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Yield and Protein Content of Wheat in Relation to N Application, Method and Irrigation Schedules

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ABSTRACT

A field experiment was conducted with wheat (*Triticum aestivum* L.) on a sandy loam soil for four years, to study the interactive effects of fertilizer N application method and timing and frequency of irrigation on grain yield and protein content. The experiment laid out in a split plot design consisted of nine irrigation treatments (ranging from zero to four in numebr and timings) in the main plots and three fertilizer N treatments (no fertilizer N, 120 kg N ha^{-1} drilled at the time of sowing and 120 kg N ha^{-1} applied just before presown irrigation) in the sub-plots. Application of N before presown irrigation transported 63% N to the subsoil, resulting in increase of 250 kg ha^{-1} in grain yield and 1.04% in the grain protein content over that with 120 kg N drilled at the time of sowing. Also, there was a significant ($p=0.05$) interaction between irrigation and fertilizer N methods. While grain yield increased with increase in irrigation frequency, the grain protein content decreased. The timings of irrigation in combination with fertilizer N application before presown irrigation was helpful in improving grain yield and protein content with respect to the numebr of irrigation(s) available.

Introduction

In India, wheat grain production has reached at sufficiency level, but grain quality particularly the protein content (GPC) is quite low. Although GPC is a genetic character, yet it can be manipulated to some extent, through water and fertilizer N management (Sajo *et al.*, 1992; Fischer *et al.*, 1993; Akaya, 1994; Abderrazak *et al.*, 1995; Kattimani *et al.*, 1996). Earlier studies (Sah *et al.*, 1990; Bengtsson, 1992; Lopez *et al.*, 1998) indicate that fertilizer N application increases GPC. Drewitt and Dyson (1987) reported that lower yield of higher quality was obtained by reducing irrigation input but increase in irrigation frequency decreased grain qualtiy. On the other hand, wheat yields have been reported to increase with increase in irrigation frequency (Prihar *et al.*, 1976; Far and Allam, 1995) and an early irrigation at crown root initiation (Bhardwaj and Wright, 1967; Chauhan *et al.*, 1970; Cheema *et al.*, 1973). But GPC has been reproted to increase with late application i.e. at heading, grain formation and maturation (Abderrazak *et al.*, 1995). The increase in water availability during the terminal phase of grain development causes more intense protein accumulaiton (Cuiducci, 1988). These findings indicate that crop response to amount and time of irrigation differs in relation to grain yield and GPC.

It was also observed (Jackson *et al.*, 1983; Olson, 1984; Benbi, 1990) that crop response to fertilizer N is mainly determiend by the amount of plant available water and its availability during the crop growing period (Sandhu *et al.*, 2000) and that fertilizer N application with presown irrigation was better than the placement method (Sandhu and Sidhu, 1996). This shows that there exists a strong interaction betwen water and N, which is well established for grain yield. However, such observations regarding both i.e. grain yield and protein content are lacking. We, therefore, undertook this study to explore a suitable N application method and timing and frequency of irrigation(s) so that both grain yield and GPC could be taken care of.

Materials and Methods

A field experiment was conducted with wheat for four years (1996-97 through 1999-2000) on a sandy loam soil at Punjab Agricultural University Research Farm, Ludhiana (30° 56'N, 75° 52'E), India. The soil belonging to Typic Ustocrept is deep, well drained and non-saline. The surface soil (0-15 cm) tested 0.34% organic carbon, 21 kg ha^{-1} $NaHCO_3$ extractable phosphorus (P) and 101 kg ha^{-1} neutral ammonium acetate extractable potassium (K). Some important physico-chemical properties of the soil are given in Table 1. Mienral N ($NH_4^+ + NO_3^-$) content of the top 120 cm soil was determined (Black, 1965) in the experimental plots, a week after broadcasting 120 kg N ha^{-1} as urea in one set of plots and nothing in the other just before applying 7 cm presowing irrigation. The mineral N distribution profile (Fig. 1) shows that 63% of the applied N was transported to the subsoil (15-120 cm).

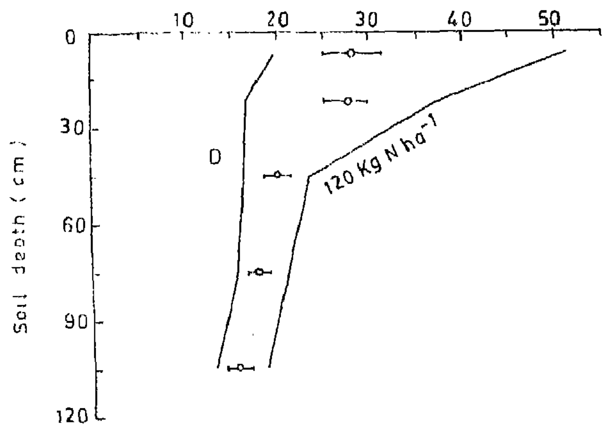

Fig. 1. Mineral N distribution in the soil profile a week after applying 7 cm irrigation at 0 and 120 kg N ha^{-1}. (-ʘ-) represents LSD (0.05).

Experimental procedure

The experiment, replicated thrice, was laid in a split plot design in 1.8 x 8 m^2 measuring sub plots. The main plots consisted of 9 irrigation treatments i.e. no irrigation (I_o), 7 cm irrigation at 4 weeks after sowing 'WAS' (I_a), 12 WAS (I_b) and 18 WAS (I_c) and 7 cm irrigations at 4 and 12 WAS (I_{ab}), 4 and 18 WAS (I_{ac}), 12 and 18 WAS (I_{bc}), 4, 12 and 18 WAS (I_3) and 4, 8, 12 and 18 WAS (I_4). A 7 cm presown irrigation was applied to all plots, a week before sowing. The sub plots consisted of three fertilizer N treatments i.e. no fertilizer N (N_o), 120 kg N ha^{-1} (as urea) broadcast just before applying presown irrigation (N_I) and 120 kg N ha^{-1} (as urea) broadcast just before applying presown irrigation (N_I) and 120 kg N ha^{-1} (as calcium ammonium nitrate - urea was not used to avoid its injurious effects to young seedlings) drilled below the seed at the time of sowing (N_D). A basal dose of 60 kg P_2O_5 ha^{-1} (through single super phosphate) and 30 kg K_2O ha^{-1} (through muriate of potash) was drilled at the time of sowing. Soil water content was determined gravimetrically from 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm depths at the time of sowing. The available stored water was computed as total water storage at sowing minus storage at 1.5 MPa in teh 180 cm profile. Rainfall and pan evaporation recorded at Punjab Agricultural University meteorological observatory, located at two km from the experimental site, are given in Table 2. Wheat (*Triticum asestivum* L. cv. PBW 343) was sown in 20 cm apart rows @ 100 kg seed ha^{-1} in the month of November. The seed ws treated with chlorpyrifos @ 4 ml kg^{-1} against termite attack and standard agronomic practices were followed. The crop was harvested on maturity for grain yield, in the month of April.

Table 1. Some physico-chemical properties of the field soil

Soil Depth (cm)	pH (1:2)	EC (1:2) ds m^{-1}	Sand (%)	Silt (%)	Clay (%)	Bulk density Mg m^{-3}	Water retention g $100g^{-1}$	
							0.03	1.5 MPa
0-15	8.1	0.21	80	14	6	1.45	12.0	4.5
15-30	8.0	0.23	75	16	9	1.57	14.3	5.4
30-60	7.6	0.25	75	14	11	1.50	16.1	6.0
60-90	8.0	0.27	74	16	10	1.53	15.4	5.5
90-120	8.1	0.27	74	15	11	1.48	15.7	5.7
120-150	8.1	0.24	73	16	11	1.46	15.9	5.8
150-180	8.1	0.24	74	15	11	15.5	5.6	

Table 2. Soil mineral N ($NH_4^+ + NO_3^-$) at the time of sowing (Nmin), available stored water (Sw), seasonal rainfall (Ppt) and open pan evaporation (PE) during different years of study

Year	Nmin (mg kg^{-1})	Sw (cm 180 cm^{-1})	Ppt (cm)	PE (cm)
1996-97	10.5	17.7	12.4	33.5
1997-98	20.1	17.9	24.3	27.6
1998-99	20.8	22.0	9.3	32.1
1999-2000	19.3	22.0	9.1	37.0

Grain samples were dried for 48 hours at 60°C for estimating the crude protein content (referred as GPC in the text) using microkjeldahl method (Jackson, 1973). Effects of irrigation and fertilizer N were assessed by analysis of variance (Cochran and Cox, 1957).

Results and Discussion

Mean grain yields varied between 2915 and 4315 kg ha^{-1} during four years and were significantly (p=0.05) higher over 1996-97 (Table 3). Grain protein content (GPC) also varied significantly (p=0.05) during the years (Table 4). The variation in GPC appears to be affected by the soil mineral N content and cropping season rainfall / pan evaporation (Table 2).

Irrigation effects

Irrigation had a significant effect (p=0.05) on grain yield in 1996-97 and 1999-2000 only. During these years, cumulative pan evaporation exceeded available stored water plus cropping season rainfall by $\geq$ 3.4 cm (Table 2) but during 1997-98 and 1998-99 the differences were less than a cm. In an earlier study, Sandhu and Sidhu (1996) reported that the crop response to irrigation was associated with cropping season water deficits. The pooled analysis also showed significant (p=0.05) resposne. On an average, one irrigation increased 270 kg grain ha^{-1}, two irrigations 557 kg and three irrigations 754 kg over no irrigation. Beyond three irrigations, there was no response.

Grain protein content was also affected significantly (p=0.05) by irrigation during 1996-97 and 1998-99. The pooled analysis also showed a significant effect (Table 4). Grain protein content declined progressively with increase in numebr of irrigations. For example, the mean GPC with no irrigation under 120 kg N ha^{-1} applied at sowing was 11.52% and the same was reduced to 9.86% with three irrigations. Some earlier studies (Gruszka and Martyniak, 1995; Lopez *et al.*, 1998) also indicated that GPC was inversely related to crop growing season rainfall and reduced further with irrigation.

Method of N application effects

Grain yield was minimum under no fertilizer N application (Table 3). Application of 120 kg N ha^{-1} at the time of sowing increased grain yield significantly (p=0.05) over no fertilizer N and the increase varied between 1203 and 3022 kg ha^{-1}. Interestingly, application of 120 kg N ha^{-1} with presowing irrigation caused significant (p=0.05) increase in grain yield over 120 kg N ha^{-1} (p=0.05) drilled at the time of sowing. This increase may be attribtued to the enhanced N availability in the sub soil (Fig. 1).

Grain protein content was also minimum under no fertilzier N application (Table 4) but with 120 kg N ha^{-1} drilled at sowing during all the years. The pooled analysis showed an average increase of 1.04% in GPC. It appears that applying N with presowing irrigation provides better synchronization between roots and applied N in the subsoil. Gass *et al.* (1971) also opined that the subsoil mineral N could be useful for the crop when N in the surface soil is unavailable or is not accessible because of the dry top soil.

Interactive effects

Pooled data for grain yield (Table 3) and grain protein content (Table 4) showed a significant interaction (p=0.05) between irrigation and fertilizer N application method. These interactive effects need further understanding for achieving higher GPC at a given grain yield target. An attempt was, therefore, made to relate grain yield and GPC with frequency of irrigation and method of N application. The results (Fig. 2) show that with no irrigation and 120 kg N ha^{-1} drilled at sowing produced 3840 kg grain having 10.4% GPC. But 120 kg N applied with presown irrigation

Table 3. Wheat grain yield (kg ha^{-1}) as affected by timing and frequency of irrigation (I) and fertilizer N application method (M)

Method	Irrigation treatment									Mean
	I_o*	I_a	I_b	I_c	I_{ab}	I_{ac}	I_{bc}	I_3	I_4	
					1996-97					
N_o**	1061	1297	1276	1070	1339	1309	1294	1285	1436	1263
N_D	2700	3268	3320	2909	4012	3891	3650	3946	4384	3564
N_I	3114	3925	3519	3498	3876	3964	4233	4580	4560	3919
Mean	2292	2830	2705	2492	3076	3055	3059	3270	3460	2915
LSD(0.05) I = 474, M = 155, IxM = 465										
					1997-98					
N_o	2424	2052	2386	2114	2834	2048	2433	2005	2067	2262
N_D	4905	5029	5252	5857	5329	5243	5338	5443	5162	5284
N_I	5252	5295	5138	5352	5229	5419	5843	5300	5757	5398
Mean	4194	4125	4259	4441	4464	4237	4538	4249	4329	4315
LSD (0.05) I = NS, M = 199, IxM = NS										
					1998-99					
N_o	2556	2433	2600	1972	2289	2128	2878	2511	2395	2418
N_D	3761	4322	4311	3906	4400	4894	4439	4833	4950	4424
N_I	3967	4394	4417	4356	4650	4789	4950	5189	5056	4630
Mean	3428	3713	3776	3378	3780	3937	4089	4178	4133	3824
LSD (0.05) I = NS, M = 214, IxM = NS										
					1999-2000					
N_o	2902	3178	3362	2989	3695	3028	3893	3425	3643	3346
N_D	4000	4833	4264	4079	4588	4638	4565	5103	4868	4549
N_I	3931	4787	4368	4395	4870	5039	4749	5994	5672	4867
Mean	3611	4266	3998	3821	4384	4235	4402	4841	4728	4254
LSD (0.05) I = 618, M = 236, IxM = NS										
					Pooled					
N_o	2236	2240	2406	2036	2539	2128	2625	2307	2385	2322
N_D	3842	4363	4287	4188	4582	4667	4498	4831	4841	4455
N_I	4066	4600	4361	4375	4656	4803	4944	5266	5261	4704
Mean	3381	3735	3684	3533	3926	3866	4022	4135	4162	3827
LSD (0.05) I = 242, M = 99, Y = 231, IxM = 298, YxM = 199, IxY & IxYxM = NS										

*Subscripts o, a, b, c, 3 & 4 represent no irrigation, 7 cm irrigation at 4, at 12, at 12, at 18, at 4, 12 and 18 and at 4, 8, 12 and 18 weeks after sowing; and **0, D and I represent no N, 120 kg N ha^{-1} drilled at sowing and 120 kg N ha^{-1} applied with presowing irrigation, respectively. NS stands for non significant and Y for year.

and no irrigation resulted in 4070 kg grain ha^{-1} with 11.52% GPC. Similarly, three irrigations produced 4830 kg grain ha^{-1} having 9.04% GPC under drill applied N and 5270 kg grain having 9.86% GPC when the same N was applied with presown irrigation. This illustrates that fertilizer N application with presown irrigation is superior over the drill application for both grain yield and GPC. Further comparisons with respect to timing of one irrigation (Table 3 and 4) indicate that irrigation at 4 weeks after sowing was better than those at 12 or 18 weeks after sowing. In case of

Table 4. Grain protein content (%) as affected by timing and frequency of irrigation (I) and fertilizer N application method (M)

Method	Irrigation treatment									Mean
	I_o*	I_a	I_b	I_c	I_{ab}	I_{ac}	I_{bc}	I_3	I_4	
					1996-97					
N_o**	7.29	7.07	6.74	7.93	6.75	7.02	6.91	7.23	6.54	7.05
N_D	9.37	7.61	8.94	8.03	7.02	7.07	7.71	7.07	7.39	7.80
N_I	8.99	8.35	8.83	9.15	7.98	8.67	7.61	7.71	8.38	8.41
Mean	8.55	7.68	8.17	8.37	7.25	7.59	7.41	7.34	7.44	7.76
LSD (0.05) I = 0.84, M = 0.48, IxM = NS										
					1997-98					
N_o	8.15	8.01	7.60	7.85	8.70	8.04	7.77	8.04	8.40	8.06
N_D	10.32	9.41	10.75	8.51	8.61	9.84	8.92	9.47	9.42	9.47
N_I	9.94	10.60	11.10	10.79	9.62	9.60	9.56	9.60	9.16	9.99
Mean	9.47	9.34	9.81	9.05	8.97	9.16	8.75	9.04	8.99	9.18
LSD (0.05) I = NS, M = 0.42, IxM = 1.25										
					1998-99					
N_o	9.35	8.44	8.08	7.98	7.71	8.36	9.75	8.57	8.24	8.50
N_D	11.23	11.12	10.70	11.49	10.22	10.85	10.32	10.47	10.22	10.73
N_I	13.30	12.60	11.32	11.59	11.32	11.17	11.38	10.00	9.52	11.36
Mean	11.29	10.72	10.03	10.35	9.75	10.13	10.48	9.68	9.33	10.20
LSD (0.05) I = 1.10, M = 0.38, IxM = 1.14										
					1999-2000					
N_o	9.16	8.30	9.16	9.14	8.82	9.37	9.37	8.21	8.30	8.87
N_D	10.66	11.38	10.30	10.53	10.64	9.58	10.64	9.14	9.79	10.29
N_I	13.84	13.40	13.09	13.36	12.35	11.91	12.24	12.12	12.33	12.74
Mean	11.22	11.03	10.85	11.01	10.60	10.29	10.75	9.82	10.14	10.63
LSD (0.05) I = NS, M = 0.48, IxM = NS										
					Pooled					
N_o	8.49	7.96	7.90	8.23	8.00	8.20	8.45	8.01	7.87	8.12
N_D	10.40	9.88	10.17	9.64	9.12	9.34	9.40	9.04	9.21	9.58
N_I	11.52	11.24	11.09	11.22	10.32	10.34	10.20	9.86	9.85	10.62
Mean	10.13	9.69	9.72	9.70	9.15	9.29	9.35	8.97	8.98	9.44
LSD (0.05) I = 0.54, M = 0.22, Y = 0.38, IxM = 0.65, YxM = 0.43, IxMxY = NS										

*Subscripts o, a, b, c, 3 & 4 represent no irrigation, 7 cm irrigation at 4, at 12, at 18, at 4, 12 and 18 and at 4, 8, 12 and 18 weeks after sowing; and **0, D and I represent no N, 120 kg N ha^{-1} drilled at sowing and 120 kg N ha^{-1} applied with presowing irrigation, respectively. NS stands for non significant and Y for year.

two irrigations, irrigations at 4 and 18 WAS were the best for drill applied N and could produce 4670 kg grain having 9.34% GPC. In case of N application with presown irrigation, irrigatinos at 12 and 18 WAS could produce higher grain yield and that also of higher quality i.e. 4940 kg grain ha^{-1} having 10.2% GPC. Comparisons between two and three irrigation regimes further reveal that fertilizer N application with presown irrigation under two irrigation regime was not only superior to the drill applied N under two irrigation regime but was also superior to the three irrigation regime

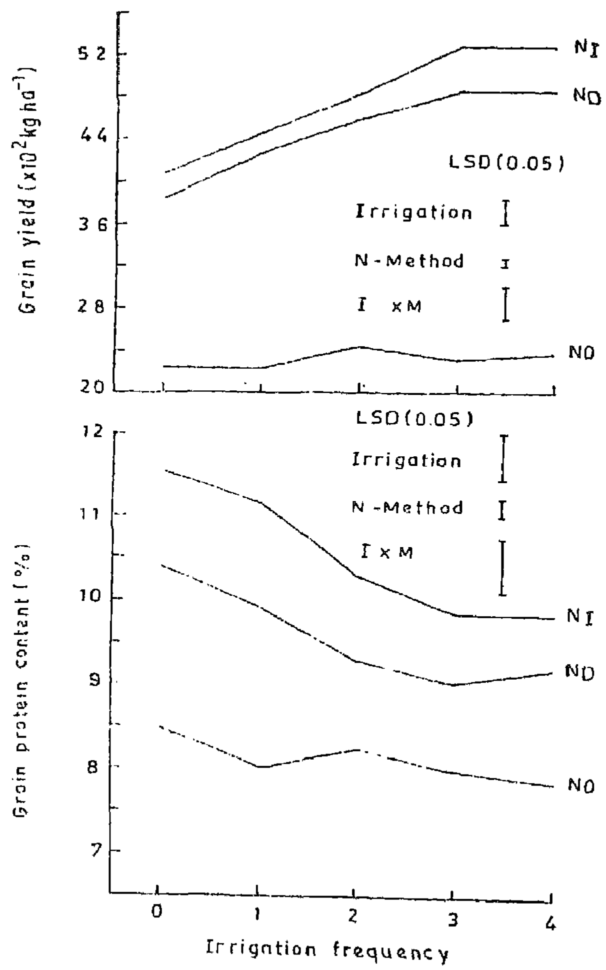

Fig. 2. Effect of frequency of irrigation and fertilizer N application method on grain yiedl and protein content. N_o, N_D and N_I stand for no fertilizer N, 120 kg N ha^{-1} drilled at sowing and 120 kg N ha^{-1} applied with presown irrigation, respectively.

with drill applied N, both in terms of GPC and grain yield. This shows that fertilizer N application with presown irrigation should be preferred and the number of irrigations may be reduced to three.

Conclusions

From the foregoing, it may be concluded that irrigation without N is of little use. And fertilizer N application with presown irrigation is much better over the drill application. Further, grain yields increase wiui increase in the number of irrigations but at the cost of GPC. Fertilizer N application with presown irrigation helps in maintaining higher GPC and grain yield. Efforts must be made to enhance GPC to achieve the international standard (12%) through higehr N rates and its time of application.

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