EVALUATION OF THE ILLINOIS SOIL NITROGEN TEST FOR CORN PRODUCTION IN WISCONSIN

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JUSTIFICATION AND STATEMENT OF PROBLEM

Improved nitrogen (N) management in corn production is needed to optimize economic returns to farmers and minimize environmental impacts associated with agricultural N use, specifically, nitrate enrichment of groundwater and hypoxia of the Gulf of Mexico. In recent years, improving nitrogen management has been made through the use of soil nitrate testing in Wisconsin (Bundy and Andraski, 1995; Andraski and Bundy, 2002), although additional improvements in predicting crop N requirements on a site-specific basis are needed. A North Central Regional study (Bundy et al., 1999) showed that preplant (PPNT) and presidedress (PSNT) soil nitrate tests could improve identification of sites where corn would not respond to N fertilization, but the use of soil nitrate tests in cropping systems with substantial amounts of organic N mineralization was less promising and indicated a need to better understand and quantify N mineralization in cropping systems (Bundy et al., 1999). A major obstacle to improve N management is the lack of a reliable technique to estimate the N mineralization component of the crop N supply. A recent test based on measuring the amino sugar content of soils (Khan et al., 2001) shows promise for predicting corn N response where variation in N availability is mainly due to differing levels of N provided by N mineralization. Amino sugars are a structural component of the microbes that result in nitrogen mineralization, therefore measuring amino sugars could be an indirect indication of N-mineralization. Research is needed to evaluate this method (Illinois soil nitrogen test) in a range of soil climates and previous management environments to determine its potential for improving N management in Wisconsin and other locations.

OBJECTIVE

Calibrate the amino sugar N test method (Illinois soil nitrogen test – ISNT) for predicting corn nitrogen rates in Wisconsin using established experiments with a range in N availability.

SUMMARY OF PREVIOUS WORK

Amino sugar-N accounts for about 10-15% of the total N in most soils. Recent work in Illinois (Khan et al., 2001; Mulvaney et al., 2001) shows that amino sugar-N content is a good indicator of the need for N fertilization in corn production. In the Illinois research, 11 of 18 corn N response experiments showed no response to additional N fertilizer. Analysis of amino sugar-N in soils from these 18 N response experiments showed a good inverse relationship between the magnitude of corn yield response to N and the amino sugar content of the soil. All of the non-responsive sites had amino sugar-N test values of more than 250 ppm while sites where applied N fertilizer resulted in increased yields test values were less than 250 ppm. These findings indicate that the Illinois soil nitrogen test has the potential to improve N fertilization recommendations for corn on a wide range of soils. This paper will discuss the performance of the Illinois soil nitrogen test alone and in conjunction with soil nitrate-N measurements for predicting corn yield response to N fertilization in southern Wisconsin.

PROCEDURE

The experiments were located on several of the established cropping systems treatments in the Wisconsin Integrated Cropping Systems Trial (WICST) at the Arlington Agricultural Station. Access to the WICST experimental site is provided through the cooperation of Dr. J.L. Posner, University of Wisconsin-Madison, Department of Agronomy.

Research using the Wisconsin Cropping Systems Trial (WICST):

The Wisconsin Integrated Cropping Systems Trial (WICST) at the Arlington Research Station was initiated in 1990 and includes six cropping systems with a range of crop diversity, management intensity, and external or purchased inputs (Griffith and Posner, 2001). The trial features large individual plot size (0.70 acres) and the cropping systems have been managed uniformly for more than ten years. Two systems were of special interest for the evaluation of the amino sugar N test, specifically, fall plowed continuous corn (CC) and no-till soybean-corn rotation (SC). Nitrogen response experiments were established in each of these two cropping systems using a randomized complete block design with four replications. Nitrogen fertilizer treatments were hand broadcast as ammonium nitrate at rates of 0, 60, 90, 120, 150, 180, and 210 lb N/acre soon after corn planting. Individual plots were six rows wide and 30 ft. long. Corn was planted using an adapted hybrid, 30-inch row spacing, and a target plant density of 28,000-30,000 plants/acre. Corn silage yield by harvesting 6 randomly selected plants from the two center rows. Corn grain yields were determined in each plot by harvesting the two center rows with a plot combine. The N rate structure in the corn sequences allowed determination of corn yield response to N and an estimate of the economic optimum N rate (EONR). Regression analysis was used to establish the relationship between (EONR) for corn and soil N tests.

Soil samples were collected before corn planting from each plot according to the following plan: 1) Preplant soil samples (0-3 ft depth in 1-ft increments) for soil nitrate determinations were taken in April; 2) Soil samples for the amino sugar-N analysis were collected at the same time from the 0-6 and 6-12 inch depths; 3) Pre-sidedress soil samples to one foot depth were collected in early June, at approximately the v-6 stage; and 4) at the end of season (November) soil samples were collected after corn grain harvest (0-3 ft depth in 1-ft increments) to see if any residual nitrate-N remained after the growing season. Preplant soil samples were analyzed for nitrate-N (Bundy and Meisinger, 1994) and amino sugar-N analysis was performed as described by Khan et al. (2001). Nitrate analysis for the pre-sidedress and fall nitrate tests were conducted following the preplant sampling method. The second year experiments in the WICST experiment were moved to a new location within the experiment to avoid any residual effects of the N rate treatments from the previous year.

RESULTS AND DISCUSSION

Soil nitrate and amino sugar-N content:

In the 2003 growing season, preplant soil profile (0-3 ft) NO_3-N contents obtained in April were significantly higher in CC (142 lb/a) than in SC (84 lb/a) and about one-half of this was in the top one foot (Table 1). Pre-sidedress soil NO_3-N contents (0-1 ft) obtained in June were not significantly different between previous crops (57 lb/a in CC and 40 lb/a in SC.

During the 2004 growing season, preplant soil profile (0-3 ft) NO_3-N contents obtained in April were nearly equal in both CC (44 lb/a) and SC (53 lb/a) resulting in no credit in the CC rotation and only 3 lb/a N-credit in the SC rotation (Table 2). Pre-sidedress soil NO_3-N contents (0-1 ft) obtained in June were not significantly different between previous crops (33 lb/a in CC and 26 lb/a in SC),

The preplant samples were also analyzed using the ISNT. The values also show that in both years only the CS rotation in 2003 would have responded to additional N fertilizer based on the critical value of 235 ppm determined by Khan and Mulvaney (Khan et al., 2001). However, this is not the N response that was observed in the field.

In both 2003 and 2004, soil samples were also obtained in approximately 7-day increments from two depths (0-6 and 6-12 in.) from one replication for each of the two previous crops throughout the growing season. In general, little change in ISNT values was apparent over the course of the growing season and the apparent differences over time are likely due to spatial variability. This suggests that the ISNT is measuring a more constant and stable fraction of the soil N pool instead of a variable and plant available N pool.

Corn silage and grain yield:

Corn Silage Analysis:

The 2003 corn silage yield averaged across N rates for CC and SC was 8.95 and 9.03 tons DM/acre, respectively, and was not significantly different. Silage yield without N fertilizer was 6.90 and 5.90 tons DM/acre for CC and SC, respectively. Regression analysis of the N response data resulted in an economic optimum N rate (EONR) of 175 lb/acre for CC and 156 lb/acre for SC (Table 4). Silage yields at the EONR were 9.70 tons/acre for CC and 9.81 tons/acre for SC.

The 2004 corn silage yield averaged across N rates for CC and SC was 6.60 and 7.26 tons DM/acre, respectively, and was not significantly different. Silage yield without N fertilizer was 5.51 and 5.66 tons DM/acre for CC and SC, respectively. Regression analysis of the N response data resulted in an economic optimum N rate (EONR) of 63 lb/acre for CC and 109 lb/acre for SC (Table 5). Silage yields at the EONR were 5.98 tons DM/acre for CC and 7.64 tons/acre for SC.

Corn Grain Analysis:

In 2003, the effect of previous crop on corn grain yield was not significant. Grain yields without N fertilizer were 119 bu/acre for CC and 109 bu/acre for SC. A significant grain yield response to N fertilizer occurred with yield increases of about 55% for CC and 90% for SC at the non-limiting N rate. Similar to silage, grain yield responded to slightly higher N rates in CC compared with SC (Table 6). The EONR for CC was 196 lb/acre resulting in a yield of 184 bu/acre compared with SC which had an EONR of 160 lb/acre with a corresponding yield of 206 bu/acre.

During 2004, the effect of previous crop on corn grain yield was not significant. Grain yields without N fertilizer were 144 bu/acre for CC and 146 bu/acre for SC. A significant grain yield response to N fertilizer occurred with yield increases of about 33% for CC and 36% for SC at the non-limiting N rate. Similar to silage, grain yield responded to slightly higher N rates in CC

compared with SC (Table 7). The EONR for CC was 109 lb/acre resulting in a yield of 188 bu/acre compared with SC which had an EONR of 100 lb/acre with a corresponding yield of 191 bu/acre.

End-of-season soil nitrate:

In 2003, soil profile (0-3 ft) NO_3-N contents at the end of the growing season were significantly higher in CC than in SC at all N rates (Table 8). A linear relationship between N rate and soil NO_3-N content was apparent for both previous crops. For CC, soil NO_3-N values ranged from 21 to 120 lb/acre at the 0 to 210 lb/acre N rate. For the full range of N rates in SC, NO_3-N values ranged from 7 to 106 lb/acre.

The 2004 growing season soil profile (0-3 ft) NO_3-N contents at the end of the growing season were not significantly different in either rotation all N rates (Table 9). A linear relationship between N rate and soil NO_3-N content was apparent for both previous crops. For CC, soil NO_3-N values ranged from 33 to 70 lb/acre at the 0 to 210 lb/acre N rate. For the full range of N rates in SC, NO_3-N values ranged from 22 to 119 lb/acre.

SUMMARY

The amino sugar-N content of soil based on the results of the ISNT is not adequate to correctly determine crop N need. The N recommendation based on the ISNT results given the critical value of 235 ppm would have resulted in no additional N application in both 2003 and 2004 except in the 2003 CS rotation, resulting in under application of N.

The 2003 and 2004 growing seasons resulted in very different N recommendations for each year and for each crop rotations. The ISNT values differed very little from one growing season to the next and throughout each of the growing seasons. This shows that the ISNT is measuring a more constant and stable fraction of the soil N pool instead of a variable and plant available N pool.

Nitrogen rate recommendations based on the preplant soil nitrate test (PPNT) would have resulted in below optimum N rates for both CC and SC in 2003, while in 2004 over-application would have resulted in both cropping rotations. Nitrogen rate recommendations based on the presidedress soil nitrate test (PSNT) for the 2003 season underestimated the EONR for both rotations. In 2004, the PSNT resulted in a slight over-application of N fertilizer in both the CC and SC rotation (about 20-30 lb. over-application). Table 10 summarizes the EONR compared UW recommendations and soil nitrate tests. Further research will evaluate whether a combination of soil N tests (i.e. PPNT or PSNT and ISNT) will improve site-specific N rate recommendations.

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Table 1. Effect of previous crop on preplant (April) soil profile NO_3-N levels, Arlington 2003.

	Previous crop †	
Soil depth	Corn	Soybean
	---------- soil NO_3-N, lb/acre ----------	
0 - 1	69	36
1 - 2	49	32
2 - 3	24	16
0 - 3	142	84

† Previous crop (0-3 ft) $p>f = 0.01$.

Table 2. Effect of previous crop on preplant (April) soil profile NO_3-N levels, Arlington 2004

	Previous crop †	
Soil depth	Corn	Soybean
	---------- soil NO_3-N, lb/acre ----------	
0 - 1	18	20
1 - 2	14	16
2 - 3	12	17
0 - 3	44	53

† Previous crop (0-3 ft) $p>f = 0.25$.

Table 3. Preplant ISNT values

Crop Rotation	Sample Depth (ft)	Average ISNT Value (ppm)	
		2003	2004
Cont. Corn (CS1)	0-1	291	252
Soybean Corn (CS2)	0-1	207	259

Table 4. Economic optimum N rate for corn silage yield following corn and soybean, Arlington 2003.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	ton/acre
Corn	27	$y = 6.98 + 0.029x - 0.000077x^2$	0.42	175	9.70
Soybean	20	$y = 5.83 + 0.049x - 0.00015x^2$	0.58	156	9.81

† Based on $0.15/lb N fertilizer and $20/ton corn silage at 70% moisture.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage.

Table 5. Economic optimum N rate for corn silage yield following corn and soybean, Arlington 2004.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	ton/acre
Corn	27	$y = 5.5443 + 0.00998x - 0.0000492x^2$	0.37	63	5.98
Soybean	20	$y = 5.6875 + 0.0321x - 0.00013x^2$	0.26	109	7.64

† Based on $0.25/lb N fertilizer and $20/ton corn silage at 70% moisture.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage

Table 6. Economic optimum N rate for corn grain yield following corn and soybean, Arlington 2003.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	bu/acre
Corn	27	$y = 120 + 0.60x - 0.0014x^2$	0.64	196	184
Soybean	20	$y = 108 + 1.17x - 0.0035x^2$	0.63	160	206

† Based on $0.15/lb N fertilizer and $2.50/bu corn grain.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage

Table 7. Economic optimum N rate for corn grain yield following corn and soybean, Arlington 2004.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	bu/acre
Corn	27	$y = 144 + 0.705 - 0.00278x^2$	0.84	109	188
Soybean	20	$y = 147 + 0.781x - 0.0034x^2$	0.81	100	191

† Based on $0.25/lb N fertilizer and $2.50/bu corn grain.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage

Table 8. Effect of previous crop and corn N rate on end-of-season (October) soil NO_3-N levels (0 to 3 ft) following corn, Arlington 2003.

Previous crop	N rate, lb/acre							
	0	60	90	120	150	180	210	Mean †
	---------- soil NO_3-N, lb/acre ----------							
Corn	21	41	55	79	93	103	120	72 a §
Soybean	7	19	37	34	66	87	106	51 b
Mean ‡	16 e	32 de	46 cde	59 bcd	84 abc	94 ab	115 a	

† Previous crop $p>f = 0.03$.
‡ N rate $p>f = <0.01$. Previous crop x N rate $p>f = 0.97$. CV = 56%.
§ Mean values followed by the same letter are not significantly different at the 0.05 probability level.

Table 9. Effect of previous crop and corn N rate on end-of-season (October) soil NO_3-N levels (0 to 3 ft) following corn, Arlington 2004.

Previous crop	N rate, lb/acre							
	0	60	90	120	150	180	210	Mean †
	---------- soil NO_3-N, lb/acre ----------							
Corn	34	33	36	40	47	46	70	44
Soybean	22	26	23	33	33	119	68	46
Mean ‡	28 b §	29 b	30 b	36 b	40 b	82 ab	69 ab	

† Previous crop $p>f = 0.86$.
‡ N rate $p>f = 0.03$. Previous crop x N rate $p>f = 0.23$.
§ Mean values followed by the same letter are not significantly different at the 0.05 probability level.

Table 10. Summary of EONR compared to UW recommendations and soil nitrate tests.

Growing Season	2003		2004	
Previous Crop	Sb	C	Sb	C
EONR †	160	196	100	109
UW Recommendation	120	160	120	160
PPNT ‡	86	68	117	160
PSNT §	103	120	134	127

† Economic optimum nitrogen rate (lb/a).
‡ Preplant soil nitrate test recommendation (lb/a).
§ Pre-sidedress soil nitrate test recommendation (lb/a).