Assessment of the Amino Sugar–Nitrogen Test on Iowa Soils: I. Evaluation of Soil Sampling and Corn Management Practices

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ABSTRACT

A soil N test capable of measuring the soil organic N fraction that contributes to plant available N would be useful to corn (*Zea mays* L.) producers as they make N fertilizer rate decisions. The objectives of this study were to evaluate the effects of soil sampling time, sampling depth, long-term crop rotation, and long-term N fertilizer application on the amino sugar–N test (ASNT). Soil samples from 43 N rate trials were analyzed using the ASNT procedure. The ASNT was also determined on soil samples from two sites having several crop rotations and N fertilizer rates in place for the past 18 and 24 yr. The ASNT results were consistent over time but show variation from week to week and were more variable at sites with high soil organic C or manure application history. Amino sugar–N test values from the 0- to 15-cm soil depth were usually greater than the 15- to 30-cm or 0- to 30-cm depths. Crop rotations that included alfalfa (*Medicago sativa* L.) resulted in greater ASNT values than continuous corn and corn rotated with soybean [*Glycine max* (L.) Merr.]. Therefore, sampling depth and rotation should be taken into consideration when calibrating the ASNT. Long-term N fertilization rate did not consistently influence ASNT values. Differences between soils had larger effects on the ASNT than corn management practices. Sampling before N application in the fall, early spring before planting, or late spring during the growing season should provide similar ASNT results and flexibility in sample collection before N application.

Soil N testing can be an important component of managing N fertilizer for corn in the U.S. Corn Belt. A significant amount of N available to corn during the growing season originates from readily mineralized soil organic N. Researchers have proposed numerous chemical and biological methods for measuring various organic N fractions in soil (Stevenson, 1957a, 1957b; Cornfield, 1960; Keeney, 1965; Keeney and Bremner, 1966a, 1966b; Stanford, 1968; Smith and Stanford, 1970; Fox and Piekielek, 1978a, 1978b; Stanford, 1978). The methods with promising results for estimating mineralizable N have been too complex or time consuming to be adopted by most soil testing laboratories. For example, the standard procedure for fractionating components of organic soil N requires acid hydrolysis of soil under reflux for 12 to 24 h. Steam distillation is then used for quantitative determination of the N fractions in the soil hydrolysate. Some limitations of the procedure are that amino sugar–N can be partially destroyed by acid hydrolysis (and subsequently underestimated), and the amount of amino sugar–N must be calculated by subtracting the amount of NH_3–N recovered in separate distillation procedures (Stevenson, 1996).

Researchers in Illinois have been working to correct deficiencies in the determination of amino sugar–N in soil using an improved technique for fractionating N in soil hydrolysates (Mulvaney and Khan, 2001). Mulvaney and Khan (2001) used a diffusion method that is more accurate and specific than steam distillation. Quantitative analysis of a group of diverse Illinois soils for amino sugar–N was 74 to 317% greater with diffusion than with steam distillation. Further work by Mulvaney et al. (2001) using the improved fractionation technique revealed that amino sugar–N in soil hydrolysates was highly correlated with check plot yield and N fertilizer response in corn. The amount of hydrolyzable amino sugar–N correctly classified 18 soils as responsive or nonresponsive to N fertilizer.

A simpler N soil test was later developed for use as a routine soil test based on direct soil diffusion by heating with NaOH (Khan et al., 2001). The concept of this alkali diffusion procedure is to quickly and easily estimate the amino sugar–N fraction rather than using the difficult and lengthy fractionation process. The procedure was highly correlated with hydrolyzable amino sugar–N. The results of the method also include exchangeable NH_4–N. Khan et al. (2001) concluded that the simple N soil test accurately classified 25 Illinois soils as responsive or nonresponsive to N fertilizer application. Hoeft and Nafziger (2002) refer to this simplified N soil test as the Illinois N soil test (amino sugar–N test), but it is referred to in this paper as the amino sugar–N test (ASNT). They also indicated that additional research was needed to establish soil sampling protocols, to assess accuracy of the test over a wide range of soils and growing conditions, and to determine if crop and N management practices affect ASNT values.

Few studies have been conducted to ascertain the change in ASNT values over time during the growing season. A temporal study in Minnesota found a small decline in test values during the summer months of the growing season and greater ASNT variability at the 15- to 30-cm depth compared with the 0- to 15-cm depth (Randall and Vetsch, 2002). Also, the 0- to 15-cm depth had consistently greater ASNT values than the 15- to 30-cm depth. Hoeft et al. (2005) analyzed soil samples from four U.S. Midwest states and reported a similar trend of ASNT values, with test values decreasing in early summer. However, the change in ASNT values was not consistent across locations. Ellsworth et al. (2005) found the highest ASNT values in early spring and late summer at four Illinois sites. Studies conducted

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Published in Agron. J. 98:1345–1351 (2006).
Nitrogen Management
doi:10.2134/agronj2006.0033

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Abbreviations: ASNT, amino sugar–nitrogen test; CCCC, continuous corn; CCOA, corn–corn–oat–alfalfa; CCS, corn–corn–soybean; COA, corn with alfalfa in the rotation; COAA, corn–oat–alfalfa–alfalfa; CS, corn with soybean in the rotation; CSCS, corn–soybean–corn–soybean.

in fields with different crop management, such as tillage practice, crop rotation, or N fertilizer and manure application history, have not established clear relationships to changes in the ASNT (Mulvaney et al., 2004; Ellsworth et al., 2005; Hoeft et al., 2005).

The objectives of this study were to evaluate the effects of soil sampling time, soil sampling depth, long-term crop rotation, and long-term N fertilizer application on ASNT values across Iowa soils and climatic conditions.

MATERIALS AND METHODS

Nitrogen Rate Trial Description

Nitrogen fertilizer rate trials were conducted during 2001–2003 at 43 sites in Iowa. Trials were located on producer fields and were chosen to represent major soil regions across corn production areas in Iowa (Table 1). The crop grown before the year studied at all sites was soybean. There was no manure applied during the fall or spring before the study year. Corn management practices, such as hybrid selection, tillage system, and weed and insect control, were chosen by the producer and intended to produce high corn yield. Plot size varied from four to eight rows wide (76, 86, or 97-cm row spacing) by 15-m in length. Nitrogen fertilizer rates were a no-N control, 45, 90, 135, 180, and 225 kg N ha^{-1} applied as dry, granular NH_4NO_3 broadcast by hand on the soil surface shortly after planting. Nitrogen rates were replicated four times in a randomized complete-block design at each site.

Soil Sampling at Nitrogen Rate Trials

Soil samples were collected at three sampling periods and two sample depths. Soil sampling periods were in October

Table 1. Characterization of the 43 N rate trial sites, 2001–2003.

			Field history‡			
Site†	Soil series	Soil classification	N fert.§	Corn yield	Manure¶	Tillage#
			kg ha^{-1}	Mg ha^{-1}		
		2001				
1	Canisteo clay loam	fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls	157	9.6	none	CNT
2	Clarion loam	fine-loamy, mixed, superactive, mesic Typic Hapludolls	157	9.6	none	CNT
3	Colo silty clay loam	fine-silty, mixed, superactive, mesic Cumulic Endoaquolls	148	8.7	swine 1996	MT
4	Nicollet clay loam	fine-loamy, mixed, superactive, mesic Aquic Hapludolls	146	9.5	none	MT
5	Clyde silty clay loam	fine-loamy, mixed, superactive, mesic Typic Endoaquolls	157	10.3	none	MT
6	Kenyon loam	fine-loamy, mixed, superactive, mesic Typic Hapludolls	168	10.0	cattle 1999	CNT
7	Mahaska silty clay loam	fine, smectitic, mesic Aquertic Argiudolls	151	10.0	none	MT
8	Galva silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	146	9.8	none	CVT
9	Marshall silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	168	10.3	none	MT
10	Marshall silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	168	9.3	none	CNT
11	Zook silty clay loam	fine, smectitic, mesic Cumulic Vertic Endoaquolls	168	10.7	none	CNT
12	Tama silty clay loam	fine-silty, mixed, superactive, mesic Typic Argiudolls	190	9.3	cattle 2000	MT
13	Nevin silty clay loam	fine-silty, mixed, superactive, mesic Aquic Argiudolls	168	9.4	none	NT
14	Webster silty clay loam	fine-loamy, mixed, superactive, mesic, Typic Endoaquolls	196	10.6	none	CVT
		2002				
15	Zenor sandy loam	course-loamy, mixed, superactive, mesic Typic Hapludolls	84	10.8	swine 2001	CNT
16	Webster silty clay loam	fine-loamy, mixed, superactive, mesic, Typic Endoaquolls	140	10.7	none	MT
17	Exira silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	134	9.1	swine 2000	NT
18	Galva silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	179	10.7	none	ST
19	Galva silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	112	9.4	swine 2000	MT
20	Marcus silty clay loam	fine-silty, mixed, superactive, mesic Typic Endoaquolls	129	10.2	none	MT
21	Downs silt loam	fine-silty, mixed, superactive, mesic Mollic Hapludalfs	112	9.5	none	NT
22	Downs silt loam	fine-silty, mixed, superactive, mesic Mollic Hapludalfs	112	10.0	cattle 1990	NT
23	Marshall silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	149	10.8	none	MT
24	Marshall silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	157	9.2	none	MT
25	Macksburg silty clay loam	fine, smectitic, mesic Aquic Argiudolls	168	9.4	none	NT
		2003				
26	Clarion loam	fine-loamy, mixed, superactive, mesic Typic Hapludolls	174	10.2	none	CNT
27	Webster silty clay loam	fine-loamy, mixed, superactive, mesic, Typic Endoaquolls	168	9.8	none	MT
28	Galva silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	179	11.0	none	ST
29	Marcus silty clay loam	fine-silty, mixed, superactive, mesic Typic Endoaquolls	157	9.9	none	CNT
30	Kenyon loam	fine-loamy, mixed, superactive, mesic Typic Hapludolls	–	–	none	CNT
31	Fayette silt loam	fine-silty, mixed, superactive, mesic Typic Hapludalfs	134	8.2	none	CNT
32	Clyde silty clay loam	fine-loamy, mixed, superactive, mesic Typic Endoaquolls	157	10.3	none	NT
33	Kennebec silt loam	fine-silty, mixed, superactive, mesic Cumulic Hapludolls	168	9.7	swine 1998	NT
34	Monona silt loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	168	9.4	none	NT
35	Dinsdale silty clay loam	fine-silty, mixed, superactive, mesic Typic Argiudolls	196	10.3	none	CVT
36	Mahaska silty clay loam	fine, smectitic, mesic Aquertic Argiudolls	151	9.7	none	MT
37	Haig silt loam	fine, smectitic, mesic Vertic Argiaquolls	224	10.3	none	CVT
38	Webster silty clay loam	fine-loamy, mixed, superactive, mesic, Typic Endoaquolls	134	9.7	none	CNT
39	Marshall silty clay loam	fine-silty, mixed, superactive, mesic Typic Hapludolls	168	10.3	none	NT
40	Tama silty clay loam	fine-silty, mixed, superactive, mesic Typic Argiudolls	190	9.3	cattle 2000	NT
41	Otley silty clay loam	fine, smectitic, mesic Oxyaquic Vertic Argiudolls	196	11.3	swine 2000	MT
42	Downs silt loam	fine-silty, mixed, superactive, mesic Mollic Hapludalfs	123	10.7	none	MT
43	Kossuth silty clay loam	fine-loamy, mixed, superactive, mesic Typic Endoaquolls	–	–	–	CNT

† Five of the study sites in 2001 (2, 5, 7, 9, and 12) were also study sites in 2003 (26, 32, 36, 39, and 40).
‡ Management practices of the producer during the 5-yr period before the study.
§ Past N fertilization rate when corn was grown.
¶ Swine (*Sus scrofa*); cattle (*Bos taurus*). Year indicates the most recent application before the study.
# CVT, conventional tillage; CNT, conservation tillage; MT, minimum tillage; ST, strip tillage; NT, no-tillage.

after soybean harvest before the crop year studied (fall), in late March to early April before planting (early spring), and in late May to early June when the corn was 15- to 30-cm tall (late spring). Samples from the fall and early spring consisted of 12 soil cores (19 mm i.d.) collected at random from each of the four replications before N fertilizer application at each site. Samples collected in late spring consisted of 12 soil cores (19 mm i.d.) collected at random from the no-N control plots at each site. Soil samples were collected from each sampling period at the 0- to 15-cm and 0- to 30-cm depths. A ratio of the two soil sample depths (ASNT values from the 0- to 15-cm depths divided by ASNT values from the 0- to 30-cm depths) was used to characterize the test in relation to soil sample depth. A ratio of 1.0 indicates the ASNT values in both depths were the same, >1.0 indicates greater ASNT values in the 0- to 15-cm sample, and <1.0 indicates greater ASNT values in the 0- to 30-cm sample.

Temporal Soil Sampling

Four N rate trial sites (Sites 15 and 16 in 2002 and Sites 26 and 32 in 2003) were soil sampled every 7 to 14 d from one of four no-N control plots at each site. Sampling began at each of these sites in the fall before the study year after soybean harvest in October and continued until the soil surface was frozen. Soil sampling resumed in early spring as soon as the soil surface thawed and continued through the growing season until the end of September. A permanent flag in the middle of the plots was used to locate the same sampling area each time. Five soil cores (19 mm i.d.) were sampled from the same areas within the plots at the 0- to 15-cm and 15- to 30-cm soil depths.

Long-Term Crop Rotation and Nitrogen Fertilization Study Description

Two continuous crop rotation-N fertilization studies were soil sampled in October 2002 after harvest. The studies were conducted at two Iowa State University Research and Demonstration Farms located at Kanawha and Nashua. The studies had been in place for the past 18 and 24 yr, respectively, before sampling. The soil at Kanawha was a Kenyon loam (fine-loamy, mixed, superactive, mesic Typic Hapludolls). The soil at Nashua was a Canisteo clay loam (fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls). Treatments included four crop rotations and four N fertilizer rates with two replications at Kanawha and three replications at Nashua. The rotations at Kanawha were continuous corn (CCCC), corn–soybean–corn–soybean (CSCS), corn–corn–oat (*Avena sativa* L.)–alfalfa (CCOA), and corn–oat–alfalfa–alfalfa (COAA). The rotations at Nashua were CCCC, CSCS, corn–corn–soybean (CCS), and CCOA. Nitrogen fertilizer rates of no-N control, 90, 180, and 270 kg N ha^{-1} were applied as urea incorporated before corn planting each year in the rotation. Crop rotations were arranged in a randomized complete-block design with the four fertilizer N rates nested within each crop rotation. Twelve soil cores (19 mm i.d.) were collected at random from the 0- to 15-cm depth in each fertilizer N rate-crop rotation combination when corn was to be planted in 2003.

Soil Sample Handling and Analysis

All soil samples were dried or frozen within 6 h of collection from the field. Samples were dried at 40°C in a forced-air oven and ground to pass through a 2-mm sieve (James and Wells, 1990). The Iowa State University Soil Testing Laboratory analyzed soil samples for pH, organic C, P, K, presidedress soil NO_3–N test, and total soil N. Soil pH was determined using a 1:1 soil water paste (Watson and Brown, 1998). Total soil N and organic C was determined by dry combustion using a LECO CHN-2000 analyzer (LECO Corp., St. Joseph, MI) (Nelson and Sommers, 1996). Phosphorus and K were determined using the Mehlich-3 extraction method (Frank et al., 1998; Warncke and Brown, 1998). Nitrate-N was analyzed using colorimetric cadmium reduction (Gelderman and Beegle, 1998). Exchangeable NH_4–N was determined using direct soil diffusion (Khan et al., 2000). The ASNT was performed in duplicate on each soil sample using direct soil diffusion (Khan et al., 2001; Mulvaney, 2006).

Statistical Analysis

The PROC GLM procedure was used for all statistical analysis (SAS Institute, 2001). A linear regression model was used to compare ASNT values collected at different timings. Standard deviation of the mean was calculated to compare temporal variation in ASNT values. Analysis of variance was used to analyze the effects of soil depth and crop rotation on ASNT values. Soil depth and crop rotation differences were considered statistically significant at the 0.05 probability level. Quadratic and linear regression models were used to characterize the effects of long-term N fertilizer application on ASNT values at each of the crop rotation–N fertilization study sites.

RESULTS AND DISCUSSION

Soil Sampling Periods at Nitrogen Rate Trials

To analyze the effects of different soil sampling periods, comparisons were made between soil collected from the 0- to 30-cm depth in fall, early spring, and late spring (Fig. 1). The results for both depths sampled were

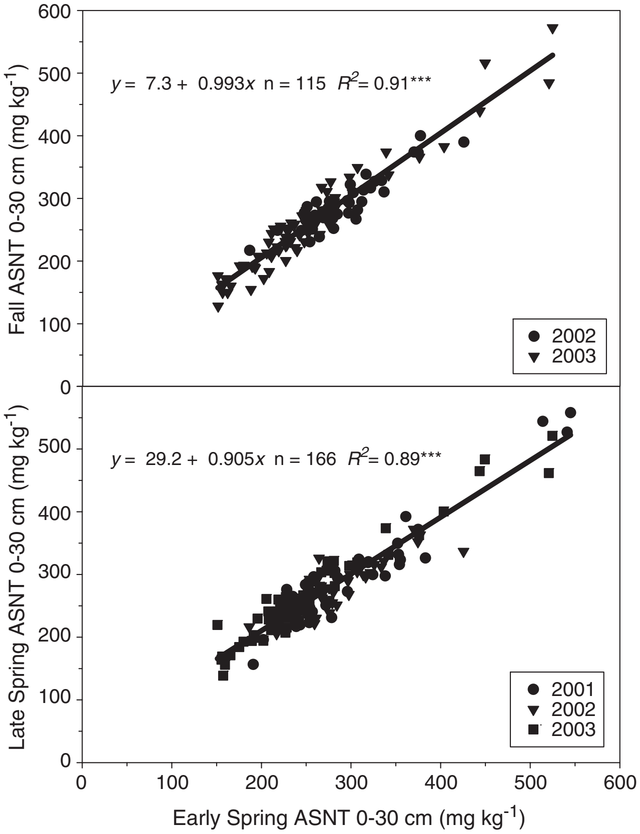

Fig. 1. Comparison of amino sugar–N test (ASNT) values from soil collected at the 0- to 30-cm depth in fall, early spring, and late spring at 43 N rate trials. ***Statistically significant at the 0.001 probability level.

similar; therefore, only data from the 0- to 30-cm depth are shown (Fig. 1). The fall vs. early spring sampling periods show a strong linear relationship ($R^2 = 0.91^{***}$), with little change occurring during the winter months in Iowa (7 mg kg^{-1} greater ASNT in fall). Temperatures between the fall and early spring periods are typically below 10°C, which dramatically reduces soil microbial activity and subsequent N cycling between these two sampling times. The early spring vs. late spring comparison also showed a strong linear relationship ($R^2 = 0.89^{***}$) between the two sampling periods. The trend of ASNT concentrations for samples collected in late spring was 29 mg kg^{-1} greater than samples from early spring. The ASNT increase in late spring may be due to greater soil microbial activity and N processing with warmer temperatures. This is also the period in Iowa with the greatest amount of rainfall. The increased potential for leaching and runoff of soil N from rainfall between the early and late spring periods did not reduce ASNT values.

Studies from neighboring states have reported small decreases in ASNT values in early summer (Randall and Vetsch, 2002; Hoeft et al., 2005), whereas others have observed greater ASNT values in early spring and in late summer (Ellsworth et al., 2005). In Iowa, these ASNT values are consistent, given the diverse climatic conditions between sampling periods. Soil conditions historically range from dry and cool in fall to moist and warm in late spring.

Temporal Soil Sampling

Figure 2 shows the ASNT values from four N rate trials sampled every 7 to 14 d beginning in the previous fall after soybean harvest until winter and continuing in spring through the growing season until corn harvest. The fall, early spring, and late spring sampling periods reported in Fig. 1 are indicated by vertical dashed lines in Fig. 2. Site 32 had the greatest yearly average ASNT concentration (637 mg kg^{-1}, 0- to 15-cm depth) and was the most variable over time (SD = 39). The yearly average ASNT concentrations at other sites for the 0- to 15-cm depth were 333 (SD = 23), 256 (SD = 13), and 230 mg kg^{-1} (SD = 8) at sites 15, 26, and 16, respectively. Comparison of ASNT values within the 14-d sampling period in the fall at Site 32 showed especially large differences. The ASNT concentrations increased by 47 mg kg^{-1} and then decreased by 105 mg kg^{-1} in this short period. In the early spring sampling period, ASNT concentrations at Site 15 were also variable, decreasing by 26 mg kg^{-1} and then increasing by 51 mg kg^{-1}.

Figure 2 also shows the ASNT values over time at the 15- to 30-cm soil depth. The yearly average ASNT concentrations for each site were 508 (SD = 63), 290 (SD = 22), 274 (SD = 18), and 244 mg kg^{-1} (SD = 13) at Sites 32, 26, 15, and 16, respectively. The ASNT results at the 15- to 30-cm depth were more variable than at the 0- to 15-cm depth for some sites, especially at Site 32 (SD = 63). Sites with larger ASNT values also showed more variability (larger SD) from week to week.

Sites 15 and 32 had larger average ASNT values in the 0- to 15-cm depth than the 15- to 30-cm depth, whereas sites 16 and 26 had larger average ASNT values in the 15- to 30-cm depth. Amino sugar–N test results reported in other studies were also consistent over time and had larger variability at the 15- to 30-cm depth, and the 0- to 15-cm depth had consistently larger ASNT values than the 15- to 30-cm depth (Randall and Vetsch, 2002; Hoeft et al., 2005). This trend was evident in only two of the four sites that were sampled throughout the year in Iowa. Sites 15 and 32 had greater surface ASNT values and were high in soil organic C (Site 32, Table 2) or had a history of manure application (Site 15, Table 1). The study areas with greater ASNT values at the 15- to 30-cm depth compared with the 0- to 15-cm depth (Sites 16 and 26) may be soils that have experienced surface erosion due to continuous row cropping, may have leaching of N components to the subsurface, or may possess natural soil depth variability.

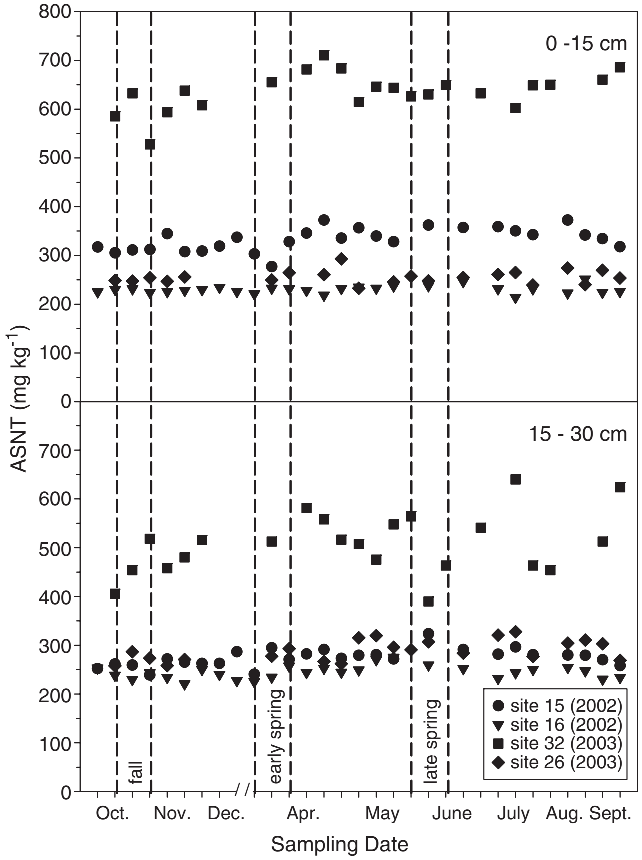

Fig. 2. Amino sugar–N test (ASNT) values from four N rate trials sampled throughout the year in 2002 and 2003 at two soil depths. Vertical dashed lines show the change in ASNT values between 14 d sampling periods in fall, early spring, and late spring sampling periods.

Some of the ASNT variability from week to week may be a reflection of lab analysis variability associated with the procedure. An example is the potential variability in diffusion temperature between samples during analysis as noted by Khan et al. (2001) and Klapwyk and Ketterings (2005).

Soil Sampling Depth at Nitrogen Rate Trials

Figure 3 shows ASNT values at two soil sample depths (0- to 15-cm and 0- to 30-cm) and the ratio of ASNT

Table 2. Routine soil tests, exchangeable NH_4–N, and total soil N for the 43 N rate trial sites, 2001–2003.

Site	Routine soil tests†				PSNT‡	Exchangeable NH_4–N§		Total soil N§	
	pH	Organic C	P	K		0–15 cm	0–30 cm	0–15 cm	0–30 cm
		g kg^{-1}	mg kg^{-1}						
1	8.1	35.6	28	89	7	26	10	2751	2290
2	6.0	23.8	19	109	5	19	13	1566	1556
3	6.5	21.4	44	272	6	20	17	1617	1501
4	7.0	29.6	43	174	13	20	12	2140	1733
5	6.3	49.9	32	114	12	31	15	4293	3255
6	7.5	21.7	149	324	30	22	14	1848	1494
7	6.3	21.2	43	292	4	21	12	1576	1422
8	7.1	27.4	63	354	5	25	14	2229	2032
9	7.5	22.4	29	246	9	22	10	1730	1533
10	5.8	21.1	18	279	9	25	10	1600	1494
11	7.1	22.1	162	420	8	23	11	1693	1653
12	7.9	19.6	49	190	6	21	7	1081	1125
13	6.5	20.7	25	209	3	19	16	1253	1459
14	6.1	29.3	29	140	10	23	21	1804	1809
15	6.3	21.6	183	308	12	21	12	1928	2008
16	6.1	21.1	23	136	8	18	22	2111	1877
17	6.2	23.9	110	379	10	24	14	2521	2349
18	6.4	25.4	22	166	11	25	15	2597	2295
19	5.9	26.0	46	208	12	28	17	2691	2270
20	6.5	33.9	27	196	11	26	17	3273	3094
21	6.8	21.6	22	141	13	24	21	2282	2023
22	7.4	25.5	202	383	17	21	20	2478	2113
23	7.2	21.6	33	239	22	20	16	2237	2002
24	6.0	18.6	21	232	11	18	12	2080	1935
25	6.5	21.4	26	188	9	20	20	2102	2003
26	6.0	23.8	19	109	10	17	18	2021	1892
27	7.4	32.5	19	150	20	20	16	2667	2620
28	5.5	25.4	34	160	10	15	14	2569	2407
29	6.1	34.7	36	167	7	15	13	2943	2876
30	6.8	13.2	29	142	8	8	9	1404	1072
31	5.6	15.5	12	95	–	26	24	1610	1292
32	6.3	49.9	32	114	13	20	16	4317	4071
33	5.7	16.4	42	397	10	12	12	1668	1473
34	5.8	15.9	38	214	10	12	10	1873	1710
35	6.6	23.2	39	139	17	18	15	1890	1869
36	6.3	21.2	43	292	5	17	11	2113	1822
37	6.9	21.0	35	148	10	18	10	1833	1598
38	7.2	33.5	35	165	8	19	13	2945	2390
39	7.5	22.4	29	246	10	17	13	2265	1965
40	7.9	19.6	49	190	7	16	13	1664	1431
41	6.3	21.5	28	218	11	20	15	2091	1766
42	6.0	19.7	15	117	9	21	19	1989	1862
43	6.8	27.9	17	151	9	20	16	2473	2252

† Soil collected in fall or early spring before N application at the 0- to 15-cm soil depth. Mehlich-3–extracted P and K.

‡ Soil collected in late spring when the corn was 15- to 30-cm tall from the no-N control plots at the 0- to 30-cm soil depth. PSNT, pre-sidedress soil NO_3–N test.

§ Soil collected in early spring before N application.

values for the two sample depths (0- to 15-cm divided by 0- to 30-cm). The majority of soils had greater ASNT values at the 0- to 15-cm depth (ratio > 1.0), although there were some soils with greater ASNT values at the 0- to 30-cm soil depth (ratio < 1.0). There was a statistically significant difference between the two sample depths. Among years, the average ASNT at the 0- to 15-cm depth compared with the 0- to 30-cm depth was statistically greater ($p < 0.01$) by 31, 18, and 27 mg kg^{-1} in 2001, 2002, and 2003, respectively. The overall difference in ASNT concentrations between the two sample depths was 25 mg kg^{-1} greater ($p < 0.01$) for the 0- to 15-cm depth.

The ASNT values in soils from this study differed with soil sample depth (Fig. 3), but no trends with past management, such as tillage practice or manure application (Table 1), could explain the ASNT differences in sample depth among sites. These site differences were also evident in the total soil N for the two sample depths (Table 2). Total soil N was generally greater in the 0- to 15-cm depth, although some sites possessed greater total soil N in the 0- to 30-cm depth.

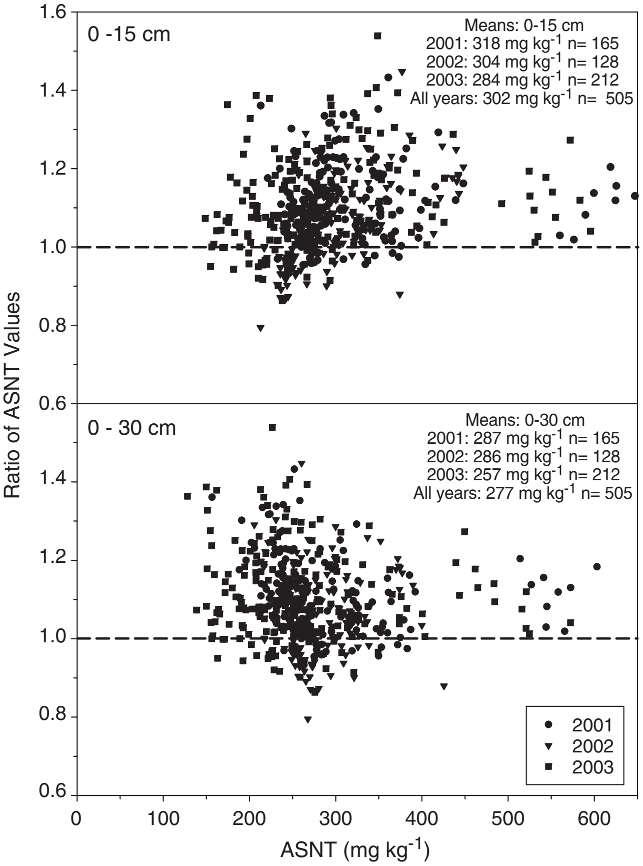

Fig. 3. Comparison of amino sugar–N test (ASNT) values at two sample depths and the ratio of ASNT values (0- to 15-cm divided by 0- to 30-cm) at 43 N rate trials. Test values are from fall, early spring, and late spring sampling periods.

Long-Term Crop Rotation

Figure 4 compares ASNT values for several crop rotations. At each site, there were no statistically significant differences between CCOA and COAA or between CSCS and CCS rotations; therefore, they were combined into corn with alfalfa in the rotation (COA) and corn with soybean in the rotation (CS). The interaction between crop rotation and N rate was not statistically significant at either site. At Kanawha, the COA rotation had an ASNT concentration that was 47 mg kg^{-1} larger ($p = 0.01$) than the ASNT concentration in the CCCC rotation and 29 mg kg^{-1} greater ($p = 0.02$) than the CS rotation. The ASNT difference between the CCCC and CS rotations was 18 mg kg^{-1} but was not statistically significant. At Nashua, the ASNT concentrations in the CCCC and COA rotations were statistically the same (267 mg kg^{-1}, $p = 0.97$), and the ASNT in the CS rotation was 25 mg kg^{-1} less ($p = 0.01$) than the CCCC and COA rotations. The effects of CCCC or CS on ASNT values were not consistent between sites,

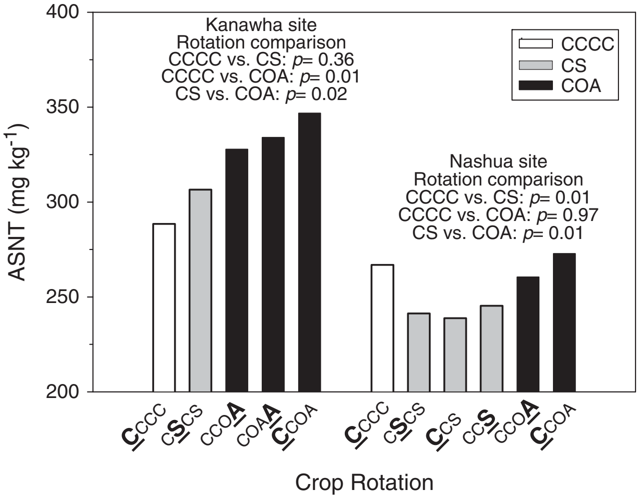

Fig. 4. Amino sugar–N test (ASNT) values as a result of long-term crop rotation history. Soil samples were collected in the fall of 2002 after harvest and when corn was to be planted in the rotation in 2003. The bold, underlined crop letter indicates the crop in the rotation when the soil samples were collected. CCCC, continuous corn; CCOA, corn–corn–oat–alfalfa; CCS, corn–corn–soybean; COA, corn with alfalfa in the rotation; COAA, corn–oat–alfalfa–alfalfa; CS, corn with soybean in the rotation; CSCS, corn–soybean–corn–soybean.

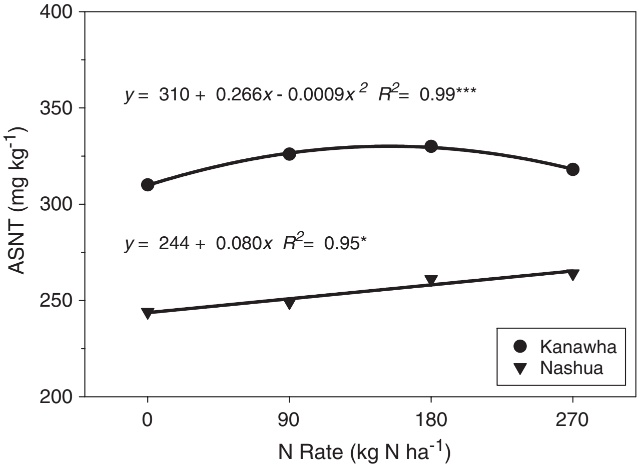

Fig. 5. Amino sugar–N test (ASNT) values as a result of long-term N fertilizer application history. Soil samples were collected in the fall of 2002 after harvest and when corn was to be planted in the rotation in 2003. *Statistically significant at the 0.05 level. ***Statistically significant at the 0.001 probability level.

but including alfalfa in the rotation resulted in the greatest ASNT values. The greater ASNT values for the COA rotation at Kanawha indicate the ASNT may be capable of detecting the level of N response in some soils. When alfalfa is in the rotation, corn response to applied N is typically reduced (Morris et al., 1993). However, the increase in ASNT values with alfalfa in the rotation was not consistent between sites, which may limit the usefulness of the ASNT to predict change in soil N supply in corn across many soils.

Long-Term Nitrogen Fertilizer Application

Long-term N fertilization rate had a much smaller effect on ASNT values than crop rotation (Fig. 5). At Nashua, there was a small but statistically significant linear increase in ASNT concentrations from no-N to the highest N rate (<20 mg kg^{-1}). At Kanawha, ASNT values increased up to 180 kg N ha^{-1} (20 mg kg^{-1} increase above the no-N rate) and then decreased with the 270 kg N ha^{-1} rate. These results indicate the ASNT is not sensitive to large differences in long-term N application rates.

CONCLUSIONS

Amino sugar–N test values are relatively consistent over time for soils in Iowa. However, soils high in organic C or having prior manure applications can possess considerably more ASNT variability. Amino sugar–N test values varied more among soils than among sampling periods. There were no trends to suggest that a specific sampling period (fall, early spring, or late spring) would result in different ASNT results; therefore, any of these time periods would be appropriate for sampling. A majority of Iowa producers apply N fertilizer before corn planting. Collecting soil samples in the fall or early spring would accommodate those producers and those who sidedress N in late spring.

The 0- to 15-cm sampling depth generally had greater ASNT values, although there were some exceptions to this trend. Specific soil depths should be considered when calibrating the ASNT to corn N response. The ASNT was originally developed in Illinois for analysis of soil collected at the 0- to 30-cm soil depth in spring before planting (Mulvaney, 2006). This timing and depth should be confirmed through calibration studies in other geographic regions.

Crop rotations that included alfalfa can produce greater ASNT values. Rotations that include perennial crops may need to be accounted for when interpreting ASNT results. Other practices, such as high N fertilizer application, manure application history, or corn with soybean in the rotation, did not significantly affect ASNT values.

ACKNOWLEDGMENTS

Appreciation is extended to the cooperators for their time and use of production fields. Also, appreciation is extended to A.P. Mallarino for soil samples collected from the long-term crop rotation and N fertilization study sites. This work was supported in part by the Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation through funds appropriated by the Iowa General Assembly for the Integrated Farm and Livestock Management Demonstration Program.

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