WHAT DOES THE LATE-SPRING SOIL TEST REALLY MEASURE?

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The late-spring test for soil nitrate has been available in Iowa for about 10 years. Guidelines for using this test clearly indicate that the test measures concentrations of nitrate in the surface foot of soil when corn plants are 6 to 12 inches tall. Ongoing discussions concerning the reliability of the soil test, however, indicate uncertainty in what should be concluded from the soil nitrate concentrations measured.

It is generally accepted that measured soil nitrate concentrations indicate "N availability" in soils and "N fertilizer needs" for crops. The terms "N availability" and "N fertilizer needs", however, lack quantitative and universally accepted definitions. The use of such terms, therefore, causes uncertainty about what the soil test really measures. This uncertainty makes it impossible to define the reliability of the soil test and leaves opportunity for endless discussions that are more philosophical than scientific.

The objective of this paper is to offer a new way to explain what soil nitrate concentrations really measure. The new explanation includes estimates of the uncertainty associated with interpretations of soil nitrate concentrations. Data from many response trials are used to demonstrate how the new explanation can be used to interpret results of the late-spring test for soil nitrate.

Realistic Expectations of the Soil Test

The soil test should not be expected to predict yields of corn. Yield levels often are influenced by soil nitrate concentrations, but they also are influenced by many other factors (hybrid, water availability, temperature, insect damage, competition from weeds, planting density, soil compaction, availability of other nutrients, etc.). No useful relationship between soil nitrate concentrations and yields should be expected across the range of conditions normally found in Iowa cornfields.

The soil test should not be expected to predict yield responses to added N in individual cornfields. Yield responses to added N in individual fields are influenced by all the factors that influence yields. In addition, they are influenced by how much of the N applied could be used by the plant. The soil test, for example, obviously could not be expected to predict losses of fertilizer N by ammonia volatilization soon after application.

When properly calibrated, a good soil test indicates the probability of a yield response on a given field and the mean yield response that could be expected across many fields having similar soil nitrate concentrations. Grouping soils by measured soil nitrate concentrations is useful because soil nitrate concentrations are a major factor affecting responses to N fertilization. By definition, calibration of a soil test refers to the process of defining relationships between soil test values and yield responses to N. The relationships should be established by making observations across a range of conditions representative of those found where the soil test is used.

The late-spring test for soil nitrate was calibrated in Iowa by using data collected in N-response trials where various amounts of fertilizer N or animal manure-N were applied before the corn was planted. This method of calibration focused on identifying the minimum concentration of soil nitrate needed to essentially maximize yields. It is noteworthy that the calibrations did not focus on ability of the soil test to predict yield responses to N on individual fields, especially low-testing fields, because it would be unreasonable to expect any soil test to make such predictions. The soil test can be considered to give "site-specific" information, however, because it shows the net effects of all factors influencing nitrate concentrations at that site.

When prices of fertilizer and grain are considered, the soil test indicates probability of obtaining a profit on a given field and the mean profit that should be expected across many fields having similar nitrate concentrations. Interpretation of soil nitrate tests in terms of expected profits gives appropriate consideration to costs of fertilization and directly addresses the primary reason for fertilization.

Calibrations for Cornfields Treated with Animal Manure

Table 1 shows the effects of soil nitrate concentrations on mean net returns to various fertilization rates across 205 trials on cornfields treated with animal manure. The percentages of sites where each rate of fertilization resulted in a profit are shown in parentheses. These studies were conducted over a period of 6 years, and farmers applied the manure by using their normal practices. Fertilizer (urea or ammonium nitrate) was surface applied shortly after the soils were sampled in early June. The fields were selected to include great variety with respect to rates of manure application, times of manure application, and methods of manure application.

Mean net returns to fertilization are presented for three different grain-to-fertilizer price ratios to show the effects of normal fluctuations in price conditions. Net returns are expressed in terms of bushels of grain per acre to show results that are applicable to all price ratios. Net returns to fertilization can be easily converted to dollars per acre once a relevant price for grain is selected.

Data presented in Table 1 show mean net returns to fertilization were always positive for the lowest soil nitrate category. For soils testing in this category, the highest rate applied in the study gave the highest mean net returns at all price ratios. The end-of-season test for cornstalk nitrate showed that this rate usually supplied sufficient N to maximize yields. In the absence of better information, therefore, this rate should be considered the best rate to apply in the future. This recommendation is not altered by the fact that fertilization was not profitable at many (14 to 36% depending on prices) individual sites testing in this category.

Table 1. Mean net returns to added N across 205 trials on manured cornfields that are grouped by nitrate concentrations before fertilization.

Soil N category	N rate	Mean net returns to added N at various price ratios [a]		
		6	11	22
ppm N	lb/a	----------	bu/a	----------
<10	30	6.9 (79) [b]	9.6 (86)	10.8 (89)
	60	8.0 (68)	13.4 (79)	15.9 (82)
	90	9.6 (64)	17.5 (82)	21.7 (86)
10-14	30	-1.6 (46)	1.1 (52)	2.4 (60)
	60	-1.3 (42)	4.0 (52)	6.7 (58)
	90	-5.6 (29)	2.4 (48)	6.4 (54)
15-19	30	-2.2 (43)	0.5 (55)	1.8 (63)
	60	-2.7 (40)	2.7 (58)	5.4 (65)
	90	-8.1 (20)	-0.2 (45)	4.0 (60)
20-24	30	-5.1 (20)	-2.4 (37)	-1.1 (40)
	60	-7.7 (23)	-2.2 (33)	0.5 (47)
	90	-12.6 (17)	-4.6 (30)	-0.6 (43)
≥25	30	-6.9 (17)	-4.1 (31)	-2.9 (37)
	60	-13.4 (5)	-8.1 (14)	-5.4 (27)
	90	-19.0 (0)	-11.0 (7)	-6.9 (19)

a: Price ratios indicate the number of pounds of N that can be purchased by a bushel of corn. Mean net returns were calculated by subtracting the cost of N fertilizer expressed in bushels of grains from the yield increase due to fertilization. An application cost of 1.6 bu/a was included.

b: Percentage of sites where fertilization resulted in positive net returns.

Table 2. Mean net returns to added N across 70 trials in which fertilizer N was applied before crops were planted. Plots are grouped by soil nitrate concentrations found in late spring and compared to plots that received different rates of N before planting.

Soil N category	N rate	Mean net returns to added N at various price ratios [a]		
		6	11	22
ppm N	lb/a	----------	bu/a	----------
<10	25	7.8 (77) [b]	10.0 (82)	11.2 (85)
	50	16.1 (86)	20.6 (91)	22.8 (95)
	100	29.7 (90)	38.6 (100)	43.1 (100)
10-14	25	4.5 (67)	6.7 (72)	7.8 (73)
	50	6.4 (56)	10.8 (64)	13.1 (74)
	100	9.1 (72)	18.0 (76)	22.5 (88)
15-19	25	2.4 (61)	4.6 (66)	5.7 (68)
	50	0.6 (50)	5.1 (55)	7.3 (60)
	100	-4.3 (31)	4.5 (54)	8.9 (62)
20-24	25	-1.9 (42)	3.2 (59)	1.4 (66)
	50	-2.6 (49)	1.9 (51)	4.1 (63)
	100	-10.7 (19)	-1.8 (33)	2.7 (48)
≥25	25	-2.7 (35)	-0.5 (47)	0.6 (53)
	50	-9.1 (18)	-4.6 (28)	-2.4 (36)
	100	-16.7 (11)	-7.8 (21)	-3.3 (29)

a: Price ratios indicate the number of pounds of N that can be purchased by a bushel of corn. Mean net returns were calculated by subtracting the cost of N fertilizer expressed in bushels of grains from the yield increase due to fertilization. An application cost of 1.6 bu/a was included.

b: Percentage of sites where fertilization resulted in positive net returns.

Mean net returns to fertilization were negative for essentially all combinations of N rates and price ratios when soil nitrate concentrations were greater than 20 ppm. The best recommendation currently available, therefore, is to apply no N to these soils even though fertilization at many individual sites may be profitable.

For soils testing in the range of 10 to 19 ppm, grain-to-fertilizer price ratios were the major factor determining whether or not fertilizers should be applied. Rate of N application was relatively unimportant because the costs of increasing rates of fertilization tended to be offset by small increases in yields. Although any recommendation has a high probability of being wrong in any given field, errors in selecting the best rate within a price ratio have relatively little effect on profits.

Calibrations for Soils Treated with Commercial Fertilizer

Table 2 shows mean net returns to fertilization and probability of obtaining a profit from fertilization in fields that received various rates of commercial fertilizer before planting. The data were collected in studies where many (8 to 10) rates of N were applied, but plots are grouped by soil nitrate concentrations found in late spring and compared with plots receiving higher rates of N before planting in the same trial. Use of these data to select rates of N application during the growing season, therefore, must involve the assumption that N is equally effective whether applied before planting or during the growing season.

Data presented in Table 2 show similar trends to those in Table 1, but increases in rates of N application tended to be profitable at slightly lower concentrations of nitrate. This difference may be due to greater mineralization of N in the manured soils after the soils were tested. This explanation would suggest that soil test values from soils treated with animal manure should be interpreted differently than those from soils treated with commercial fertilizers.

In the calibration studies reported, however, the animal manures were often applied in the fall whereas the commercial fertilizer was usually applied in the spring. Part of the difference between Tables 1 and 2, therefore, could be attributed to movement of N to depths not sampled but within the rooting zone of the crop. Evidence for this explanation is provided by observations that the calibrations in Table 1 seem to be more reliable than those in Table 2 when interpreting results of the soil nitrate test on soils treated with fall-applied anhydrous ammonia. Additional research is in progress to address these and other questions needed to improve interpretations of the soil test.

Concluding Comments

Results of the late-spring test for soil nitrate can be interpreted in terms of probability of obtaining a profit from fertilization of a given field and the mean amount of profit that should be expected across many sites having similar concentrations of nitrate. Such interpretations give meaningful assessments of the uncertainty that accompanies any N recommendation. Meaningful assessments of uncertainty are important because they promote realistic evaluations of the reliability of any recommendation.

Soil testing for nitrate in late spring after soils have been fertilized should be recognized as an important tool for reducing risks associated with N fertilization. Such testing reveals fields where losses of manure or fertilizer N soon after application are likely to cause yield-limiting deficiencies of N. This information can be used to select appropriate rates of N fertilization after losses have occurred and to select fertilization practices that minimize these losses in the future. Mounting evidence suggest that the old rules of thumb often used to select N rates greatly underestimate the risks associated with N losses and the opportunities for improving N management by selecting methods to minimize these losses.