Pakistan j. sci. ind. res., vol. 38, no. 2, February 1995

SIGNIFICANCE OF PREANTHESIS AND POSTANTHESIS N ASSIMILATION IN DETERMINING GRAIN YIELD AND GRAIN N YIELD IN WHEAT

F. Azam, M. Ashraf and A. Lodhi

Soil Biology Division, Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan

(Received October 27, 1993; revised August 22, 1994)

In a pot experiment, 8 wheat varieties were compared for N partitioning at anthesis and maturity to study the significance of preanthesis and postanthesis N uptake and postanthesis dry matter accumulation in determining grain yield, grain N yield and grain nitrogen concentration (GNC). The wheat varieties (Lu-26, Sind-81, Pak-81, Durum, Punjab-85, Fbd-85, Sarsabz and M-143) were grown with and without applying fertilizer N. Varietal differences were observed for N uptake and response to applied N. However, the efficiency of N translocation from shoot to grain during maturation was almost identical in all the varieties except for Punjab-85, which showed lower translocation, but derived a higher amount of N from soil after anthesis. Remobilization of vegetative N ranged between 74 and 85% in different varieties at the two N levels. However, substantial quantities of N were also taken up after anthesis. The amount of this N was much higher in fertilized than in unfertilized plants. The results of this study suggested the both pre and post-anthesis N uptake are important in influencing the grain yield.

Key words: N partitioning, N uptake, Wheat.

Introduction

Dry matter yield in general and grain yield in particular are closely related to N uptake by wheat and other cereals [1,2]. Of the total plant N at maturity, 80% or even more, is taken up by the plants before anthesis [1,3]. It is estimated that 2/3 or more of the grain N in wheat is derived from remobilization of vegetative N assimilated prior to anthesis [4]. Vegetative N also has a strong bearing on grain yield and grain protein content [1, 5-7]. However, a continuous uptake of N after anthesis (i.e., postanthesis N uptake or PANU) is essential to achieve high yields [5, 8-9].

Although the contribution of preanthesis N assimilation to grain N and grain yield is significant, the correlation between the source (vegetative N) and sink (grains) is low and variable, suggesting that preanthesis N assimilation is of little use as an indirect criterion for high yielding varieties [9]. Cox *et al.* [9] emphasized that N assimilation after anthesis was important to realize high yield.

Our objectives were: (i) to compare nitrogen use efficiencies of different wheat varieties grown in soil with and without fertilizer N, (ii) to study the significance of preanthesis N uptake, (PANU) and postanthesis dry matter accumulation (PADMA) to grain yield, grain N yield and grain N concentration (GNC) of different wheat varieties and (iii) to study the sources and sinks for nitrogen in wheat and their utilization for predicting wheat yield.

Materials and Methods

A sandy clay-loam soil was collected from the surface (0-15 cm) of an experimental field at the Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. The soil was air dried and ground (<0.5 mm). Physico-chemical analyses of the soil gave the following results: pH (1:1, soil: water suspension), 7.4; organic C, 0.6%; total N, 0.06%; sand, 30%; silt, 42% and clay, 28%.

Five and one-half kg portions of the soil were placed in 96 plastic pots of 6 kg capacity. In all pots, K and P were applied at 31 and 25 $\mu g\ g^{-1}$ soil, equivalent to 124 and 100 mg pot^{-1}, respectively, using a solution of KH_2PO_4. Soil in half of the pots was supplied with $(NH_4)_2\ SO_4$ (+N treatment) to obtain an N addition rate of 30 $\mu g\ g^{-1}$ soil (165 mg pot^{-1}). Remaining pots were left unfertilized (-N treatment) and moisture content of the soil in all pots was adjusted to field capacity. Twelve pots (6 from+N and 6 from-N treatment) were sown in November 1989 to each of the following wheat varieties: Lu-26, Sind-81, Pak-81, Durum, Punjab-85, Fbd-85, Sarsabz and M-143. Of these, Sind-81, Sarsabz and M-143 were obtained from the Atomic Energy Agricultural Research Centre, Tandojam, Pakistan and the others were procured locally. Six seeds were planted initially after treatment with Vitavax fungicide. After germination, 3 seedlings were left per pot and the plants were irrigated with deionized water to maintain the soil moisture content near field capacity. At maximum tillering, a second dose of N equivalent to 30 $\mu g\ g^{-1}$ soil (165 mg N pot^{-1}) was given to the +N pots.

Plants were harvested at two growth stages. First harvest from triplicate pots of each variety (both +N and -N treatments) was obtained at anthesis and the second harvest at maturity. Roots were carefully removed from the soil to achieve maximum recovery and the above ground portion was partitioned into grain and straw (in case of plants harvested at maturity). All the plant components were dried at 70°C, finely powdered, and duplicate samples analyzed for Kjeldahl N [10].

The data were subjected to analysis of variance (ANOVA) followed by least significant difference (LSD) test for planned comparison of paired treatment means (Steele and Torrie 1980). COSTAT and LOTUS 1-2-3 computer software programmes were used for statistical analyses.

Different abbreviations used in the text include: NUE, nitrogen utilization efficiency (dry matter yield/total plant N); HI, harvest index (grain weight/weight of plant tops); NHI, nitrogen harvest index (grain N/N in plant tops); PADMA, postanthesis dry matter accumulation (dry matter at maturity - dry matter at anthesis); PANU, postanthesis N uptake (N yield at maturity - N yield at anthesis); PASND, postanthesis shoot N decrease (shoot N at anthesis - shoot N at maturity); ExGrN, grain N in excess of PASND.

Results and Discussion

At anthesis, different varieties showed significant differences in root biomass, in the presence and absence of N (data not shown). Dry matter yield of tops in different varieties ranged between 6.7 and 12.5 g pot^{-1} in the -N treatment and between 8.1 and 12.9 in the +N treatments (Table 1). Fertilizer N had no consistent effect on root biomass in different varieties. However, addition of N had, in general, a positive effect on shoot portion which was not always significant. Shoot N yield varied in different varieties but the differences were generaly nonsignificant. Only M-143 showed significantly higher N yield than some other varieties. Application of fertilizer N had a significantly positive effect on shoot N yield in all the varieties but intervarietal differences were generally nonsignificant. Because of high N content of root and shoot portions in +N treatment, the % N content of plant tops was significantly higher than that in -N treatment; an observation in conformity with other reports [11,12].

At maturity, dry weight of plant tops (Table 2) was considerably higher than that at anthesis and the positive effect of N application on straw weight showed up at this stage. However, the differences between varieties were generally nonsignificant in both -N and +N treatments. All varieties showed a significant increase in grain weight due to N application (e.g., lowest and highest values of 12.6 and 16.7 g pot^{-1} as compared with 7.1 and 12.1 g pot^{-1} in the -N treatment, respectively, in the eight varieties).

There was no consistent change in nitrogen yield of the root between anthesis and maturity (data not shown), while a decrease in shoot N is reported in many studies dealing with partitioning of N [7]. Nitrogen in plant tops was significantly higher in the +N treatment and that in grain was approximately twice that in the -N treatment resulting in a significant increase in N concentration (% N) of both straw and grain portions. Increase in dry matter and N yield of plants following N application is in agreement with many other reports [2,12]. However, varietal response to N application was highly variable. Punjab-85 was prominent in its response to applied N showing 3 times higher N yield in grain compared to the -N treatment. This variety also had the highest N in grain as well as in straw.

TABLE 1. DRY MATTER YIELD (DMY), N YIELD AND % N CONTENT OF PLANT TOPS AT ANTHESIS.

Wheat	DMY		N yield		% N content	
variety	-N	+N	-N	+N	-N	+N
Lu-26	12.4	12.9	209.2	334.0	1.68	2.58
Sind-81	10.6	10.9	191.2	320.9	1.81	2.95
Pak-81	10.0	12.1	195.3	336.6	1.96	2.79
Durum	7.9	8.9	190.8	314.7	2.41	3.53
Pun-85	7.0	8.1	186.6	303.5	2.66	3.76
Fbd-85	6.7	9.2	188.2	294.0	2.82	3.19
Sarsabz	10.4	10.7	209.8	336.4	2.03	3.16
M-143	12.5	11.9	214.9	375.0	1.72	3.16
LSD* (P=0.05)	0.9		24.3		0.08	

* LSD values compare all the figures in -N and +N columns of respective parameters.

TABLE 2. ANALYSIS OF PLANT TOPS AT MATURITY.

Wheat	Dry matter yield				N yield*			
	Straw		Grain		Straw		Grain	
variety	-N	+N	-N	+N	-N	+N	-N	+N
Lu-26	11.2	12.3	9.9	15.5	34.2	61.9	148.7 (1.5)	335.6 (2.2)
Sind-81	12.0	13.8	9.4	12.6	35.5	56.1	153.3 (1.6)	320.9 (2.3)
Pak-81	11.7	14.0	9.0	15.3	36.6	54.6	143.4 (1.6)	349.9 (2.3)
Durum	9.9	12.6	9.7	16.4	28.3	63.8	140.1 (1.4)	350.8 (2.1)
Pun-85	11.1	13.9	7.1	14.6	48.4	71.7	143.4 (2.0)	433.7 (3.0)
Fbd-85	10.4	12.3	9.1	12.8	34.1	60.5	171.5 (1.9)	341.8 (2.7)
Sarsabz	12.6	14.9	12.1	16.7	41.7	75.9	184.3 (1.5)	348.2 (2.1)
M-143	11.9	14.4	12.0	16.4	37.5	65.3	189.9 (1.6)	379.4 (2.3)
LSD** (P = 0.05)	1.4		2.1		8.2		30.2 (0.11)	

* Figures in parentheses indicate % N content in the respective plant part.

**LSD values compare all data in the -N and +N columns of respective parameters.

A significant correlation is generally observed between vegetative N at anthesis and final grain yield and grain N yield [1-7]. In the present study, from 74 to 85% of the N assimilated at anthesis was remobilized during maturation (Table 3). Punjab-85 showing significantly lower remobilization efficiency (74 and 76% in the -N and +N treatment, respectively). Preanthesis N assimilation (vegetative N at anthesis) is reported to determine final grain yield and grain N yield and from two third to almost all of this N is remobilized to grain during maturation [1,4,6,16]. The application of fertilizer N had no significant effect on the efficiency of remobilization, although the amount of remobilized N was significantly higher in the +N treatments; an observation in agreement with other reports [15].

Computation of data from both -N and +N treatments and all varieties showed a significant correlation between vegetative N remobilized and grain yield (r = 0.91) and grain N yield (r = 0.90. However, when values of -N and +N treatments were computed separately, a significant correlation (r = 0.85) between vegetative N remobilized and grain yield was observed only in -N treatmtnt. A positive correlation was also observed between remobilized N and grain N concentration (GNC) but was significant (r = 0.80) only for -N treatment. Almost similar relationships were obtained between shoot N at anthesis and different grain parameters. Studies by other workers [9] show that correlation between the source (shoot N at anthesis) and sink (grain) is low and variable, suggesting that preanthesis N assimilation will be of little use as a selection criterion. They maintain that postanthesis N uptake (PANU), which shows a significant correlation with grain yield, is important to realize high yields in spite of wide variation in different cultivars. In our study, contribution of PANU to total plant N at maturity varied widely (ranging from negative values to up to 50%) among the varieties used. Similar observations have been reported by others [1, 17-19]. In the present study, Punjab-85 showed the highest value of PANU, but its translocation efficiency (% of total vegetative N disappearing between anthesis and maturity) was the lowest. Cox *et al.* [9] observed that lines with high PANU translocated less N than those with low PANU. In our study, however, PANU did not show a positive correlation with grain yield but exhibited a significant correlation with grain N yield and GNC, the correlation was particularly high in the +N treatment (r = 0.8 and 0.78, respectively). Cox *et al.* [9] also observed that almost the entire PANU ended up in grain. In the present study, PANU together with vegetative N at anthesis showed higher correlation with grain N compared to that observed for PANU alone. Similarly, PANU and vegetative N remobilized taken together yield significant correlation with grain N. These results suggest that a continu-

TABLE 3. VARIETAL DIFFERENCES IN NITROGEN USE EFFICIENCY AND OTHER PARAMETERS AT MATURITY*.

Wheat variety	NUE		PADMA		PANU		PASND**		ExGrN	
	-N	+N	-N	+N	-N	+N	-N	+N	-N	+N
Lu-26	118.6	73.4	9.1	15.7	-17.7	60.5	175.0 (83.7)	272.1 (81.5)	-26.3	63.6
Sind-81	123.8	76.1	12.1	18.8	0.2	72.9	155.7 (81.4)	264.8 (82.5)	-2.4	56.1
Pak-81	123.3	80.4	10.7	20.5	-22.8	76.9	158.7 (81.3)	282.0 (83.6)	-15.3	67.9
Durum	120.4	74.3	13.6	21.8	-7.7	104.0	162.5 (85.2)	250.9 (79.7)	-22.4	99.9
Pun-85	106.5	62.6	14.1	22.8	15.3	196.0	138.2 (74.1)	231.8 (76.4)	5.2	201.9
Fdb- 85	105.6	68.8	15.2	17.6	18.9	107.2	154.1 (81.9)	233.5 (79.4)	17.4	108.2
Sarsabz	118.5	78.4	16.0	20.9	16.5	76.5	168.1 (80.1)	260.5 (77.4)	16.2	87.7
M-143	115.8	73.7	12.2	20.1	18.5	64.9	177.4 (82.6)	309.7 (82.6)	12.5	69.7
LSD (P = 0.05)	8.2		1.9		6.3		31.4		6.5	

*Please refer to M & M section for definition of abbreviations used in the table.
**Figures in parentheses indicate PASND in percentage.

ous supply of N from both pre and postanthesis N uptake is essential for grain proteins.

In the -N treatment, PANU was either negative or very low, suggesting a significant loss of plant N during maturation. Such losses are particularly high during grain fill [20]. Loss of N may have occurred in the +N treatment also, but was probably masked by a more active uptake of N from soil after anthesis. Senescence of leaves, which is a key factor in foliar N losses [7, 16, 20], would be expected to commence earlier in the -N treatment since a good supply of N is reported to maintain a higher photosynthetic activity of the leaves for an extended period of time [21]. In addition, early senescence will have a negative effect on transport of photosynthates to the roots, leading to decreased root activity and N uptake between anthesis and maturity. On the contrary, in the +N treatment, a higher PANU could be attributed to N fertility of the soil and a higher N uptake efficiency of roots throughout plant growth. Recently, we have demonstrated enhanced N uptake efficiency of maize roots at increasing levels of soil-applied N, although root biomass *per se* was not improved [12].

Nitrogen use efficiency (dry matter yield/total plant N) varied with the varieties, but the differences were generally nonsignificant. It was significantly higher (by up to 50%) in -N treatment in all varieties. This difference in -N and +N treatments could be explained on the basis of differences in PANU and PADMA; the former being several times lower in the -N treatment as compared with the +N treatment, while the reduction in PADMA was not as great. In all cases, however, the efficiency was almost twice as high at maturity as at anthesis (data not shown), suggesting a slower rate of PANU than PADMA. Nevertheless, utilization efficiency (grain N x 100/ total plant N) was higher with the +N treatment and ranged between 76.5 and 82.7% as compared to 64.8 and 78.0% with the -N treatment. Harvest index and N harvest index were higher in the +N treatment, but generally the differences were significant only in the case of HI (data not tabulated). Varietal differences in HI and NHI were also generally nonsignificant and no correlation was observed between NHI and GNC. Heitholt *et al.* [1] observed an NHI between 0.57 and 0.78 and genotypes with higher yield showing a higher value of NHI, but no correlation between NHI and grain N concentration or grain yield. Similar observations have been reported by others [22].

In summary, the results of this study suggest that wheat plants meet a significant portion of their N requirements from preanthesis N accumulation. However, postanthesis N uptake, together with vegetative N at anthesis determine the crop performance, particularly the grain proteins. Nevertheless, PANU affects postanthesis dry matter accumulation positively and may thus indirectly affect the yield.

Acknowledgement. Technical assistance by Muzaffar Hussain Sajjad is gratefully acknowledged.

References

1. J. J. Heitholt, L. I. Croy, N. O. Maness and H. T. Nguyen, Field Crops Res., **23,** 133 (1990).
2. F. Azam, M. Ashraf, A. Lodhi and M. I. Sajjad, Biol. Fertil. Soils, **10,** 134 (1990).
3. D. A. Van Sanford and C. T. MacKown, Crop Sci., **27,** 295 (1987).
4. A. N. Pavlov and T. I. Kolesnik, Sov. Plant Physiol (Engl. Transl.), **22,** 267 (1974).
5. J. H. J. Spiertz and N. M. De Vos, Plant and Soil, **75,** 379 (1983).
6. P. J. Gregory, D.V. Crawford and M. McGowan, J. Agric. Res., **93,** 485 (1979).
7. L. A. Harper, R. R. Sharpe, G. W. Langdale and J. E. Giddens, Agron. J., **79,** 965 (1987).
8. M. C. Cox, C. O. Qualset and D. W. Rains, Crop Sci., **25,** 430 (1985).
9. M. C. Cox, C. O. Qualset and D. W. Rains, Crop Sci., **25,** 435 (1985).
10. J. M. Bremner and C. S. Mulvaney, *Methods of Soil Analysis* (Page A. L. *et al.* Eds) (Am. Soc. Agron. Madison, Wisconsin, 1982), pp.595.
11. A. Szmigiel, Acta Agraria et Sivestria Agraria, **24,** 187 (1985).
12. F. Azam, A. Lodhi and M. Ashraf, Soil Biol. Biochem., **23,** 473 (1991).
13. F. X. Paccaud, A. Fossati and H. S. Cao, Z. Pflanzenzeucht., **94,** 89 (1985).
14. G. L. Terman, R. E. Ramig, A. F. Dreier and R. A. Olson, Agron. J., **61,** 755 (1969).
15. R. C. Muchow, Field Crops Res., **25,** 265 (1990).
16. L. A. Daigger, D. H. Sander and G. A. Peterson, Agron. J., **68,** 815 (1976).
17. R. B. Austin, M.A. Ford, J. A. Eldrich and R. D. Blackwell, J. Agric. Sci., (Camb.), **88,** 159 (1977).
18. F. H. McNeal, M.A. Berg and C. A. Watson, Agron. J., **58,** 605 (1966).
19. J. H. J. Spiertz and J. Ellen, Neth. J. Agric. Sci., **26,** 210 (1978).
20. J. A. Morgan and W. J. Parton, Crop Sci., **29,** 726 (1989).
21. J. A. Morgan, Crop Sci., **28,** 95 (1988).
22. M. C. Cox, C. O. Qualset and D. W. Rains, Crop Sci., **26,** 737 (1986).