Soil Tests for Predicting Corn Response to Nitrogen Fertilizer in New York

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ABSTRACT

The presidedress nitrate test (PSNT) is currently the best tool available for Northeastern producers to determine if corn (*Zea mays* L.) will benefit from sidedress N. The PSNT requires 0- to 30-cm soil samples, which can be difficult to obtain on stony soils, and samples need to be taken in late-spring, an inopportune time for dairy (*Bos taurus*) farmers. Additionally, the in-season nature of the PSNT prevents its use by producers who apply preplant broadcast N. The Illinois soil N test (ISNT) is a simple test that estimates a potentially mineralizable fraction of soil organic N, amino sugar N. The test was able to identify sites that are nonresponsive to sidedress N fertilization in Illinois. From 2002 to 2004, 33 field trials were conducted to assess the effectiveness of the ISNT as compared with the PSNT in New York. Results confirmed the ability of the PSNT to separate responsive from nonresponsive corn sites. The ISNT was not an effective predictor by itself. However, when ISNT results and soil organic matter (OM) were considered, critical values could be developed that separated fields that were responsive to sidedress N from nonresponsive sites for corn silage dry matter yield, N concentration, N uptake, and estimated milk yield (kg of milk per ha predicted based on yield and quality of the silage). Further evaluation of the ISNT with consideration for OM could improve the accessibility of soil N testing to corn producers who apply N as sidedress as well as those who fertilize with preplant broadcast applications in the Northeast.

Soil testing as a means to determine N fertilizer recommendations for corn has been a high priority for soil scientists in past decades. For successful widespread adoption of a soil N test for corn four important criteria must be met: (i) the test must be a reliable indicator of corn N needs, (ii) it must be easy to obtain the soil samples (i.e., timing and depth of sampling cannot interfere with normal farming operations), (iii) the test must provide information to farmers before decisions need to be made regarding purchase and/or application of N, and (iv) the test must be economical. In a thorough review of N availability indices, Bundy and Meisinger (1994) covered nitrate tests, biological N availability indices, and incubation methods. There is limited adoption of these soil N tests for N management on commercial farming operations in the Northeast because most tests fail to meet all four criteria for adoption.

In New York and many other humid Northeastern states and provinces, the presidedress nitrate test (PSNT) is currently the best tool available for determining if corn will benefit from additional sidedress N. The PSNT estimates nitrate from mineralization and nitrification of organic N and was shown to be effective in determining if additional N beyond a small starter application is needed at sidedress time (Magdoff et al., 1984, 1990; Fox et al., 1989; Magdoff, 1991; Klausner et al., 1993; Bundy and Meisinger, 1994). However, the adoption of the PSNT in New York is limited because the protocol requires soil samples to be taken at 0- to 30-cm depth, which is difficult in stony soils, and samples need to be taken in late-spring, which conflicts with first hay harvest on many dairy farms. In addition, the test is of no value to the many producers who apply additional N (beyond N in starter fertilizer) as broadcast N before planting.

The ISNT was recently developed to estimate amino sugar N as a fraction of soil organic N that is potentially mineralized during the growing season (Khan et al., 2001; Mulvaney et al., 2001). The ISNT uses simple procedures and affordable equipment, and has potential to allow for more flexibility in depth and timing of sampling than the PSNT. Consequently, the ISNT has the potential to meet the four criteria outlined above with the added improvement in sampling protocols over the PSNT. The objective of this study was to assess the effectiveness of the ISNT as compared with the PSNT in predicting sites where corn silage dry matter yield and estimated dairy milk production based on yield and quality of the corn silage are likely to increase from N fertilizer application in New York.

MATERIALS AND METHODS

Thirty-three field trials were conducted at research stations (7 trials) and on commercial farms (26 trials) throughout New York from 2002 to 2004. Most trials consisted of three treatments: (i) no N, (ii) starter only, and (iii) starter plus sidedress N. Treatments that were included at each location are shown in Table 1. Each trial was established as a randomized complete block design with four blocks at research stations (Trials 1, 3, 8, 12, 15, 29, and 32) and in two blocks on commercial farms. Nitrogen in the starter fertilizer did not exceed 44 kg N ha^{-1} and was banded with the planter 5 cm below and beside corn seed. Sidedress N was applied when corn was 15 to 30 cm tall at a rate of 112 kg N ha^{-1} or at a rate that farmer/extension educator determined would provide sufficient N to achieve maximum yield.

Soil fertility (Table 1) and soil types (Table 2) covered a representative range of soils used for New York corn production. Records on site history for each trial were limited to previous cropping history since manure records were largely unavailable. Most of the on-farm trials were located on dairy farms except for Trials 18, 20, 24, and 30, which were located at mixed beef/dairy facilities, Trial 32, which was a heavily manured field next to a horse barn, and Trial 33, which was located at a sheep facility.

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Abbreviations: CP, crude protein; ISNT, Illinois soil N test; IVTD, in vitro true digestibility; NDF, neutral detergent fiber; NIR, near infrared reflectance; OM, organic matter; PSNT, presidedress nitrate test; RY, relative yield.

Table 1. Treatments and properties of corn field trials.

No.	Year	Trt†	Prev. crop‡	Corn yr§	pH¶	OM#	Sand††	Clay††	P‡‡	K‡‡	ISNT§§	PSNT¶¶
						g kg^{-1}			mg kg^{-1}			
1	2003	1,2,3	C	>2	7.9	34	440	180	2.5	24	161	15.1
2	2004	1,2,3	C	2	5.9	26	910	10	1.1	27	161	7.6
3	2004	1,2,3	C	>2	7.8	33	440	180	2.8	25	164	5.9
4	2004	2,3	C	>2	6.3	32	500	90	1.9	37	178	21.5
5	2004	1,2,3	C	1	6.2	31	590	90	2.9	51	191	25.8
6	2003	1,2,3	C	1	6.8	33	530	100	7.9	41	196	20.2
7	2003	1,2,3	C	>2	6.5	39	460	100	3.3	50	199	40.4
8	2004	1,2,3	G/A	0	6.4	33	840	50	4.1	21	208	21.1
9	2004	2,3	C	1	6.3	39	650	110	2.1	56	215	23.2
10	2002	1,2,3	A/G	0	6.5	34	450	120	5.0	32	223	16.8
11	2003	1,2,3	C	>2	5.9	39	340	170	5.3	92	234	26.9
12	2003	1,2,3	C	>2	7.3	53	230	200	2.0	46	235	18.7
13	2002	2,3	C	>2	6.5	46	660	80	1.1	38	257	11.7
14	2003	2,3	C	1	7.6	46	370	150	7.3	77	261	31.8
15	2004	1,2,3	C	1	6.5	49	480	110	1.1	54	262	–
16	2003	2,3	C	1	6.5	44	640	40	17.6	220	263	35.3
17	2004	2,3	C	1	7.6	48	380	150	7.7	73	273	23.5
18	2002	2,3	C	>2	6.7	69	270	170	2.1	89	287	30.6
19	2003	2,3	A	0	6.8	58	100	240	10.5	81	300	77.7
20	2003	2,3	C	>2	6.7	58	220	220	4.1	61	316	40.8
21	2004	1,2,3	C	2	6.4	65	40	340	3.8	56	328	59.8
22	2004	1,2,3	C	2	6.9	74	70	500	4.5	63	337	17.6
23	2003	1,2,3	C	2	6.6	55	520	80	0.3	24	352	11.7
24	2004	1,2,3	A	0	6.8	71	120	290	1.3	33	356	32.9
25	2004	1,2,3	C	>2	6.0	62	310	240	1.3	40	358	23.3
26	2004	1,2,3	C	1	6.0	61	450	170	0.5	36	361	51.0
27	2003	1,2,3	A/G	0	6.1	65	720	30	6.6	168	405	52.7
28	2004	1,2,3	C	>2	6.4	81	320	170	1.3	58	432	34.4
29	2004	1,2,3	C	2	6.8	85	230	260	2.6	45	441	6.6
30	2002	2,3	A	0	7.0	78	320	170	6.3	74	450	23.7
31	2004	1,2,3	C	>2	6.2	73	300	180	8.3	66	473	30.2
32	2003	1,2,3	C	>2	7.3	94	240	210	26.4	229	501	9.7
33	2002	2,3	A	0	6.5	88	220	210	14.3	80	524	33.6

† Treatments: (1) no N, (2) starter only, and (3) starter plus sidedress N.

‡ Previous crop: C, corn; A, alfalfa; A/G, alfalfa > grass mixture; G/A, grass > alfalfa mixture.

§ Years of continuous corn before year of study.

¶ pH with 1:1 (w/v) water extract.

\# Organic matter determined by loss on ignition.

†† Sand (0.05–2.0 mm) and clay (<0.002 mm) by the pipette method (Gee and Or, 2002).

‡‡ P and K using Morgan extraction.

§§ Illinois soil N test means for 0- to 20-cm depth samples at planting.

¶¶ Presidedress nitrate test (Morgan extractable NO_3–N) for 0- to 30-cm depth samples taken when corn was 15 to 30 cm tall.

Soils

Soils were kept cool while sampling in the field and either refrigerated (4°C), frozen (−20°C), or oven-dried within a few hours after sampling. Frozen soils were thawed in a refrigerator before oven-drying. Following standard procedures for soil preparation (Greweling and Peech, 1965), all soils were oven-dried (<50°C) for at least 48 h and crushed to pass 2 mm before storage for later analysis.

General Site Fertility

A bulk sample was prepared for each site by mixing equal volumes of soil from samples collected at planting from each plot (i.e., 3 treatments × 2 blocks = 6 plots). A soil fertility assessment was performed including pH (1:1 w/v water extract), organic matter (OM) by loss on ignition, and Morgan (0.72 *M* NaOAc + 0.52 *M* CH_3COOH) extractable P and K (Morgan, 1941) to characterize each trial location as shown in Table 1. For the Morgan extraction, samples were shaken in a 1:5 (v/v) ratio for 15 min and filtered through a Whatman no. 2 filter paper. Phosphorus was determined using colorimetric determination (Murphy and Riley, 1962) with a Technicon Autoanalyzer I (Pulse Instrumentation Ltd., Saskatoon, SK, Canada) at a wavelength of 660 nm. Potassium was analyzed by ICP using a JY70 Type II ICP–AES (Jobin Yvon, Edison, NJ). The pipette method (Gee and Or, 2002) was used for soil texture analysis (Table 1).

Presidedress Nitrate Test (PSNT)

Soil samples were collected for PSNT analysis when corn was 15 to 30 cm tall. Samples were taken to a 30-cm depth with a minimum of eight cores per plot and analyzed for nitrate N using the Morgan extraction (Morgan, 1941). Site means are shown in Table 1. One trial (Trial 15) did not have PSNT samples taken.

Illinois Soil Nitrogen Test (ISNT)

Soil samples were collected from each plot at two depths (0–20 and 0–30 cm) with a minimum of eight cores per plot at three times over the growing season: (i) at planting, (ii) at 15 to 30 cm tall corn just before sidedress N application, and (iii) at harvest. Soils were analyzed for ISNT according to Khan et al. (2001) with the enclosed-griddle modification (Klapwyk and Ketterings, 2005). Site means for at planting samples taken to a 20-cm depth are shown in Table 1.

Harvest

Silage Yield

A minimum of two rows of 12 m length per plot were harvested for aboveground biomass when the whole plant moisture content was between 600 and 700 g kg^{-1}. For silage harvests, a five-plant subsample from each plot was chopped in the field with a gas-powered chipper-shredder. Samples were

Table 2. Soil characteristics of 33 corn field trials in New York from 2002 to 2004.

No.	Series	Texture†	Taxonomy
1	Honeoye	L	fine-loamy Glossic Hapludalfs
2	Croghan	FSL	sandy, isotic, frigid Aquic Haplorthods
3	Honeoye	L	fine-loamy Glossic Hapludalfs
4	Howard	L	loamy skeletal Glossic Hapludalfs
5	Barbour	VFSL	coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Fluventic Dystrudepts
6	Barbour	SL	coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Fluventic Dystrudepts
7	Howard	L	loamy skeletal Glossic Hapludalfs
8	Stafford	FSL	mixed, mesic Typic Psammaquents
9	Knickerbocker	SL	sandy, mixed, mesic Typic Dystrudepts
10	Barbour	L	coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Fluventic Dystrudepts
11	Lansing	L	fine-loamy Glossic Hapludalfs
12	Mardin	SiL	coarse-loamy Typic Fragiudepts
13	Tunkhannock	SL	loamy-skeletal, mixed, superactive, mesic Typic Dystrudepts
14	Honeoye	L	fine-loamy Glossic Hapludalfs
15	Hogansburg	L	coarse-loamy Aquic Eutrudepts
16	Knickerbocker	FSL	sandy, mixed, mesic Typic Dystrudepts
17	Honeoye	L	fine-loamy Glossic Hapludalfs
18	Bath	SiL	coarse-loamy, mixed, active, mesic Typic Fragiudepts
19	Howard	SiL	loamy skeletal Glossic Hapludalfs
20	Chagrin	SiL	fine-loamy, mixed, active, mesic Dystric Fluventic Eutrudepts
21	Ontario	SiCL	fine-loamy Glossic Hapludalfs
22	Muskellunge	SiC	fine, mixed, active, frigid Aeric Epiaqualfs
23	Hogansburg	SL	coarse-loamy Aquic Eutrudepts
24	Chagrin	SiCL	fine-loamy, mixed, active, mesic Dystric Fluventic Eutrudepts
25	Amenia	L	coarse-loamy Aquic Eutrudepts
26	Muskellunge	L	fine, mixed, active, frigid Aeric Epiaqualfs
27	Summerville	VFSL	loamy, mixed, active, frigid Lithic Eutrudepts
28	Howard	SiL	loamy skeletal Glossic Hapludalfs
29	Valois	SiL	coarse-loamy, mixed, active, mesic Typic Dystrudepts
30	Howard	SiL	loamy skeletal Glossic Hapludalfs
31	Bath	SiL	coarse-loamy, mixed, active, mesic Typic Fragiudepts
32	Palmyra	SiL	fine-loamy over sandy or sandy-skeletal Glossic Hapludalfs
33	Valois	SiL	loamy-skeletal, mixed, active, mesic Glossic Hapludalfs

† Soil texture: L, loam; FSL, fine sandy loam; VFSL, very fine sandy loam; SL, sandy loam; SiL, silty loam; SiCL, silty clay loam; SiC, silty clay.

well-mixed, subsampled to fill approximately 3.5 L volume in a sealed plastic bag, and kept in a cooler before drying. Samples were dried at 60°C in forced-air ovens for a minimum of 48 h for moisture determination. Two trials (11 and 23) were harvested as grain corn and corrected to estimated equivalent silage yield (2.5 Mg silage Mg grain^{-1}).

Nitrogen Uptake, Nitrogen Concentration, Silage Quality, and Milk Yield

Dried silage samples were sent to DairyOne Forage Testing Laboratory, Ithaca, NY, for dry matter, P, K, crude protein (CP), neutral detergent fiber (NDF), starch, and 48 h in vitro true digestibility (IVTD). A dry matter correction factor for 60°C dried forage was determined by near infrared reflectance (NIR) based on a calibration of the NIR scan with dry matter contents obtained after drying at 135°C for 2 h according to AOAC 930.15 (AOAC, 1990). Samples were prepared for P and K analyses according to Greweling (1976). Samples were dry-ashed for 4 h at 500°C, cooled, and then dried again on a 100 to 120°C hot plate after addition of 3 mL of 6 *M* HCl. Nitrogen concentration was determined by combustion (Leco Instruments, St. Joseph, MI) according to AOAC 976.06 (AOAC, 1990) and multiplied by 6.25 to obtain CP, based on the assumption that maize protein contains 160 mg N kg^{-1}. Corn N uptake was determined as the product of N concentration and dry matter yield. In vitro true digestibility was determined using a Daisy II 200/220 in vitro incubator and ANKOM 200/220 fiber analyzer (ANKOM Technology, Fairport, NY). Neutral detergent fiber was analyzed according to Van Soest et al. (1991) using the ANKOM system. The 48 h NDF digestibility (dNDF) was calculated as (NDF − IVTD residue at 48 h)/NDF × 100. Milk2000 Version 7.54 (www.uwex.edu/ces/forage/pubs/milk2000.xls; verified 21 Feb. 2006), a model developed at the University of Wisconsin, was used to estimate silage quality for dairy milk production (kg milk Mg silage^{-1}) and dairy milk yields (kg milk ha^{-1}). Silage quality was calculated from CP, starch, NDF, dNDF, and assumptions of 34 g kg^{-1} ash, 13 g CP kg^{-1} NDF, 32 g kg^{-1} ether extract, and 650 g kg^{-1} moisture content of silage as fed to dairy cows. Milk yield was determined as the product of silage quality and dry matter silage yield.

Statistical Analysis

With only two replications per treatment for the 27 on-farm trials, determining individual trial relative yield responses can be highly susceptible to over- or underestimation of yield and/or quality due to spatial variability. However, the data can be analyzed for overall effects of the treatments and predictive value of the soil tests by considering the 33 field trials as random and fertility treatments as fixed effects. A random locations model (Littell et al., 1996) was used with mixed procedures (SAS Institute, 2001) with treatment as fixed effect and location and block nested within trial location as random effects. A similar approach was shown to be effective in evaluating winter wheat varieties using unreplicated strip trials in Ontario, Canada (Yan et al., 2002). Two data sets were used, each with two treatments, to assess starter response (no fertilizer check and starter fertilizer treatments) and sidedress response (starter and starter plus sidedress treatments). The initial model was run to determine if there was a treatment effect on five separate response variables described above: (i) silage yield, (ii) N concentration, (iii) N uptake, (iv) silage quality for dairy production (kg milk Mg silage^{-1}), and (v) dairy milk yield (kg milk ha^{-1}). Significant treatment effects ($p < 0.05$) indicated that starter response or sidedress response differences were found. Where significant treatment effects were found, soil test results were added as fixed effects with full interactions with other fixed effects to determine if different soil tests could explain the treatment differences (i.e., significant interaction of soil test with treatment). The six soil parameters (determined as described earlier) used in the assessment were (i) PSNT, (ii) P, (iii) OM, (iv) sand, (v) clay, and (vi) ISNT at three timings (at planting, at sidedress, and at harvest) and two sampling depths (0–20 and 0–30 cm). For the PSNT and ISNT, data were generated at the plot level whereas for P, OM, sand and clay, composite samples were analyzed at the trial level (i.e., one bulk sample per trial). When P, OM, sand, clay, OM × sand, or OM × clay were used as fixed effects in a model, interactions between these parameters and trial location were included as random effects. Least square means of full models were used to determine where the probability of starter or sidedress response was 95% (i.e., $p =$

0.05). This allowed for multiple soil tests to be used in combination to predict critical levels that could separate responsive from nonresponsive sites.

RESULTS AND DISCUSSION

Starter Response

Comparison of the no N and starter treatments (22 trials) showed significant silage yield, N uptake, and milk yield responses to starter (all $p < 0.0001$). Nitrogen concentration and silage quality were not responsive to starter ($p = 0.18$ and 0.32, respectively), indicating that dry matter yield was the driving factor for N uptake and milk yield response. Significance levels of soil parameters in accounting for starter response are shown in Table 3. Eighteen trials tested low or medium in P (≤ 4 mg kg^{-1}) where a response to P in the starter might be expected. However, soil test P did not account for starter responses ($p = 0.21$). Similarly, K ($p = 0.10$), P × K ($p = 0.68$), and texture parameters did not account for differences in the no N and starter treatments, suggesting that P and K were not likely limiting and that starter responses were due to the N in the starter. The ISNT results were not effective in predicting a starter response when considered alone ($p > 0.10$) but addition of OM and sand to the statistical models did account for starter response (Table 3). The model that included all three soil parameters did not account for any differences in N uptake response to starter and its success in predicting yield responses was better for samples taken at planting than for those collected at sidedress time. Least square means estimates from the ISNT (20-cm depth, at planting), OM, and sand means for each trial indicate the interactive effects of the three soil parameters in predicting silage yield response to starter fertilizer (Table 4). The effectiveness of the ISNT, OM, and sand model suggests that early season N mineralization is an important factor in starter response in New York. Since N mineralization can be affected by water holding capacity (Flowers and O'Callaghan, 1983), temperature (Hadas et al., 1983; Grundmann et al., 1995), and aeration (Thomsen and Olesen, 2000), OM and sand content are likely to influence early season N supply. Research by Gordillo and Cabrera (1997) and Sorensen and Jensen (1995) showed that sand content increased mineralization of N from manure as well. In addition, effects of sand on nitrate leaching may influence starter response. Efficacy of the ISNT, OM, and sand in accounting for starter response could be explained if the three soil parameters are indicators of the size of the labile organic N pool and impact N availability through their effects on soil moisture, temperature, and leaching. As indicators of soil moisture and temperature, both sand and clay content improve models that include ISNT and OM in accounting for corn response to starter but sand content appears to be

Table 3. Significance of soil parameters in explaining corn silage yield, N uptake and estimated milk yield response to starter (no fertilizer vs. starter fertilizer only).

Soil parameters†‡	Silage yield	N uptake	Milk yield
	Mg ha^{-1}	—— kg ha^{-1} ——	
PSNT	NS	NS	NS
P	NS	NS	NS
OM	NS	NS	NS
Clay	NS	NS	NS
Sand	NS	*	§
OM + clay	NS	NS	NS
OM + sand	NS	NS	NS
ISNT at planting			
0–20 cm ISNT	NS	NS	NS
0–20 cm ISNT + OM	NS	NS	NS
0–20 cm ISNT + OM + clay	*	NS	*
0–20 cm ISNT + OM + sand	**	NS	*
0–30 cm ISNT	NS	NS	NS
0–30 cm ISNT + OM	NS	NS	NS
0–30 cm ISNT + OM + clay	*	NS	§
0–30 cm ISNT + OM + sand	**	NS	*
ISNT at sidedress			
0–20 cm ISNT	NS	NS	NS
0–20 cm ISNT + OM	NS	NS	NS
0–20 cm ISNT + OM + clay	§	NS	NS
0–20 cm ISNT + OM + sand	*	NS	*
0–30 cm ISNT	NS	NS	NS
0–30 cm ISNT + OM	NS	NS	NS
0–30 cm ISNT + OM + clay	NS	NS	NS
0–30 cm ISNT + OM + sand	*	NS	§
ISNT at harvest			
0–20 cm ISNT	NS	NS	NS
0–20 cm ISNT + OM	NS	NS	NS
0–20 cm ISNT + OM + clay	*	NS	*
0–20 cm ISNT + OM + sand	**	NS	*
0–30 cm ISNT	NS	NS	NS
0–30 cm ISNT + OM	NS	NS	NS
0–30 cm ISNT + OM + clay	*	NS	§
0–30 cm ISNT + OM + sand	**	NS	*

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

† Soil parameters indicated were included with treatment as fixed effects, with full interactions of all fixed effects in separate random locations models. Indicated significance levels are for the highest interaction of each model, which included treatment and all parameters in each row.

‡ PSNT, presidedress nitrate test by Morgan extractable NO_3–N to 30-cm depth; P, Morgan extractable; OM, organic matter to 20-cm depth by loss on ignition; clay content at planting to 20-cm depth; ISNT, Illinois soil N test N from samples taken at planting, just before sidedressing, and at harvest at 0- to 20- or 0- to 30-cm depth.

§ Significant at the 0.1 probability level.

Table 4. Predicted corn silage yield response to starter fertilizer based field trial mean Illinois soil N test N (ISNT20), organic matter (OM), and sand levels from 20-cm depth samples at planting.

Trial no.†	ISNT20	OM	Sand	Estimate‡	SE‡	$P > t$
	mg kg^{-1}	— g kg^{-1} —		—— Mg ha^{-1} ——		
1	161	34	440	1.27	0.51	0.0158
2	161	26	910	5.00	1.06	<0.0001
3	164	33	440	1.35	0.51	0.0112
5	191	31	590	1.77	0.43	0.0001
6	196	33	530	1.36	0.39	0.0011
7	199	39	460	0.75	0.39	0.0594
8	208	33	840	1.41	0.73	0.0597
10	223	34	450	1.11	0.53	0.0396
11	234	39	340	1.02	0.51	0.0490
12	235	53	230	1.14	0.50	0.0253
15	262	49	480	0.10	0.55	0.8530
21	328	65	40	2.14	0.75	0.0061
22	337	74	70	1.60	0.81	0.0539
23	352	55	520	0.32	0.56	0.5762
24	356	71	120	1.45	0.58	0.0156
25	358	62	310	1.19	0.53	0.0299
26	361	61	450	0.74	0.50	0.1490
27	405	65	720	1.07	1.10	0.3361
28	432	81	320	1.54	0.59	0.0123
29	441	85	230	0.79	0.50	0.1155
31	473	73	300	1.77	0.78	0.0274
32	501	94	240	0.48	0.77	0.5352

† Trial number as indicated in Tables 1 and 2.

‡ Estimate and standard error of the difference of starter vs. no N check silage yield (dry matter).

a stronger indicator than clay (Table 3), possibly due to a greater range in sand than clay content for these trials (Table 1). These data suggest that a model with ISNT, OM, and sand could be developed for predicting silage yield response to starter N but the use of such a model is likely prohibited by costs associated with each of the analyses and thus likely to result in low adoption rates.

Sidedress Response

Comparison of the starter and starter plus sidedress treatments (32 trials) showed significant silage yield, N concentration, N uptake, and milk yield response to sidedress N (all $p < 0.0001$). Silage quality (kg milk Mg silage^{-1}) was not responsive to sidedress N ($p = 0.41$). Highly significant PSNT × treatment interactions ($p < 0.0001$, Table 5) showed that silage yield, N concentration, N uptake, and milk yield response to sidedress N were effectively predicted by the PSNT. Least square means for the 3 yr combined showed that a silage yield response to sidedress N could be expected (with 95% confidence) when PSNT levels were 38 mg kg^{-1} or less. At this critical level, the yield increase with sidedress N was 0.64 Mg ha^{-1}. This critical level is higher than the 20 to 25 mg kg^{-1} levels that are commonly used (Bundy and Meisinger, 1994) to determine the level where sidedress N should no longer be necessary. However, the results are consistent with the literature given that currently used critical levels are most often derived assuming relative yield (RY) goals of 93 to 95.5% (Fox et al., 1989; Blackmer et al., 1989; Meisinger et al., 1992). For example, Meisinger et al. (1992) determined a RY plateau (quadratic plateau model) at 30.2 mg kg^{-1} in Maryland and determined that for a RY goal of 95%, 22 mg kg^{-1} was the critical value. Similarly, solving for quadratic models (as opposed to the linear-response-and-plateau models) for data reported in Blackmer et al. (1989) resulted in maxima ranging from 37.1 to 46.7 mg kg^{-1}.

Table 5. Significance of soil parameters in explaining silage yield, N concentration, N uptake, and estimated milk yield response to sidedress N (starter fertilizer vs. starter plus sidedress N).

Soil parameters†‡	Silage yield	N conc.	N uptake	Milk yield
	Mg ha^{-1}	g kg^{-1}	— kg ha^{-1} —	
PSNT	***	***	***	***
P	§	NS	NS	NS
OM	NS	§	NS	NS
Clay	NS	NS	NS	NS
Sand	NS	NS	NS	NS
OM + clay	§	NS	NS	NS
OM + sand	NS	NS	NS	NS
ISNT at planting				
0–20 cm ISNT	§	*	§	NS
0–20 cm ISNT + OM	**	**	**	**
0–20 cm ISNT + OM + clay	§	NS	NS	NS
0–20 cm ISNT + OM + sand	NS	NS	NS	NS
0–30 cm ISNT	NS	§	NS	NS
0–30 cm ISNT + OM	*	**	**	**
0–30 cm ISNT + OM + clay	*	NS	NS	NS
0–30 cm ISNT + OM + sand	NS	NS	NS	NS
ISNT at sidedress				
0–20 cm ISNT	NS	*	§	NS
0–20 cm ISNT + OM	§	*	§	*
0–20 cm ISNT + OM + clay	*	NS	*	NS
0–20 cm ISNT + OM + sand	NS	NS	NS	NS
0–30 cm ISNT	NS	*	NS	NS
0–30 cm ISNT + OM	NS	*	§	NS
0–30 cm ISNT + OM + clay	*	NS	*	NS
0–30 cm ISNT + OM + sand	NS	NS	NS	NS
ISNT at harvest				
0–20 cm ISNT	NS	§	NS	NS
0–20 cm ISNT + OM	*	*	*	*
0–20 cm ISNT + OM + clay	§	NS	NS	NS
0–20 cm ISNT + OM + sand	NS	§	NS	NS
0–30 cm ISNT	§	NS	§	NS
0–30 cm ISNT + OM	*	*	*	*
0–30 cm ISNT + OM + clay	*	NS	NS	NS
0–30 cm ISNT + OM + sand	NS	NS	NS	NS

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

† Soil parameters indicated were included with treatment as fixed effects, with full interactions of all fixed effects in separate random locations models. Indicated significance levels are for the highest interaction of each model, which included treatment and all parameters in each row.

‡ PSNT, presidedress nitrate test by Morgan extractable NO_3–N to 30-cm depth; P, Morgan extractable; OM, organic matter to 20-cm depth by loss on ignition; clay content at planting to 20-cm depth; ISNT, Illinois soil N test N from samples taken at planting, just before sidedressing, and at harvest at 0- to 20- or 0- to 30-cm depth.

§ Significant at the 0.1 probability level.

The ISNT was ineffective in explaining sidedress response differences at either 20- or 30-cm sampling depth at planting, at sidedress, or at harvest time (Table 5). However, when OM was included in the model, significant treatment × ISNT × OM interactions ($p < 0.01$) indicated ISNT in combination with OM can be used to determine silage yield, N concentration, N uptake, and milk yield response to sidedress N. Including clay or sand content in models provided minimal improvement except when including clay in models for ISNT samples taken at sidedress time. Various soil sampling depths and times for ISNT minimally affected performance of ISNT and OM models for accounting for sidedress response. Samples taken at sidedress time did not perform as well as those taken at planting or at harvest. Though the ISNT measures a relatively stable fraction of soil N, the labile nature of amino sugar N should result in moderate fluctuations over the growing season with N cycling (Klapwyk et al., 2006). It is possible that moderate fluctuations in ISNT may have weakened the performance of the ISNT at sidedress time. However, this is less relevant as successful adoption of the ISNT in New York requires that sampling can be done before planting and with cores taken over a 20-cm depth.

Results from least square means gave an indication of the relationship of ISNT and OM in predicting test levels where yield response to sidedress N might be expected. Regression analysis of ISNT critical values (samples taken at planting over 0–20 cm) separating responsive from nonresponsive sites (i.e., where $p = 0.05$) for the range of OM found in these trials, showed a quadratic relationship (Fig. 1):

$$\text{ISNT critical values} = 126.36 + (4.0944 \times \text{OM}) - (0.0199 \times \text{OM}^2) \quad [1]$$

$$r^2 = 0.985;\ n = 32$$

Organic matter levels for the trials in this study ranged from 26 to 94 g kg^{-1} with median of 53 g kg^{-1} and mean of 54 g kg^{-1} (Table 1). In the 25 field trials used by Khan et al. (2001) to develop the ISNT, OM levels (assuming

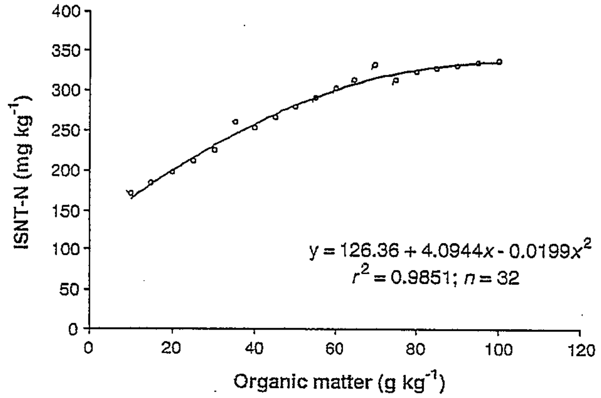

Fig. 1. Separation of locations where silage yield response to sidedress N is expected with 95% confidence (below curve) and is not expected (above the curve) based on organic matter and Illinois soil N test (ISNT) results from 32 field trials in New York.

OM = organic C × 1.7) ranged from 10 to 47 g kg^{-1} with a median of 28 g kg^{-1} and a mean of 29 g kg^{-1}. Solving Eq. [1] for 29 g kg^{-1} OM gives an ISNT critical value of 228 mg kg^{-1}, which is consistent with the critical range of 225 to 235 mg kg^{-1} as originally proposed by Khan et al. (2001) for preplant samples to a 30-cm depth.

This study was designed to encompass the broad spectrum of farming practices (i.e., tillage, rotation, manure application, etc.) of New York corn producers. Many of the farm sites did not have recent manure application records and it was not always certain what applications had occurred in the springtime. Spring manure additions could influence ISNT levels and N responsiveness in two ways. First, sampling shortly after manure addition could result in overestimation of the organic N fraction as the ISNT measures ammonium N in addition to estimating amino sugar N. A comparison of ISNT values of the three different sampling times employed in this study (at planting, at sidedress, and at harvest) showed very similar ISNT levels over time indicating that ammonium from manure was not likely influencing the conclusions of this study. Second, spring manure applications followed by direct-incorporation can conserve inorganic N. This could lead to high NO_3–N levels that would not be detected by the ISNT but could mask N response as tested by the fertilizer treatments. Limited site records supplied by the producers indicated that for only two trials (Trials 4 and 7) manure had been applied and incorporated shortly before planting. Analysis of the dataset without these two trials did not affect our conclusions and thus the full 33 trial dataset was used for this study.

CONCLUSIONS

The results from this study indicate that ISNT may estimate a potentially available pool of mineralizable N, but that additional consideration of soil OM is needed for crediting contributions of that pool for crop N supply. Our results suggest that soil samples taken to 20 cm at planting and analyzed for both ISNT and OM can be used to predict the need for additional N for corn beyond starter fertilizer in New York. Possibly the biggest advantage in implementation of the ISNT, and motivation for further development of this test, lies in its potential for use by the majority of corn producers who apply additional N (beyond starter N) as preplant broadcast N.

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