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Nitrogen Relations During Spring Growth in Varieties of *Triticum aestivum* L. Differing in Grain Protein Content[1]

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ABSTRACT

Field-grown hard red winter wheat varieties harvested at weekly intervals differed in plant nitrogen content, but the differences were not associated with the protein content of their grain. Plants of 'Warrior,' a low grain protein variety, were consistently higher in nitrogen than higher grain protein varieties. High protein derivatives of 'Atlas 66' × 'Comanche' were intermediate or comparatively low in plant nitrogen. Their grain was significantly higher in nitrogen content than the low protein varieties throughout the grain development period. Nitrogen content of the grain first decreased from an initially high level, then increased during the last 3 weeks of grain maturation. In the high protein varieties the decrease was less pronounced and the subsequent increase more rapid than in the low protein varieties.

OUR cooperative investigations have demonstrated the feasibility of breeding productive, high protein varieties of hard red winter wheat (*Triticum aestivum* L.) (1, 2, 7). With 'Atlas 66' (4, 6) as the source of high protein, genetically induced protein increases in the wheat grain in the range of 2 to 3% actual protein have been reported (7). The identification of heritable protein differences has led to renewed interest in the physiological aspects of nitrogen metabolism and protein synthesis in wheat (3)

As early as 1915 Thatcher (8) published data on the wheat varieties 'Turkey' and 'Bluestem' showing that percentage of protein in the developing kernel decreases somewhat until milk stage and increases thereafter until maturity. Mature kernels possessed more protein than the immature. Miller (5) in 1939 showed a similar pattern of protein synthesis in the developing grain of the varieties 'Kanred' and 'Harvest Queen.' Significant varietal differences were not demonstrated. Despite the early findings of Thatcher and Miller, a commonly accepted version of protein synthesis in wheat has been that nitrogen accumulates early in kernel development and is followed by starch deposition and protein dilution in the later stages.

A study of nitrogen accumulation in plants and grain of selected varieties of hard red winter wheat differing in the protein content of their grain was initiated at the Nebraska Station in 1962.

MATERIALS AND METHODS

Six varieties and five high protein experimental lines were studied. The varieties were Comanche (C. I. 11673), 'Wichita' (C. I. 11952), 'Warrior' (C I 13190), 'Scout' (C. I. 13546), 'Lancer' (C I. 13547), and 'Gage' (C. I. 13532). The high protein experimental lines included Atlas 66 × Comanche F_8-derived families 60305, 60306, and 60308, and Atlas 66 × Comanche Selections 631250 and 631267 Line 631250 is a selection from 60305 and 631267 is from 60306. Not all varieties and lines were used in all experiments

The varieties were grown at Lincoln in replicated nursery plots consisting of four rows 3 meters long We used four replications in 1962 and 1963 and two in 1964 and 1965. Plant samples were taken at weekly intervals beginning April 23 in 1962 and April 11 in 1963 Sampling continued until the wheat was mature Samples consisted of all aboveground plant material in a 7 5-cm section of row taken at four places in the border rows of each plot The unsampled center rows were retained for yield determinations and other agronomic measurements Within-plot samples were composited; oven-dried at 70 C; ground, and analyzed for total nitrogen content by the Kjeldahl procedure As soon as feasible after anthesis, the developing grain was removed from the spikes and analyzed separately from the other plant material We followed the same procedure in 1964 and 1965 except that sampling was delayed until May 12 in 1964 and June 17 in 1965.

RESULTS AND DISCUSSION

Table 1 summarizes yield and agronomic data for six varieties grown in 1962 and 1963. Scout was the highest-yielding variety on the average, but with Warrior it produced grain having the lowest protein content. Atlas 66 × Comanche (60306) was slightly more productive than Warrior, Lancer, and Comanche, and its grain possessed over 2% more protein than the latter three varieties. Both leaf and stem rust were heavy on susceptible varieties. Selections 60305 and 60306 exhibited resistance to both rusts, while Scout and Lancer were resistant to stem rust. Scout and 60306, the earliest varieties, were similar in heading date. Warrior, Lancer, and 60305 also were similar in date of heading.

Figure 1 shows the nitrogen content in above-ground plant parts and in the grain of four varieties at weekly intervals during the spring of 1962. Plant nitrogen (dry weight basis) in all four varieties decreased from approximately 5% on April 23 to about 1% on June 27 when the wheat was ripe. Plants of Warrior had a higher nitrogen content than the other varieties on every sampling date except one. The nitrogen superiority of Warrior over the other varieties was statistically significant on all but three dates. The high

Table 1. Average grain protein, yield, other agronomic data, and disease data for six varieties of hard red winter wheat grown in replicated nurseries at Lincoln, Nebr., in 1962 and 1963.

Variety	C.I. or Sel. No.	Date headed	Winter survival	Plant height	Infection severity* Puccinia graminis tritici	Infection severity* Puccinia recondita	Test wt	Grain yield	Grain protein†
		May	%	cm	%	%	kg/hl	kg/ha	%
Scout	13546	17	100	81	60	5	45.9	2357	13.8
Atlas 66 × Comanche	60306	18	99	84	Tr‡	5-70	45.8	2030	16.5
Warrior	13190	23	100	81	50	60	42.6	1934	13.8
Lancer	13547	22	100	81	60	5	45.8	1929	14.2
Comanche	11673	20	100	84	50	60	44.8	1929	14.3
Atlas 66 × Comanche	60305	22	97	79	Tr-60	5-70	44.9	1629	17.0

* Data from 1962 only. † Calculated on 14% moisture basis. ‡ Tr = trace severity.

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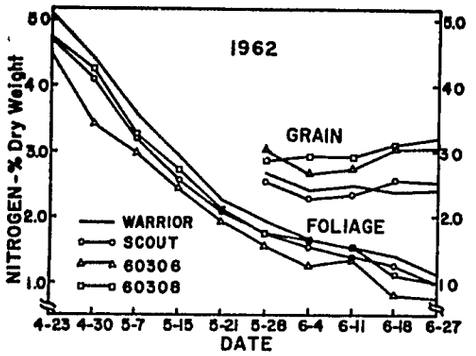

Figure 1. Nitrogen content of the plants and grain of four varieties of winter wheat grown at Lincoln, Nebr., in 1962.

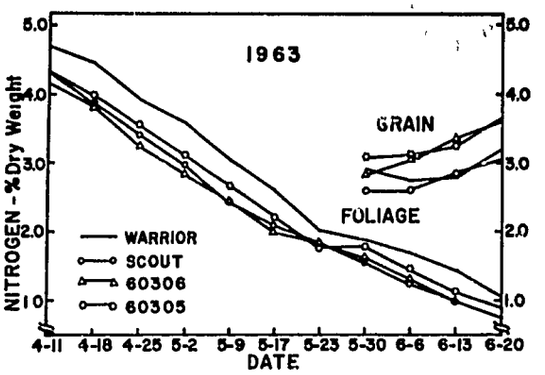

Figure 2. Nitrogen content of the plants and grain of four varieties of winter wheat grown at Lincoln, Nebr., in 1963.

protein Selection 60308, which is comparable in maturity to Warrior, had the lowest plant nitrogen content on all sampling dates. Plant nitrogen contents of Scout and 60306 were similar throughout the spring.

Physical separation of the developing grain from other plant parts was possible in 1962, beginning May 28. Even at this early stage of kernel development, grain of the high protein selections 60305 and 60308 contained a higher percentage of nitrogen than Scout and Warrior Nitrogen content of all varieties except 60308 decreased from May 28 to June 4. Nitrogen level of Scout and Warrior remained nearly constant throughout the remainder of their grain maturation. In contrast, nitrogen content of the grain of 60306 and 60308 increased steadily until the grain was mature. It is significant that the June 11-18 period of most rapid grain nitrogen increase in 60306 and 60308 coincided with a sharp drop in plant nitrogen in these varieties during the same period. The superiority in grain nitrogen content of 60306 and 60308 over Scout and Warrior was statistically significant at all sampling dates.

Comparisons of high protein selections 60305 and 60306 with Warrior and Scout in 1963 are made in Fig. 2. Again, plant nitrogen content of Warrior was significantly higher than the varieties with which it was compared throughout the entire spring growing period. Also, plants of 60306 had the lowest nitrogen content on most sampling dates although the difference between 60306 and Scout was not as large as in 1962.

Only Warrior decreased in grain nitrogen content after May 30, the date on which separate analysis of the grain was initiated. Both high protein lines 60305 and 60306 showed steady increases in kernel nitrogen content throughout their grain maturation period. Nitrogen increased in the grain of Warrior and Scout after June 6 but at a significantly lower level than the high protein lines.

Atlas 66 × Comanche Selection 631250 was substantially more productive than the four varieties with which it was compared in 1964 and 1965 (Table 2). Selection 631267 and Scout were similar in yield and test weight, but the grain of 631267 possessed 2% more protein than Scout. Wichita and Comanche, which were susceptible to leaf and stem rust, were low in both grain yield and protein content. Winterkilling occurred at Lincoln in 1964 and 1965. Winter survival of 631250 and 631267 was comparable to that of Comanche but less than the survival of Scout.

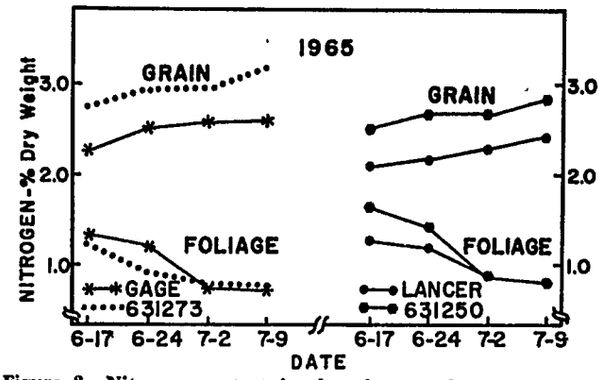

Figure 3. Nitrogen content in the plants and grain of four varieties of winter wheat grown at Lincoln, Nebr., in 1964.

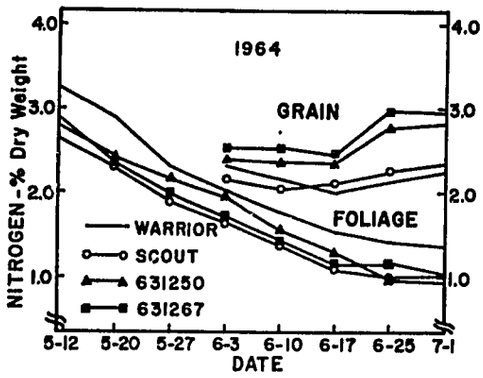

Figure 4. Nitrogen content in the plants and grain of four varieties of winter wheat during grain maturation in 1965.

Table 2. Average grain protein, yield, other agronomic data, and disease data for five varieties of hard red winter wheat grown in replicated nurseries at Lincoln, Nebr., in 1964 and 1965.

Variety	C.I. or Sel. No	Date headed	Winter survival	Reaction to* Puccinia graminis tritici	Reaction to* Puccinia recondita	Test wt	Grain yield	Grain protein†
		May	%			kg/hl	kg/ha	%
Atlas 66 × Comanche	631250‡	25	53	MR	MR	44.5	2411	15.4
Atlas 66 × Comanche	631267¶	26	55	MR	MR	45.2	1870	15.4
Scout	13546	23	73	S	R	44.9	1795	13.4
Wichita	11952	22	60	S	S	43.9	1323	12.5
Comanche	11673	26	55	S	S	40.4	1141	13.3

* Data from 1965 only. † Calculated on 14% moisture basis. ‡ Selection from 60305. § R = Resistant, MR = Moderately resistant, S = Susceptible.
¶ Selection from 60306.

Sampling of plants was delayed until May 12 in 1964. Selections 631250 and 631267 were compared with Warrior and Scout (Fig. 3). Plants of Warrior contained the highest percentage of nitrogen throughout the sampling period, as they did in 1962 and 1963. Scout plants had a slightly lower nitrogen content than 631267, a selection from 60306. Nitrogen in the grain of all varieties decreased slightly after June 3. The decrease continued until June 17 except in Scout. In the week following June 17 nitrogen in the grain of both 631267 and 631250 increased sharply. Both lines were higher in the nitrogen content of their grain than Warrior and Scout at all stages of kernel development.

In 1965 comparisons of 631273 and 631250 with Gage and Lancer were made. Since Gage and 631273 are similar in date of heading and both possess adult resistance to stem and leaf rust, comparison of one with the other was particularly appropriate. Lancer and 631250 likewise were comparable in maturity and resistance to stem rust but differed in reaction to leaf rust. Sampling was initiated as soon after anthesis as the grain could be separated from other plant parts. Kernel and plant nitrogen differences between varieties are shown in Figure 4. Varietal differences in plant nitrogen content tended to disappear as grain maturation progressed. Wide differences in grain nitrogen content in favor of the high protein lines were measured on the first sampling date. The differences persisted until the grain was ripe. Kernel nitrogen content of all varieties increased throughout the period of grain development.

In each year of the 3-year period that Warrior was included among varieties analyzed for their plant and grain nitrogen content, it had the highest plant nitrogen content. Its grain, on the other hand, had the lowest nitrogen content among the varieties in two of the three years. We must conclude that Warrior has the capacity to take up more of the available soil nitrogen than the other varieties tested. However, it seems unable to translocate as much nitrogen to its grain as the other varieties. In contrast to Warrior, plants of the high protein line 60306 contained the least nitrogen among varieties studied in 1962 and 1963, but the relatively high nitrogen content of its grain throughout the grain development period indicates the capacity of 60306 to translocate nitrogen to the grain more readily and completely than Warrior and other low protein varieties. This suggests that nitrogen uptake and nitrogen translocation function as separate and independent physiological systems in the wheat plant. This agrees with the conclusion of McNeal et al. (3) that kernel nitrogen was not closely associated with nitrogen content of other plant parts of spring wheat varieties.

The capacity of 60305, 60306, and 60308 to synthesize more protein in their grain than other varieties was reflected from the very early stages of kernel development. By one week after flowering significant differences in nitrogen content of the kernels could be demonstrated. Had the high protein lines been less productive than the named varieties with which they were compared it might be postulated that their grain contained more protein because there was less of it. Productiveness of the high protein lines does not support this theory.

Evidence was obtained that the nitrogen content of the grain is high initially, decreases, then increases again until the grain is ripe. This agrees with the findings of Thatcher (8) and Miller (5). Continued increase of nitrogen during the late stages of kernel development indicates acceleration of protein synthesis in the grain as its development progresses. The late stages of kernel development are clearly an important period of nitrogen assimilation in the wheat kernel. Factors of environment during the two weeks pre-ripe period that interfere with translocation of nitrogen from the plant to the grain could exert drastic influence on the final level of protein in the grain.

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