minimum cost of cultivation was observed with 75% RDF. The quantity of organic manures requirement to replace inorganic fertilizer is very high and hence the cost of cultivation is higher compared to chemical fertilizers. But owing to the beneficial effect of organic manures, the farmers needs to apply the organic manures. Significantly higher net returns were recorded with 100% RDF, followed by the treatment which received 75% RDF.

Table 6. Interaction effect of treatments applied to maize and wheat on grain yield (t/ha) of wheat

Treatment to wheat	Treatment to maize					
	Control	100% RDF	75% RDF + 25% RDN	50% RDF + 50% RDN	50% RDF + 25% RDN+BF	Mean
Control	2.47	4.20	4.27	4.33	4.32	3.92
100% RDF	4.95	4.96	4.97	5.00	4.99	4.97
75% RDF	4.58	4.65	4.65	4.65	4.65	4.63
50% RDF + 25% RDN	4.70	4.72	4.72	4.73	4.72	4.72
37.5% RDF + 37.5% RDN + BF	4.84	4.84	4.84	4.87	4.84	4.84
Mean	4.31	4.67	4.69	4.71	4.70	
SEm±			0.24			
CD (P=0.05)			0.68			

RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; BF, biofertilizer

Maximum benefit: cost ratio of 2.76 was observed in the control. Higher cost of cultivation was observed with the treatment which received the maximum amount of recommended dose of nitrogen through CRFYM. This confirms the findings of Kumar *et al.* (2007) and Kumari *et al.* (2010).

Hence application of 50% RDF through fertilizers and 50% RDN through CRFYM in maize and 37.5% RDF through fertilizers 37.5% RDN through CRFYM and use of biofertilizers in wheat was found better nutrient-management practice using fertilizers and crop residues in the form of FYM for higher growth, yield, and net returns from maize–wheat cropping system.

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