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Effect of integrated nutrient management on productivity of wheat (*Triticum aestivum*) under limited and adequate irrigation supplies

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ABSTRACT

A field experiment was conducted during the winter seasons of 2000–01 and 2001–02 at Hisar, Haryana, to find out a suitable combination of chemical and organic nutritional sources for wheat (*Triticum aestivum* L. emend. Fiori & Paol.) grown at 2 irrigation levels, viz. adequate irrigation and limited irrigation, and 10 levels of nutrients. Wheat crop under adequate irrigation one each at crown-root initiation, late tillering, late jointing, flowering and milk stages recorded better growth, yield attributes, grain and straw yields and higher consumptive use of water and nutrient uptake. Application of 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter* recorded significantly higher growth, nutrient uptake, available N and grain and straw yields of wheat. The net income and benefit : cost ratio and water-use efficiency were also highest with 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter* + followed by 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter.* Available N content also increased compared with its initial soil status under these treatments. The content of organic carbon and available phosphorus in soil increased and the bulk density and pH decreased in all the integrated nutrient-management practices involving FYM (10 t/ha). Thus on integrating FYM (10 t/ha) + *Azotobacter* with 187.5 and 150 kg N/ha or FYM (10 t/ha) with 187.5 kg N/ha, productivity and monetary return can be increased by maintaining or improving the residual soil-fertility status after the harvest of wheat crop.

Key words : Consumptive use, Irrigation, Nutrient uptake, Water use efficiency

Significant efforts have been made to economise the use of fertilizers in field crops through application of biofertilizer and farmyard manure (FYM). Long-term fertilizer effects show that application of fertilizer alone has a deleterious effect on soil health and crop productivity. Integration of various sources of nitrogenous (organic and inorganic) fertilizers is more suitable because this reduces the application of chemical fertilizers and cost of cultivation, besides being an environment friendly approach (Ram and Mir, 2006). Gupta *et al.* (2006) also indicated the beneficial effect of FYM in combination with chemical fertilizer to wheat from the results of a long-term experiment conducted at Jabalpur, Madhya Pradesh. Saving of fertilizer N and increase in wheat yield owing to *Azotobacter* application have been reported by many workers. Since limited information is available on the comparative performance of integrated nutrient management under various moisture regimes, the present investigation was taken up with wheat.

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MATERIALS AND METHODS

A field experiment was conducted during the winter seasons of 2000–01 and 2001–02 at research farm of the university at Hisar. The soil was sandy loam, having available N, P and K 149.9, 10.5 and 354.2 kg/ha respectively, with pH 7.90 and electrical conductivity 0.29 dS/m. The treatments consisted of 2 levels of irrigation, viz. adequate irrigation (one each at crown-root initiation, late tillering, late jointing, flowering and milk stages) and limited irrigation (one each at crown-root initiation and flowering stage) and 10 nutritional treatments, viz. no nitrogen – control, 150 kg N/ha, FYM (10 t/ha), *Azotobacter*, 112.5 kg N/ha + *Azotobacter,* FYM (10 t/ha) + *Azotobacter*, 112.5 kg N/ha + FYM (10 t/ha) + *Azotobacter*, 150 kg/ha + FYM (10 t/ha) + *Azotobacter*, 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter* and 187.5 kg N/ha + FYM (10 t/ha). These were replicated 4 times in randomised block design. Seeds were treated with *Azotobacter* strain (Mac-68) @ 25 g/kg as per treatment. The N, P and K contents of FYM were 0.63, 0.28 and 0.71% (2000–01) and 0.64,

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0.30 and 0.72% (2001–02), respectively, on oven-dry weight basis. A pre-sowing irrigation of 8 cm was applied to all plots 10 days before sowing. The depth of irrigation was 6 cm in all post-sowing irrigation treatments. A common dose of P (26.2 kg/ha), K (25 kg/ha) and $ZnSO_4$ (25 kg/ha) was applied at sowing. FYM (10 tonnes/ha) as per treatment was applied before a month of sowing. Half of the N as per treatment was drilled at the time of sowing. Remaining N was top-dressed after the first irrigation. Wheat 'PBW 343' was sown at 20 cm row spacing using 100 kg seed/ha on 19 and 7 November and harvested on 22 and 11 April in first and second year respectively. Total amount of rainfall received was 61.8 mm and 27.5 mm respectively during crop seasons. Organic carbon, bulk density, pH, available N, P, K of soil and N, P, K content in plant were estimated by standard methods. Nutrient uptake was estimated by multiplying the dry-matter accumulation at maturity in grain and straw of wheat by their respective percentages. Total uptake was calculated by adding uptake of grain and straw. Soil-moisture content was determined by gravimetric method. The yield parameters and yields were recorded and economics was worked out.

RESULTS AND DISCUSSION

Growth and yield

The growth of wheat measured in terms of plant height varied significantly under two irrigation conditions (Table 1). Wheat under adequate irrigation had taller plants than that of crop under limited irrigation supply. The better growth under adequate irrigation supply might be attributed to adequate soil moisture coupled with nutrient supply. With the increase in N dose either through fertilizer N, organic manure, biofertilizer alone or in combination, plant height of wheat was improved. Application of 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter* being statistically on par with 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter* recorded significantly more plant height. The enhancement in growth with increase in fertility was owing to rapid conversion of synthesized photosynthates into protein to form more protoplasm, thus increasing the number and size of cell which might have increased the plant height. The favourable effect of FYM might be attributed to increased activities of heterotrophic bacteria and fungi in soil, which in turn increased the activity of soil enzymes responsible for the conversion of unavailable form of nutrients to available form. *Azotobacter* not only provided nitrogen but also produced amino acids, vitamins and growth-promoting substances like indole acetic acid (IAA) and gibberellic acid (GA), which might have promoted crop growth (Singh *et al.*, 2006).

Wheat crop with adequate irrigation gave significantly higher yield attributes, viz. spikes/m row length and grains/spike and grain and straw yields than limited irrigation (Table 1). Increasing level of N alone or in combination with organic manure (FYM) improved various yield attributing characters and grain and straw yields of wheat than no-nitrogen control, FYM (10 t/ha), *Azotobacter* and FYM (10 t/ha) + *Azotobacter*. Integration of 150 and 187.5 kg N/ha with FYM (10 t/ha) + *Azotobacter* and 187.5 kg N/ha with FYM (10 t/ha) increased spike/m row length by 6.1, 9.0 and 7.6%, respectively, over recommended dose of N (150 kg/ha). The respective increase in grains/spike was 4.1, 6.4, 4.8%. Application of 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter*, being statistically on par with 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter*, recorded significantly higher grain and straw yields than rest of the treatments. It might be owing to beneficial effect of N, FYM and *Azotobacter* on crop growth, which influenced the yield-attributing characters positively. Moreover, proper decomposition of FYM, which supplied available plant nutrients directly to plants and created favourable soil environment, ultimately increased the nutrients and water-holding capacity of soil for longer time, which resulted in better growth, yield attributes and ultimately grain and straw yields of wheat. The results confirm those of Gupta *et al.* (2006) and Ram and Mir (2006).

Nutrient uptake

Adequate irrigation resulted in significantly higher N, P and K uptake than limited irrigation (Table 1). The increase in supply of irrigation provided adequate moisture in soil, which played an important role in nutrient uptake (Dutta and Mondal, 2006).

Application of 187.5 kg N/ha integrated with FYM (10 t/ha) and biofertilizer (*Azotobacter*) being on a par with 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter* recorded significantly higher N, P and K uptake than rest of the treatments. Such results are obvious, as application of fertilizer N in combination with organic manures and biofertilizer is known to improve various physico-chemical properties resulting in enhanced nutrient absorption or uptake. These findings confirm those of Singh (2006).

Soil fertility

After 2 years of experimentation, irrigation treatments did not influence the organic carbon, soil pH, bulk density and available N, P and K content in soil (Table 2). However, nutritional treatments significantly influenced the available N and P content in soil. Application of 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter* being on a par with 150 kg N/ha + FYM (10 t/ha) + *Azotobacter* and 187.5 kg

Table 1. Effect of irrigation and nutrient treatments on growth, yield, nutrient uptake and water-use efficiency of wheat (pooled data of 2 years)

Treatment	Plant height (cm)	Spikes/m row length	Grains/ spike	Grain yield (t/ha)	Straw yield (t/ha)	Nutrient uptake (kg/ha)			Consumptive use of water (mm)	Water-efficiency (kg/ha-mm)
						N	P	K		
Irrigation supply										
Adequate irrigation	85.0	50.6	35.1	3.87	5.29	95.99	16.62	90.12	307.6	12.58
Limited irrigation	80.9	47.7	31.7	3.26	4.62	82.18	13.68	57.55	233.1	13.98
SEm±	0.5	0.3	0.2	0.04	0.06	1.35	0.32	1.28		
CD (P=0.05)	1.4	1.0	0.7	0.10	0.16	3.83	0.89	3.62		
Nutrient management										
No (control)	70.0	32.4	24.3	1.72	2.25	38.95	6.41	35.59	228.1	7.54
150 kg N/ha	86.9	54.8	36.4	4.34	6.02	105.97	17.85	101.34	270.8	16.03
FYM (10 t/ha)	75.5	39.6	28.9	2.52	3.23	57.83	9.40	53.55	245.6	10.24
Azotobacter	72.9	35.7	26.5	2.06	2.66	46.59	7.66	43.01	237.7	8.66
112.5 kg N/ha + *Azotobacter*	86.2	53.3	35.7	4.18	5.87	101.65	17.17	97.78	265.4	15.73
FYM (10 t/ha) + *Azotobacter*	76.0	43.5	30.3	2.90	3.84	68.12	11.48	63.72	252.7	11.49
112.5 kg N/ha + FYM (10 t/ha) + *Azotobacter*	88.2	55.5	36.8	4.43	6.11	108.97	18.37	103.45	274.1	16.17
150 kg N/ha + FYM (10 t/ha) + *Azotobacter*	90.1	58.2	37.9	4.78	6.46	117.97	20.23	111.25	284.4	16.81
187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter*	92.5	59.8	38.6	4.97	6.60	123.93	21.93	115.49	290.1	17.13
187.5 kg N/ha + FYM (10 t/ha)	91.3	59.0	38.2	4.87	6.53	120.91	21.05	112.98	286.9	16.98
SEm±	1.1	0.8	0.5	0.08	0.12	3.03	0.70	2.86		
CD (P=0.05)	3.1	2.1	1.5	0.21	0.35	8.55	1.98	8.09		

Table 2. Effect of irrigation and nutrient treatments on economics and soil-fertility status after 2 years

Treatment	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	Benefit : cost ratio	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic carbon (%)	pH	Bulk density (g/cc)
Irrigation supply									
Adequate irrigation	16,198	11,363	1.70	140.7	12.1	347.6	0.38	7.78	1.41
Limited irrigation	15,883	7,457	1.47	143.7	11.9	343.5	0.37	7.76	1.41
SEm±				1.2	0.2	1.5	0.01	0.06	0.01
CD (P=0.05)				NS	NS	NS	NS	NS	NS
Nutrient management									
No (control)	14,513	–2,380	0.84	130.4	11.0	343.2	0.34	7.84	1.43
150 kg N/ha	15,904	14,308	1.90	144.7	10.3	340.2	0.36	7.78	1.42
FYM (10 t/ha)	15,563	1,815	1.12	134.9	13.0	352.9	0.37	7.75	1.41
Azotobacter	14,618	–296	0.98	132.0	10.8	342.5	0.34	7.82	1.43
112.5 kg N/ha + *Azotobacter*	15,662	13,567	1.87	139.9	10.5	341.4	0.36	7.80	1.42
FYM (10 t/ha) + *Azotobacter*	15,668	4,402	1.28	137.0	12.9	349.5	0.37	7.74	1.41
112.5 kg N/ha + FYM (40 t/ha) + *Azotobacter*	16,712	14,082	1.84	146.9	12.8	348.0	0.38	7.73	1.40
150 kg N/ha + FYM (10 t/ha) + Azotobacter	17,059	15,857	1.93	151.4	12.6	346.9	0.38	7.72	1.40
187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter*	17,407	16,614	1.95	157.5	12.5	345.5	0.38	7.71	1.40
187.5 kg N/ha + FYM (10 t/ha)	17,302	16,130	1.93	155.2	12.5	346.2	0.38	7.70	1.40
SEm ±				2.6	0.4	3.5	0.02	0.12	0.03
CD (P=0.05)				7.3	1.0	NS	NS	NS	NS

N/ha + FYM (10 t/ha) resulted in significantly higher available N content in soil than rest of the treatments. The available N of soil also improved from the initial value under these treatments. The nutritional treatments involving FYM (10 t/ha) improved available P of soil after the harvest of wheat crop. This indicates that soil fertility with respect P can be maintained with the application of FYM (10 t/ha) alone or in combination with fertilizer N. Despite large gap between K uptake and application, the available K status declined marginally, probably because crop requirement of K was largely met from the non-exchangeable part of soil K. Although organic carbon, pH and bulk density were not significantly influenced by different nutritional treatments, the value of bulk density and pH decreased with nutritional treatments involving FYM (10 t/ha). This could be ascribed to higher organic carbon content in these treatments, which had better soil aggregate and higher macrospore space (Singh *et al.,* 2006).

Water-use

Mean seasonal consumptive use of water was markedly higher with adequate irrigation than that with limited irrigation (Table 1). This might be due to the fact that under more frequent wetting cycles, evaporation was at potential rate due to availability of more water (soil moisture) than the crop irrigated at wider intervals (as was the case with limited irrigation condition). Averaged over irrigation treatments, seasonal consumptive use of water by wheat was recorded to be markedly higher with 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter,* closely followed by 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter.*

The water-use efficiency was higher with limited irrigation and decreased with adequate irrigation condition (Table 1). This means that production of grain per mm of water used decreased with increase in water supply and the relative increase in the grain yield of wheat has not been in proportion to the increase in consumptive use, thereby resulting in decrease in water-use efficiency under adequate irrigation. Dutta and Mondal (2006) also reported increase in moisture supply leading to increase in water use and reduction in water-use efficiency. The water-use efficiency increased with the increase in the levels of fertilizer N alone and or in combination with FYM and biofertilizer (*Azotobacter*). Application of 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter* recorded the highest water-use efficiency and was closely followed by 187.5 kg N/ha + FYM (10 t/ha) and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter.* The increase in water-use efficiency with the treatment involving higher doses of fertilizer nitrogen alone or integrated with FYM (10 t/ha) with or without *Azotobacter* might be attributed to their favourable effect on yield-attributing characters and ultimately grain yield.

Economics

Net return and benefit : cost realised from adequate irrigation were higher than those from limited irrigation (Table 2). Similarly, application of 187.5 kg N/ha + FYM (10 t/ha) + *Azotobacter* recorded the highest net return (Rs 16,614) and benefit : cost ratio (1.95), followed by 150 kg N/ha + FYM (10 t/ha) [Rs 16,130 and 1.93] and 150 kg N/ha + FYM (10 t/ha) + *Azotobacter* (Rs 15,857 and 1.93).

Thus, application of adequate irrigation increases the productivity, net return and benefit : cost ratio of wheat. Integration of FYM (10 t/ha) + *Azotobacter* with 187.5 and 150 kg N/ha or FYM (10 t/ha) with 187.5 kg N/ha, productivity and monetary return can be increased by maintaining or improving the residual soil-fertility status after the harvest of wheat crop.

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