BRIEF COMMUNICATION

Effect of nitrogen and water stress on photosynthesis and nitrogen content in wheat

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Abstract

The relationships between photosynthesis, leaf nitrogen content and water stress were studied in ten genotypes of wheat differing in the presence of dwarfing genes. Net photosynthetic rate (P_N) was mostly higher at ear emergence stage than at anthesis stage. P_N decreased with water stress (leaf water potential from -2.0 to -2.5 MPa), and with reduced leaf N content in all genotypes studied. Among the various genotypes, single dwarf and wild types showed higher P_N rate and maintained higher leaf N content under different N doses and water supply as compared to the other types studied.

Additional key words: dwarfing genes, moisture stress, *Triticum aestivum*.

Drought is the most limiting factor for wheat production in the Indian subcontinent. In addition to water stress, nitrogen is a yield-limiting factor in these areas; N deficiency accentuates the depressive effect of drought. Although physiological responses of plants to either water or N have been extensively studied (*e.g.*, Evans 1989, Karrou and Maranville 1995, Frederick 1997), the interactive effects of these two environmental variables have not received sufficient attention.

Reduction in plant height with the introduction of *Rht* dwarfing genes might have also changed the yield in dry lands. Allen *et al.* (1986) reported that the dwarf and the semi-dwarf wheat appeared to be better suited to the dry areas than their tall counterparts. Many workers had shown that the semi-dwarf types perform very well under high moisture and high N levels (Uddin and Marshall 1989) but we do not know their potential under lower levels of nitrogen and moisture.

Photosynthesis is strongly influenced by leaf nitrogen content. This relationship can vary widely between species (Sinclair and Horie 1989). Leaves with high nitrogen content have a greater maximum rate of net photosynthesis and higher carboxylation efficiency than that deficient in nitrogen (Lawlor *et al.* 1987). However, the rate of CO_2 assimilation per unit of nitrogen is lower in leaves with high nitrogen content than with low N content (Evans and Seeman 1984).

With this background an experiment was designed to determine the relationship between photosynthesis and leaf N content in different genotypes of wheat differing in their dwarfing genes under the water stress and nitrogen deficiency.

The experiment was conducted in the Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi. Seeds of ten wheat (*Triticum aestivum* L.) genotypes (Table 1) were sown in the pots (30 × 30 cm) containing a mixture of soil and sand (1:1) and grown under natural condition. The treatments comprised of two levels of N and two watering regimes. Nitrogen (in the form of urea) was applied in two doses [at the time of sowing and 25 d after sowing (DAS)] at concentrations corresponding to 120 kg(N) ha^{-1} which is considered as

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Abbreviations: DAS - days after sowing; P_N - net photosynthetic rate.
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optimum, and 30 kg(N) ha^{-1} which is considered as low. The watering regimes consisted of well-watered treatment during the entire experimental period which served as control, and the water deficit treatment in which pots were watered regularly upto 25 DAS, and thereafter stressed by withholding the water supply for 5 d. The flag leaf water potential determined by pressure chamber (*Model 3005, Soil Moisture Equipment Corporation,* USA) according to Scholander *et al.* (1964) at the time of sampling ranged from -1.0 to -1.5 MPa and -2.0 to -2.5 MPa in control and stressed plants, respectively. Treatments are designated as T1 [control + high N], T2 [control + low N], T3 [water stressed + high N], and T4 [water stressed + low N]. Plants were sampled at ear emergence and anthesis and rapidly expanding flag leaves were selected for the study.

Total nitrogen in the dried leaf samples was estimated using an N-autoanalyser (*Technicon*, New York, USA). The method consisted of two main steps: acid digestion of plant material and the colorimetrical measurement of nitrogen as ammonia in the digested plant samples after converting it into the indophenol dye. A portable photosynthesis system (*Model Li-6200*, *LI-COR*, Lincoln, USA) was used for measuring photosynthetic rate. Data were collected between 10:00 and 11:30. Analysis of variance was performed on all dependent variables. If main or interaction effects were significant (P < 0.05), $LSD_{0.05}$ applicable across treatment means was calculated.

The net photosynthetic rate (P_N) measured in all the ten cultivars was maximum at ear emergence stage except one tall cultivar NP- 818, which showed maximum P_N at anthesis (Table 2). Inflorescence growth is rapid at this stage of development, and the rise in P_N may have been due to the increased demand for photosynthates. Single dwarf genotypes DL-153-2 and HD-2402 and wild types *T. vavilovii* and *T. sphaerococcum* showed higher P_N than tall, double and triple dwarf cultivars at both the stages studied. Control plants sufficiently supplied by N (Tl) showed significantly higher P_N than treated plants (T2, T3 and T4) of all genotypes studied.

Total leaf N content in all the genotypes was maximum at ear emergence irrespective of the treatments and the presence of dwarfing genes. Triple dwarf genotypes showed highest N content at ear emergence as well as at anthesis. T3 plants showed higher N than other treatments at ear emergence stage. But latter on at anthesis T1 plants showed the higher N in comparison to T2 treatments; and T3 treatments showed significantly higher N in comparison with T4 plants in all the genotypes (Table 3).

Low leaf N decreased P_N at both the stages in all the cultivars studied. The most affected group was of tall and triple dwarf types, while single dwarf cultivars showed higher P_N and maintained higher leaf N content than most

Table 1. List of wheat genotypes used for the experiment.

Genotypes	Year of release	*Rht*
NP-818	1965	-
C-306	1965	-
DL-153-2	1985	*Rht1*
HD-2402	1985	*Rht1*
HD-2204	1977	*Rht1* or *Rht2*
Kalyansona	1967	*Rht1* or *Rht2*
HD-2428	1988/89	*Rht1+Rht2* or *Rht3*
HD-1949	1974	*Rht1+Rht2* or *Rht3*
Triticum vavilovii	-	
T. sphaerococcum	-	

Table 2. Effects of water and nitrogen stresses on photosynthetic rate [μmol(CO_2) m^{-2} s^{-1}] at ear emergence and at anthesis in ten genotypes (GT) of wheat differing in the presence of dwarfing genes. T1 - control + high N, T2 - control + low N, T3 - water stressed + high N, and T4 - water stressed + low N.

Genotypes	Ear emergence				Anthesis			
	T1	T2	T3	T4	T1	T2	T3	T4
NP-818	17.12	14.72	11.86	6.27	24.34	18.59	6.55	4.52
C-306	15.91	8.21	8.71	7.88	14.43	13.75	4.48	3.64
DL-153-2	20.71	13.17	11.51	7.45	16.31	15.04	6.18	4.13
HD-2402	28.42	21.68	13.09	9.46	21.42	20.16	9.21	8.98
HD-2204	20.95	11.96	20.04	10.93	10.03	8.19	7.00	2.00
Kalyansona	18.30	12.49	12.92	7.82	19.11	10.53	9.43	4.82
HD-2428	21.80	14.81	15.59	12.49	7.75	5.33	5.14	4.06
HD-1949	17.99	15.55	12.40	11.14	9.05	6.87	5.24	3.09
Triticum vavilovii	29.54	22.30	18.13	12.54	28.33	22.50	15.25	8.75
T. sphaerococcum	30.63	21.25	17.28	14.39	30.47	21.09	17.37	10.63
$LSD_{0.05}$	GT = 3.38	T = 2.14	GT × T = 8.98		GT = 4.13	T = 2.61	GT × T = 8.26	

Table 3. Effects of water and nitrogen stresses on total leaf nitrogen content [mg g^{-1}(leaf d.m.)] at ear emergence and at anthesis in ten genotypes (GT) of wheat differing in the presence of dwarfing genes. T1 - control + high N, T2 - control + low N, T3 - water stressed + high N, and T4 - water stressed + low N.

Genotypes	Ear emergence				Anthesis			
	T1	T2	T3	T4	T1	T2	T3	T4
NP-818	27.48	19.74	33.72	19.20	19.59	20.72	21.79	17.53
C-306	25.68	18.96	35.88	24.78	26.64	19.43	17.28	12.61
DL-153-2	32.52	23.10	34.74	22.80	25.02	13.92	26.86	17.18
HD-2402	26.04	31.56	30.96	35.10	25.72	14.29	29.13	15.79
HD-2204	31.20	23.70	39.48	34.74	28.67	13.76	21.59	14.74
Kalyansona	35.04	26.34	36.36	34.32	17.59	13.52	18.45	20.18
HD-2428	34.56	27.42	38.64	35.10	29.93	16.70	26.54	19.92
HD-1949	38.88	38.94	38.76	36.36	28.50	16.79	27.60	12.86
Triticum vavilovii	27.42	27.66	33.84	28.44	21.96	19.70	24.50	22.19
T. sphaerococcum	33.30	23.52	27.72	31.62	24.85	12.62	22.37	18.86
$LSD_{0.05}$	GT = 3.74	T = 2.79	GT × T = 7.87		GT = 3.27	T = 2.79	GT × T = 6.89	

of other genotypes. P_N did not decrease with increased N content under water stress (Table 2). In contrast, Chen *et al.* 1996 found that P_N decreased more by water stress when N was sufficient than with N deficiency. High N rates delayed the loss of leaf area and extended the duration of photosynthetic activity only under irrigated conditions. Similar results were reported by Frederick and Camberato (1995), where irrigation extended the filling period at high N rate but had little effect on the effective filling period at low N rate.

Our results showed good correlation between leaf N content and P_N. Single dwarf cultivars showed higher P_N and higher leaf N content under different doses of N and water supply as compared to most of the other types. The higher P_N during ear emergence may have favoured higher kernel number per head (Frederick and Camberato 1995). This is in agreement with the findings of McNeal *et al.* (1972) that single dwarf genotypes showed higher yield than both the tall and double gene dwarf genotypes. The result of Uddin and Marshall (1989) suggested in conformity with our studies that semi dwarf and dwarf wheat cultivars may yield better not only under favourable conditions but also under drought stress.

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