Plant science and Illinois amino sugar N test

Introduction

The Illinois soil nitrogen test (ISNT) was initially developed as a means to identify fields where corn would not respond to fertilizer nitrogen (N) addition (Khan et al. 2001). The ISNT is a simplified version of a diffusion technique that determines different forms of N in soil hydrolysates (Mulvaney and Khan, 2001). Using stored samples, Mulvaney et al. (2001) found that N fertilizer response in corn was related to amino-sugar N (ASN); whereby as ASN increased, corn N fertilizer response decreased to zero and remained non-responsive above a threshold ASN value.

The ISNT was shown to be strongly correlated to ASN (Khan et al., 2001). Other favorable characteristics of the ISNT that could aid in the adoption of the test are that soil samples could be taken from 0-15 cm at the same time as routine soil sampling (Khan et al., 2001). Also samples could be taken in the spring prior to planting corn or the fall prior to the corn crop (Barker et al., 2006a; Hoeft et al., 2001).

More recently, Mulvaney et al. (2005) reported on data from 102 N response studies conducted in 1990-1992 and 2001-2003. In this dataset, 33 sites-years were non-responsive while 69 were responsive. The ISNT correctly predicted 31 of the non-responsive sites; meaning that two sites were predicted as being responsive but were not.

The ISNT correctly predicted 50 of the responsive sites; meaning that 19 responsive sites were predicted as being non-responsive. Incorrectly classifying responsive sites as non-responsive could have a large negative economic impact to farmers as yield losses from under fertilization would have occurred. Mulvaney et al. (2005) hypothesized why these 19 failures occurred; however, they did not provide any experimental data to substantiate the hypotheses. Fully understanding situations where the test works well and where it does not is essential to providing growers with criteria for successful use of the test.

Field research in New York the past 8 years has shown a new soil N test, the Illinois Soil Nitrogen Test (ISNT), to be the best option for determining soil N supply potential for New York corn growers. The ISNT is a laboratory test that estimates the amount of readily mineralizable soil organic N. The test has been 83% accurate in our trials predicting if soil-N supply alone could provide adequate N for a corn crop in New York.

A major factor in the Cornell N equation is soil N supply, yet soil N supply is very difficult to predict accurately. The soil N-supply values used for the Cornell N equation for corn are estimates (book values) developed for more than 600 New York soil types. Book values are based on studies of N uptake by continuous corn grown without additional N. For New York soils, soil N supply can range from 50 to 140 lbs N/acre, with 60-70 lbs N/acre typical for many common agricultural soils.

There are many challenges to develop a soil test that can more accurately predict the soil N-supply for a specific field in a timely manner. Soil organic matter levels have been used to gauge soil N availability; however, this method is not accurate. Typically, to determine SOM as reported on a soil fertility report, a soil sample is burned at a very high temperature. This method is called loss-on-ignition (LOI). The difference in mass before and after burning is converted into a percent SOM (%SOM).

This LOI value on its own, although useful for other purposes, is not a good predictor of soil N supply as it does not distinguish between SOM with readily available N and SOM that does not supply N, and proportions vary across fields and farms. Until recently, the best option to estimate if there was sufficient plant available N from organic sources (manure, sod, soil) was the pre-side dress nitrate test (PSNT) but the PSNT presents some practical sampling challenges, results can be misleading in both dry and wet springs, and often N management decisions need to be made earlier in the season.

Methods and Materials

Data were compiled from studies in Iowa, Illinois, Michigan, Minnesota, Nebraska, and Wisconsin that were conducted as part of the regional CSREES NC-218 project (Assessing nitrogen mineralization and other diagnostic criteria to refine nitrogen rates for crops and minimize losses). Results of some of these studies have been reported/published by Barker et al. (2006b); Laboski, 2004; and Osterhaus (2005).

Summary information (previous crop, manure history, soil texture, and drainage class) about the sites in each state is provided in Table 1. Field experiments consisted of either small plots or field strips where N fertilizer was applied at multiple rates, including a zero check plot N rate and a non-yield limiting rate, and replicated four times. Nitrogen was applied as anhydrous ammonia, urea ammonium nitrate, or urea at preplant, sidedress, or split (starter plus sidedress or preplant plus sidedress). All N applications were made such that N losses were minimal.

An adapted corn hybrid was planted at each location. Corn grain yield and moisture were measured in each plot. In general, soil samples were collected prior to planting at depths of 0-15, 15-30, and/or 0-30 cm and in late spring prior to sidedress N application to a depth 30 cm. However, not all sampling depths were collected at each site. Preplant soil samples were analyzed for NO3-N, total N (dry combustion), soil organic matter (loss on ignition), ISNT, and extractable phosphorus, exchangeable potassium, and pH. For all samples, the ISNT analysis was performed at the University of Illinois eliminating potential lab to lab variation in ISNT values. Soil samples taken in late spring were analyzed for NO3-N.

Grain yield was adjusted to 15.5 % moisture and corn yield response to applied N was fit to either linear, linear plateau, quadratic, quadratic plateau, or spherical models. The model with the best R2 for each site was chosen to represent the yield response. The yield optimizing N rate (YONR) was determined for each site using the response model and is the N rate where yield was maximized. Relative yield was calculated as yield of the zero N check plot divided by the yield at the YONR. Nitrogen fertilizer response was calculated as the difference between yield at the YONR and the zero N check plot yield divided by the zero N check plot yield.

Illinois Soil Nitrogen Test (ISNT)

Plants take up nitrogen (N) from different sources including fertilizer N and N mineralized from organic sources such as plant aboveground residues and roots, manure and soil organic matter. Cornell University corn N guidelines account for N supply from sods, manure and soil organic matter and deduct these N credits from plant N needs to determine if additional N is needed. Soil N-supply estimates (book values) were derived for more than 600 New York soil types. These estimates of soil N supply reflect the N uptake by continuous corn grown without additional N. Typically, for New York soils, soil N supply will range from 50 to 140 lbs N/acre.

Cornell guidelines reflect soil N supply for each soil type adjusted for drainage. There has always been a desire to have a soil test that accurately predicts the soil Nsupply for a specific field in a timely way. Because the plant-available form of N is nitrate, which in our humid Northeast climate is very mobile in the soil, a simple pre-season nitrate test cannot accurately predict N needs for the coming growing season. To date, the best option for indicating whether sidedress N is needed has been the pre-sidedress nitrate test (PSNT). However, the PSNT presents some practical challenges since it requires a 12” deep soil sample that need to be taken during the busy field season, and in wet spring the PSNT is less accurate. Field research in New York the past 5 years has shown the Illinois Soil Nitrogen Test (ISNT) to be a better option for New York corn growers. In this fact sheet we show our New York specific research findings and explain how to take ISNT samples and use the test results in N management decision making.

Results and Discussion

All relationships between yield and ISNT were explored using ISNT measured on both 0-15 cm and 0-30 cm soil sample depths. There was a strong correlation between ISNT measured at 0-15 cm soil samples because there are more sites with 0-15 cm data.

There was no correlation between the ISNT and relative yield of the check plot (R2 = 0.05) (Figure 2). Nitrogen fertilizer response was not correlated to the ISNT (Figure 3). When the one Illinois site is removed that had a N fertilizer response of 554 %, the correlation between N fertilizer response and ISNT remained poor and non-significant. The Cate-Nelson procedure (Cate and Nelson, 1971) was used to separate the ISNT values into two categories. While the critical level was calculated, the R2 was poor for both relative yield and N fertilizer response (R2 = 0.11 and 0.08, respectively).

While relative yield and N fertilizer response may tell us if the ISNT can be a good predictor of non-responsive sites, the relationship between the ISNT and YONR can tell us if the ISNT can be used to select a rate of N fertilizer to be applied. Figure 4 shows this relationship. While the regression is very significant (P value < 0.001), the R2, and thus the predictive value of the relationship, is poor because of the large variability. For example, at an ISNT of 300 mg kg-1 the YONR ranges from 0 to 240 kg N ha-1. In an effort to understand whether or not management factors could influence the ISNT and subsequent YONR, the data set was broken down based on soil drainage class and previous crop. Table 2 provides the regression equations for ISNT regressed on YONR for each data subset. The relationship between ISNT and YONR was generally not changed when the data were broken into drainage classes. It is interesting to note that sub-setting the data based on previous crop resulted in even poorer R2 values compared to the whole data set.

Because of the poor relationships between ISNT and various measures of yield response to applied N in this compiled data set, relationships between ISNT and other soil characteristics were explored. The ISNT was not correlated to net N mineralized and nitrified between the preplant and late spring sampling times (Figure 5). The ISNT was strongly correlated to soil organic matter concentration (Figure 6) over a wide range of soil organic matter concentrations (< 1.0 to > 9.0 %) found throughout the region. Soil organic matter and ISNT were also strongly correlated for soils in New York (R2 = 0.89); as calculated using data provided in Klapwyk and Ketterings (2006). Organic matter is usually strongly correlated to total soil N and this relationship holds true for this study (R2 = 0.66). The ISNT is strongly correlated to total soil N and appears to be measuring a relatively constant fraction of total N (Figure 7). In work published by Khan et al. (2001) and Klapwyk and Ketterings (2005), the ISNT was also correlated to total N, although those authors did not explore this relationship. The slopes of the regression lines for the different data sets are relatively similar. In fact, the 95 % confidence interval for an individual regression line includes the regression lines for the other datasets as well. Thus, the ISNT is measuring a constant fraction of total soil N for a wide range of soils.

Total soil N or soil organic matters are not predictive of the amount of N fertilization needed by a corn crop because these parameters do not reflect the size of the readily mineralizable N pool. The ISNT does not appear to have much predictive capability for determining the N needs of corn. The poor performance of the ISNT occurs because it measures a constant fraction of total soil N rather than a specific fraction of soil N, and is not predictive of the amount of N mineralized during the growing season.

Conclusions

There is growing evidence from N-response studies that yield-based N recommendations are often inaccurate. This was the case, for example, with 75 N-response trials conducted in Illinois between 1990 and 1992, which included 55 sites where the recommended N rate exceeded the optimum N rate determined experimentally, often by more than 100 pounds per acre (Brown, 1996). More recently, Lory and Scharf (2003) concluded that maximum economic yield is a poor predictor of economically optimum N rate for corn, based on a lack of statistical significance in correlating these parameters for 298 N-response experiments in five Midwestern states (r = 0.04). The same conclusion has been reached previously by researchers in Wisconsin (Vanotti and Bundy, 1994; Bundy, 2000), Pennsylvania (Fox and Piekielek, 1995), Ontario (Kachanoski et al., 1996), and Iowa (Blackmer et al., 1997). This lack of correspondence between optimum and predicted N rates can be attributed to the fact that yield-based N recommendations do not take mineralizable soil N into account, with the result that under- or overfertilization is apt to occur in any given growing season.

The ISNT is not providing any relevant new information upon which N rate guidelines for corn can be based. The ISNT is measuring a constant fraction of total soil N and is not sensitive to the amount of N mineralized during the growing season. The ISNT can accurately predict soil N-supply capacity for corn in New York, sampling for the ISNT fits nicely into a regular soil sampling protocol (0-8 inch depth samples), and the results can be applied for the following 2-3 years of corn. The ISNT has proven to be a useful tool for fine-tuning N applications and reducing purchased N inputs costs, especially when used together with the corn stalk nitrate test.

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Appendix

Table 1. Previous crop, most recent manure application, soil texture, and drainage class for 96 research sites evaluating the ISNT for the NC-218 project in six states, 2002 to 2005.

State	Total number of sites	Previous crop †				Most recent manure application		Soil texture ‡						Drainage class §			
		C	S	DB	A	1 yr	2-5 yr	ls	l	sl	sil	sicl	cl	p	sp	mw	w
		number of sites															
IA	43	-	43	-	-	2	7	-	4	1	7	29	2	13	5	9	16
IL	5	1	4	-	-	0	1	-	-	-	4	1	-	1	4	-	-
MI	4	-	3	1	-	0	0	-	-	-	2	2	-	2	2	-	-
MN	1	-	1	-	-	0	0	-	-	-	1	-	-	-	-	-	1
NE	34 ¶	13	16	5	-	0	0	5	-	6	16	7	-	-	1	8	25
WI	9	5	3	-	1	0	0	-	-	-	9	-	-	-	-	-	9
Total	**96**	**19**	**70**	**6**	**1**	**2**	**8**	**5**	**4**	**7**	**39**	**39**	**2**	**16**	**12**	**17**	**51**

† C, corn; S, soybean; DB, dry bean; A, alfalfa.
‡ ls, loamy sand; l, loam; sl, sandy loam; sil, silt loam; sicl, silty clay loam; cl, clay loam.
§ p, poorly drained; sp, somewhat poorly drained; mw, moderately well drained; w, well drained.
¶ All NE sites were irrigated.

Table 2. Regression equations for the relationship between ISNT and yield optimizing N rate (YONR) as affected by soil drainage and previous crop for 96 research sites evaluating the ISNT for the NC-218 project in six states, 2002 to 2005.

Sites	Equation †	Model P > F	R^2	n
All sites	YONR = 225 – 0.39x	<0.01	0.22	96
Well drained	YONR = 252 – 0.49x	<0.01	0.21	51
Moderately well drained	YONR = 220 – 0.51x	0.05	0.24	17
Somewhat poorly drained	YONR = 295 – 0.59x	0.07	0.30	12
Poorly drained	YONR = 194 – 0.27x	0.06	0.24	16
Previous crop soybean	YONR = 191 – 0.28x	<0.01	0.15	70
Previous crop corn	YONR = 289 – 0.51x	0.05	0.21	19
Previous crop dry bean	YONR = 205 – 0.49x	0.60	0.07	6

† x, ISNT at 0-15 cm (mg kg^{-1}).

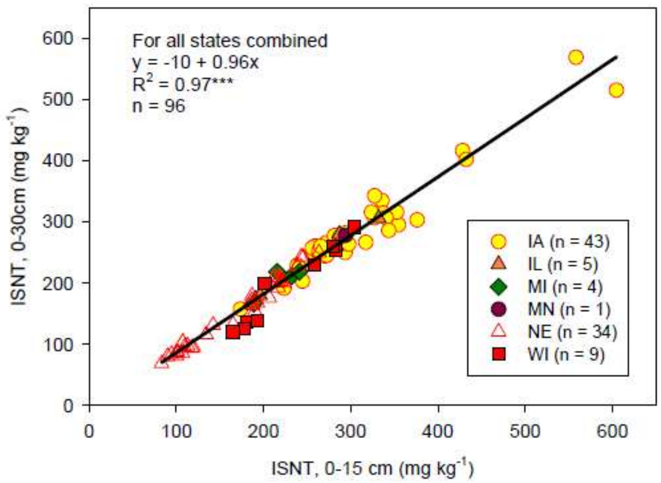

Figure 1. Comparison of ISNT values for 0-15 cm and 0-30 cm soil samples. *** Statistically significant at the 0.001 probability level.

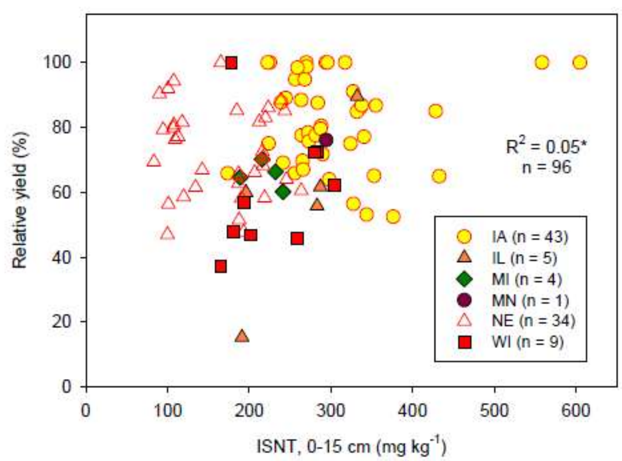

Figure 2. Relationship between the ISNT of soil samples taken preplant to a depth of 15 cm compared the relative yield of the check plot. * Statistically significant at the 0.05 probability level.

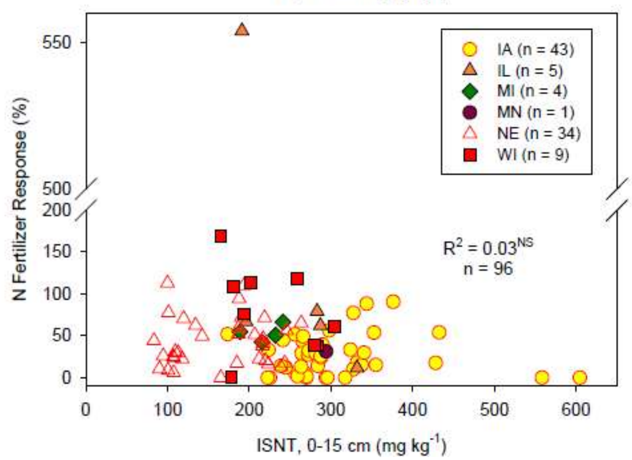

Figure 3. Relationship between ISNT of soil samples taken preplant to a depth of 15 cm compared to N fertilizer response. NS, not statistically significant.