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Effect of Water and Nitrogen Management on Water Productivity and Nitrogen Use Efficiency of Wheat in a Semi-arid Environment

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Abstract

A field experiment was carried out during 2009-11 on a sandy loam soil of IARI, New Delhi on wheat with four levels of irrigation (rainfed, irrigations to replenish 30, 60 and 100% moisture deficit from field capacity) as main plot factors and four levels of nitrogen (0, 30, 60 and 120 kg N/ha) as subplot factors in a split plot design. The soil moisture storage in the profile showed inverse relation with the nitrogen levels whereas direct relationship with the irrigation levels. The water use vs. wheat yield relation showed that 58 % variation in grain yield of wheat could be explained by water use. The grain yield showed increasing trend with increase in irrigation and nitrogen levels. The water productivity (WP) and economic water productivity (EWP) increased with increase in irrigation level up to 60 % SMD and thereafter it decreased. However, both WP and EWP showed increasing trend with increase in nitrogen levels. The agronomic nitrogen use efficiency (ANUE) and partial factor productivity of nitrogen (PFPN) increased with increase in irrigation levels, but with increase in nitrogen levels both ANUE and PFPN decreased. There was significant positive interaction between irrigation and nitrogen levels with respect to grain yield, water productivity and nitrogen use efficiency of wheat. Thus from this study, it may be concluded that wheat may be grown with irrigation to replenish 60% SMD to field capacity and at 120 kg N/ha to achieve higher water productivity and nitrogen use efficiency without any significant reduction in crop yield and thus resulting in saving of irrigation water in sandy loam soils of semiarid region of North India.

Keywords: Deficit irrigation, Nitrogen, Water productivity, Nitrogen use efficiency, Wheat.

1. Introduction

Wheat is the second most important cereal crop in India after rice covering an area of about 28 m ha. Now-a-days because of increased population and industrialization irrigated wheat of arid and semiarid tracts of India faces steep competition from other water users like domestic and industrial sectors, jeopardizing the future food security of the country. So there is an urgent need to increase wheat crop water productivity i.e., to produce more food with less water. A higher crop water productivity is possible either by increasing production from same water resources or same production from less water resources. In either way it will benefit the other fresh water users (Zwart et al., 2004). Due to rising costs of irrigation pumping, inadequate irrigation system capacities and limited irrigation supplies, deliberate application of less water to wheat is a common practice (Panda et al., 2003) in the arid and semiarid areas of the country.

After irrigation, nitrogenous fertilizer is the second most important input (Lenka et al., 2009) for wheat crop growth and development. There are many reports that nitrogenous fertilizer enhances water productivity (Pandey et al., 2001), but the efficacy of nitrogenous fertilizer depends on the availability of soil moisture. Keeping these in view, an experiment was planned to study the effect of deficit irrigation and nitrogen levels on water productivity and nitrogen use efficiency of wheat.

2. Materials and Methods

Field experiments were carried out during the years 2009-10 and 2010-11 at the research farm of the Indian Agricultural Research Institute, New Delhi (28°37' to 28°39' N latitude and 77°90' to 77°11' E longitude and at an altitude of 228.7 m above mean sea level). The soil is sandy loam (Typic Haplustept) with medium to angular blocky structure, non-calcareous and slightly alkaline in reaction. The soil (0–30 cm) has bulk density 1.56 Mgm^{-3}; hydraulic conductivity (saturated) 1.05 cm h^{-1}, saturated water content 0.42 m^{3}m^{-3}; pH (1:2.5 soil/water suspension) 7.4; EC 0.34 dSm^{-1}; organic C 3.0 g kg^{-1}; total N 0.031%; available (Olsen) P 6.9 kg ha^{-1}; available K 279.0 kg ha^{-1}; sand, silt and clay, 64.0, 16.8 and 19.2%, respectively. The soil moisture at 0.033 MPa suction ranged from 25–28% and at 1.5 MPa suction ranged from 8–10% in different layers of 0-120 cm soil depth. Wheat (cv. HD 2932) was grown in a split plot design with four levels of irrigation *viz.*, control (rainfed) and irrigations to replenish 30% (30% SMD), 60% (60% SMD) and 100% (100% SMD) moisture deficit from field capacity in 0-120 cm depth, at critical growth stages as main plot factors and four level of N viz., 0 (N0), 30 (N30), 60 (N60) and 120 (N120) kg N/ha as subplot factors. Nitrogen was applied in three equal splits at crown root initiation, maximum tillering and flowering stage. All the treatments received the recommended dose of P (60 kg P_2O_5 as SSP) and K (60 kg K_2O /ha as MOP). Irrigation was applied at critical crop growth stages in measured amount using Parshall flume.

The water productivity (WP, kg/m^3) was computed using the following equation.

$$WP = \frac{Ya}{TWU} = \frac{Ya}{P + CR + \Delta SW + I} \quad (1)$$

Where Ya is actual harvestable yield (kg/ha); TWU is the total water use (m^3/ha); P is precipitation (m^3/ha), CR is capillary rise (m^3/ha), ΔSW is the is the difference in soil water content between planting and harvest (m^3/ha) and I is the seasonal irrigation depth (m^3/ha). In the present condition, water table was below 4 m depth and therefore capillary rise (CR) was assumed to be negligible. The net sub-plot areas were harvested for grain yield.

The economic water productivity (EWP, Rs./m^3) was calculated by expressing the actual harvestable yield in rupees term. The price (Minimum Support Price of Rs. 1080/- for quintal in 2009-10 and Rs. 1100/- for quintal in 2010-11) of the actual harvestable yield or grain yield was taken from the Department of Food and Public Distribution, Government of India for the period considered.

The agronomic nitrogen use efficiency (ANUE, kg of grain/kg of N applied) was determined using the equation:

$$ANUE = \frac{Y_N - Y_0}{F_N} \quad (2)$$

Where Y_N is grain yield of N-fertilized plot (kg/ha); Y_0 is grain yield of control plot (kg/ha) and F_N is amount of fertilizer N (kg/ha applied).

The partial factor productivity of nitrogen (PFPN, kg of grain/kg of N applied) was determined using the equation:

$$PFPN = \frac{Y_N}{F_N} \quad (3)$$

Where Y_N is grain yield of N-fertilized plot (kg/ha) and F_N is amount of fertilizer N (kg/ha applied). The data were analyzed by analysis of variance as outlined by Gomez and Gomez (1984).

3. Results and Discussion

The relation between water use (m^3/ha) and grain yield under various irrigation and nitrogen treatments combined for both the years of study showed significant and positive linear relationship between grain yield and water use (Fig. 1). The good correlation between grain yield and water use in this study also indicates that grain yield is strongly influenced by the pattern of water use during the crop season and emphasizes the importance of adequate water supply for higher yield. The seasonal water use could account for 58 % variation in grain yield of wheat. Many workers have also reported linear relationships between water use and grain yield (Goswami and Sarkar, 2008).

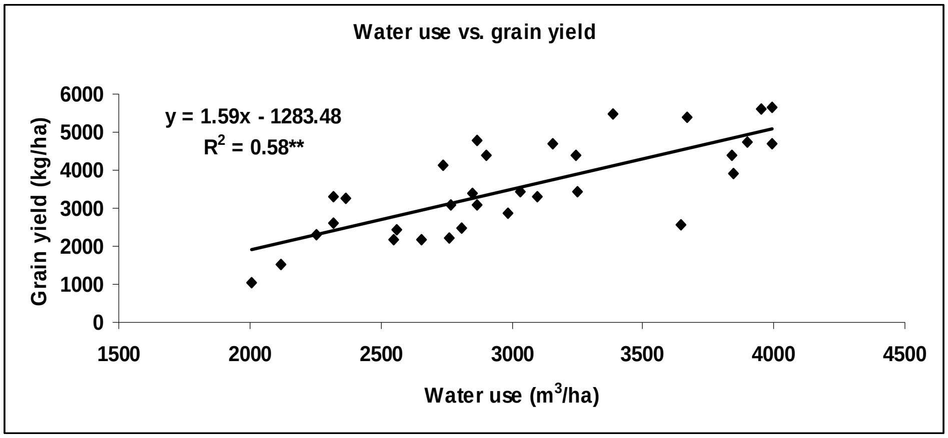

Fig. 1: Relation between water use and wheat grain yield (combined for the years 2009-10 and 2010-11).

In both the years of study, grain yield increased significantly with the increased level of irrigation, being highest at 100 % SMD treatment and lowest in rainfed treatment (Table 1). Pooled over the years, the grain yield increased by 42, 80 and 90 % over rainfed treatment in 30% SMD, 60% SMD and 100 % SMD treatments, respectively. The higher yield with increasing levels of irrigation may be attributed to better water and nutrient availability, which gave rise to better plant growth and yield. Similar results have been reported in wheat by many workers (Bandyopadhyay et al., 2010). The grain yield also significantly increased with increasing nitrogen levels. Pooled over the years, the grain yield increased by 41, 63 and 101 % over N0 treatement in N30, N60 and N120 treatments, respectively. The interaction effect of irrigation and nitrogen on grain yield was significant and the highest grain yield was recorded in 100% SMD irrigation treatment with N120 levels of nitrogen, which was statistically at par with that at 60% SMD irrigation and N120 levels of nitrogen.

Table 1: Grain yield, Water productivity (WP) and Economic water productivity (EWP), agronomic nitrogen use efficiency (ANUE) and partial factor productivity of nitrogen (PFPN) of wheat (pooled for the year 2009-10 and 2010-11).

	Grain yield (kg/ha)	**WP (kg/m3)**	**EWP (Rs./m3)**	**ANUE (kg of grain /kg of nitrogen)**	**PFPN (kg of grain /kg of nitrogen)**
	Effect of irrigation				
Rainfed	2309D*	0.95C	10.31C	23.03B	47.87D
30% SMD	3284C	1.13B	12.30B	21.90B	64.77C
60% SMD	4148B	1.38A	15.07A	26.13AB	81.89B
100% SMD	4376A	1.14B	12.47B	29.98A	88.07A
	Effect of nitrogen				
N0	2334D	0.87D	9.54D	-	-
N30	3280C	1.09C	11.87C	31.52A	109.33A
N60	3811B	1.22B	13.26B	24.62B	63.52B
N120	4691A	1.42A	15.46A	19.64C	39.1C

* Letters followed by same numbers are not significantly different at $P \leq 0.05$ as per DMRT.

Both the irrigation and nitrogen levels had significant effect on WP and EWP (Table 1). Pooled over the years, the 30% SMD and 100% SMD irrigation levels were statistically at par with respect to WP and EWP. Goswami and Sarkar, (2007) also observed either decreased or non significant change in water productivity at higher levels of irrigation. The WP and EWP was also significantly affected by nitrogen levels. Pooled over the years, the WP was 63, 40 and 25% higher, respectively in N120 and N60 and N30 treatments compared to N0 treatment. Similarly, pooled over the years, the EWP was 62, 39 and 24 % higher, respectively in N120 and N60 and N30 treatments compared to N0 treatment. The higher water productivity at higher nitrogen doses was mainly due to higher grain yield of crops with similar water use at higher nitrogen doses. These results are in agreement with Pandey et al. (2001).

Both ANUE and PFPN were significantly affected by irrigation and nitrogen levels (Table 1). Pooled over the years, ANUE increased from 23.03 kg of grain/kg of N for rainfed treatment to 30 kg of grain/kg of nitrogen for 100 % SMD irrigation treatment. Bandyopadhyay et al. (2009) also observed higher nitrogen use efficiency at higher levels of irrigation, which they attributed to the better N mineralization and least nitrogen loss through leaching and volatilization at optimum soil moisture condition ultimately leading to better plant uptake of nitrogen and hence growth and yield. ANUE was highest in N30 treatment (31.52 kg of grain / kg of N) followed by N60 (24.62 kg of grain / kg of N) and N120 (16.85 kg of grain / kg of N) treatment. This may be attributed to losses of N at higher levels of N and to the fact that yield of wheat did not increase with the same proportion as the fertilizer application. The PFPN also showed trend similar to ANUE. Among irrigation treatments, it was highest for 100 % SMD treatment (88.07 kg of grain / kg of N) followed by 60% SMD (81.89 kg of grain / kg of N), 30% SMD (64.77 kg of grain / kg of N) and rainfed treatments (47.87 kg of grain / kg of N). Among nitrogen treatments, N30 treatment (109.33 kg of grain / kg of N) showed highest PFPN followed by N60 (63.52 kg of grain / kg of N) and N120 (39.10 kg of grain / kg of N) treatments. Pooled over the years, irrigation at 100 % SMD and N30 registered the highest ANUE and PFPN in wheat.

4. Conclusion

Thus from this study, it may be concluded that wheat may be grown with irrigation to replenish 60% SMD to field capacity and at 120 kg N/ha to achieve higher water productivity and nitrogen use efficiency without any significant reduction in crop yield in sandy loam soils of semiarid region of North India.

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