USING THE ILLINOIS SOIL NITROGEN TEST TO PREDICT OPTIMUM NITROGEN RATES FOR CORN IN WISCONSIN

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Abstract

Development of a diagnostic test to estimate soil N supplying capability is a continuing research need. The Illinois soil nitrogen test (ISNT) has been proposed as a method for adjusting corn (*Zea mays* L.) N recommendations to account for soil organic N contributions. We evaluated the ISNT as a tool for predicting corn N response in Wisconsin by comparing ISNT values and corn N response data from 80 experiments conducted between 1984 and 2004 with a range of crop rotations, management histories, and soils. Relationships between various hydrolyzable soil N fractions (including amino sugar-N) and corn N response data were evaluated using a subset (13 sites) of the 80 N response experiments selected to obtain a wide range of anticipated soil N availability. Results showed that ISNT values were not related to observed economic optimum N rates (EONR) in the corn N response experiments and that the ISNT had no ability to separate N responsive from non-responsive sites. ISNT values were well correlated ($r^2 = 0.88$) with the soil organic matter content of the experimental sites suggesting that the ISNT is measuring a constant fraction of the soil organic N rather than the readily mineralizable N component. Soil organic N fractions measured in 13 experiments were not related to corn N response although these experiments included cropping systems ranging from first year corn following alfalfa to continuous corn. Results from this work indicate that the ISNT and the soil organic N fractions studied are not reliable predictors of corn N response.

Introduction

Nitrogen recommendations for corn production that avoid yield losses due to under-fertilization and also avoid the economic and environmental problems associated with over-application have been the goal of researchers for decades. Development of improved N recommendations has been hampered by the lack of a reliable method of predicting soil N supplying capability, although many attempts to develop such a method have been made. The accurate assessment of available N production through mineralization of soil organic matter (SOM) is critical for improving corn N recommendations because this component can vary over soils, cropping systems, and years. The Illinois soil nitrogen test (ISNT) has been proposed as a diagnostic tool to predict soil organic N contributions to the available N supply (Kahn et al., 2001), and thus could address the long-standing need for a diagnostic test for assessing the soil organic N mineralization component of the available N budget. In developing this procedure, Kahn et al. (2001) reported a very high correlation between ISNT test values and hydrolyzable amino sugar-N in soils, and Mulvaney et al. (2001) showed that soil concentrations of amino sugar-N were closely related to check plot corn yields and fertilizer N response in field experiments.

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The purpose of this paper is to present the results of an evaluation of the ISNT conducted in Wisconsin to determine if this soil test is an effective tool for predicting corn N requirements. For this evaluation, ISNT values and corn N response data were compared in 80 experiments conducted from 1984-2004 and representing a variety of crop rotations, management histories, and soils. In addition, an evaluation of relationships between various hydrolyzable soil N fractions (including amino sugar-N) and corn N response in field experiments was conducted for a subset of the 80 experiments mentioned above.

Materials and Methods

Laboratory Methods

Soil samples (0- to 12-inch depth) from 80 corn N response experiments were analyzed using the ISNT method of Khan et al. (2001) as described in University of Illinois Technical Note (2002) with the following exceptions. Ammonia evolved from soil during the 5-hr heating period used in the ISNT was sorbed in 0.05 *M* H_2SO_4 and quantified using a colorimetric method described by Mulvaney (1996) with a modified buffer to accommodate the use of 0.05 *M* H_2SO_4 in place of 4% boric acid as the ammonia sorbing solution. The modified buffer consisted of adding 4.08g of NaOH/100 mL instead of the 2.96 g/100 mL specified in the original method.

Soil organic matter (SOM) content was measured on 0- to 12-inch samples from the 80 experimental sites. The loss on ignition method described by Storer (1984) was used for the analysis.

Soil Hydrolysates

Soil samples (0- to 6-inch depth) from 13 of the 80 corn N response experiments (Table 1) were subjected to the soil hydrolysis and organic N fractionation procedure described by Mulvaney and Khan (2001). This procedure provides estimates of the following soil organic N fractions: total hydrolyzable N, ammonium-N (NH_4), (ammonium + amino sugar)-N, and amino acid-N.

Field Methods

Experiments used to evaluate the ISNT for its ability to predict economic optimum N rates (EONR) for corn consisted of N response studies conducted in Wisconsin from 1984 to 2004. In total, information from 80 experiments conducted on a range of soils and eight different cropping systems was included in the evaluation. Cropping systems in this data set ranged from corn following alfalfa to long-term continuous corn and included sites with a history of manure application. These systems would be expected to have major differences in soil N availability. All experiments had multiple rates of applied N including non-limiting N rates to allow for the determination of maximum corn grain yield and calculation of the EONR. Most of the previously conducted N response experiments are described in previous papers (Bundy and Andraski, 1995; Andraski and Bundy 2002). Experiments used for the soil hydrolysis and organic N fractionation study consisted of a subset (n = 13) of the experiments included in the ISNT evaluation.

Soil samples used for the ISNT were collected to a depth of 0 to 12 inches while soils used in the soil hydrolysis and organic N fractionation studies were from the 0- to 6-inch depth. All samples were collected in the spring (April or May) and dried in a forced air dryer at a temperature of 40ºC. Samples were then ground to pass a 2-mm sieve for the ISNT and 150-µm sieve for the soil hydrolysis study.

Economic optimum nitrogen rates were determined using regression analysis with a correction for economic factors (i.e., the cost per pound of N applied and the price paid per bushel of grain) when quadratic and quadratic plateau equations were used for determining N response. Nitrogen fertilizer response was calculated as a percentage and was determined by the equation: 100 x (maximum yield - check yield) / check yield.

Results and Discussion

Illinois Soil Nitrogen Test

The relationship between ISNT values and economic optimum nitrogen rates (EONR) in the 80 experiments used in this evaluation is illustrated in Figure 1. These results indicate that that there is a poor relationship ($r^2 = 0.0013$) between ISNT and EONR. In addition, the ISNT critical value of 225 ppm N identified by Khan et al. (2001) does not separate N responsive from non-responsive sites in this data set. In contrast, a strong correlation ($r^2 = 0.88$) was found between soil SOM and ISNT values (Figure 2). Sawyer et al. (2003) reported a similar strong relationship between ISNT and soil organic matter content in Iowa experiments. These findings suggest that the ISNT probably measures a constant fraction of soil organic N rather than the readily mineralizable portion of soil N. To assess soil N supplying capability on a site specific basis, a diagnostic tool must selectively estimate the size of the readily mineralizable soil N pool. Results to date suggest that the ISNT does not have this ability and therefore, is not providing relevant new information about the N supplying capability of a soil. The poor relationship found between ISNT and EONR in corn N response experiments (Figure 1) is consistent with this conclusion.

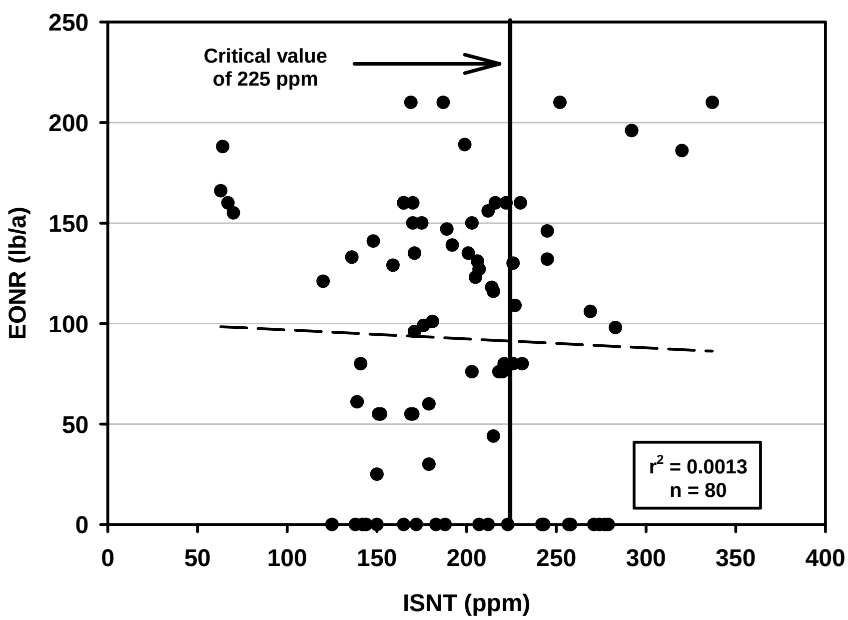

Figure 1. Relationship between Illinois soil nitrogen test (ISNT) values and economic optimum nitrogen rates (EONR) in 80 N-response experiments (1984-2004).

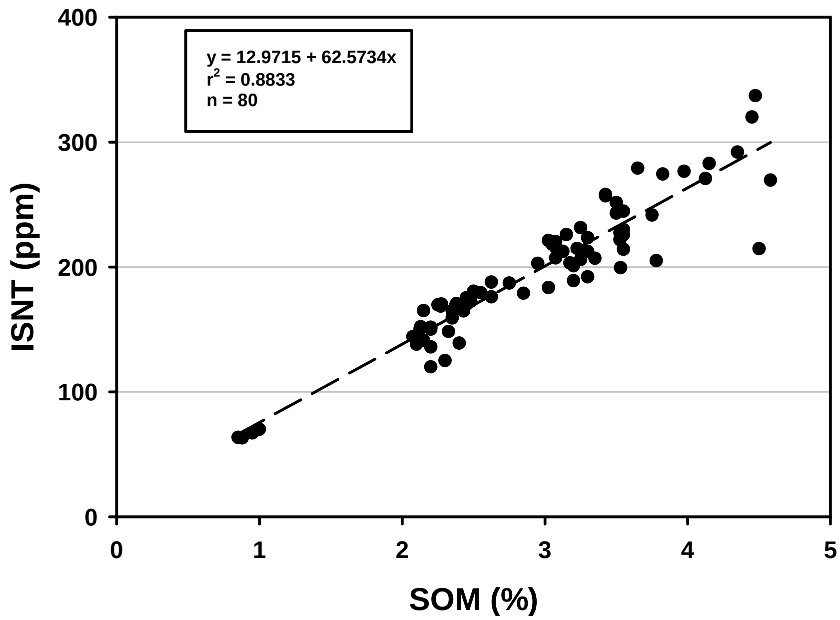

Figure 2. Relationship of Illinois soil nitrogen test (ISNT) values to soil organic matter (SOM) content in 80 N-response experiments (1984-2004).

Soil Hydrolysates

Since Mulvaney et al. (2001) found a strong relationship between soil amino sugar-N content and corn response to N fertilizer, we examined the relationships between several soil organic N fractions and N fertilizer response in field experiments (Table 1). As illustrated in Figure 3, no relationship was found between the soil amino sugar-N content and fertilizer N response in 13 corn N response experiments. Furthermore, none of the soil organic N fractions produced using the Mulvaney and Khan (2001) soil hydrolysis procedure were related to the observed response to N fertilization in the field experiments (Table 2).

Table 1. Site characteristics, soil organic N fractions, and corn N response in 13 Wisconsin experiments.

Location	Year	Crop rotation †	SOM	ISNT	Amino sugar-N	NH_4-N	Amino acid-N	Tot. hyd. N ‡	Check yield	Max. yield
			%	------------------	------------------ppm	------------------	------------------	------------------	bu/a	bu/a
Bloomington	1998	CC	2.85	179	190	286	170	1007	190	228
Bloomington	1998	CC	3.98	277	341	458	330	1618	207	223
Bloomington	1998	CC	4.13	271	330	445	234	1388	226	243
Bloomington	1998	CC	3.08	207	315	318	176	1340	203	225
Lancaster	2001	CC	2.20	139	165	215	272	1265	76	104
Lancaster	2001	AC	2.35	180	202	256	479	1560	121	167
Lancaster	2001	ACC	2.55	187	214	291	409	1823	94	132
Lancaster	2001	SC	2.70	173	192	280	463	908	95	162
Arlington	2003	CC	4.35	292	384	441	455	1704	119	192
Arlington	2003	SC	3.55	230	321	423	376	1764	121	207
Arlington	2004	CC	4.50	253	376	364	343	2028	145	194
Arlington	2004	SC	4.58	269	338	362	330	1761	140	200
Arlington	2004	CC	3.53	199	309	327	226	1299	101	208

† Crop rotation where C = corn, A = alfalfa, and S = soybean.

‡ Total hydrolyzable nitrogen.

Table 2. Relationships between soil organic N fractions and corn response to N fertilization.

Fraction	R^2	$p > f$ †
Total hydrolysable N	0.0033	0.8517
NH_4-N	0.0126	0.7153
NH_4+Amino sugar-N	0.0039	0.8384
Amino sugar-N	0.0000	0.9898
Amino acid-N	0.1039	0.2835

† $p > f$ = probability that tabular f ratio exceeds f ratio calculated by analysis of variance.

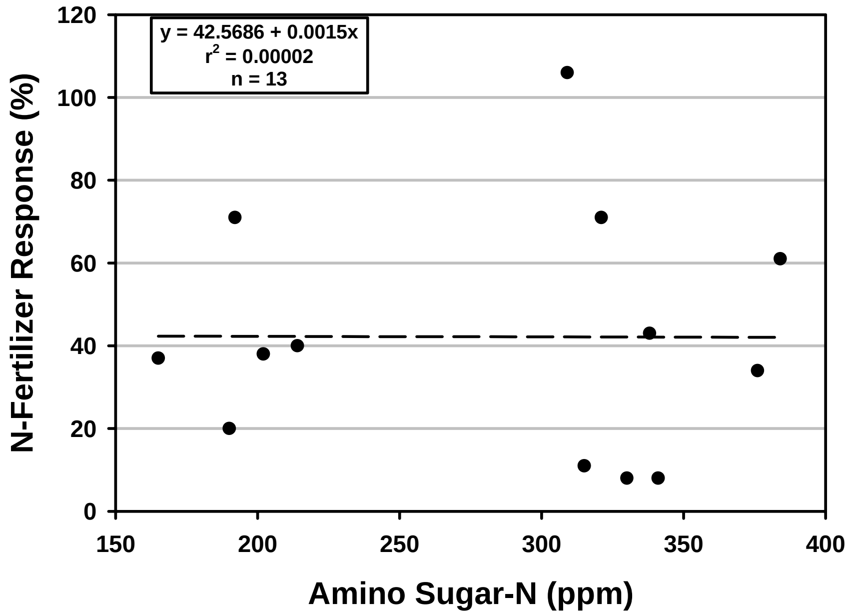

Figure 3. Relationship of hydrolyzable amino sugar-N content to N-fertilizer response.

Relationships between soil organic N fractions and ISNT values (Table 3) show that NH_4-N, (NH_4 + amino sugar)-N, and amino sugar-N fractions were strongly related to ISNT. However, NH_4-N had a stronger correlation with ISNT than amino sugar-N (r^2 = 0.91 and r^2 = 0.79, respectively), and NH_4+amino sugar-N had the strongest correlation of these three fractions. The stronger correlation of NH_4-N to ISNT than amino sugar-N to ISNT suggests that the hydrolyzable NH_4-N fraction represents a substantial portion of the soil organic N measured by the ISNT. Furthermore, comparison of the hydrolysable organic N fractions with ISNT values in Table 1 show that the ISNT recovers only a portion of the various N fractions.

Table 3. Relationship between several soil organic N fractions and ISNT.

Fraction	R^2	$p > f$ †
Total hydrolysable N	0.3017	0.0519
NH_4-N	0.9098	< 0.0001
NH_4+Amino sugar-N	0.9222	< 0.0001
Amino sugar-N	0.7975	< 0.0001
Amino acid-N	0.0139	0.7013

† $p > f$ = probability that tabular *f* ratio exceeds *f* ratio calculated by analysis of variance.

Conclusions

Results from 80 corn N response experiments in Wisconsin showed that ISNT values were not related to observed economic optimum N rates (EONR) and that the ISNT had no ability to separate N responsive from non-responsive sites. ISNT values were well correlated ($r^2 = 0.88$) with the soil organic matter content of the experimental sites suggesting that the ISNT is measuring a constant fraction of the soil organic N rather than the readily mineralizable N component. Soil organic N fractions measured in 13 experiments were not related to corn N response although these experiments included cropping systems expected to have major differences in soil N availability. Results from this work indicate that the ISNT or the soil organic N fractions studied are not reliable predictors of corn N response.

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