Evaluation of the Accuracy of a Wheat Stem Nitrate Test in Predicting Nitrogen Requirements of Irrigated Durum Wheat

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ABSTRACT

The procedure currently recommended by the University of Arizona for predicting the nitrogen (N) requirements of durum wheat has proven to be quite accurate at sites where grain yields exceeded 5,400 lbs/acre. However, the method slightly overestimated N needs when the yield possibility was below that level. Additional information on the relationships between N rates, stem NO_3-N levels and grain yields are needed for the wide range of agronomic conditions found in Arizona. Three N fertility trials were conducted at the Maricopa Agricultural Center to: 1) document the accuracy of the currently recommended soil + stem NO_3-N testing procedure in predicting the N needs of durum wheat on soils of varying residual N content and grain yield potentials; and 2) to evaluate the use of the current stem testing procedure on two durum varieties 'Aldura' and 'Westbred-881'.

The University of Arizona procedure was found to accurately predict the minimum amount of N required for optimum production of durum wheat on two sites where yield potentials were 5,400 and 6,300 lbs. grain/A, but it slightly overpredicted N rates on two sites with maximum yield levels of 5,400 lbs/a. 'Aldura' consistently out-yielded 'Westbred-881' by about 12% but 'Aldura' also averaged 0.78% lower in grain protein content. Little statistical or practical differences were observed in the quantities of NO_3-N contained in the stem tissue of these two varieties, which should simplify the interpretation of stem NO_3-N values for various wheat cultivars. The currently recommended procedure for predicting optimum N rates in durum wheat production has proven to be accurate when yield levels exceed 5,400 lbs. grain/A. A slight modification of the procedure may be needed to more closely predict N requirements on lower yielding sites.

INTRODUCTION

The use of nitrogen (N) fertilizers is normally needed to attain acceptable wheat grain yields and quality. Recent legislation in Arizona mandates that Best Management Practices be adopted by 1989 to minimize the amount of nitrate entering groundwater supplies. Therefore, accurately predicting the minimum amount of N fertilizer needed for optimum wheat production would benefit both producers and the environment.

Previous research has demonstrated the accuracy of the procedure currently recommended by the University of Arizona to predict the nitrogen needs of durum wheat. This procedure utilizes preplant soil NO_3-N analysis and periodic stem tissue NO_3-N tests to monitor the N status of the crop and to provide the basis for determining how much N fertilizer, if any, is required for optimum production. The procedure, as outlined by Pennington et al. (1983), has proven to be very accurate when grain yields of durum wheat were between 5,800 and 7,200 lbs/acre. When maximum grain yields at a given site did not exceed 5,100 lbs/a, the stem testing procedure tended to over-predict the amount of N required by approximately 50 lbs N/acre (Doerge et al., 1987).

Three experiments were conducted at the Maricopa Agricultural Center during the 1987-88 crop year with the following objectives: 1) to determine the accuracy of the currently recommended soil + stem NO_3-N testing procedure in predicting the N needs of durum wheat on soils of varying residual N content; and 2) to evaluate the response of two popular durum wheat varieties to a wide range of N application rates with respect to stem NO_3-N levels, grain yield, grain protein content and other growth characteristics.

METHODS AND MATERIALS

Three N fertility trials were conducted with durum wheat using similar cultural practices on each. The cropping history, soil test characteristics, and N treatments used on each of the three sites will be detailed below.

All plots received a uniform application of 100 lbs. P_2O_5/A, as treble superphosphate, which was hand-broadcast and worked into the surface 4-6 inches of soil prior to the first irrigation. All mid-season applications of N were hand-broadcast onto dry soil no more than two hours before irrigation. Individual irrigations were scheduled, using a neutron probe, to supply adequate, but not excessive, moisture based on measurements taken from plots receiving adequate N for maximum yield (Erie et al., 1982).

Stem-tissue samples were taken periodically from all three trials, according to the recommended procedure of Pennington et al. (1983). With this method, the plant part sampled was the stem between ground level and the seed (for samples taken prior to joining) and the two inches of stem just above ground level (for the remaining dates). Samples were separated from the wheat plants immediately in the fields and then dried at 60°C, ground to pass a 30 mesh screen and analyzed for NO_3-N content using a specific ion electrode (Knowles et al., 1987).

Grain yields were estimated using a small plot combine with a swath of 4.0 feet. Following harvest, a subsample of grain from each plot was dried, ground and analyzed for total ammonium + organic-N, using the Kjeldahl digestion-steam distillation method. An estimate of grain protein content was made by multiplying the total ammonium + organic-N value by a conversion factor of 6.25. A subsample of grain from each plot was separated into vitreous and non-vitreous kernels for determination of percent yellowberry. Bushel weights, and 1000 seed weights were also determined on subsamples for all plots.

Experiment I - Accuracy of Stem Test Procedure

This trial was conducted on a Trix clay loam [fine-loamy, mixed (calcareous), hyperthermic, Typic Torrifluvent]. The plots had been cropped with wheat the preceding year and had an average preplant soil test value of 6.6 ppm NO_3-N in the surface foot of soil. Other chemical properties of the surface soil were pH, 7.5; electrical conductivity 2.5 dS/m; organic matter, 0.9%; ammonium acetate extractable sodium, 2.4 meq/100g; free $CaCO_3$, "high"; and cation exchange capacity, 26.4 meq/100g.

The N treatments used are listed in Table 1. All preplant applications of N were as ammonium sulfate and were made simultaneously with the treble superphosphate used. All midseason N was applied as urea. The amount of N applied in Treatment 2 was made in accordance with the current University of Arizona procedure (Pennington et al., 1983), with Treatments 1 and 3 being 80 and 120% of that amount, respectively.

Table 1. Rates and timing of N applied to 'Aldura' wheat grown on a Trix clay loam.

Treatment	Nitrogen Applied				
	Preplant	5-6 Leaf	Boot	Anthesis	Total
	lbs./a				
1	28	24	52	32	136
2	35	30	65	40	170
3	42	36	78	48	204
4 (Control)	0	0	0	0	0

'Aldura' wheat seed was drilled into dry soil on flat borders at the rate of about 150 lbs./A and irrigated on 18 November, 1987. A total of 32 inches of water, containing about 39 lbs. NO_3-N/A, was applied in 4 irrigations. Rainfall during the growth period was 2.9 inches. Individual plots were 8 x 50 feet; treatments were replicated 4 times in a randomized complete block design. Weed control was accomplished by hoeing and hand-roughing. Grain was harvested on 3 June.

Experiment II - Durum Wheat Variety X Nitrogen Rate Trial

The soil used in this trial was also a Trix clay loam. It had been cropped to unfertilized Sudan grass in the preceding season and had a NO_3-N soil test level in the surface foot of 2.7 ppm. Other soil chemical characteristics were similar to those measured in Experiment I.

The rates and timing of N treatments used are listed in Table 2. All preplant N was from ammonium sulfate with mid-season N supplied as urea. The amount of N applied in Treatment 4 was determined by using the current University of Arizona procedure for predicting the N needs of wheat (Pennington et al., 1983). Treatments 2, 3, 5 and 6 were then assigned to cover a range of total N applied of 200 lbs. N/A in 50 lb. increments.

Table 2. Rates and timing of N applied to 'Aldura' and 'Westbred-881' durum wheat varieties grown on a Trix clay loam.

Treatment	Nitrogen Applied				
	Preplant	5-6 Leaf	Boot	Flower	Total
	lbs./a				
1	0	0	0	0	0
2	45	0	40	25	110
3	60	15	55	30	160
4	75	25	65	45	210
5	90	35	75	60	260
6	105	50	90	65	310

Table 3. Rates and timing of N applied to 'Aldura' wheat grown on a Casa Grande sandy loam.

Treatment	Nitrogen Applied				
	Preplant	5-6 Leaf	Boot	Anthesis	Total
	lbs./a				
1	0	0	0	0	0
2	0	0	20	15	35
3	0	20	40	25	85
4	0	40	60	35	135
5	20	60	70	35	185
6	40	80	80	35	235

Two popular durum wheat varieties, 'Aldura' and 'Westbred-881', were planted in a split plot design with variety as main plots and the six N rates as subplots, with 4 replications. These plots were established on the same date as in Experiment I and were subject to the same irrigation and rainfall conditions. Individual plots were 9 x 33 feet in size. Weed control was obtained by hoeing and hand roughing with no herbicides applied. Stem tissue samples were taken at the 3-4 leaf, 5 leaf, joint, boot and anthesis growth stages on 28 December, 22 January, 22 February, 11 March and 1 April respectively. A visual estimate of the percent area lodged within each plot was recorded on 3 June just prior to harvest.

Experiment III - N Rate Trial On Soil with High Residual N

This N fertility trial with durum wheat was conducted on a Casa Grande sandy loam [coarse-loamy, mixed, hyperthermic Typic Natrargid (reclaimed)]. The plot area was cropped with alfalfa prior to the planting of wheat to provide a high level of available N in the rooting zone. Prior to planting, a composite soil sample was taken to a depth of twelve inches and analyzed for nitrate-N using 1N KCl extraction and Kjeldahl steam distillation. The nitrate-N content of this sample was 16.0 ppm.

The rates, timing and N sources of the six treatments used are listed in Table 3. All preplant N was from ammonium sulfate with mid-season N supplied as urea. The amount of N applied in Treatment 4 was determined by using the current University of Arizonan procedure for predicting the N needs of wheat (Pennington et al., 1983). Treatments 2, 3, 5 and 6 were then assigned to cover a range of total N applied of 200 lbs. N/A in 50 lb. increments. 'Aldura' wheat seed was drilled on flat borders at the rate of about 150 lbs./A on 18 November, 1987. Individual plots were 13 x 50 feet and all treatments were replicated 4 times in a randomized complete block design.

A total of 31 inches of water containing about 29 lbs. NO_3-N/A was applied in five irrigations. Rainfall during the growth period was 2.9 inches. A visual estimate of the percent area lodged within each plot was recorded on 3 June, 1988 just prior to harvest. Weed control was achieved with hoeing and hand-roughing.

Table 3. Rates and timing of N applied to 'Aldura' wheat grown on a Casa Grande sandy loam.

Treatment	Nitrogen Applied				
	Preplant	5-6 Leaf	Boot	Anthesis	Total
	lbs./a				
1	0	0	0	0	0
2	0	0	20	15	35
3	0	20	40	25	85
4	0	40	60	35	135
5	20	60	70	35	185
6	40	80	80	35	235

Stem tissue samples were taken at the 3-4 leaf, 5 leaf, joint, boot and anthesis growth stages on 28 December, 22 January, 22 February, 9 March, and 1 April, respectively. Grain yields were measured on 3 June.

RESULTS AND DISCUSSION

Experiment I - Accuracy of Stem Test Procedure

The application of N resulted in no significant increase in grain yield in this experiment (Table 4). The observed yields of 5,200 to 5,400 lbs/A are well below the expected maximum yield for this site, indicating that factors other than N availability were important in determining the final yield. The currently recommended stem testing procedure predicted the need for 170 lbs N/a to achieve optimum yield. These results suggest that, under low-yielding conditions, the recommended procedure tends to over-predict the quantity of N required. The nature of N response curve observed in this experiment makes it difficult to estimate what was the "optimum" rate of N under these conditions.

Table 4. Growth characteristics of 'Aldura' wheat receiving various rates of N fertilizer.

N Rate	Lodging	Grain Protein	Yellow Berry	Bushel Weight	Grain Yield+
lbs/a	%	%	%	lbs./bu	lbs./a
136	0 a*	14.9 b	0 a	62.7 ab	5223 a
170	0 a	16.0 c	0 a	63.4 a	5251 a
204	0 a	16.6 c	0 a	63.6 ab	5371 a
0 (Control)	0 a	10.1 a	46 b	64.2 b	4842 a

*means followed by the same letter within each column are not significantly different at the 0.05 level according to the SNK method.

+the yields reported have been adjusted to 10% moisture content and represent clean grain weights.

Table 4. Growth characteristics of 'Aldura' wheat receiving various rates of N fertilizer.

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*means followed by the same letter within each column are not significantly different at the 0.05 level according to the SNK method.

+the yields reported have been adjusted to 10% moisture content and represent clean grain weights.

The only economically important trend in the response of 'Aldura' wheat to the range of N applications made in this study was a significant increase in grain protein as the amount of N increased from 0 to 170 lbs N/A. This may, or may not, have an economic impact, depending on the pricing structure for durum wheat as affected by protein content.

Experiment II - Durum Wheat Variety X Nitrogen Rate Trial

This experiment permitted a detailed evaluation of the growth response of 'Aldura' and 'Westbred-881' durum wheats to a wide range of N application rates. Table 5 gives the statistical interpretations of the growth characteristics analyzed in this study. "Westbred-881" was characterized by higher protein levels, lower bushel weights, lower grain yields (averaging 12% less than 'Aldura'), and lower incidence of yellowberry at low rates of applied N. The reputation of 'Westbred-881' as a slightly lower yielding variety than 'Aldura', but one with somewhat higher protein levels, appears to be justified by the results of this test as well as similar previous research at the Maricopa Agricultural Center (Doerge et al., 1987).

Table 5. Growth characteristics of 'Aldura' and 'Westbred-881' durum wheats receiving various N fertilizer treatments.

N Rate	Grain Yield+ Ald.	Grain Yield+ 881	Protein Ald.	Protein 881	Yellowberry Ald.	Yellowberry 881	Lodging Ald.	Lodging 881	Bushel Wt. Ald.	Bushel Wt. 881
lbs./a	------ lbs./a ------		------------------------- %	----------------------------					------lbs./bu -----	
0	3928a#	3371a	9.1a	9.5a	69d	54c	0	0	63.4def	61.9a
110	5433bc	4931b	12.6b	13.4c	4b	0a	0	0	64.2g	63.0cd
160	5823bc	5363bc	14.9d	16.2e	0a	0a	0	0	63.8f	62.7bc
210	6296c	5112b	16.4e	17.2f	0a	0a	0	0	63.6ef	62.4ab
260	5878bc	5377bc	17.0f	17.8g	0a	0a	0	0	63.4def	62.2a
310	5962bc	5321bc	17.9g	18.5g	0a	0a	0	0	63.1cde	62.2a

	Grain Yield	Protein	Yellowberry	Lodging	Bushel Wt.
Variety F	----*----	----*----	----**----	----NS----	----**----
N Rate F	----**----	----**----	----**----	----NS----	----**----
VxN Rate F	----NS----	----NS----	----**----	----NS----	----NS----

+ The yields reported have been adjusted to 10% moisture content and represent clean grain weights.

Means for either variety under the columns for each parameter followed by the same letter are not significantly different at the 5% level according to the SNK method.

Figure 1 gives comparisons of stem NO_3-N levels measured in 'Aldura' and 'Westbred-881' wheat plants at the 3-4 leaf, joint and boot growth stages that had received varying N treatments. No significant effect of variety on stem NO_3-N content was measured on any of these three sampling dates. This confirms previous findings for both durum and bread wheat cultivars (Doerge et al., 1987 and Gardner and Jackson, 1976).

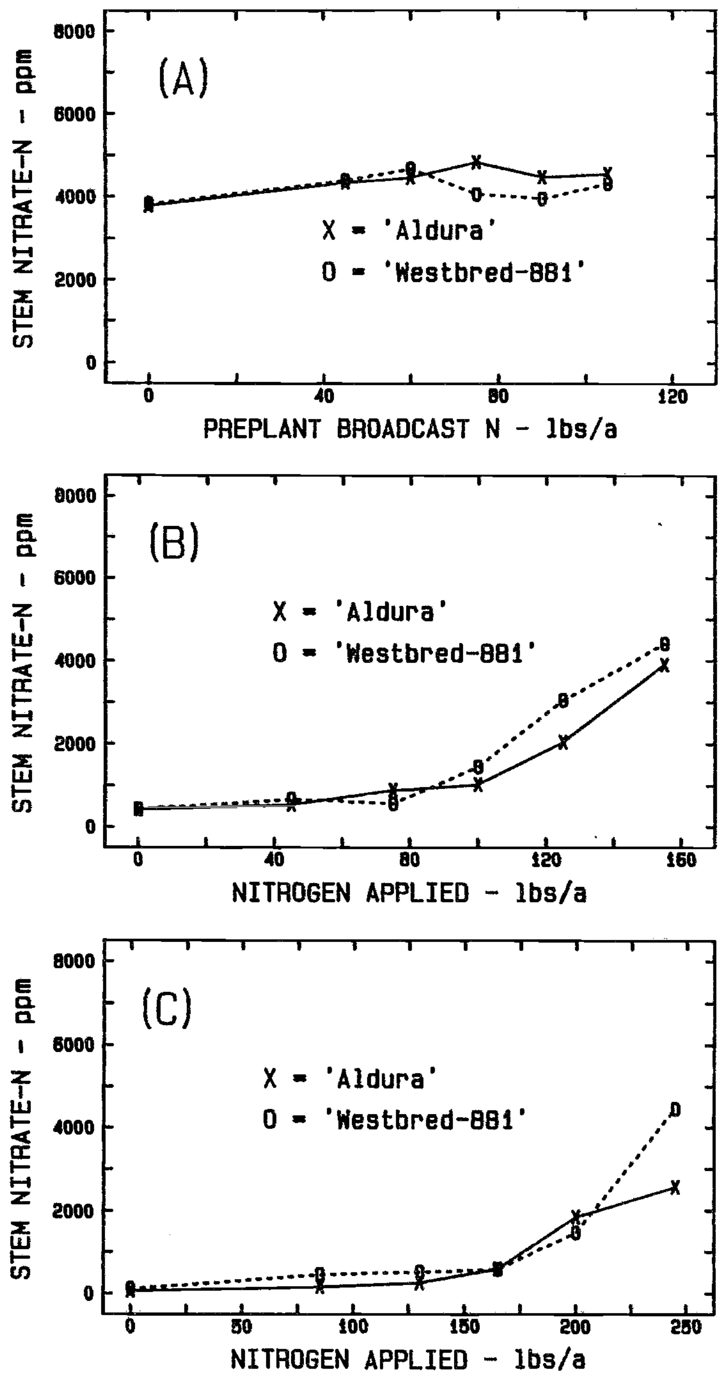

Figure 1. Comparison of stem NO_3-N levels measured in 'Aldura' and 'Westbred-881' wheat plants at the 3-4 leaf (A), joint (B) and boot (C) growth stages which had received varying N treatments.

The similarity of stem NO_3-N levels measured in the two varieties is further demonstrated in Figure 2. These findings strongly suggest that there is little statistical or practical difference in the amount of NO_3-N accumulated in stem tissue by various wheat varieties when grown under otherwise comparable conditions. It further suggests that interpretation of stem NO_3-N levels for various wheat cultivars can be safely made using one set of general guidelines.

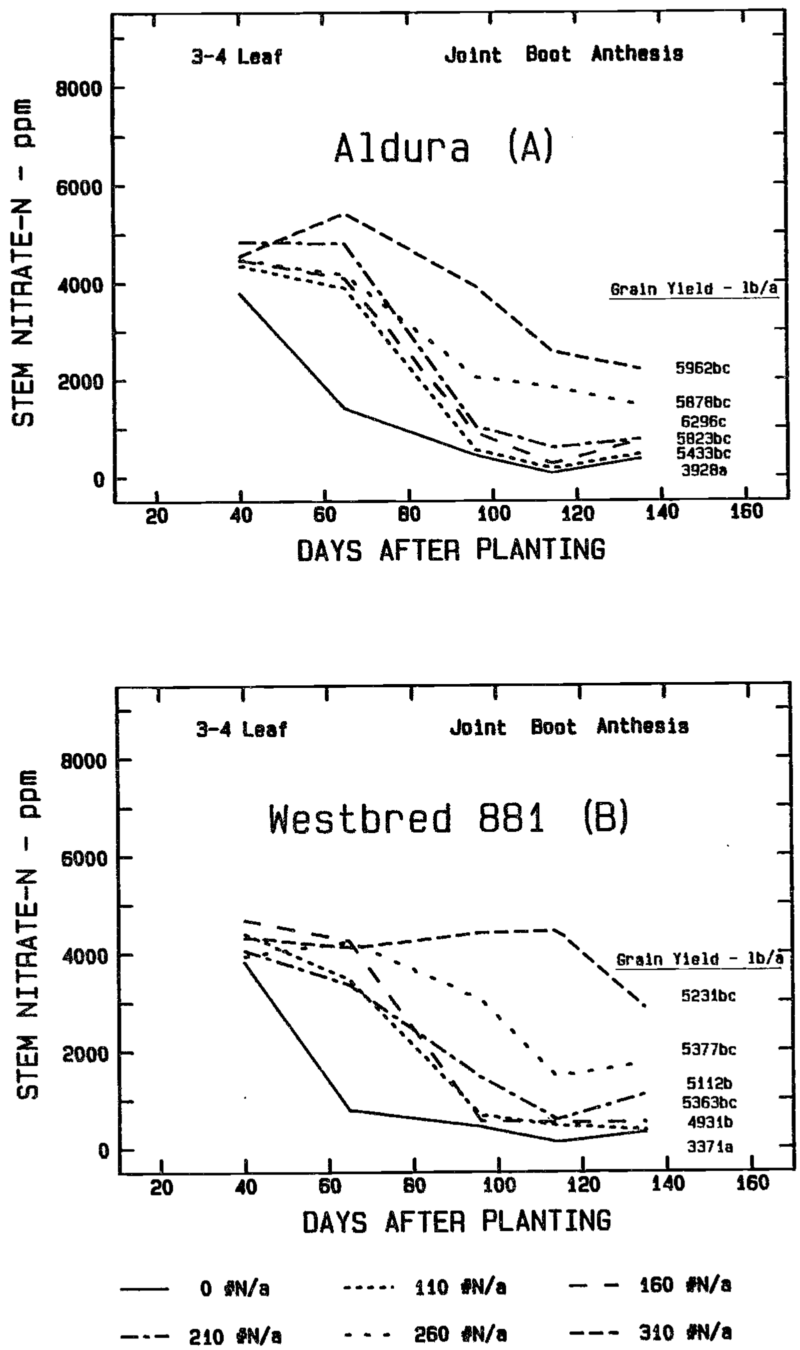

Figure 2. Seasonal stem nitrate-N measured in 'Aldura' (A) and 'Westbred-881' (B) durum wheats receiving different quantities of N fertilizer.

The application of 210 lbs N/A on 'Aldura' and 160 lbs N/A on 'Westbred-881' resulted in maximum grain yields with protein levels exceeding 14%. Therefore, these N rates would be considered the optimum ones since the application of additional N did not increase economic returns. However, the NO_3-N measured in wheat stems from these treatments declined below 2000 ppm just prior to the joint growth stage. Stem nitrate-N values below 2000 ppm are considered by some to indicate N deficient conditions (Gardner and Jackson, 1976). Others have suggested 1000 ppm NO_3-N as the critical level for wheat at all growth stages (Doerge et al., 1987 and Papastylianou et al., 1982).

The results of this study confirm that optimum grain production occurs when the stem levels of NO_3-N at the joint stage do not exceed 1000 ppm. Likewise, stem NO_3-N levels of wheat attaining optimum rates of N did not exceed 1000 ppm at the boot growth stage. This is consistent with previous findings and a stem nitrate-N level of 1000 ppm could be considered the critical level for irrigated durum wheat at these growth stages. It should be noted however, that while 1000 ppm NO_3-N may be the critical level at the joint and boot stages, the current diagnostic procedure of Pennington et al. (1983) would still recommend that some N be applied, even if wheat plants contained this level of NO_3-N. From these observations, one could hypothesize that it is more efficient to provide wheat with smaller quantities of N more frequently than it would be to apply larger doses less often and rely on the plant to store up N reserves for later use.

Experiment III - N Rate Trial On Soil With High Residual N

As expected, the yield response of durum wheat to applied N was rather small at this site due to the high level of residual N remaining from alfalfa stubble, crown, and root tissue returned to the soil when the preceding legume crop was removed. Despite grain yields approaching 5,000 lbs/A in unfertilized plots, the stem testing procedure accurately predicted the quantity of N that produced maximum grain yield (i.e. 135 lbs N/A) and also resulted in grain protein levels of at least 14% (Table 6).

Table 6. Growth characteristics of 'Aldura' wheat receiving various N treatments.

N Rate	Lodging	Grain Protein	Yellowberry	Bushel Weight	1000 Seed Weight	Grain Yield*
lbs/a	%	%	%	lbs./bu	gm	lbs./a
0	0	9.7a	10c	64.5c	48.6	4918a
35	0	11.4b	4b	64.3c	50.7	4794a
85	0	13.2c	0	63.7b	50.3	5362a
135	0	16.4d	0	63.2a	50.1	5281a
185	0	16.9d	0	63.4a	50.0	5320a
235	0	17.2d	0	63.4a	50.0	5182a
LSD 0.05	NS	1.1	2.1	0.3	NS	NS

Means followed by the same letter are not significantly different at the 5% according to the SNK method.

* The yields reported have been adjusted to 10% moisture content and represent clean grain weights.

Figure 3 shows the pattern of NO_3-N measured in wheat stem tissue throughout the growing season. The NO_3-N levels in the stems from plots receiving 135 lbs. N/A approached 1000 ppm by the joint stage and showed no further decrease for the remainder of the season. This is further evidence the deficiency level for NO_3-N in stem tissue is less than 2000 ppm at the joint growth stage and later.

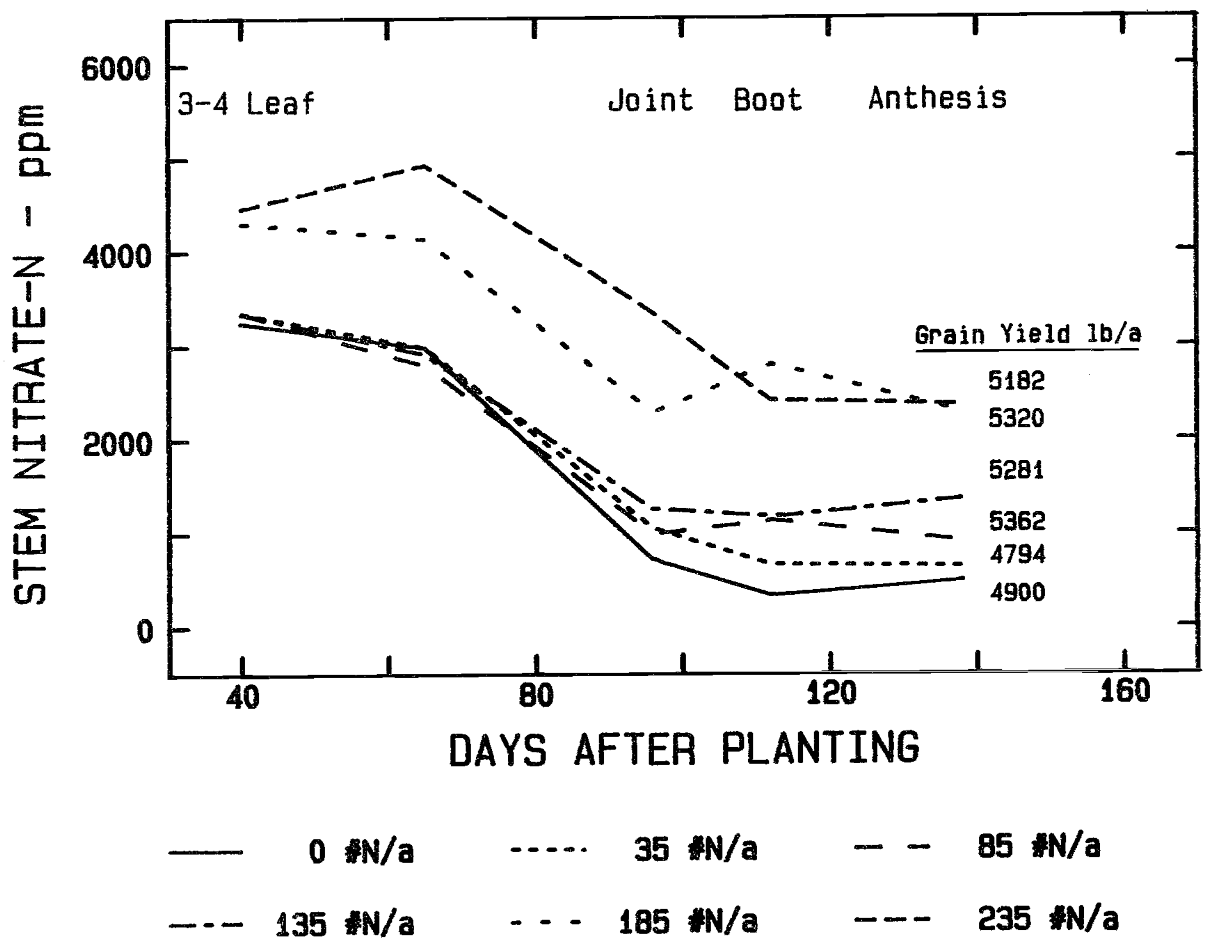

Figure 3. Stem nitrate levels in 'Aldura' wheat at various growth stages as affected by N fertilizer rates.

CONCLUSIONS

The results of these three studies provide additional information as to the accuracy and adaptability of the University of Arizona's currently recommended procedures for predicting the N needs of durum wheat. In all cases, the quantity of N recommended by the tests resulted in maximum grain yields and protein levels in excess of the normal quality threshold of 14%. At sites where the maximum yields did not exceed 5,400 lbs. grain/A, the test procedure usually (but not always) over-predicted the N requirement by about 50 lbs. N/A. At sites with yield potentials exceeding 5,400 lbs. grain/A, the stem test guidelines consistently predicted the minimum quantity of N required to attain optimum production and grain quality.

These data also show that grain yields and quality do not suffer when stem NO_3-N levels decrease to 1000 ppm at the joint stage and later. They further suggest that the value of 2000 ppm NO_3-N in stem tissue as the deficience level may need to be reevaluated.

The two durum wheat varieties investigated showed similar behavior with respect to the relationships between stem NO_3-N levels and yield/quality characteristics. This is very favorable because it supports the idea that one set of guidelines for interpreting durum wheat stem NO_3-N levels can be safely applied to various wheat cultivars with reasonable accuracy.

REFERENCES

1. Doerge, T.A., T.C. Knowles and M.D. Ottman. 1987. Improved nitrogen management in irrigated wheat production using stem nitrate analysis. Forage and Grain Report, Cooperative Extension, Agric. Expt. Sta. Report Series P-71. Univ. of Arizona, Tucson. p. 106-120.

2. Doerge, T.A. and M. Ottman. 1986. Predicting the nitrogen needs of wheat using stem nitrate analysis. Forage and Grain Report, Cooperative Extension, Agric. Expt. Sta. Report Series P-67, Univ. of Arizona, Tucson. p. 69-75.

3. Erie, L.J., O.F. French, D.A. Bucks and K. Harris. 1982. Consumptive use of water by major crops in the Southwestern United States. Conservation Report No. 29. U.S. Water Conservation Laboratory. USDA - ARS.

4. Gardner, B.R. and E.B. Jackson. 1976. Fertilization, nutrient composition, and yield relationships in irrigated spring wheat. Agronomy Journal 68:75-78.

5. Knowles, T., T. Doerge and M. Ottman. 1987. Standardization of the wheat stem tissue NO_3-N test procedure. Forage and Grain Report, Cooperative Extension, Agric. Expt. Sta. Report Series P-71, University of Arizona. Tucson.

6. Papasylianou, I., R.D. Graham and D.W. Puckridge. 1982. The diagnosis of nitrogen deficiency in wheat by means of a critical nitrate concentration in stem bases. Commun. in Soil Sci. Plant Anal. 13:473-485.

7. Pennington, D.A., B.R. Gardner, and T.C. Tucker. 1983. Fertilizing small grains in Arizona. NO. 8366. The University of Arizona, Cooperative Extension Service.