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Effect of irrigation and nitrogen level on yield, nutrient uptake and water use of late-sown wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 1996–97 to 1998–99 at Bilaspur, Chhattisgarh, to study the yield, water use and nutrient uptake of wheat (*Triticum aestivum* L. emend. Fiori & Paol.) as affected by varieties, irrigation and nitrogen level under late-sown conditions. Among the varieties, 'DL 788-2' and 'DL 803-3' were superior to 'GW 190' and 'GW 173'. Irrigation applied at 1.2 IW : CPE ratio gave significantly higher grain yield than 0.6 and 0.9 ratios. Application of 120 kg N/ha gave higher yield and yield attributes than 80 kg N/ha. Total nutrient uptake was positively influenced by irrigation and N levels. Total water use was lowest (29.60 cm), while water-use efficiency was highest with 0.6 IW : CPE. The WUE decreased with the increase in frequency of irrigation. The moisture depletion from upper soil layers (0–60 cm) was higher than lower layers (60–90 cm). However, total profile moisture contribution was highest with limited water supply (0.6 IW : CPE) and decreased with the increase in number of irrigation. Canopy temperature was comparatively low than ambient temperature under higher moisture (1.2 or 0.9/1.2 IW : CPE) than lower moisture regime (0.6 IW : CPE).

Key words : Canopy temperature, Grain yield, Irrigation, Moisture extraction, Nutrient uptake, Water use, Wheat

Rice–wheat is the most important cropping sequence, in India, occupying an area of 10.5 million ha (Katyal *et al.,* 2000). It is well known that substantial increase in wheat yield can be realized if it is planted on time. There is an optimum date for sowing which is location specific and beyond which there is almost a linear decline in yield. In Chhattisgarh region, the optimum sowing time for wheat is the second week of November to first week of December (AICRPWIP 1993). But the sowing of wheat in the region is generally delayed due to late harvest of rice resulting in poor yields. The efficiency of inputs such as fertilizer and water is also affected by delayed sowing. However, adoption of modern agronomic management, favourable soil-moisture regimes and suitable varieties can create congenial conditions for higher crop productivity. In the present study, an attempt was made to assess the effect of irrigation scheduling and nitrogen levels on the productivity of wheat varieties under late-sown condition.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) seasons of 1996–97 to 1998–99 at Bilaspur, Chhattisgarh. The soil was clay loam, with pH 7.3, low in organic carbon (0.47%) and in available N (208 kg/ha), and medium in available P (20.1 kg/ha) and available K (387 kg/ha). The experiment was laid out in split-plot design with 3 replications. Twentyfour treatment combinations, comprised 4 irrigation schedules based on IW : CPE ratio, viz. 0.6, 0.9, 1.2 and 0.9 up to maximum tillering and 1.2 from maximum tillering to maturity, 3 varieties, viz. 'GW 190', 'GW 173' and 'DL 803-3', and 2 nitrogen levels, viz. 80 and 120 kg/ha. The performance of 'GW 190' was significantly poor than other 2 varieties and therefore, it was replaced by 'DL 788-2' in the third year. The irrigation schedule was assigned to main plots, variety in subplots and N level to sub-subplots. A common dose of 50 and 30 kg/ha of P_2O_5 and K_2O respectively was applied to all the treatments. Half N with full dose of P and K were applied at sowing and remaining N was top-dressed in 2 equal splits at crown-root initiation and at panicle-initiation stages. Wheat was sown on 18, 24 and 20 December in 1996, 1997 and 1998 respectively. Irrigation treatments were imposed after common irrigation applied at crown-root-initiation stage. A water depth of 60 mm was applied in each irrigation. The total seasonal rainfall was 64.4, 137.9 and 90 mm during first, second and third years re-

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spectively. Gravimetric method was used for soil-moisture estimation. Soil samples before sowing and just after harvesting as well as before and after each irrigation from 0–30, 30–60 and 60–90 cm soil depths were collected to estimate the moisture contribution from different soil layers. The total water use was computed by summing up water from irrigation, effective rainfall and contribution from soil profile during entire crop season. The canopy temperature was recorded at top, middle and bottom of crop canopy with the help of infrared thermometer AG 43. The difference between canopy temperature and ambient temperature was calculated in different layers of crop canopy.

RESULTS AND DISCUSSION

Yield and yield attributes

Grain yield of wheat varieties increased significantly with increasing irrigations in all the years (Table 1). The highest grain yield was recorded with 0.9 or 1.2 IW : CPE, which was at par with 1.2 IW : CPE. Nevertheless, irrigation applied at 0.6 or 0.9 IW : CPE ratios gave significantly lower yield than in former irrigation schedules. Frequent irrigations under ratios 1.2 or 0.9/1.2 IW : CPE might have helped in reducing the adverse effect of rise in temperature in the later part of growth period (Table 2). These findings corroborate the findings of Patel *et al.* (1996) and Khan *et al.* (2000). Canopy temperature from top to bottom of the canopy was comparatively low at 1:2 or 0.9 1.2 IW : CPE ratios than either 0.6 or 0.9 IW : CPE indicates that frequent irrigations help in lowering the canopy temperature in the micro-environment of wheat and in turn better crop growth and yield. The significant increase in grain yield under higher moisture regimes was due to higher ear-bearing tillers, grains/spike and 1,000-grain weight (Table 1).

Among the varieties, 'DL 788-2' and 'DL 803-3' were significantly superior 'GW 190' and 'GW 173' in all the years (Table 1). The mean maximum grain yield (over the irrigation and nitrogen level) of 3,045 kg/ha was recorded with 'DL 788-2' followed by 'DL 803-3'. The better performance of the former varieties was owing to more spikes and grains/spike. Application of 120 kg N/ha caused a significant increase in grain yield as compared to 80 kg N/ha. Increase in yield was attributed to ear-bearing tillers, grains/panicle and 1,000-grain weight. Improved performance in response to input was generally associated with better stand establishment, and with significant increase in yield attributes and above-ground biomass (Badaruddin *et al.* 2000). Addition of N fertilizer tended to produce higher yields, regardless of quantity or distribution of water (Sardana *et al.*, 2000; Camara *et al.*, 2003).

Moisture-extraction pattern

Soil-moisture depletion from upper layers (0–60 cm) of profile was higher than lower layers (60–90 cm). The moisture depletion at higher moisture regimes was higher from upper layer compared to the lower moisture regimes. This may be attributed to more proliferation of roots in the upper layer under higher moisture regimes. The total water depletion from soil profile varied appreciably with moisture present in soil profile due to timing of irrigations. The moisture depletion from the surface layer, though higher than from the deeper layer, decreased in general as

Table 1. Effect of varieties, irrigation and nitrogen level on yield and yield attributes of wheat

Treatment	Grain yield (kg/ha)				Effective tillers/m row	Grains/ spike	1,000-grain weight (g)
	1996–97	1997–98	1998–99	Mean			
Irrigation (IW : CPE ratio)							
0.6	2,328	1,960	2,225	2,171	312	47	45.25
0.9	2,997	2,201	2,412	2,537	380	50	43.60
1.2	3,610	2,367	2,799	2,925	422	47	40.85
0.9/1.2	3,740	2,486	2,910	3,045	430	50	40.10
CD (P=0.05)	249	266	232	249	37	NS	3.13
Variety							
'GW 190'	2,456	1,975		2,215	322	48	39.35
'GW 173'	3,210	2,389	2,112	2,517	386	51	40.40
'DL 803-3'	3,714	2,491	2,465	2,890	407	50	41.22
'DL 788-2'			3,179	3,179	439	47	46.65
CD (P=0.05)	144	166	201	170	33	NS	2.82
N (kg/ha)							
80	2,863	2,150	2,402	2,472	362	46	41.25
120	3,393	2,357	2,720	2,840	414	52	44.15
CD (P=0.05)	107	134	169	137	29	45	2.19

the irrigation timing was delayed due to lower IW : CPE (Table 3). When less number of irrigation was applied under 0.6 IW : CPW, deeper layers were subjected to more moisture depletion since moisture-stress condition promoted extensive root growth up to deeper layers. Prihar *et al.* (1978) also found deeper rooting with inadequate irrigation when adequate water is present in the subsoil. Misra (1980) also found higher density of roots in deeper layers when irrigation was delayed. There was not much variation in soil-moisture extraction pattern from different

Table 2. Effect of treatments on average canopy temperature (°C) at maximum tillering and flowering stages of wheat

Treatment	Maximum tillering			Flowering		
	Top	Middle	Bottom	Top	Middle	Bottom
Irrigation (IW : CPE ratio)						
0.6	25.92 (-0.28)	26.26 (+0.06)	28.68 (+0.48)	32.55 (-0.57)	33.05 (-0.07)	35.90 (+2.78)
0.9	25.88 (-0.32)	26.08 (-0.12)	27.12 (+0.92)	31.40 (-1.72)	32.60 (-0.52)	35.22 (+2.10)
1.2	24.69 (-1.51)	24.40 (-1.80)	25.62 (-0.58)	30.40 (-3.02)	31.85 (-1.27)	34.22 (+1.10)
0.9/1.2	24.59 (-1.61)	24.38 (-1.82)	25.76 (-0.44)	30.05 (-3.07)	31.70 (-1.33)	34.36 (+1.24)
Variety						
'GW 190'	26.05 (-0.15)	25.60 (-0.60)	27.22 (+1.02)	31.00 (-2.12)	32.30 (-0.82)	34.90 (+1.78)
'GW 173'	26.09 (-0.11)	25.38 (-0.32)	27.20 (+1.00)	31.20 (-1.92)	31.80 (-1.32)	35.00 (+1.88)
'DL 803-3'	24.42 (-1.78)	25.28 (-0.92)	26.45 (+0.25)	31.02 (-2.10)	32.63 (-0.50)	35.15 (+2.03)
'DL 788-2'	24.32 (-1.88)	25.00 (-1.20)	26.28 (+0.08)	31.08 (-2.04)	32.54 (-0.58)	35.05 (+1.93)
N (kg/ha)						
80	25.68 (-1.37)	25.74 (-0.46)	26.61 (+0.41)	31.30 (-1.82)	31.85 (-0.27)	35.00 (+1.88)
120	24.84 (-1.36)	24.82 (-1.38)	26.97 (+0.77)	31.19 (-1.93)	32.79 (0.33)	35.10 (+1.98)

Values in parentheses are the deviation from ambient temperature

Table 3. Profile moisture contribution (%) from different soil layers in wheat as influenced by irrigation, nitrogen and variety

Treatment	Soil layer depth (cm)			Water applied (cm)	Effective rainfall (cm)	Profile moisture (cm)	Total water (cm)	WUE (kg/ha-cm)
	0–30	30–60	60–90					
Irrigation (IW : CPE ratio)								
0.6	43.20 (2.65)	37.50 (2.30)	19.30 (1.18)	18.00	5.57	6.13	29.70	73.10
0.9	49.65 (2.43)	34.80 (1.70)	15.50 (0.76)	30.00	4.96	4.90	39.86	63.65
1.2	58.43 (1.67)	32.72 (0.93)	8.85 (0.25)	42.00	4.53	2.86	49.39	59.22
0.9/1.2	56.15 (1.81)	33.90 (1.09)	9.95 (0.32)	36.00	4.67	3.22	43.89	69.38
Variety								
'GW 190'	49.15 (1.74)	35.10 (1.24)	15.75 (0.56)	31.50	4.94	3.55	39.99	55.39
'GW 173'	48.65 (1.86)	34.75 (1.33)	16.60 (0.63)	31.50	4.94	3.82	40.26	63.83
'DL 803-3'	47.35 (2.36)	32.60 (1.62)	20.05 (1.00)	31.50	4.94	4.98	41.42	69.77
'DL 788-2'	46.00 (2.20)	33.45 (1.61)	20.55 (0.99)	31.50	4.94	4.83	41.27	77.01
N (kg/ha)								
80	45.30 (2.52)	31.95 (1.00)	22.75 (0.71)	31.50	4.94	3.12	39.56	62.49
120	46.25 (2.52)	30.00 (1.64)	23.75 (1.29)	31.50	4.94	5.45	41.89	67.80

WUE, Water-use efficiency
Figures in parentheses are profile moisture contribution (cm)

Table 4. Nutrients content (%) in grain and straw of wheat as influenced by variety, irrigation and N level

Treatment	Content						Total uptake (kg/ha)		
	Grain			Straw			N	P	K
	N	P	K	N	P	K			
Irrigation (IW : CPE ratio)									
0.6	1.74	0.37	0.42	0.56	0.19	0.71	54.64	12.28	24.99
0.9	1.83	0.41	0.49	0.52	0.23	0.75	60.93	16.81	33.35
1.2	1.75	0.43	0.52	0.50	0.22	0.76	67.21	19.62	39.57
0.9/1.2	1.77	0.43	0.51	0.57	0.23	0.75	70.96	20.78	40.62
CD (P=0.05)	0.12	0.06	0.06	0.05	NS	0.04	3.92	2.97	3.77
Varriety									
'GW 190'	1.83	0.40	0.45	0.53	0.21	0.73	53.46	13.98	27.78
'GW 173'	1.82	0.39	0.49	0.53	0.19	0.74	61.53	15.31	33.20
'DL 803-3'	1.79	0.41	0.52	0.51	0.22	0.75	67.11	18.48	37.35
'SL 788-2'	1.82	0.41	0.52	0.50	0.23	0.74	74.36	20.63	40.98
CD (P=0.05)	NS	NS	NS	NS	NS	NS	2.99	2.53	3.01
N (kg/ha)									
80	1.74	0.39	0.46	0.49	0.19	0.71	57.54	14.76	30.50
120	1.90	0.45	0.50	0.55	0.23	0.77	70.96	19.89	38.00
CD (P=0.05)	0.09	0.05	0.04	0.03	ns	0.03	2.43	1.97	2.67

layers due to different varieties and nitrogen levels. However, there was slightly more moisture extraction from deeper layer with higher level of N (Table 3).

Total water use increased with the increase in number of irrigations in all the years (Table 3). It was maximum at 1.2 IW : CPE, while water-use efficiency was higher at 0.6 IW : CPE. The total water use was not significantly influenced by the varieties. However, the WUE was higher in 'DL 788-2' followed by 'DL 803-3' due to higher grain yield with almost equal quantity of irrigation water. Similarly, different levels of N did not show much variation in total water use, but the water-use efficiency (WUE) was highest with higher level of N (Table 3).

Nutrient content and uptake

There was a significant effect of irrigation on N, P and K content of both grain and straw (Table 4). The N content decreased, while P and K content increased with the increase in number of irrigations. The higher N content under lower moisture regime may be attributed to lower total dry matter (grain and straw). On the other hand, P and K content increased under wetter treatments owing to greater availability of these nutrients than at lower level of soil moisture. Reddy and Shastry (1983) attributed reduced uptake of phosphorus and potassium under restricted moisture supply to their reduced mobility at low moisture level. Since total biomass was significantly more with higher moisture regimes, total nutrient uptake was increased as compared to lower moisture regimes (Table 4). The nutrient content both in grain as well as in straw differed significantly among the varieties (Table 4). The total uptake of the nutrients was higher in 'DL 788-2' followed by 'DL 803-3' due to significantly higher biomass compared with other varieties. In general, application of N increased the percentage of N, P and K content both in grain and in straw and also the total dry matter at harvest. Therefore, nutrients uptake was also higher as compared to lower level of N (Table 4).

It could be inferred that under late-sown condition, frequent irrigations at 1.2 or 0.9/1.2 IW : CPE ratio were found to create congenial micro-environment through reduction in canopy temperature resulting higher yield and yield attributes of wheat varieties compared to less frequent irrigation at 0.6 IW : CPE ratio. However, water-use efficiency decreased with the increase in number of irrigation. Among varieties, 'DL 788-2' and 'DL 803-3' were superior to 'GW 190' and 'GW 173'. Higher dose of N was beneficial irrespective of number of irrigations and varieties than lower level.

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