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Effect of organic manuring and nitrogen fertilization on productivity, nutrient-use efficiency and economics of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was carried out during the winter (*rabi*) season of 1996–97 and 1997–98 on sandy-loam soils of Hisar. Haryana, to study the effect of organic (FYM@0, 10, 20 and 30 tonnes/ha) and inorganic (N @ 0, 60, 120 and 180 kg/ha) and 1 recommended fertility level of 120 kg N + 26.2 kg P + 25 kg $ZnSO_4$/ha) sources of N on productivity, profitability, optimum dose of N and its use efficiency in wheat (*Triticum aestivum* L. emend. Fiori & Paol.). Application of recommended fertility level along with 10 tonnes FYM/ha resulted significantly higher grain yield, N, P and K uptake by 9.0, 11.0, 21.6 and 9.87% compared with recommended fertility level alone and by 4.0, 2.0, 7.8 and 7.6% as compared with 10 tonnes FYM/ha along with 180 kg N/ha. Application of 10, 20 and 30 tonnes FYM/ha enhanced the agronomic efficiency by 4.4, 7.1, 7.9 kg grain added/kg N; apparent recovery of N by 10.6, 19.3, 21.5% and partial factor productivity of N by 4.4, 7.1, 7.9 kg grain/kg N compared with no FYM. Increasing levels of N from 60 to 120, 180 kg N/ha and recommended fertility level reduced the agronomic efficiency, apparent recovery of N and partial factor productivity of N; however, the reduction was low at recommended fertility level. Highest physiological efficiency of N (41.1), P (213.9) and K (39.9) was recorded at 60 kg N/ha, which was decreased by 2.3 kg grain/kg N absorbed, 14.1 kg grain/kg P absorbed and 5.4 kg grain/kg K absorbed at recommended fertility level as compared with 60 kg N/ha. Optimum dose of N with 10 tonnes FYM/ha was 135.6 kg N/ha for wheat. Application of 10 tonnes FYM/ha substituted 34.1 kg N requirement compared to without FYM. Application of 10 tonnes FYM and 180 kg N/ha recorded higher net returns of Rs 9,294 and Rs 12,519/ha with the highest benefit : cost ratio of 1.92 and 2.13 respectively.

Key words : Nitrogen, Farmyard manure, Nutrient-use efficiency, Yield, Optimum N dose, Net returns, Benefit : cost ratio

Wheat is an exhaustive feeder and requires substantial amount of nutrients for higher productivity. In many parts of Haryana, decline in yield and factor productivity has been reported in wheat due to deterioration in soil health in terms of depletion of organic matter and other nutrients. Organic manures are a good source of nutrients and contribute towards build-up of organic matter in soil. Nitrogen is an indispensable element for optimum functioning of crops and generally fertilizers account for about half of the cost of cultivation for most of the crops. Efficiency of N by most crops ranges from 20 to 60% (Aulakh *et al.*, 1992). The low recovery of applied N by crops raises the question of the fate of the fertilizer N that is not absorbed by the crop. This nitrogen may be lost from the soil–plant system through run-off, leaching, denitrification and ammonia volatilization or made unavailable to the plant through immobilization in the soil. Ammonia volatilization is a major loss mechanism that affects the efficiency of N fertilizer under irrigated conditions. Hence use efficiency of applied fertilizers needs to be increased to sustain the productivity of wheat. Balanced fertilizer use along with organic manures like farmyard manure (FYM) is considered as promising agro-technique to sustain yield, increase fertilizer-use efficiency and restore soil fertility. In the present study, effect of different rates of FYM and N fertilizer on yield, nutrient-use efficiency and economics was studied in wheat.

MATERIALS AND METHODS

An experiment was conducted during the winter (*rabi*) season of 1996–97 and 1997–98 at Hisar on sandy-loam soil, having pH 8.06, low organic carbon 0.34% and available N (151.2 kg/ha), medium available P (10.36 kg/ha) and high available K (329.4 kg/ha). The experiment was laid out in split-plot design with 4 replications. The treatments comprised 4 levels each of FYM (0, 10, 20 and 30

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tonnes/ha) in main plots, and N (0, 60, 120 and 180 kg/ha besides 1 recommended fertility level of 120 kg N + 26.2 kg P + 25 kg $ZnSO_4$/ha) in subplots. Well-decomposed FYM, containing 0.63% N, 0.27% P and 0.72% K on oven-dry basis was applied uniformly as per treatment and incorporated into the soil 1 month before sowing. Full dose of P and $ZnSO_4$ (in recommended treatment only) was given just before sowing, while N was applied in 3 splits, half at sowing, one-fourth after first irrigation and remaining after second irrigation. Wheat 'UP 2338' was sown on 10 and 18 December in 1996 and 1997, respectively, at 20 cm row spacing using 125 kg seed/ha.

The grain and straw samples of wheat were analysed for N, P and K content by Nassler's reagent method, vanado-molebdophosphoric acid yellow colour method and by flame photometer method respectively. The total uptake of these nutrients was computed as:

$$\text{Nutient uptake (kg/ha)} = \frac{\text{Nutrient content (\%) (grain/straw)} \times \text{yield (kg/ha)}}{100}$$

In order to quantify the effect of FYM and fertilizer N on the nutrient-use efficiencies in wheat, computations were made using following equations:

$$AE_N = \Delta Y \div F_N$$

where, AE_N is the agronomic efficiency, often termed as incremental efficiency, of applied N fertilizer, ΔY is the incremental yield due to fertilizer N input and F_N is the amount of fertilizer N applied.

$$AR_N = (\Delta U \div F_N) \times 100$$

where, AR_N is the apparent recovery of fertilizer N, ΔU is the incremental uptake of N due to fertilizer application.

$$PFP_N = Y \div F_N$$

where PFP_N is the partial factor productivity of applied N, Y is the yield.

$$PE_{N \text{ or } P \text{ or } K} = (\Delta Y \div \Delta U_{N \text{ or } P \text{ or } K}) \times 100$$

where $PE_{N \text{ or } P \text{ or } K}$ is the physiological efficiency of N, P and K, $\Delta U_{N \text{ or } P \text{ or } K}$ is the incremental uptake of N, P and K due to fertilizer application.

RESULTS AND DISCUSSION

Grain yield

Mean data of 2 years showed that application of FYM @ 10, 20 and 30 tonnes/ha increased the grain yield significantly by 17.56, 27.42 and 30.56% over no FYM respectively (Table 1). The yield was also increased significantly up to 180 N/ha and recommended fertilizer level. Increase in grain yield with recommended level was 115.7, 42.9, 16.6 and 4.17 over 0, 60, 120 and 180 kg N/ha respectively. Interaction revealed that recommended fertility level along with FYM @ 10 and 20 tonnes/ha resulted in 9.0 and 14.9% higher grain yield than recommended fertility level alone (Table 2). The improvement in grain yield with the application of FYM and N fertilizer was owing to the beneficial effect of these on nutrient uptake, crop-growth rate (CGR), relative growth rate and yield-attributing components like effective tillers. Tomar *et al.* (1997) also reported higher grain yield of wheat with increasing dose of fertilizer application.

Nutrient uptake

Application of FYM @ 10, 20 and 30 tonnes augmented nutrient uptake by 19.9, 32.7 and 37.4% N; 29.5, 44.7 and 49.5% P; and 20.4, 32.5 and 38.6% K compared with no FYM (Table 1). The increase in nutrient uptake with FYM was due to increased availability of nutrients to the plants. It also improved the soil environment, which encouraged proliferous root-system, resulting in better absorption of moisture and nutrient and thus resulting in higher biomass production.

The total uptake of N, P and K was enhanced significantly with N application up to 180 kg/ha (Table 1). The difference in N and P uptake between 180 kg N/ha and recommended fertility levels was non-significant. The N, P and K uptake in wheat was increased by 67.9, 56.7 and 55.3% with 60 kg N/ha; 115.2, 100.0 and 101.4% with 120 kg N/ha; and 152.4, 127.0 and 134.7% with 180 kg N/ha; 157.3, 144.5 and 153.6% with recommended fertility level over no N respectively. Application of recommended fertility level improved the N uptake by 53.9, 19.5 and 1.9%; P uptake by 56.0, 22.2 and 7.7%; and K uptake by 63.2, 25.8 and 8.0% over 60, 120 and 180 kg N/ha respectively. The results of interaction effect of FYM and fertilizer levels showed that application of recommended fertility level along with 10 tonnes FYM/ha recorded significantly higher nutrient uptake than with other treatment combinations (Table 2). However, the differences in nutrient uptake between 180 kg N/ha and recommended fertility level at all the FYM levels was non-significant. Improvement in nutrient uptake with the application of FYM and N levels was due to the increase in dry-matter accumulation and nutrient concentration. Singh *et al.* (1996) also observed increased N, P and K uptake by fertilizer application.

Agronomic efficiency

Agronomic efficiency increased from 15.3 at no FYM to 23.2 at 30 tonnes FYM/ha application (Table 1). Application of 10, 20 and 30 tonnes FYM/ha enhanced the agronomic efficiency by 4.4, 7.1 and 7.9 kg grain added/kg N compared with no FYM, whereas it reduced from 25.5

at 60 kg N/ha to 14.3 kg grain added/kg N at 180 kg N/ha application. Agronomic efficiency was improved by 7.5, 11.2 and 2.7 kg grain added/kg N with application of 60 kg N/ha compared with 120, 180 kg N/ha and recommended fertility level. Application of recommended fertility level also recorded higher agronomic efficiency by 4.8 and 8.5 kg grain added/kg N compared with 120 and 180 kg N/ha. Reduced losses of N and higher availability of nutrients with the application of FYM probably led to improvement in grain yield and consequently the higher agronomic efficiency. Sharma (2002) reported that agronomic efficiency of N was increased by 5–7 kg grain/kg N fertilizer over no N.

Apparent nitrogen recovery

Apparent recovery of N was increased from 33.1% at no FYM to 54.6% with 30 tonnes FYM/ha. Application of 10, 20 and 30 tonnes FYM/ha enhanced the apparent recovery of N by 10.6, 19.3 and 21.5% compared with no FYM respectively. Apparent recovery of N was reduced from 59.2% at 60 kg N/ha to 32.6% at 180 kg N/ha application. Apparent recovery of N was enhanced at recommended fertility level by 10.3 and 19.1% compared with 120 and 180 kg N/ha respectively (Table 1). Application of 120, 180 kg N/ha and recommended fertility level reduced the apparent recovery of N by 17.8, 26.6 and 7.5% compared with 60 kg N/ha. Higher apparent recovery of fertilizer N with FYM application might be due to lower N losses and synchronization of N supply with crop needs (Azam *et al.*, 1997).

Table 2. Interaction effect of farmyard manure and nitrogen levels on grain yield and nutrient uptake of wheat (mean data of 2 years)

Treatment	Nitrogen (kg/ha)				Recommended fertility level
	0	60	120	180	
FYM (tonne/ha)	*Grain yield (kg/ha)*				
0	1,265	2,246	2,844	2,400	3,628
10	1,889	2,787	3,296	3,802	3,956
20	2,062	3,032	3,747	4,040	4,168
30	2,191	3,120	3,824	4,104	4,231
	N uptake (kg/ha)				
0	24.3	47.6	63.4	78.6	84.0
10	37.2	60.7	74.7	91.4	93.3
20	41.4	67.7	87.8	99.2	99.6
30	44.2	70.2	91.0	102.3	101.8
	P uptake (kg/ha)				
0	4.5	8.5	11.1	13.7	14.8
10	7.5	11.5	14.1	16.7	18.0
20	8.4	13.0	16.6	18.2	19.6
30	9.2	13.4	17.2	18.8	20.0
	K uptake (kg/ha)				
0	25.9	51.1	67.7	79.5	94.2
10	42.3	62.9	78.5	96.2	103.5
20	47.4	69.1	90.8	104.9	110.0
30	50.2	74.1	96.6	108.3	112.3
CD (P=0.05)		*Grain yield*	*N uptake*	*P uptake*	*K uptake*
2 N levels at same FYM level		165	5.3	1.8	6.2
2 FYM levels at different or same N level		217	7.4	2.5	9.1

Table 1. Effect of farmyard manure and nitrogen levels on grain yield, nutrient uptake, agronomic efficiency (AE_N), apparent recovery of N (AR_N), partial factor productivity of N (PFP_N), physiological efficiency of N, P and K (kg grain/kg N or P or K absorbed) and economics of wheat (mean data of 2 years)

Treatment	Grain yield (kg/ha)	Nutrient uptake (kg/ha)			AE_N (kg grain added/ kg N)	AR_N (%)	PFP_N (kg grain/ kg N)	Physiological efficiency			Net returns (Rs/ha)	Benefit : cost ratio
		N	P	K				N	P	K		
FYM (tonnes/ha)												
0	2,676	59.6	10.5	63.7	15.3	33.1	27.6	40.0	233.0	37.4	7,576	1.85
10	3,146	71.5	13.6	76.7	19.7	44.7	32.0	39.4	206.6	37.0	9,274	1.92
20	3,410	79.1	15.2	84.4	22.4	52.4	34.7	38.6	199.8	36.6	9,684	1.86
30	3,494	81.9	15.7	88.3	23.2	54.6	35.5	38.1	197.9	35.5	8,998	1.72
CD (P=0.05)	92	2.8	0.8	4.1								
N (kg/ha)												
0	1,852	36.8	7.4	41.4							1,984	1.21
60	2,796	61.5	11.6	64.3	25.5	59.2	46.6	41.1	213.9	39.9	7,221	1.72
120	3,427	79.2	14.8	83.4	18.0	41.4	28.6	39.3	209.6	37.6	10,513	1.99
180	3,836	92.9	16.8	97.2	14.3	32.6	21.3	37.5	207.6	36.0	12,519	2.13
Recommended fertility level	3,996	94.7	18.1	105.0	22.8	51.7	33.3	38.8	199.8	34.5	12,179	1.98
CD (P=0.05)	70	3.7	1.1	3.7								

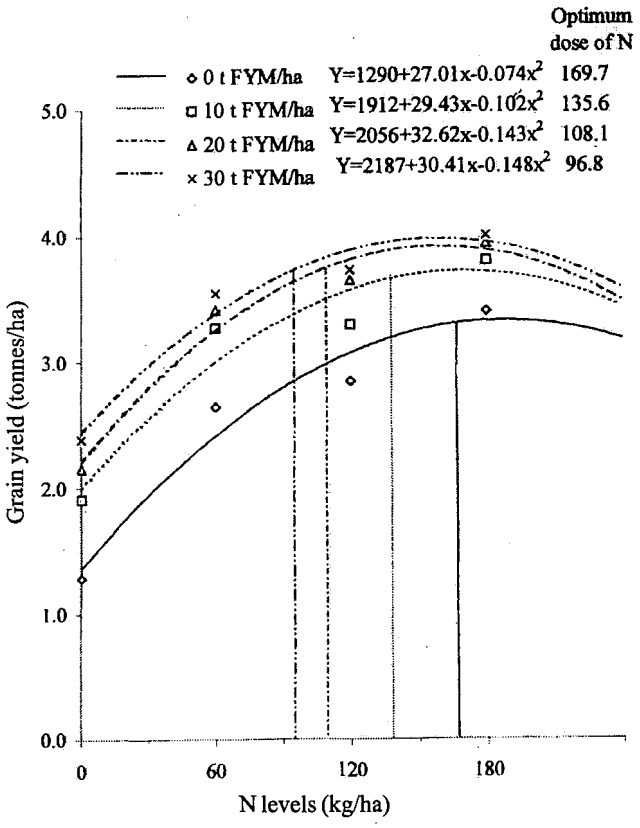

Fig. 1. Response curve of N for wheat under different FYM levels (mean data of 2 years)

Partial factor productivity of applied N

Maximum partial factor productivity of 35.5 and 46.6 kg grain/kg N was recorded at 30 tonnes FYM and 60 kg N/ha application respectively. Partial factor productivity of applied N was increased by 4.4, 7.1 and 7.9 kg grain/kg N with 10, 20 and 30 tonnes FYM/ha, respectively, compared without FYM. Partial factor productivity of applied N was decreased by 18.0, 25.3 and 13.3 kg grain/kg N with 120, 180 and recommended fertility level compared with 60 kg N/ha (Table 1). Recommended fertility level improved the partial factor productivity by 4.7 and 12.0 kg grain/kg N compared with 120 and 180 kg N/ha.

Physiological efficiency

Physiological efficiency of N, P and K decreased by 1.9, 35.1 and 1.9 kg grain/kg N or P or K absorbed at 30 tonnes FYM/ha compared to without FYM. The highest physiological efficiency of 41.1 kg grain/kg N, 213.9 kg grain/kg P and 39.9 kg grain/kg K was recorded at 60 kg N/ha application (Table 1). Application of 120, 180 kg N/ha and recommended fertility level reduced the physiological efficiency of N by 1.8, 3.6 and 2.3 kg grain/kg N absorbed; P by 4.6, 6.3 and 14.1 kg grain/kg P absorbed; and K by 2.3, 3.9 and 5.4 kg grain/kg K absorbed respectively.

Response equation and optimum dose of nitrogen

The relationship between N levels and grain yield at various FYM levels was found to be quadratic. Optimum dose of N under 0, 10, 20 and 30 tonnes FYM/ha was worked out to be 169.7, 135.6, 108.1 and 96.8 kg N/ha respectively (Fig. 1). Application of 10, 20 and 30 tonnes FYM/ha substituted 34.1, 61.6 and 71.1 kg N requirement compared to without FYM.

Economics

Maximum net returns of Rs 9,684 were recorded with 20 tonnes FYM/ha, which was higher by Rs 2,108 and Rs 410/ha compared with 0 and 10 tonnes FYM/ha. Application of 180 kg N/ha recorded the maximum net returns of Rs 12,519, followed by Rs 12,179 with recommended fertility level (Table 1). The benefit : cost ratio was highest (1.92) at 10 tonnes FYM/ha application. Increasing levels of FYM beyond 10 tonnes/ha reduced the benefit : cost ratio in wheat due to increased cost of these inputs. Likewise, the benefit : cost was increased from 1.21 in no N to 2.13 and 1.98 in 180 kg N/ha and recommended fertility level respectively. The increase in net returns by the application of organic manure and N fertilizer might be due to positive effect of these on grain yield.

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