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## Planting Method and Fertilization Timing Effects on Ridge-Till Corn

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Fertilizer application technology has improved fertilizer use efficiency in ridge-till systems, but little work on planting methods and application timing within these systems has been done. A study was conducted to evaluate corn (*Zea mays* L.) response to injected nitrogen (N) fertilizer applied to different planting methods at common application times. The performance of the late spring soil nitrate and the basal stalk nitrate tests was examined within these systems. A continuous corn and a corn-soybean [*Glycine max* (L) Merr.] rotation were used in 1989-1991 at two Iowa locations on Nicolett and Monona series soils, fine-loamy, mixed, mesic Typic Hapludolls and fine-silty, mixed, mesic Typic Hapludolls, respectively. Whole plot treatments were: 1) till planting with fertilizer N applied at layby; 2) slot planting with fertilizer N applied at planting; and 3) slot planting with fertilizer N applied at layby. Subplot treatments (0, 22, 45, 90, 157, and 224 kg N ha<sup>-1</sup>) were imposed on the whole-plots. The late spring soil nitrate test had consistently low values relative to the scale used for N fertilizer recommendations. The basal stalk nitrate test identified optima nitrate concentrations relating to N fertilizer rates which produced maximum yields. Whole plot treatments generally did not differ significantly in grain yield. Alternative methods of fertilizing corn, such as the use of point injection application equipment, provide opportunities in fertilizer N management that current recommendation tools may enhance.

INDEX DESCRIPTORS: ridge-till, placement, point-injector, nitrogen fertilizer

In response to potential regulatory action and increased public awareness of the fragile agricultural resource base, farmers are adopting conservation tillage systems which provide soil resource protection without sacrificing profitability. Ridge-till systems are viewed as viable alternatives to the more traditional conservation tillage systems.

With a flat surface, no-till system, successful stand establishment may be deterred by cool, wet soil conditions. The ridge in a ridge-till system provides a seed zone environment that is typically warmer and dryer than that which exists under flat surfaces (Mahrer and Avissar 1985, Radke 1982). These positive aspects are magnified when this system is used on the poorly and somewhat poorly drained soils typically found in the Northern Corn Region.

Effective and environmentally sound applications of N fertilizer in zero and ridge-till systems have been difficult due to losses associated with surface applications and the tillage involved with knifing applications. Surface applications are unattractive for several reasons, including greater denitrification potential (Aulakh et al. 1984, Linn and Doran 1984), fertilizer immobilization (Kitur et al. 1984, Rice and Smith 1984), losses due to ammonia volatilization, and leaching and runoff concerns (Baker and Lafen 1982, Schuford et al. 1977, Thomas and Phillips 1979, Thomas et al. 1973). Point injection is another alternative with superior N recovery and grain yield over a broadcast application (Blaylock and Cruse 1992).

Management of the root zone is enhanced with ridge-till systems in a variety of ways. Compaction associated with wheel traffic is controlled, alleviating disturbance of the immediate root zone. The soil property positional variability with this system enhances compensatory root growth, which influences effective nutrient placement. Nutrients placed into the ridge, the zone most desirable for root growth, may improve uptake efficiency (Garcia et al. 1988).

The spoke-wheel fertilizer injector (Baker et al. 1985) is an alternative to conventional subsurface application tools. Point injections cause little soil disturbance, and also minimize root damage when used later in the growing season. This method also provides greater flexibility in application timing, primarily by making late applications feasible.

Because of the dry environment in the ridge, denitrification may be minimized. Point injections into the ridge put fertilizer in an area of low leaching potential compared to interrows where N is typically knife injected (Kemper et al. 1975, Hamlett et al. 1986). Improvements in N uptake efficiency may reduce the total quantity of needed inputs.

Implementation of currently available N fertilizer management tools (soil and tissue tests) in ridge tillage systems is increasing, however, the literature shows little research on the use of such tests in operations using point injection. Using point injection technology in conjunction with current planting and cultivating operations in ridge-till has not been thoroughly investigated. The objectives of this study were to: 1) evaluate corn response to point-injected N fertilizer when applied at planting or cultivating in the ridge-till system; and 2) examine use of a soil and tissue test to better manage N fertilizer inputs.

### METHODS

This field study was performed at two sites in Iowa. The study was conducted near Boone in 1989 and 1990. Similarly, the study was conducted in 1990 and 1991 near Treynor. Selected soil chemical properties of the two soil series were determined by the Iowa State University Soil Testing Laboratory. Soil samples were comprised of ten to fifteen random 1.9 cm diameter cores taken to a depth of 0.2 m from each replication. Samples were air dried and analyzed for soil pH, buffer pH, percentage C (Walkley-Black method), available P (Bray-1 acid extraction), and exchangeable K (Table 1).

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Table 1. Selected chemical properties of Nicollet and Monona soils (means of four replications).

YEAR	pH	BUFFER pH	ORGANIC MATTER	AVAIL- ABLE P	EX- CHANGE- ABLE- K
			--- g kg <sup>-1</sup> ---	----- mg kg <sup>-1</sup> -----	
			<i>Nicollet</i>		
1989	5.4	6.0	38.0	130	236
1990	5.9	6.4	40.3	128	332
			<i>Monona</i>		
1990	5.8	6.3	37.8	70	405
1991	5.9	6.4	36.7	54	380

A ridge-till system was used at both sites. The experimental design was a split-plot with three whole plot treatments and six subplot treatments. Sub and whole plot treatments were rerandomized annually at each site. The whole-plot treatments were: 1) till planting with fertilizer N applied at layby; 2) slot planting with fertilizer N applied at planting; and 3) slot planting with fertilizer N applied at layby. The planting time application of N was done immediately after planting, while layby applications were done before the last cultivation. Slot planting caused little disturbance to the ridge surface, while till planting removed approximately 0.05 m of the ridge top, displacing it to the interrow (Fig. 1).

Sub-plot treatments consisted of a control (no N fertilizer), and five fertilizer N rates (22, 45, 90, 157, and 224 kg N ha<sup>-1</sup>) applied as UAN (urea-NH<sub>4</sub>NO<sub>3</sub> solution). Fertilizer N treatments were applied as point injections 0.1 m deep, spaced 0.2 m apart along the length of the row within 0.05 m of the plant row. The subplots were 9.15 to 12.20 m long. Hand injectors designed to simulate a spoke-wheel injector (Benjamin et al. 1988) were used.

Two cultivations were performed annually at each site. A cultivation of the ridge shoulder and interrow at approximately the V4 growth stage (Ritchie and Hanway 1982) was followed by ridge rebuilding at about the V8 growth stage.

Soil samples from unfertilized subplots at each site were collected for evaluating the late spring soil nitrate test (Blackmer et al. 1989) as described by Iowa State University Extension publication Pm-1381 (Blackmer et al. 1991). Samples were air dried and ground to pass a 2-mm sieve. Sub-samples used for nitrate determination were shaken for 1 h in a solution containing 0.025 moles L<sup>-1</sup> aluminum sulfate and 0.020 moles L<sup>-1</sup> boric acid (Mills 1980). A 5:1 solution/soil ratio was used. Filtered extracts were analyzed for nitrate using an Orion pH meter equipped with the appropriate specific ion electrode.

Tissue samples used to test for excess N were collected at both sites from five plants within each subplot at one to three weeks after black layers had formed on most of the kernels. The samples were collected by cutting the stalk at 0.15 and 0.35 m above the ground and removing leaves from the resulting 0.2 m section. The stalks were dried at 60°C and then ground to pass a 1.0-mm screen. Nitrate was extracted by shaking stalk tissue samples for 30 min in 0.025 M Al<sub>2</sub>(SO<sub>4</sub>)<sub>4</sub> at a tissue to extractant ratio of 1:50. After filtering through Whatman 5 paper, 1 ml of 2 M (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> was added to each 50 ml of extract to minimize differences in ionic strength. Nitrate determination from the prepared extracts was performed with a specific ion electrode.

Corn grain yield and moisture content from the center two rows of each subplot (four or six rows wide, depending on the site) were determined with a single row plot combine. Reported yields were adjusted to 15.5% moisture content.

Analyses of Variance was performed according to SAS procedures (SAS Institute 1985) by sorting data by location and analyzing by year. Mention of statistical significance in the text refers to alpha less than or equal to 0.05 unless otherwise stated.

#### Characteristics of the experimental sites

##### Boone:

Plots were established on a Nicolett soil (fine-loamy, mixed, mesic Typic Hapludolls) within a corn-soybean rotation (C-Sb). Alternating plot areas in both corn and soybean enabled data collection in successive years. Treated corn subplots consisted of six crop rows, 0.76 m wide by 9.15 m long. Corn was planted on 8 May and 23 April in 1989 and 1990, respectively. At planting time, ridge height averaged about 0.2 m. Seeds were planted at about 80,000 ha<sup>-1</sup> and

## Ridge top conditions

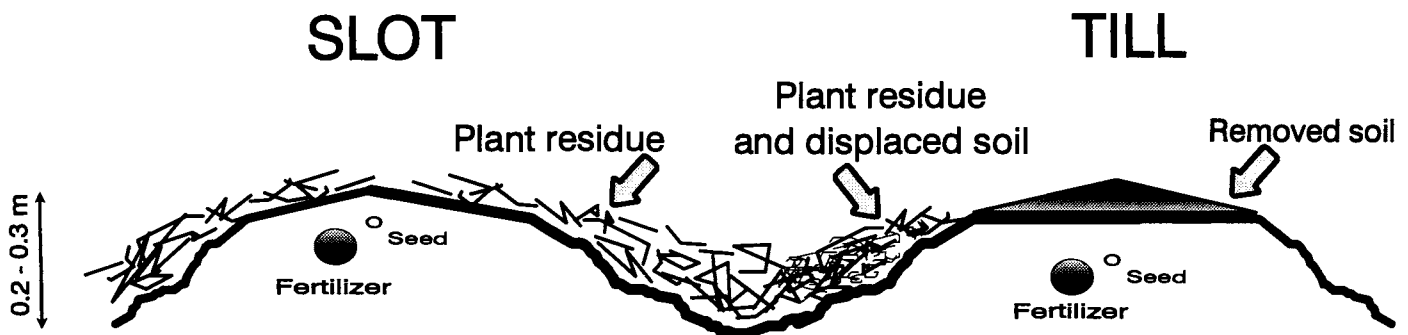


Fig. 1. Differences in ridge top surface conditions, seed zone location, and fertilizer placement after slot and till planting operations.

**Table 2.** Late spring soil nitrate analyses of variance for mean squares (Trey nor and Boone).

SOURCE	df	1989	1990	1991
----- Soil nitrate mean squares -----				
<i>Trey nor</i>				
Replication	23	—	4.85**	9.03**
Depth	1	—	1.30 <sup>ns</sup>	2.08 <sup>ns</sup>
Error	23			
Total	47			
<i>Boone</i>				
Replication (R)	23	0.87 <sup>ns</sup>	1.91**	—
Planting method (M)	1	6.25 <sup>ns</sup>	5.25 <sup>ns</sup>	—
R × M (a)	3	1.64 <sup>ns</sup>	1.48 <sup>ns</sup>	—
Depth (D)	1	7.84 <sup>ns</sup>	6.54 <sup>ns</sup>	—
M × D	1	4.84 <sup>ns</sup>	3.98 <sup>ns</sup>	—
Error (b)	6			
Total	15			

\*\*0.01 levels of significance within location columns.

<sup>ns</sup>, not significant at  $P > 0.05$ .

plants were thinned to 67,500 plants ha<sup>-1</sup> at about the V6 growth stage.

Weeds were controlled with a 0.38 m band application of Dual (metalachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)] acetamide), mixed with Bladex (cyanazine [2-[[4-chloro-6-(ethylamino)-s-triazin-2-yl]amino]-2-methylpropionitrile]) at planting time. Application rates were 2.24 kg a.i. ha<sup>-1</sup> and 1.68 kg a.i. ha<sup>-1</sup>, respectively, applied in 75.8 L H<sub>2</sub>O ha<sup>-1</sup>. A broadcast application of 67.2 kg ha<sup>-1</sup> of both P and K (oxide form) was made annually.

To examine the effect of the two planting methods on soil nitrate, late spring soil samples were collected annually from the no N (check) subplots located in the slot plant/layby-N and the till plant/layby-N whole plots.

Trey nor:

Plots were established on a Monona soil (fine-silty, mixed, mesic Typic Hapludolls) within a continuous corn (C-C) rotation. Treated subplots consisted of four rows, 0.97 m wide by 12.20 m long. Corn was planted on 8 May and 22 May in 1990 and 1991, respectively.

At planting time, ridge height averaged about 0.3 m. Seeds were planted at about 80,000 ha<sup>-1</sup> and plants were thinned to 67,500 plants ha<sup>-1</sup> at about the V6 growth stage (Ritchie and Hanway 1982). Herbicide use consisted of a post emergence broadcast application of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) at a rate of 2.8 kg ha<sup>-1</sup> mixed with crop oil concentrate and applied in 109 L H<sub>2</sub>O ha<sup>-1</sup>.

In addition to examining nitrate in the standard 0-0.3 m samples, soil samples from the 0.3-0.6 m depth were also collected to test for sampling depth effects. Late spring soil samples were collected from all subplots in the till plant/layby-N whole plots.

## RESULTS AND DISCUSSION

### Late Spring Soil Nitrate Test

At Boone, planting method (till or slot) did not significantly affect soil nitrate concentration (Table 2). Sample depth effects for the two years tested were also insignificant. In general, mean soil nitrate concentrations at Boone were quite low, relative to the scale used for nitrogen fertilizer recommendations (Blackmer et al. 1991). Typically cited critical values are in the 10 to 25 mg kg<sup>-1</sup> range. In 1989 the over all mean was 9 mg kg<sup>-1</sup>, and in 1990 the average was 4 mg kg<sup>-1</sup>.

At Trey nor, soil nitrate concentrations were not significantly affected by sampling depth in either year (Table 2). Concentrations at both depths averaged about 10 mg kg<sup>-1</sup>.

The consistently low soil nitrate values observed may suggest the need for critical levels specific to certain soils or tillage systems. Little work has been done in observing soil nitrate levels for ridge-tillage systems. These results reinforce the test developer's words of caution when attempting to apply this technology to tillage systems other than conventional, that site-specific evaluation is well advised (Blackmer et al. 1991).

### Grain Yield Response

Whole-plot and subplot grain yield results were consistent throughout the experiment. The effect of treatment (planting method/N timing) on grain yield was not significant for any of the site-years (Table 3). The effect of planting method (till or slot) on grain yield was generally not significant.

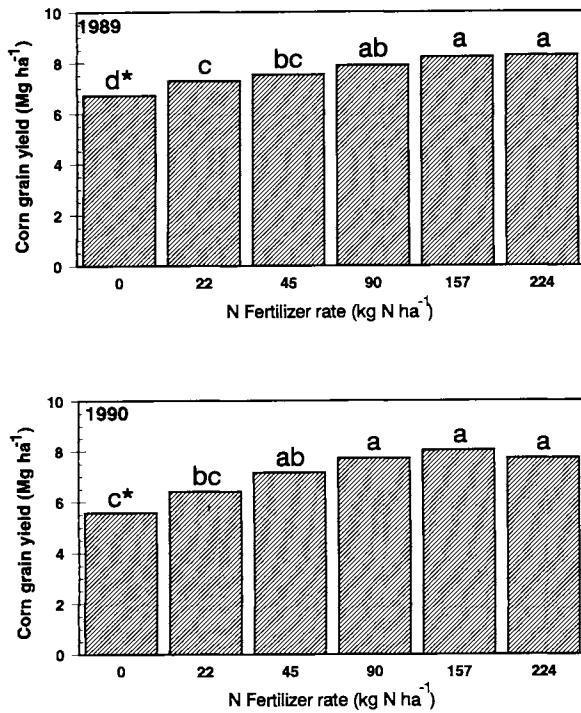
N rate effect on grain yield was significant for all site-years (Figs. 2, 3). However, at Boone N rates above 90 and 45 kg ha<sup>-1</sup> in 1989 and 1990, respectively, did not significantly increase grain yields. These rates are substantially below those commonly used for corn production at this location. Lack of response to the higher N rates

**Table 3.** Grain yield analyses of variance on replication, treatment, and N rate effects (Trey nor and Boone).

SOURCE	df	MEAN SQUARE			
		TREYNOR		BOONE	
		1990	1991	1989	1990
Replication (R)	3	160.6 <sup>ns</sup>	42.5 <sup>ns</sup>	198.0 <sup>ns</sup>	113.7 <sup>ns</sup>
Treatment (T)	2	25.7 <sup>ns</sup>	374.3 <sup>ns</sup>	186.0 <sup>ns</sup>	76.6 <sup>ns</sup>
R × T (error a)	6	154.8 <sup>ns</sup>	87.3 <sup>ns</sup>	72.8 <sup>ns</sup>	243.5 <sup>ns</sup>
N rate (N)	5	894.3**	1329.5**	1081.0**	682.5**
T × N	10	104.8 <sup>ns</sup>	43.5 <sup>ns</sup>	78.6 <sup>ns</sup>	83.5 <sup>ns</sup>
Error (b)	45				
Total	71				

\*\*0.01 levels of significance within location columns.

<sup>ns</sup>, not significant at  $P > 0.05$ .



\*N fertilizer rates with common letters did not differ significantly within years (LSD=0.05)

Fig. 2. N fertilizer rate effect on grain yield at Boone in 1989 and 1990.

may have been anticipated, considering the potential for elevated soil residual N due to low precipitation in the preceding years.

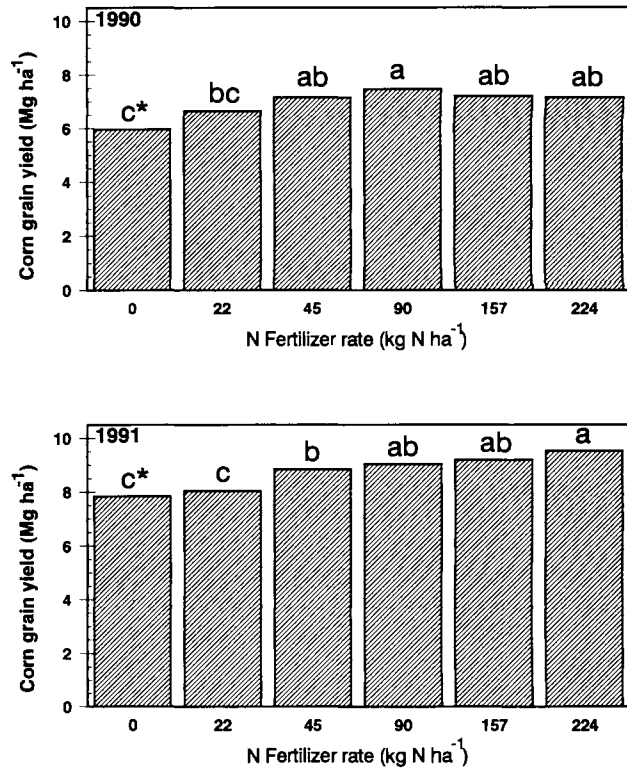
Lack of significant response to moderate and high rates of N fertilizer at Treynor was consistent with previous unpublished research. Significant yield increases above those observed with the relatively low rates of 45 and 90 kg ha<sup>-1</sup> in 1990 and 1991, respectively, were not found (Fig. 3). Once again, significant response to N rates above those considered moderate did not occur. The treatment by N rate interaction was consistently not significant for these site-years.

#### Basal Stalk Nitrate Test

At Treynor, basal stalk nitrate was not significantly affected by the planting method/N timing treatments (Table 4). No pattern or trend was observed among the treatments, and the numerical ranking for them was different for the two years. Nitrate values were similar for the two years, differing by only 0.4 g kg<sup>-1</sup>.

The Boone site had significant treatment effects in both of the years tested. In 1989, planter time N application produced more stalk nitrate than did the layby application for the slot planted plots. The 1990 data suggest that significantly more stalk nitrate was accumulated in the slot planted treatments regardless of timing, than that accumulated in the till plant/layby N treatment.

Stalk nitrate concentrations were significantly affected by rates of N fertilizer at both locations (Figs. 4, 5). At Boone in 1989, stalk N was in the optimum range or higher for fertilizer N rates at or above 45 kg ha<sup>-1</sup>. In 1990, slightly higher fertilizer N rates (90–157 kg ha<sup>-1</sup>) were needed to produce stalk nitrate values in the optimum or higher range. The Treynor data was more stable. In both years the 45 kg ha<sup>-1</sup> N rate produced stalk nitrate values positioned squarely in the optimum range. Additionally, N rates



\*N fertilizer rates with common letters did not differ significantly within years (LSD=0.05)

Fig. 3. N fertilizer rate effect on grain yield at Treynor in 1990 and 1991.

above and below 45 kg ha<sup>-1</sup> resulted in stalk nitrate values that bracketed the optimum range.

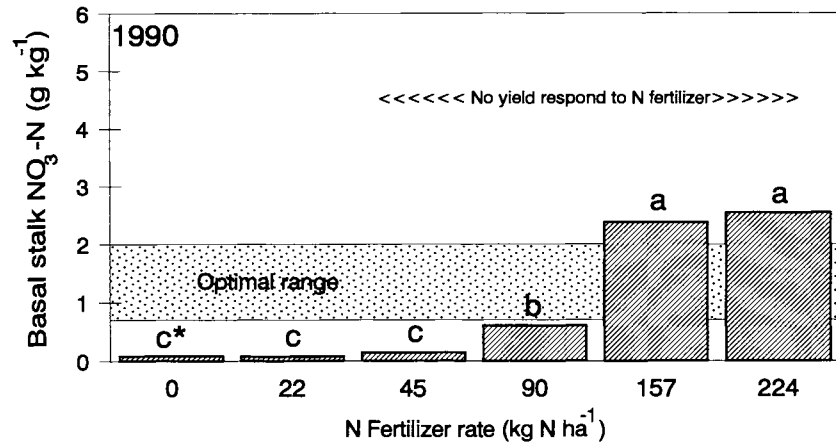
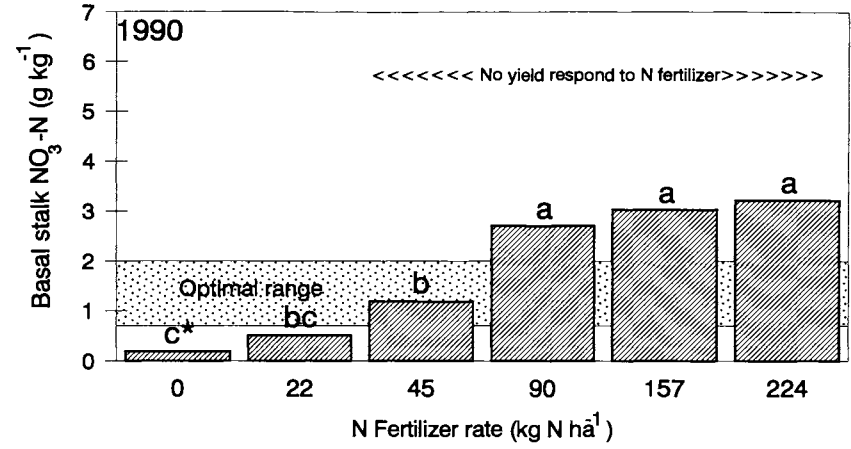
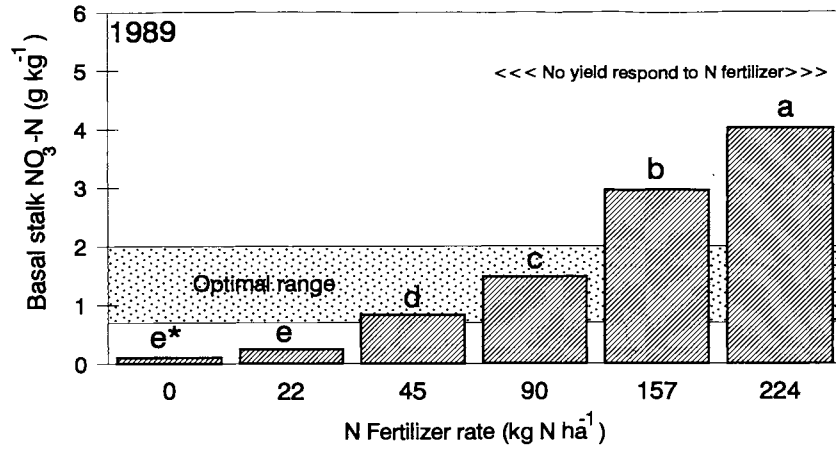
Initial work on critical concentrations of stalk nitrate identified an optimal range of 0.25 to 1.80 g N kg<sup>-1</sup> (Binford et al. 1990). Further inclusion of more correlation data and adding considerations of corn and fertilizer prices have provoked the revision of this optimal range to 0.7 to 2.0 g N kg<sup>-1</sup> (Binford 1991). These authors suggested that this tissue test is at least as reliable as analyses of yield

Table 4. Basal stalk nitrate analyses of variance on replication, treatment, and N rate effects at Treynor and Boone.

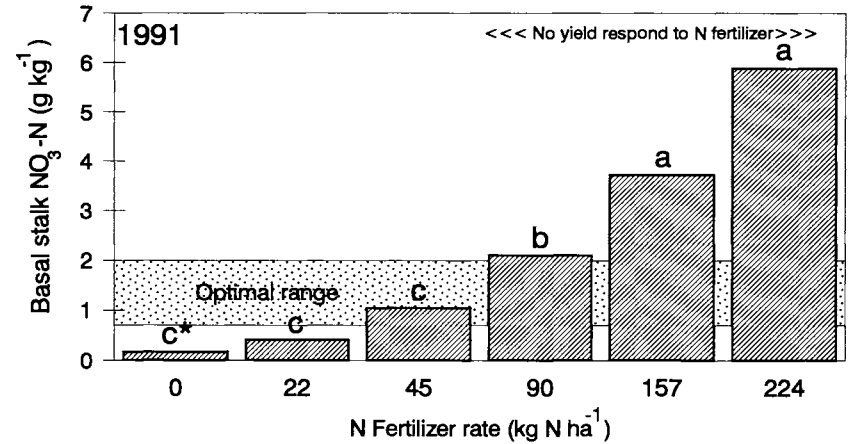
SOURCE	df	MEAN SQUARE			
		TREYNOR		BOONE	
		1990	1991	1989	1990
Replication (R)	3	0.9 <sup>ns</sup>	3.1**	0.7 <sup>ns</sup>	1.0**
Treatment (T)	2	1.2 <sup>ns</sup>	0.6 <sup>ns</sup>	1.6*	1.1*
R × T (error a)	6	0.8 <sup>ns</sup>	0.7 <sup>ns</sup>	0.2 <sup>ns</sup>	0.2 <sup>ns</sup>
N rate (N)	5	21.5**	58.9**	29.6**	16.4**
T × N	10	0.5 <sup>ns</sup>	0.9 <sup>ns</sup>	1.4**	0.6*
Error (b)	45				
Total	71				

\*, \*\*, 0.05 and 0.01 levels of significance, respectively, within location columns.

<sup>ns</sup>, not significant at  $P > 0.05$ .



\*N fertilizer rates with common letters did not differ significantly within years (LSD=0.05)



\*N fertilizer rates with common letters did not differ significantly within years (LSD=0.05)

Fig. 4. N fertilizer rate effect on basal stalk nitrate concentration at Boone in 1989 and 1990.

Fig. 5. N fertilizer rate effect on basal stalk nitrate concentration at Treynor in 1990 and 1991.

response in identifying optimal N fertilization rates. In general, our data concur. Fertilizer rates corresponding to stalk nitrate concentrations within the optimal range were generally in the 45 to 90 kg ha<sup>-1</sup> range. This agrees well with our overall interpretation of the yield response data, suggesting that with practice, use of this test within these planting method/timing systems may be viable.

Point injection of N fertilizer is an attractive alternative method of fertilizing corn as well as other crops (Blaylock and Cruse 1992, Janzen et al. 1991). This application technique used in combination with ridge tillage provides unique opportunities to farmers seeking an appropriate combination of profitability and environmental stewardship. Further work in calibrating N management tools to enhance the adoption of these systems seems pertinent. Additionally, planting method (till or slot) should not be a concern when planning adoption of this system. The soil nitrate test may require site-specific critical levels, but can be used in this system and will likely outperform traditional methods of making N management decisions.

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