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EFFECTS OF DIFFERENT NUTRIENT SUPPLY OPTIONS ON SYSTEM PRODUCTIVITY, NITROGEN USE EFFICIENCY AND SOIL ENZYME ACTIVITIES IN MAIZE - WHEAT CROPPING SYSTEM

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Key words: Enzyme activities, Maize-wheat cropping system, Nitrogen use efficiencies, System Productivity, Yield

Abstract

The field experiments were conducted during *kharif* and the following *rabi* seasons of 2011-12 and 2012-13 with five different treatments in maize (*Zea mays* L.) and wheat (*Triticumaestivum* L.) cropping systems. Application of 50% RDF + 50% RDN recorded maximum WEY of maize (3.23 and 4.58 t/ha) and system productivity (8.20 and 9.03 t/ha) over rest of the treatments, but remained statistically similar with other treatments except control during 2011-12 and 2012-13, respectively. The highest ANUE (5.07 and 15.36 kg grain yield increase/kg N applied) of maize crop was recorded at 50% RDF + 25% RDN + BF, followed by 50% RDF + 25% RDN during both the years. The highest ANUE (17.64 and 17.18 kg grain yield increase/kgN applied) of wheat crop were recorded from 37.5% RDF + 37.5% RDN + BF during both the years, respectively. Application of 50% RDF + 50% RDN to maize resulted in increased the value of MBC (18.0 and 18.4%), DH (22.9 and 18.6%), alkaline phosphatase (33.3 and 29.6%) and urease (37.1 and 37.8%) over control during 2011 and 2012, respectively. An increased value of MBC (38 and 34.6%), DH (29.2 and 29.8%), alkaline phosphatase (37.2 and 34.9%) and urease (30.1 and 25.6%) was recorded with the application of 37.5% RDF + 37.5% RDN + BF to wheat over control during both the years, respectively.

Introduction

The Rice-wheat cropping system is the major cropping system in north-western India. The continuous rice–wheat cropping system has led to the exhaustion of natural resources and deteriorated soil fertility (Hashim *et al.* 2017).To maintain soil health and sustainable crop production, a paradigm shift in cropping systems is required.Alternate cropping systems and soil management practices may prove beneficial to improve and maintain soil and environmental health.

Maize-wheat cropping system has been identified as a suitable alternative to rice–wheat system (Brankov *et al.* 2021, Meena *et al.* 2021). Maize–wheat is an important cropping system of northern and central India (Kumar and Shiva Dhar2010, Singh *et al.*2011). Maize has higher production potential compared to other cereal crops and is considered to be one of the most eminent food security crops of the world(Nayak *et al.* 2012).Wheat is an important cereal crop in large parts of the world and most of people depend on it for their daily requirements. Nitrogen, phosphorus and potassium are the primary nutrients applied to soil either through chemical fertilizers or organic manures to fulfill crop nutrient requirements (Abid *et al.* 2016, Güereña *et al.* 2016). Injudicious application of fertilizers containing micronutrients, declined use of crop residues and organic manures have resulted in micronutrient deficiencies (Bharti and Sharma, 2017). Excessive use of chemical fertilizers also deteriorated the soil organic matter and microbial

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activity. The application of organic manures (OM) in crop production not only improves soil physiochemical properties but also increases crop productivity. The use of well-decomposed farmyard manure (FYM) is a well-known practice for higher crop yield which enhance SOM, promoting microbial activities and increasing the plant-available macro and micronutrients in soil. Besides improving the nutrient availability, organic manures also affect the soil physical and biological properties. Organic nutrient sources alone do not produce spectacular increase in crop yields due to their low nutrient status. Therefore, to maintain soil productivity on a sustainable basis, organic and inorganic sources of nutrient needs to be adopted. Therefore, an integrated nutrient management system could be the best alternate strategy and feasible solution for sustaining the crop productivities, maintaining and/or restoring the fertility of soil (Sharma *et al*. 2020, Güereña *et al.* 2016). The integration of inorganic fertilizer with organic nutrient sources seems to be an environmental-friendly approach that improves soil physico-chemical and biological properties, improves the nutrient use efficiency and least impact on food quality.

Therefore, an attempt was made to examine the impact of integrated nutrient management on the productivity, nutrient use efficiency and soil biological properties under maize-wheat cropping systems.

Materials and Methods

The field experiments were conducted at Indian Agricultural Research Institute, New Delhi (India) during *kharif* and the following *rabi* seasons of 2011-12 and 2012-13 to study the effect of different nutrient supply options on system productivity, nitrogen use efficiency and soil enzyme activities in the maize-wheat cropping system. The soil of the experimental site was a sandy clay loam in texture. The experiment consists of five treatments (Control- No NPK, 100% RDF, 75% RDF + 25% RDN, 50% RDF + 50% RDN and 50% RDF + 25% RDN + BF) during *kharif*(maize) and five different regimens(Control-No NPK, 100% RDF, 75% RDF, 50% RDF + 25% RDN and 37.5% RDF + 37.5% RDN + BF) in *rabi* season (wheat).The experiments were laid out in RBD during first year and in Factorial RBD in succeeding crops and replicated thrice. The recommended Dose of Fertilizer (RDF) was given through chemical fertilizer and the recommended Dose of Nitrogen through (RDN) was applied through Crop Residue Mixed Farm Yard Manure (CRFYM) based on soil test value. Bio-fertilizer *Azotobacterchroococcum* + PSB (*Pseudomonas striata*) was used for wheat and *Azospirillum sp.* + PSB (*Pseudomonas striata*) for maize. CRFYM was prepared using 80% crop residues and 20% fresh cattle dung and urine on weight basis. This manure is prepared by wind-row composting which involves placing the mixture of raw materials in long narrow piles called wind rows, that are agitated or turned on a regular basis. The liquid microbial consortium (diluted 1:100 or 1:50 dilution with water) is sprayed on the wind-rows at the time of first turning. Productivity of maize-wheat cropping system was calculated in terms of wheat equivalent yield (WEY) by using following formula:

WEY of maize = Maize yield × Maize price/Wheat price

System productivity = Wheat yield + WEY of maize

Different N-use efficiencies were computed with the help of formulae given below:

$$\text{Agronomic N} - \text{use efficiency (kg grain/kg N applied)}$$
$$= \frac{\text{Grain yield in the test treatment (kg/ha)} - \text{Grain yield in the control plot (kg/ha)}}{\text{N applied to the test treatment (kg/ha)}}$$

$$\text{Physiological N}-\text{use efficiency (kg grain/kg N uptake)} = \frac{\text{Grain yield in the test treatment (kg/ha)} - \text{Grain yield in the control plot (kg/ha)}}{\text{Uptake of N in the test treatment (kg/ha)} - \text{Uptake of N in the control plot (kg/ha)}}$$

$$\text{Apparent N recovery (\%)} = \frac{\text{Uptake of N in the test treatment (kg/ha)} - \text{Uptake of N in the control plot (kg/ha)}}{\text{N applied to the test treatment (kg/ha)}}$$

Soil microbial activity in terms of alkaline phosphatase, urease, dehydrogenase activity and microbial biomass carbon were determined at tasseling stage in maize and at the flowering stage in wheat crop**.** Alkaline phosphatase activity was estimated colorimetrically by a visible spectrophotometer using the method as described by Tabatabai and Bremner (1969). The procedure given by Klein *et al*. (1971) was used for estimation of dehydrogenase activity. For estimation of the microbial biomass carbon, the procedure given by Nunan *et al.* (1998) was used.

For estimation of the soil urease activity urea was estimated colorimetrically, in the presence of thiosemicarbazide (TSC), H_3PO_4 and H_2SO_4. The data collected for different parameters were statistically analysed with the help of analysis of variance (ANOVA) technique as suggested by Gomez and Gomez (1984) for a factorial randomized block design.

Results and Discussion

The economic yield is an important characteristic and the ultimate output of any crop depends on grain yield. The highest grain yield of maize recorded with the application of 50% RDF + 50% RDN which was higher by 0.10, 0.17, 0.27 and 2.01 t/ha during first year while 0.10, 0.20, 0.43 and 2.19 t/ha during second year than 75% RDF + 25% RDN, 100% RDF, 50% RDF + 25% RDN +BF and control, respectively (Table 1).The factors mainly responsible for variation in the grain yield of maize were different combinations of CRFYM and fertilizer which influenced the yield components like cob length, grains/cob and test weight. Similar results were also reported by Hashim *et al*. (2016) and Abid *et al.* (2020). Significantly, highest grain yields of wheat (5.21 and 4.73 t ha^{-1}) were obtained with the application of 100% RDF over control during 2011-12 and 2012-13, respectively. Application of 37.5% RDF + 37.5% RDN +BF to wheat was the second best treatment and produced almost similar yield (5.11 and 4.58 t/ha) as obtained with the application of 100% RDF (Table 1).By reducing 25% nutrients through application of 37.5% RDF + 37.5% RDN +BF, the effect on yield is almost negligible as it produced only 2.0 and 3.3 percent less grain yield than 100% RDF. Similarly, Raisi and Nejad (2012) observed that organic manure increased number of grain per ear and 1000 seed weight of wheat as compare to control. The improvement in yield attributes was due to applied nutrients through various combinations of CRFYM and fertilizer. These nutrients are vital for many plant processes including photosynthesis, translocation of photosynthates, protein synthesis, activation of plant enzymes *etc.* The combined effect of increased level of balanced nutrients and beneficial effect of CRFYM help in increasing the availability of various macro and micro nutrients in soil. The results of our study showed that treatments received nutrients from CRFYM and chemical fertilizers, produces higher grain yield.

Irrespective of sources and levels of different nutrients applied to maize and wheat, the wheat equivalent yield (WEY) of maize in maize-wheat cropping system increased significantly over the control during both the years (Table 1). Application of 50% RDF + 50% RDN recorded maximum WEY of maize (3.23 and 4.58 t/ha) and system productivity (8.20 and 9.03t/ha) over rest of the treatments, but remained statistically similar with other treatments except control during 2011-12 and 2012-13, respectively.

Nitrogen use efficiency is the recovery of the applied fertilizer N by the harvested crop.Across the years, reverse to crops yields the ANUE decreased with each increased levels of N and recorded maximum at lower levels and minimum at maximum level. The highest ANUE of maize crop was recorded at 50% RDF + 25% RDN + BF, followed by 50% RDF + 25% RDN during both the years (Table 2). Application of 100% RDF resulted least values of ANUE during both the years. This was possibly due to N losses via denitrification and ammonia volatilization from fertilizers. Across the years, ANUE of maize crop increased from 4.20-5.07 kg grain yield increase/kg N applied in 2011 to 12.42-15.36 kg grain yield increase/kg N applied in 2012. The highest ANUE (17.64 and 17.18 kg grain yield increase/kg N applied) of wheat crop were recorded from 37.5% RDF + 37.5% RDN + BF during both the years, respectively. Across the years, ANUE of wheat increased from 13.81-17.64 kg grain yield increase/kgN applied in 2011-12 to 13.74-17.18 kg grain yield increase/kg N applied in 2012-13.Sharma and Behera (2009) reported that the behaviour of ANUE was erratic, and the highest value was recorded with zero N treatment. Abid *et al.* (2020) also reported that the ANUE was greater in all plots under the treatments that were amended with organic manures in combination with mineral fertilizers.

Soil microbial activity in terms of microbial biomass carbon (MBC), dehydrogenase (DH) activity, alkaline phosphatase and urease activity were significantly influenced with the application of different ratio of CRFYM and fertilizers (Tables3 and 4). Significantly, maximum values of soil MBC (175.2 and 181.8 µg C/g soil), dehydrogenase activity (81.7 and 86.9 µg TPF/gsoil/day), alkaline phosphatase enzyme (84.0 and 87.7 µg/hr/g soil) and urease activity (31.8 and 36.2 µg/hr/g soil) at tasseling stage of maize were observed with the application of 50% RDF + 50% RDN to maize crop over rest of the treatments during both the years, respectively and it was at par with 50% RDF + 25% RDN + BF during first year of the experiment. Application of 50% RDF + 50% RDN to maize resulted in increased the value of MBC (18.0 and 18.4%), DH (22.9 and 18.6%), alkaline phosphatase (33.3 and 29.6%) and urease (37.1 and 37.8%) over control during 2011 and 2012, respectively. The maximum values of soil MBC (161.0 and 174.3 µg C/g soil) and soil urease enzyme activity (28.6 and 30.8 µg/hr/g soil) at the flowering stage in wheat crop were recorded with the application of 37.5% RDF + 37.5% RDN + BF, and it was significantly higher than rest of the treatments during both the years, respectively. Significantly, maximum values of soil DH activity (75.8 and 78.4 µg TPF/g soil/day) were recorded with the application of 37.5% RDF + 37.5% RDN + BF over rest of the treatments and it was at par with 50% RDF + 25% RDN during both the years of the experiment. Statistical analysis of the data indicated that higher values of alkaline phosphatase enzyme (78.4 and 82.3 µg/hr/g soil) were observed with the application of 37.5% RDF + 37.5% RDN + BF treatment during both the years and it was significantly higher than rest of the treatments, except 100% RDF during 2011-12.An increased value of MBC (38 and 34.6%), DH (29.2 and 29.8%), alkaline phosphatase (37.2 and 34.9%) and urease (30.1 and 25.6%) was recorded with the application of 37.5% RDF + 37.5% RDN + BF to wheat over control during 2011-12 and 2012-13, respectively. Our results are also in conformity with the findings of Dhaliwal *et al.* (2021) who reported that chemical fertilizers with FYM enhanced the MBC content over their initial levels. Farmyard manure had a significantly positive impact on the soil microbial biomass carbon and enzyme activity, compared to mineral fertilizers. Firstly, the increased microbial biomass and enzymatic activity by organic manure may be derived from the increased root biomass which provided organic matter for microorganisms. Secondly, organic manure itself could provide abounding organic matter for the growth of microorganisms (Gong *et al.* (2009).The dehydrogenase was increased by FYM applications compared to without FYM treatment and FYM have stronger effects on dehydrogenase activity.

Table 1. Effect of CRFYM and fertilizer combinations on wheat equivalent yield (WEY) of maize and system productivity of maize-wheat cropping system.

Treatment	Maize grain yield (t/ha)		Wheat grain yield (t/ha)		WEY of maize (t/ha)		System productivity (t/ha)		
	2011	2012	2011-12	2012-13	2011	2012	2011-12	2012-13	Pooled
Treatment to maize									
Control	2.23	3.07	4.55	4.06	2.31	2.67	6.86	6.73	6.80
100% RDF	4.07	5.06	4.94	4.41	3.10	4.40	8.04	8.81	8.43
75% RDF + 25% RDN	4.14	5.16	4.95	4.43	3.16	4.49	8.11	8.91	8.51
50% RDF + 50% RDN	4.24	5.26	4.97	4.45	3.23	4.58	8.20	9.03	8.61
50% RDF + 25% RDN + BF	3.97	4.83	4.93	4.44	3.03	4.21	7.96	8.65	8.30
SEm±	0.11	0.08	0.11	0.11	0.09	0.07	0.11	0.14	
LSD (P=0.05)	0.34	0.21	0.30	NS	0.27	0.19	0.31	0.40	
Treatment to wheat									
Control		4.35	4.17	3.62		3.79	7.13	7.41	7.27
100% RDF		4.72	5.21	4.73		4.11	8.18	8.84	8.51
75% RDF		4.66	4.87	4.40		4.05	7.83	8.45	8.14
50% RDF + 25% RDN		4.76	4.98	4.46		4.14	7.95	8.60	8.27
37.5% RDF + 37.5% RDN + BF		4.88	5.11	4.58		4.25	8.08	8.83	8.45
SEm±		0.08	0.11	0.11		0.07	0.11	0.14	
LSD (P=0.05)		0.21	0.30	0.31		0.19	0.31	0.40	
Interaction (Kharif×Rabi)									
SEm±		0.17	0.24	0.25		0.15	0.24	0.32	
LSD (P=0.05)		0.48	0.67	0.70		0.42	0.69	0.90	

NS: Non-significant

Table 2. Effect of CRFYM and fertilizer combinations on nitrogen use efficiencies of maize and wheat.

Treatment	Maize						Wheat					
	ANUE[a]		PNUE[b]		ANR[c]		ANUE[a]		PNUE[b]		ANR[c]	
	2011	2012	2011	2011-12	2012-13	2011-12	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Treatment to maize												
Control	0.00	0.00	0.00	51.46	0.00	0.00	12.62	12.51	41.71	43.09	24.23	23.25
100% RDF	4.20	12.42	65.56	63.00	6.41	19.74	12.84	12.59	52.22	54.03	24.90	23.64
75% RDF + 25% RDN	4.50	12.83	57.71	59.26	7.76	21.67	12.84	12.61	52.21	53.73	24.90	23.77
50% RDF + 50% RDN	4.89	13.24	55.14	58.29	8.85	22.72	12.89	12.72	52.07	53.31	25.15	24.12
50% RDF + 25% RDN + BF	5.07	15.36	62.84	61.06	8.10	25.24	12.85	12.64	52.84	53.38	25.00	23.93
SEm±	0.57	0.31	1.13	0.61	0.92	0.57	0.74	0.74	0.47	0.25	1.39	1.34
LSD (P=0.05)	1.72	0.88	3.42	1.73	2.81	1.61	NS	NS	1.33	0.70	NS	NS
Treatment to wheat												
Control		10.22		48.46		16.90	0.00	0.00	44.66	45.04	0.00	0.00
100% RDF		10.92		61.30		18.06	13.81	13.74	52.27	53.49	26.40	25.66
75% RDF		10.78		61.42		17.90	15.89	15.86	52.79	54.52	30.06	29.05
50% RDF + 25% RDN		10.94		61.16		18.12	16.70	16.29	51.28	52.79	32.57	30.82
37.5% RDF + 37.5% RDN + BF		11.01		60.73		18.39	17.64	17.18	50.05	51.69	35.16	33.19
SEm±		0.31		0.61		0.57	0.74	0.74	0.47	0.25	1.39	1.34
LSD (P=0.05)		NS		1.73		NS	2.09	2.10	1.33	0.70	3.96	3.80
Interaction (Kharif×Rabi)												
SEm±		0.69		1.36		1.27	1.65	1.65	1.05	0.55	3.12	2.99
LSD (P=0.05)		NS		3.87		NS	NS	NS	2.97	1.56	NS	NS

[a]ANUE: Agronomic N-use efficiency; [b]PNUE: physiological N-use efficiency; [c]ANR: apparent N recovery; NS: Non-significant

Table 3. Effect of CRFYM and fertilizer combinations on soil microbial biomass carbon and enzyme activity at tasseling stage of maize.

Treatment	MBC (µg C/g soil)		Dehydrogenase (µg TPF/g soil/day)		Alkaline phosphatase (µg/hr/g soil)		Urease (µg/hr/g soil)	
	2011	2012	2011	2012	2011	2012	2011	2012
Treatment to maize								
Control	143.7	148.3	63.0	70.8	56.0	61.7	20.0	22.5
100% RDF	149.4	151.8	65.7	73.9	67.7	70.1	23.8	24.7
75% RDF + 25% RDN	157.0	162.2	70.3	78.6	76.0	75.3	25.2	29.1
50% RDF + 50% RDN	175.2	181.8	81.7	86.9	84.0	87.7	31.8	36.2
50% RDF + 25% RDN + BF	164.8	170.8	76.0	81.0	79.3	81.5	27.7	32.5
SEm±	4.3	2.5	2.6	1.5	2.5	1.3	1.38	0.7
LSD (P=0.05)	13.2	7.0	7.8	4.4	7.6	3.8	4.20	2.1
Treatment to wheat								
Control		160.0		76.8		74.1		28.5
100% RDF		163.5		78.1		75.2		29.1
75% RDF		161.1		77.5		74.6		28.7
50% RDF + 25% RDN		164.8		78.9		75.9		29.2
37.5% RDF + 37.5% RDN + BF		165.5		79.7		76.4		29.6
SEm±		2.5		1.5		1.3		0.7
LSD (P=0.05)		NS		NS		NS		NS
Interaction (Kharif × Rabi)								
SEm±		5.5		3.5		3.0		1.6
LSD (P=0.05)		NS		NS		NS		NS

NS: Non-significant

Table 4. Effect of CRFYM and fertilizer combinations on soil microbial biomass carbon and enzyme activity at flowering stage of wheat.

Treatment	MBC (µg C/g soil)		Dehydrogenase (µg TPF/g soil/day)		Alkaline phosphatase (µg/hr/g soil)		Urease (µg/hr/g soil)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Treatment to maize								
Control	125.9	140.2	64.3	66.6	66.4	70.1	23.6	25.4
100% RDF	127.7	140.9	65.6	68.0	67.5	70.8	23.9	25.8
75% RDF + 25% RDN	128.5	141.5	65.8	68.4	67.8	71.1	24.1	26.5
50% RDF + 50% RDN	129.9	142.3	66.4	69.0	68.1	71.3	24.4	26.7
50% RDF + 25% RDN + BF	129.3	141.7	66.2	68.8	68.0	71.2	24.2	26.7
SEm±	3.6	4.1	1.7	1.6	1.7	1.6	0.8	0.8
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Treatment to wheat								
Control	99.6	114.0	53.6	55.0	49.2	53.6	20.0	22.9
100% RDF	124.5	134.4	64.7	69.7	73.8	75.3	23.9	25.9
75% RDF	110.1	128.0	60.9	63.0	63.4	65.9	21.9	24.1
50% RDF + 25% RDN	145.9	156.0	73.3	74.7	73.1	77.3	25.9	27.4
37.5% RDF + 37.5% RDN + BF	161.0	174.3	75.8	78.4	78.4	82.3	28.6	30.8
SEm±	3.6	4.1	1.7	1.6	1.7	1.6	0.8	0.8
LSD (P=0.05)	10.1	11.8	4.7	4.6	4.9	4.6	2.2	2.2
Interaction (kharif×Rabi)								
SEm±	8.0	9.3	3.7	3.6	3.8	3.6	1.8	1.7
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non-significant

This might be due to the more easily decomposable components of FYM have positive impact on the metabolism of soil microorganisms. The addition of FYM significantly increased alkaline phosphatase activity. The increase in alkaline phosphatase activity over the years with the application of inorganic nutrients was attributed to greater input of root biomass which was increased due to better crop productivity.

Hence, it can be calculated that application of 50% RDF + 50% RDN in maize and 37.5% RDF + 37.5% RDN + biofertilizers in wheat was found to be the better nutrient management practice using fertilizers and crop residue mix FYM for higher yield, nitrogen use efficiency and soil enzyme activities in maize-wheat cropping system.

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