Corn Stem Nitrate N Content-Grain Yield Relationships and Their Use as a Basis for Sidedress N Rate Recommendations[1]

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Abstract

The objectives of this study were to confirm the relationship between nitrate nitrogen (NO_3-N) content of basal corn stems and grain yield in Iowa, to establish critical levels of stem NO_3-N content for obtaining various levels of maximum yield, and to perform preliminary calibration of yield responses to sidedressed nitrogen (N) at various levels of stem NO_3-N content.

Six sites across Iowa with a wide range of physical and environmental conditions were selected. N fertilizer was applied preplant, sidedressed, or as split applications in increments of 28 to 45 Kg ha^{-1} with maximum rates of 196 to 225 Kg ha^{-1} to produce a range of stem NO_3-N concentrations. Grain yield and stem NO_3-N content were highly correlated with R values from .80 to .93 at sites that were responsive to N fertilizer. Critical levels of stem NO_3-N content required to attain various levels of relative yield were established. Soil parent material was found to significantly effect the critical levels of stem NO_3-N content required to attain various levels of relative yield in this study. The critical level of stem NO_3-N content for maximum yield was 9.0 and 17.75 g N Kg^{-1} dry matter for loess and glacial till soils, respectively. Five ranges of stem NO_3-N content were established and yield response to sidedressed N rate was evaluated within each range.

Materials and Methods

Six sites across Iowa were chosen to provide a range in soil type, environmental conditions, and management systems. Sites in Benton and Johnson Co.'s were on soils derived from loess parent material and classified as Fine-silty, mixed, mesic Typic Argiudolls. The other four sites were located on glacial till soil parent material. The Boone Co. site was on a Clarion soil (Fine-loamy, mixed, mesic Typic Haplaudoll), Hancock Co. on a Nicollet (Fine-loamy, mixed, mesic Aquic Haplaudoll), and the Story Co. site on a Clarion-Nicollet Soil Association. The Greene Co. site was on a Canisteo soil (Fine-loamy, mixed (calcareous), mesic, Typic Haplaquoll).

The experiments were designed as randomized complete block with 3 or 4 replications. Nitrogen fertilizer treatments were applied by hand as preplant, sidedress, or split applications in 45. 28, or 34 Kg ha^{-1} increments with the maximum N rates being 225, 196, or 202 Kg N ha^{-1} respectively. Urea or ammonium sulfate were the N sources and were incorporated immediately after application. The hybrid planted was that used by the farm operators.

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Five cm of stem immediately above the ground were collected from 10 corn plants per plot prior to sidedress N applications (V6 growth stage) (Hanway, 1982; Iversen, et.al.,1985a). The samples were placed in coolers in the field and kept cool during transport to driers where they were dried at 60^{o} C for 48 hrs. Samples were ground through a Cyclone Mill. Nitrate was extracted from 0.4 g of sample with 40 ml of deionized water, 40 ml of buffer solution (Milham, et.al., 1970) and 0.5 g washed, deactivated charcoal. Nitrate concentration was measured with an Orion EA940 selective ion meter and nitrate electrode (Anon., 1981; Mills,1980).

Due to the variation in plot size, harvest areas varied. At each site the center rows of the plots were hand harvested, mechanically shelled, weighed, and subsampled. The subsamples were dried in forced air driers at 60^{o} C to determine moisture content. Yields were adjusted and reported at 15.5% moisture.

Results and Discussion

Incremental increases in preplant N rates resulted in a range of stem NO_3-N contents at sites that were responsive to N fertilizer. Positive linear relationships between stem NO_3-N content and grain yield were observed at five of the six sites, but a significant relationship was not observed at the Boone Co. site (Table 1.). The Boone Co. site was relatively unresponsive to N fertilizer and had stem NO_3-N concentrations that were relatively high. These factors indicate that plant available N was present in sufficient amounts at this site to maximize stem NO_3-N content at V6 growth stage and grain yield at maturity with only small N fertilizer applications.

The magnitude of grain yields varied from site-to-site Maximum yields with no sidedressed N ranged from 9.4 to 13.3 Mg ha^{-1} at Benton and Hancock Co., respectively (Table 1.). Data from all sites were combined to determine critical levels of stem NO_3-N content for various levels of relative yield, which was calculated by dividing individual plot yield by the maximum yield that occurred at an individual site.

Table 1. Stem NO_3-N content-grain yield relationships at 6 Iowa locations in 1986.

Location (County)	NO_3-N Range g Kg^{-1}	Yield Range Mg ha^{-1}	Model*	r^2
Benton	0.5 - 6.2	3.7 - 9.4	$Y = 3.18 + 0.969(NO_3\text{-}N)$	.644
Boone	8.5 - 20.0	8.0 - 12.7	$Y = 8.14 + 0.183(NO_3\text{-}N)$	.194
Greene	3.3 - 15.5	6.2 - 12.3	$Y = 5.32 + 0.394(NO_3\text{-}N)$	.664
Hancock	3.0 - 17.7	4.4 - 13.5	$Y = 2.07 + 0.609(NO_3\text{-}N)$	.871
Johnson	1.2 - 13.8	5.4 - 12.5	$Y = 6.62 + 0.459(NO_3\text{-}N)$	.713
Story	2.2 - 14.8	3.7 - 11.1	$Y = 2.47 + 0.564(NO_3\text{-}N)$	.813

* Regression models where Y is grain Yield (Mg ha^{-1}) and (NO_3-N) is stem NO_3-N content (g N Kg^{-1} dry matter).

The procedure used to estimate maximum yield was to determine the last increment of N fertilizer that produced a significant yield increase and average yields from that treatment with yields from all treatments receiving higher N applications (Pierre, et al. 1977).

Stem NO_3-N content at various levels of relative yield was determined for each site. Relative yields were regressed on stem NO_3-N content. Once the regression model that best fit the data was obtained, the stem NO_3-N content corresponding to any level of relative yield could be calculated (Table 2.) (Pierre, et.al., 1975).

Site-to-site variability in stem NO_3-N content resulting in the same relative yield was large (Table 2.). Stem NO_3-N content ranged from 5.96 to 18.48 g NO_3-N Kg^{-1} dry matter at 100% of maximum yield at Benton and Hancock Co.'s, respectively. Data from Benton and Johnson Co.'s (loess parent material, fine-silty texture) have been separated from the Boone, Greene, Hancock, and Story Co. data (glacial till parent material, fine-loamy texture) for analysis and comparison (Table 2. and Figure 1.). On the loess soils in this study, stem NO_3-N contents of 8.4 and 6.7 g N Kg^{-1} dry matter resulted in 100 and 90% of maximum yield, respectively. Stem NO_3-N contents of 9.1 and 6.8 g N Kg^{-1} dry matter resulted in only 70 and 60% of maximum yield, respectively, on the glacial till soils. It appears that soil parent material had an effect on the stem NO_3-N content.grain yield relationship.

Table 2. Calculated stem NO_3-N content of basal corn stems at various levels of relative yield.

---------- Glacial Till Soils ----------							
	Max Yld	************* Relative Yields (%) *************					
Site	Mg/ha	100	90	80	70	60	50
Boone	11.4	18.17	11.88	NA	NA	NA	NA
Greene	11.4	15.36	12.47	9.59	6.71	3.83	NA
Hancock	13.3	18.48	16.29	14.10	11.91	9.72	7.53
Story	10.4	14.12	12.27	10.42	8.57	6.73	4.88
Averages	11.6	16.53	13.23	11.37	9.06	6.76	6.20
Std. Err	1.21	2.13	2.05	2.40	2.63	2.94	1.87

---------- Loess Soils ----------							
	Max Yld	************* Relative Yields (%) *************					
Site	Mg/ha	100	90	80	70	60	50
Johnson	11.6	10.79	8.27	5.74	3.21	NA	NA
Benton	8.95	5.96	5.04	4.12	3.19	2.27	1.34
Averages	10.28	8.38	6.65	4.93	3.20	2.27	1.34
Std. Err	1.87	3.42	2.28	1.15	0.01	NA	NA

Note: Values replaced with NA are Not Applicable due to extrapolation beyond the range of observed data.

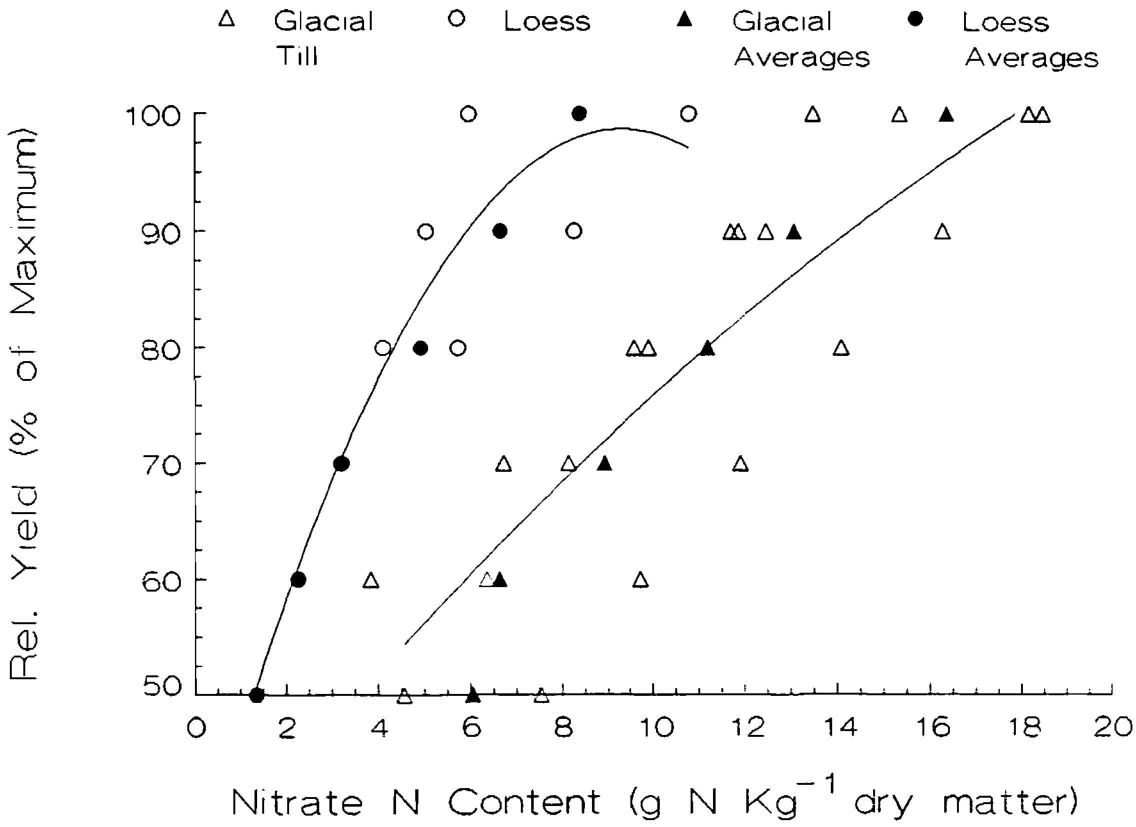

Figure 1. Stem NO_3-N content-relative yield relationships. Regression lines, values from individual sites, and site averages for loess and glacial till soils.

Relative yields and stem NO_3-N contents obtained from the direct regression procedure (Table 2) were used in a separate regression analysis to obtain equations that could be used to predict relative yields from the stem NO_3-N content of samples taken from any field. The quadratic equations describing the stem NO_3-N content-relative yield relationship (presented graphically in Figure 1.) are:

$$Y_{RG} = 33.3716 + 4.9088 * \{NO_3\text{-}N\} - 0.0661 * \{NO_3\text{-}N\}^2 \quad [1]$$

$$Y_{RL} = 33.1364 + 14.0714 * \{NO_3\text{-}N\} - 0.775 * \{NO_3\text{-}N\}^2 \quad [2]$$

where: Y_{RG} is the relative yield for glacial till soils; Y is the relative yield for loess soils; and {N03-N} is the stem NO_3-N content.

To calibrate relative yield response to sidedressed N fertilizer at various levels of stem NO_3-N content, the entire data sets from each site in this study were used. Relative yield levels of 100, 90, 75, and 60% were arbitrarily chosen to divide the data into five subsets. The subsets are defined as: exceeding 100% of maximum yield, or "High";

90-100% of maximum yield. or "Adequate"; 75-90% of maximum, or "Medium"; 60-75% of maximum yield, or "Low"; and below 60% of maximum yield, or "Very Low". Using equations 1 and 2, the stem NO_3-N content associated with each level of relative yield were calculated. For loess soils, relative yields of 100, 90, 75, and 60% correspond to stem NO_3-N contents of 9.0, 6.0, 3,7, and 2.15 g N Kg^{-1} dry matter. respectively. For glacial till soils, relative yields of 100, 90, 75, and 60% correspond to stem NO_3-N contents of 17.75, 14.2. 9.75. and 5.9 g N Kg^{-1} dry matter, respectively.

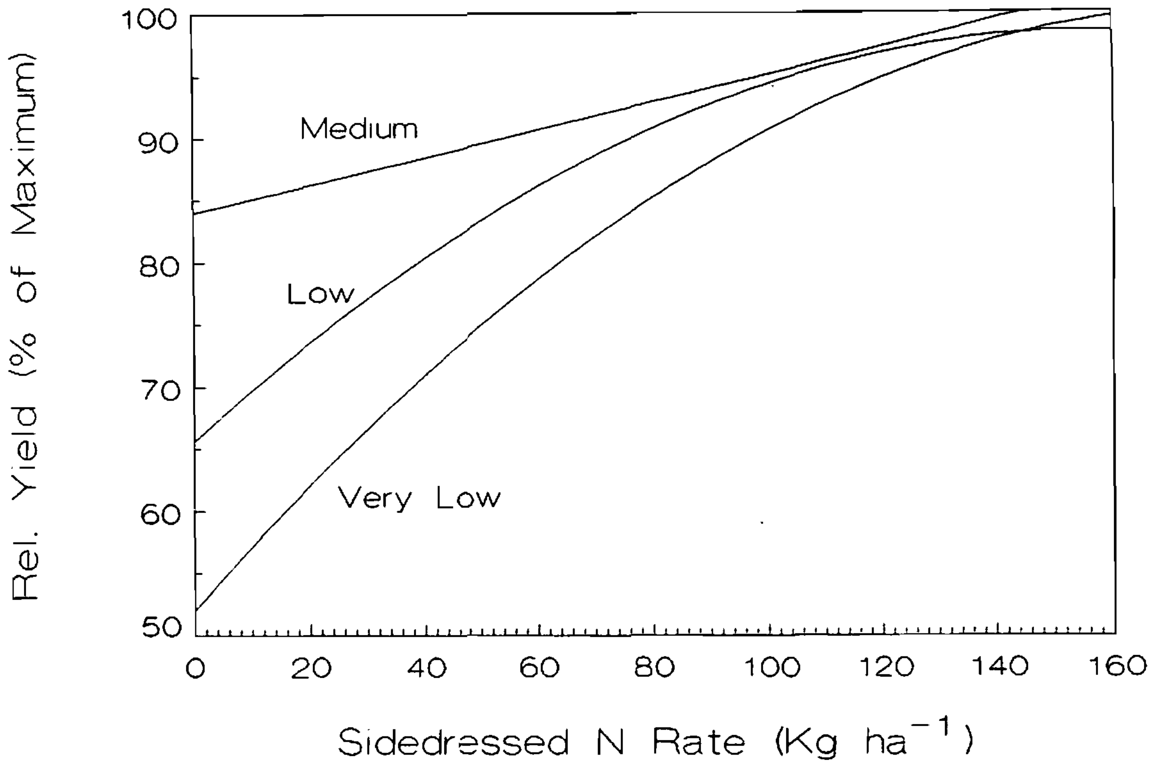

Figure 2. Relative yield response to sidedressed N fertilizer with medium, low and very low levels of stem NO_3-N content.

Data sets from each site were divided into subsets based on these stem NO_3-N content values. No single site had observations in all subsets and observations from single sites, within a given subset, often failed to cover the entire range of sidedress N rates applied. Within each subset, for each site, relative yield was regressed on sidedressed N rate. When more than one site had observations in a subset the response surfaces were not significantly different between sites, within subsets. Since differences in yield responses to sidedressed N were not observed between sites (within the same stem NO_3-N content subset), data from all sites were combined.

Within each subset relative yield was regressed on sidedressed N rate. There was a significant quadratic response to sidedressed N in plots with Low and Very Low stem NO_3-N contents (equations 4 and 5). A linear relationship was observed between relative yield and stem NO_3-N content in plots with Medium stem NO_3-N contents (equation 3). Plots with stem NO_3-N contents in the Adequate and High ranges did not respond to sidedressed N.

$$Y_{RM} = 84.0 + 0.111\{NO_3\text{-}N\}^2$$

$$Y_{RL} = 65.7 + 0.422\{NO_3\text{-}N\} - 0.0014\{NO_3\text{-}N\}^2$$

$$Y_{RVL} = 52.0 + 0.532\{NO_3\text{-}N\} - 0.0015\{NO_3\text{-}N\}^2$$

Y_{RM} is Relative Yield, Medium stem NO_3-N content range; relative yield, low stem NO_3-N content range; Y_{RVL} is yield, very low stem NO_3-N content; and $\{NO_3\text{-}N\}$ is stem NO_3-N content. These equations are presented graphically in Figure 2.

Conclusions

When N is limiting grain production, N deficiencies can be detected from the NO_3-N content of 5 cm segments of basal corn stems at V6 growth stage.

Site-to-site variations in stem NO_3-N content can be large even at identical levels of relative yields. Sources of this variation need to be identified and accounted for if rate recommendations over wide geographic areas are to be possible. Soil parent material was a significant source of variation in this study. Corn grown on loess soils required lower stem NO_3-N content than corn grown on glacial till soils to achieve the same relative yield.

The need exists for an index of plant available N early enough in the development of the crop to allow N applications to correct deficiencies. The stem NO_3-N content of basal corn stems at V6 growth stage has the potential of being this index. More data are required to identify sources of stem NO_3-N content variation and for development of more accurate critical stem NO_3-N content ranges.

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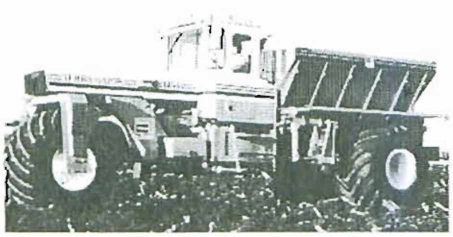

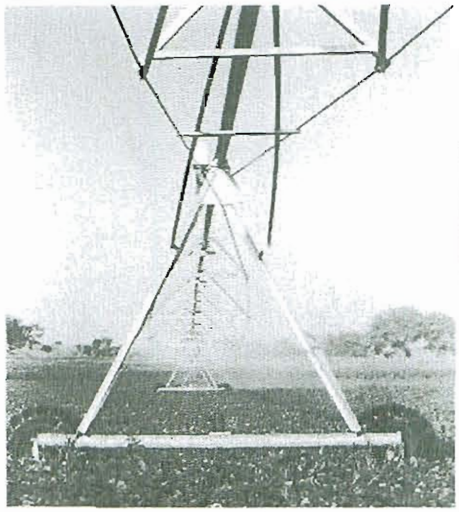

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