Indian Journal of Agronomy **48** (3) : 186–191 (September 2003)

Influence of irrigation, nitrogen and zinc on productivity and water use by late-sown wheat (*Triticum aestivum*)

A.M. KIBE[1] AND SUBEDAR SINGH

Water Technology Centre, Indian Agricultural Research Institute, New Delhi 110 012

Received : December 2002

ABSTRACT

A field experiment was conducted on deep sandy soil (Typic Ustochrept) at the Water Technology Centre, Indian Agricultural Research Institute, New Delhi, during winter seasons of 1999–2000 and 2000–2001 with late-sown 'HD 2285' wheat (*Triticum aestivum* L. emend. Fiori & Paol.). The treatments comprising 4 irrigation levels [I_0, no post-sowing irrigation; I_1, 1 irrigation at crown-root intiation (CRI) stage; I_2, 2 irrigations, each at CRI and flowering stages; I_3, 4 irrigation each given at CRI, jointing, flowering and dough stages] in main plots and combinations of 3 N levels (0, 50 and 100 kg N/ha) and 2 zinc levels (0 and 5 kg Zn/ha) in subplots were laid out in split-design, replicated 3 times, to find out the influence of irrigation, nitrogen, zinc and their interactions on yield and moisture use by the crop. Progressive increase in irrigations from 0 to 4 and N levels from 0 to 100 kg/ha, increased wheat yield attributes and grain yield significantly over the control treatments (I_0 and N_0). The average seasonal consumptive water use (CU) by wheat increased with every additional irrigation level to a maximum of 328.4 mm and 301.7 mm in the first and second season respectively. On an average (2 seasons), water-use efficiency (WUE) was the highest (1.38 kg grain/m^3) with I_2. However, the straw yield (6,808.5 kg/ha) and grain yield (3,962.5 kg/ha) were highest with I_3. The average moisture use rate increased with increase in irrigation to a maximum of 2.63 mm/day. Maximum moisture extraction of 59.4 to 65.8 % was from the 0–30 cm and the minimum (7.10 to 5.32%) from the 90–120 cm soil depth. The WUE increased markedly with the increase in N level.

Key words : Wheat, Irrigation, Nitrogen, Zine, Consumptive use, Water-use efficiency, Moisture extraction

Wheat growth and yield result in from the combined effects of the inherited genetic potential and the conditions under which plants grow. Irrespective of irrigation water-scheduling criteria, it is universally acknowledged that wheat growth and yield increase significantly with water availability. This increase in production does not, however, commensurate with similar trend in water-use efficiency (Mishra *et al.,* 1994; Pal *et al.,* 1996 b). Because of the ever-changing scenario that wheat is grown, an understanding of the crop's response to irrigation and added nutrients like nitrogen and zinc which are deficient in Indian soils, and inter-dependence of yield attributes towards production of the ultimate compounded biomass and grain yield at harvest is worth of investigation. It will help in optimization of irrigation water scheduling, N and Zn doses and therefore the maximization of wheat yields, as well as increased water-use efficiency at minimal loss of water and nutrients.

MATERIALS AND METHODS

A field experiment was conducted on a sandy-loam soil (Typic Ustochrept) at the Water Technology Centre, I.A.R.I., New Delhi, during winter (*rabi*) seasons of 1999–2000 and 2000–2001. The soil was low in available N (160.8 kg/ha), medium in available phosphorus (20.4 kg/ha) and Zn (57.4 ppm), with pH 7.5. Plant-available water was 18 cm/120 cm root zone profile. Treatments comprised 4 levels of irrigation levels (I_0, no post-sown irrigation; I_1, 1 irrigation at (crown-root initiation) (CRI) stage, I_2, 2 irrigations, each at CRI and flowering stages; I_3, 4 irrigations each given at CRI, jointing, flowering and dough stages) in main plots and combination of 3 N levels (N_0, 0; N_{50}, 50 and N_{100}, 100 kg N/ha) and 2 zinc levels (Z_0, 0, and Z_5, 5 kg/ha) in the subplot of split-plot design, replicated thrice. Wheat cv. 'HD 2285' was sown on 22 December 1999 and 13 December 2000, phosphorus (P_5O_5) and potassium (K_2O) were applied through single superphosphate (SSP) and muriate of potash uniformly as basal @ 60 and 40 kg/ha respectively. Nitrogen and zinc were applied as per treatment through urea and $ZnSO_4 . 7H_2O$ at the time of sowing. The crop was drilled with 25 cm inter-

Present address : [1]Division of Agronomy, IARI, Pusa, New Delhi 110 012
Part of Ph.D. Thesis, submitted to P.G. School, IARI, New Delhi 110 012

row spacing manually by hand-plough at the seed rate of 120 kg/ha. The crop received 76.8 mm and 42.6 mm rainfall in the respective seasons. Groundwater table remained below 4.0 m throughout the growth period and groundwater contribution was considered to be negligible. Moisture use by crop such as consumptive use (CU), weter-use efficiency (WUE) and moisture-use efficiency (MUE) were computed following the method of Dastane (1972).

RESULTS AND DISCUSSION

Effect of irrigation, nitrogen and zinc

Yield attributes: Taller plants were observed with higher irrigation water levels as compared to the no post-sown irrigation (Table 1). The tallest plants were obtained with 4 irrigations each applied at CRI, jointing, flowering and dough stages of wheat.

Differential response of wheat to irrigation with respect to yield attributes such as effective tillers, length of ear, grains/ear and 1,000-grain weight was evident between the 2 seasons, because of the 68.9 mm rainwater in the first season that caused similar growth and development of wheat in response to unirrigated control (I_0) and 1 irrigation (I_1) treatments (Table 1). Irrigating wheat up to 4 irrigations resulted in significantly higher effective tillers/m row length, length of ears, grains/ear and 1,000-grain weight of wheat over the control (I_0) in both the seasons, except of ear length in first season (1999–2000). Irrigating at CRI stage normally enhances tillering while at jointing it increases growth rates and the irrigation given at flowering and dough stages enhances grain filling, as it improves translocation of photosynthates to the sink (Arnon, 1972), so long other factors like nitrogen are not limiting. Therefore effective tillers/m row length increased significantly with increasing irrigation frequencies, whereas ear length and 1,000-seed weight of wheat were similar with 2 and 4 irrigations (Table 1). This was not the case, however, with the number of grains/ear, probably because the grains/ear are normally influenced at the panicle initiation, which commences after CRI stage of wheat growth (28–30 DAS).

The 1,000-grain recorded for I_2 (2 irrigations) and I_3 (4 irrigations) were at par in the first season of 1999–2000 only (Table 1). The probable reason for this is that the photosynthates deposited in grain are known to come from remobilization of assimilates deposited in other plant organs and photosynthesis of the flag leaf, stem and ear (Gardner *et al.,* 1988). Therefore, the rainwater received (up to 50 DAS) enabled the crop to accumulate sufficient carbohydrate reserve and leaf area to sufficiently provide assimilates for grain filling that compare well with the 4 irrigations. Water stress during grain filling reduced 1,000-seed weight and therefore, wheat under I_0 and I_1 recorded lower 1,000-grain weight (Table 1) and grain yield (Table 2) as compared to wheat receiving higher frequency of water (I_2 and I_3) in both the seasons. Similar observations were reported by Drewitt (1979) and Tomar *et al.* (1993).

Increase of N application from 0 to 100 kg N/ha, significantly and progressively increased the effective tillers/m row length, length of ear, grains/ear, and 1,000-grain weight in both the seasons (Table 1). This was in agreement with the findings of Bayles (1977). Increased effective tillers/m with higher dose of N was probably due to stimulatory effect of N on tillering through cytokinins synthesis, resulting into more number of effective tillers (Gardner *et al.,* 1988; Sinha *et al.,* 1989). For grains/ear successive addition of N from 0 to 100 kg/ha increased grains/ear significantly. Adequate N might have increased grains/ear by preventing the degeneration of spikelets when grain development takes place. Reddy and Bhardwaj (1984) also reported similar results. The 1,000-grain weight was highest when fertilized with 50 and 100 kg N/ha wheat crop in the second season. At the time of grain-filling, assimilates are remobilized from leaves and stems (source) to grains (sink) if photosynthesis is not able to meet out the assimilate requirement of grains (sinks). During heading to flowering stage of plant, the assimilates produced by photosynthesis are normally more than required by these processes, when inputs like nutrients and water are adequate (Gardner *et al.,* 1988).

The increased growth and thereby more assimilates resulted in a higher number of effective tillers and grain number and yield attributes, owing to interactive effects of 100 kg N/ha with 4 irrigations given at CRI, jointing, flowering and dough stages compared to the control (no N and no irrigation after sowing) in both the seasons, which in turn contributed to the increase in the grain, straw yields and harvest index. Reddy and Bhardwaj (1984) and Mishra *et al.* (1994) also concluded that irrigation and nitrogen substituted each other within certain limits.

Grain yield: Increase in number of irrigations increased the grain yield progressively and significantly over no post-sowing irrigation during both the seasons (Table 2). The per cent increase in grain yield owing to 1, 2 and 4 irrigations over no irrigation treatment was 36.2, 58.0 and 71.5 in 1999–2000, and 32.0, 57.8 and 73.9 in 2000–2001 respectively.

The maximum average grain yield of 4.0 tonnes in the first season and 3.9 tonnes/ha in the second season was obtained with 4 irrigations (I_3) given at CRI, jointing, flowering and dough stages of the crop. Minimum yields of 2.3 tonnes/ha in both seasons were obtained with no post-sowing irrigation (I_0).

Application of 50 kg and 100 kg N/ha application resulted significantly more grain yield than that of no N application. The effect of 100 kg N/ha application on grain yield production was statistically more than to the effect of 50 and 0 kg N/ha in both the seasons. Increase in grain yield as a results of N application over the control (2,751 kg/ha in the first season and 2,631 kg/ha in the second season) was 21.4% and 39.2 % in the first season and 22.6% and 39.3% in the second season respectively.

Each addition of either irrigation or N resulted in a progressive and significant increase in grain yield up to I_3N_{100} level in first and second year respectively (Table 3). The minimum grain yields were obtained with I_0N_0 in the respective seasons.

Straw yield: Straw yield increased significantly with addition of irrigation attaining a maximum of 6.4 tonnes/

Table 1. Effect of irrigation, nitrogen and zinc levels on yield attributes of late-sown wheat

Treatment	Plant height (cm)		Effective tillers/m row length		Length of ears (cm)		Grains/ ear		1,000-grain weight (g)	
	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Irrigation										
I_0	60.3	58.4	71.6	67.0	10.3	8.6	34.4	30.9	34.9	36.0
I_1	68.1	69.9	75.9	71.7	10.4	9.2	35.1	31.9	35.6	36.5
I_2	72.7	74.1	79.8	76.0	10.5	6.6	38.5	36.3	38.4	38.0
I_3	78.4	77.9	103.8	95.6	10.8	9.9	40.2	37.1	39.2	39.5
CD (P=0.05)	2.3	3.7	3.4	1.7	NS	0.2	1.0	0.5	0.8	1.1
Nitrogen										
N_0	66.3	66.1	73.0	68.9	9.7	8.7	34.4	32.0	35.6	36.1
N_{50}	69.9	70.8	88.8	77.1	10.7	9.3	36.9	33.9	37.3	37.5
N_{100}	73.4	73.3	92.5	86.8	11.2	9.9	39.8	35.5	38.1	38.9
CD (P=0.05)	1.56	1.6	1.2	1.2	0.4	0.2	0.8	0.6	0.5	0.6
Zinc										
Z_0	69.45	69.6	82.6	76.9	10.4	9.3	36.5	33.5	36.9	37.2
Z_5	70.3	70.5	83.3	78.3	10.6	9.4	37.6	34.1	37.2	37..8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.6	0.5	NS	0.5

Details of treatments are given under Materials and Methods

Table 2. Influence of irrigation, nitrogen and zinc on grain yield, straw yield and harvest index of late-sown wheat

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)		Harvest index	
	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Irrigation						
I_0	2,337	2,251	4,723	4,601	33.2	33.5
I_1	3,183	2,973	5,656	5,382	36.8	35.9
I_2	3,695	3,553	6,181	6,000	37.8	37.9
I_3	4,008	3,917	6,446	6,571	40.2	39.0
SEm±	33	28	53	47	0.5	0.2
CD (P=0.05)	100	89	160	141	1.4	0.6
Nitrogen						
N_0	2,751	2,631	5,248	5,114	35.3	34.5
N_{50}	3,335	3,225	5,690	5,664	37.3	36.8
N_{100}	3,828	3,665	6,242	6,138	38.3	38.4
SEm±	37	34	61	59	0.6	0.3
CD (P=0.05)	113	103	183	177	1.8	1.0
Zinc						
Z_0	3,277	3,167	5,705	5,635	36.8	36.4
Z_5	3,335	3,180	5,748	5,642	37.1	36.7
SEm ±	31	28	50	48	0.5	0.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Details of treatments are given under Materials and Methods

ha under 4 irrigations in 1999–2000 and 6.6 tonnes/ha in 2000–2001 (Table 2). Application of 1 and 2 irrigations resulted in increase of the straw yield by 17.6 and 30.9% in the first season and 17.0 and 30.4% in the second season over the control (I_0) respectively.

Nitrogen application at 50 and 100 kg/ha increased the straw yield significantly over the control by 8.4% and 10.8% in the first season and 18.9% and 20.0% in the second season respectively (Table 2).

Interactive effects of irrigation and N on straw yield were significant (Table 3). The control (I_0N_0) showed the lowest straw yield compared to all other treatments except I_0N_{50} in both seasons and I_1N_0 in second season only. Irrigations caused significant variations at every level of N application in first season, whereas in second season, 1 and 2 irrigations given with 50 kg N/ha were at par. The rest differed significantly with higher number of irrigations. Interaction within I_0 application of 50 kg N/ha did not increase straw yield significantly in the first season, while they differed statistically in the second season. With 1 irrigation only, wheat grown with 0 and 50 kg N/ha was similar in straw yield in the first season, but significantly different in the second season; however wheat grown under 50 and 100 kg N/ha was at par with each other in both seasons. With 2 irrigations, N_0 and N_{50} had similar wheat straw yields, which were lower to that obtained with 100 kg N/ha in the first season. In the second season, however, straw yields differed at every level of N application. Application of 100 kg N/ha resulted in maximum straw. Wheat straw obtained with 4 irrigations increased significantly at every additional N level in both seasons, except in second season, where I_3N_{50} and I_3N_{100} were statistically similar.

Harvest index (HI): Effect of different irrigation levels on the harvest index was significant in both seasons (Table 2). Irrigation at higher frequencies at different phytophases of the wheat crop enhanced the harvest index significantly than irrigating at lower frequencies and no irrigation treatments in both the years, except irrigating once or twice in the first season. Maximum harvest index values 40.2 in first season and 39.0 in second season were obtained under 4 irrigations. The increase was 21.2 and 16.5% over the control.

Table 3. Interactive effects of irrigation and nitrogen on grain yield (kg/ha) of late-sown wheat

Interaction	1999–2000				2000–2001			
	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3
N_0	2,039	2,650	3,013	3,301	1,960	2,408	2,886	3,272
N_{50}	2,337	3,200	3,713	4,109	2,260	3,011	3,587	4,042
N_{100}	2,637	3,700	4,360	4,615	2,535	3,500	4,187	4,436
	N within I		*I within N*		*N within I*		*I within N*	
SEm±	144		150		130		136	
CD (P=0.05)	298		302		269		275	

Details of treatments are given under Materials and Methods

Table 4. Influence of irrigation, nitrogen and zinc on moisture use by late-sown wheat

Treatment	Seasonal consumptive water use (mm)		Water-use efficiency (kg grains/m³ water used)		Moisture-use rate (mm/day)	
	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Irrigation						
I_0	191.5	178.2	1.22	1.26	1.60	1.49
I_1	232.7	223.7	1.37	1.33	1.94	1.86
I_2	276.1	249.1	1.34	1.42	2.30	2.08
I_3	328.4	301.7	1.22	1.31	2.74	2.51
Nitrogen						
N_0	253.1	234.4	1.09	1.12	2.11	1.95
N_{50}	257.1	237.9	1.30	1.35	2.14	1.98
N_{100}	261.3	242.2	1.46	1.52	2.18	2.02
Zinc						
Z_0	257.1	238.2	1.27	1.32	2.14	1.98
Z_5	257.2	238.2	1.30	1.34	2.14	1.98

Details of treatments are given under Materials and Methods

Nitrogen application (Table 2) increased the harvest index significantly over the control in both seasons. In the first season, however, N_{50} and N_{100} were at par. Maximum harvest index was under N_{100} (38.3% in 1999–2000 and 38.4% in 2000–2001). Zinc application did not bring about any significant change over the control.

Effect of irrigation on moisture use

The seasonal consumptive use of water (CU) and daily moisture-use rate of wheat increased progressively with the increase in irrigation frequency. The maximum values were recorded in order of I_3, I_2, I_1 and I_0 respectively (Table 4). The increased soil water-use rate at higher soil-moisture availability was probably due to enhanced growth leading to higher leaf-area indices and stomatal apertures opening for longer periods of time (Slatyer, 1967; Davis, 1994).

Water-use efficiency (WUE) of wheat did not follow the same trend as CU, since the grain increase did not commensurate with increase in evapotranspiration under enhanced water supply (Table 4). Four irrigation treatment (I_3) consumed the maximum amount of water, but could not increase grain yield in the same proportion as treatments I_2 and I_1. Water-use efficiency was the maximum with 2 irrigations (I_2) given at CRI and flowering stages in the first season and with 1 irrigation (I_1) given at CRI stage in the second season, followed by no post-sowing treatment (I_0). On the other hand, crop receiving no post-sowing irrigation (I_0) treatment gave the lowest grain yield, but also used soil water more economically by regulating there stomatal opening and physiological activities towards grain production (Slatyer, 1967). Similar findings were reported by Mishra *et al.* (1994), Pal *et al.* (1996) and Chandra *et al.* (1999).

The range of seasonal soil moisture extracted was 58.1–65.8% from the 0–30 cm soil profile, 21.62–19.30% from 30–60 cm soil profile and sharply declined thereafter to 7.10–5.32% from 90–120 cm soil layer during both seasons (Table 5). The contribution of top 30 cm soil layer to total water use increased with the increase in irrigations because of more moisture availability and greater root proliferation in this layer, besides surface evaporation would be more from frequently irrigated plots. Plants extracted more water from deeper soil layers when crop experienced water stress (I_0) because, with the drying of the surface soil layer, the water potential dropped in this layer which forced roots to enter deeper into the profile having higher water potentials. Being new and active, the roots absorbed proportionately more water. This corroborated the findings of Kumar *et al.* (1986) and Mishra *et al.* (1994).

Effect of nitrogen on water use

Applied N had marginal and significant influence on seasonal CU and moisture use rate, but the highest CU was recorded with 100 kg N/ha treatment. Water-use efficiency was also increased with addition of N fertilizer to a maximum with 100 kg N/ha in both the seasons (Table 4). This is because applied higher N results in higher grain yield, which is proportionately more than the increase in water use thereby resulting into higher WUE. Tomar *et al.* (1993) and Mishra *et al.* (1994) also reported similar findings.

Table 5. Influence of irrigation, nitrogen and zinc on the soil moisture-extraction pattern (%) by late-sown wheat

Treatment	1999–2000				2000–2001			
	Soil layer				Soil layer			
	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm
Irrigation								
I_0	59.35	21.90	11.65	7.10	58.10	21.62	12.50	7.75
I_1	61.50	21.98	11.12	6.40	60.15	21.00	12.05	6.80
I_2	64.32	20.05	10.00	5.63	61.62	20.25	11.65	6.48
I_3	65.80	19.30	9.58	5.32	64.68	19.72	10.13	5.47
Nitrogen								
N_0	63.56	20.70	10.58	5.16	61.43	20.54	11.78	6.26
N_{50}	62.94	20.53	10.60	5.94	61.13	20.63	11.60	6.65
N_{100}	61.73	20.45	10.59	7.24	60.86	20.78	11.40	6.96
Zinc								
Z_0	62.69	20.54	10.56	6.21	61.10	20.62	11.56	6.73
Z_5	62.79	20.58	10.62	6.02	61.18	20.68	11.63	6.53

Details of treatments are given under Materials and Methods

Nitrogen application did not enhance the soil-moisture extraction (Table 5). This was in agreement with the findings of Yadav and Kumar (1991).

REFERENCES

Arnon, I. 1972. Systematic treatments of the principal crops. (In) *Crop Production in Dry Lands*, vol. 2. pp. 1–65. Pollunin, N (Ed.). Barnes & Noble Books, New York.

Bayles, R.A. 1977. Poorly filled grain in the cereal crop. 3. The effects of nitrogen fertilizer on grain filling in winter wheat. *Journal of National Institute of Agricultural Botany* **14** (2) : 250–261.

Chandra, B. and Ashok, K. 1990. Consumptive use, water-use efficiency and yield of wheat genotypes as influenced by irrigation frequency. *Annals of Biology, Ludhiana* **15**(2) : 213–216.

Dastane, N.G. 1972. *Practical Manual for Water Use Research in India*, edn 2, 120 pp. Navbharat Publication, Pune, India.

Davis, G.J. 1994. Managing plant nutrients for optimum water use efficiency. *Advances in Agronomy* **53** : 85–110.

Drewitt, E.G. 1979. Relationships between grain yield, grain N%, and grain weight in irrigated and non-irrigated late-winter- and spring-sown Karamu wheat. *New Zealand Journal of Experimental Agriculture* 7(2) : 169–173.

Gardner, F.P., Pearce, B.R. and Mitchell, R.L. 1988. *Physiology of Crop Plants*. Scientific Publication, Jodhpur, Rajasthan.

Kumar, A., Dhiman, S.D. and Yadav, S.K. 1986. Studies on evapotranspiration, water use efficiency and moisture extraction patterns by wheat genotypes in irrigated and unirrigated conditions. *Indian Journal of Agronomy* **31** (1) : 11–15.

Mishra, R.K., Pandey, N. and Bajpai, R.P. 1994. Influence of irrigation and nitrogen on yield and water use pattern of wheat. *Field Crop Research*. **10** (2) : 125–134.

Pal, S.K., Kaur, J., Thakur, R., Verma, U.N. and Singh, M.K. 1996a. Efffect of irrigation, seeding date and fertilier on growth and yield of wheat. *Indian Journal of Agronomy* **41** (3) : 386–389.

Pal, S.K., Thakur, R.,Verma, U.N. and Singh, M.K. 1996b. Water requirement of wheat (*Triticum aestivum*) as affected by different levels of irrigation seeding, date and fertilizer. *Indian Journal of Agricultural Sciences* **66** (6) : 328–332.

Reddy, A.S. and Bhardwaj, R.B.L. 1984. Effect on N and P on growth yield of wheat under limited and adequate irrigation. *Indian Journal of Agronomy* **29**(4) : 505–509.

Sinha, H.N., Singh, R.D., Sinha, R.K. and Singh, R.K. 1986. Effect of irrigation and nitrogen on wheat. *Indian Journal of Agronmy* **31** (4) : 326–330.

Sinha, M.N., Pandey S.K. and Rai, R.K. 1989. Effect of N, P and moisture on yield, water use efficiency and moisture extraction of pattern of wheat. *Annals of Agricultural Research* **10** (3) : 230–236.

Slatyer, R.O. 1967. *Plant Water Relationships*, 366 pp. Academic Press, New York.

Tomar, R.K.S., Raghu, J.S., Yadav, L.N. and Ghuraya, R.S. 1993. Response of wheat (*Triticum aestivum*) varieties to irrigation under different fertility levles. *Indian Journal of Agronomy* **38** (2) : 291–293.

Yadav, G.L. and Verma, J.K. 1991. Effect of irrigation regime, nitrogen and zinc fertilization on growth and yield of late-sown wheat (*Triticum aestivum*). *Indian Jouranl of Agronomy* **36** (Supplement) : 50–53.