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NITROGEN for minnesota soils

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Nitrogen is the most needed nutrient on nonlegume crops. Even where soil fertility has been built to high levels, more nitrogen is nearly always needed annually. Phosphorus and potassium can sometimes be omitted for a year or two.

Profits

Nitrogen fertilizer can be one of the most profitable investments in an agricultural business. In some situations use of nitrogen has increased corn yields by more than 100 bushels per acre and the net return for nitrogen can be more that $1 per pound of nitrogen purchased. The long time average, however, is closer to 40 or 50 cents per pound for corn or wheat production. Table 1 shows some economic estimates from data on corn at three experimental sites in southern Minnesota. Current value of corn times yield increase, and current value of nitrogen times N rate can be used to make figures current. These are merely rough estimates, but indicate the nitrogen profits possible.

Table 1. Profit estimates from nitrogen fertilizer use on corn, three locations in Minnesota*

*Waseca County—6-year average; Martin County—7-year average***

Nitrogen lbs/a	Yield increase bu/a		Net return/a		Return/lb N	
	Waseca	Martin	Waseca	Martin	Waseca	Martin
50	28	14	$48.50	$20.50	.97	.41
100	41	24	67.50	33.00	.67	.33
150	57	20	91.50	17.50	.61	.12
200	63	20	96.00	10.00	.48	.05
400	66	25	72.00	10.00	.18	-.05

*Lamberton—18-year average****

Nitrogen lbs/a	Yield increase bu/a	Net return/a	Return/lb N
40	29	$52.00	1.30
80	43	74.00	.92
160	42	60.00	.37

*Corn @ $2 per bushel; Nitrogen @ 15 cents per pound.
**Data from Miscellaneous Report 153.
***Data from 1979 Soil Science Annual Report.

Nitrogen carryover

On fine-textured soils there is considerable nitrogen carryover. even from rates as low as 50 pounds per acre. An example of this carryover from rather low rates of nitrogen is shown both in Waseca and Martin County experiments. In Waseca County 50 pounds of nitrogen per acre had been compared to no nitrogen treatment for two years. On the third year 50 pounds per acre of nitrogen were applied to the no nitrogen plots as well as the other plot, the carryover from the two preceding years showed a yield of 20 bushels more per acre.

In Martin County the reverse was done. Plots receiving 50 pounds per acre nitrogen for seven years had outyielded no nitrogen plots by 22 bushels per acre. When the 50 pound treatment was omitted for 2 years these plots still outyielded the no nitrogen plots by 12 bushels because of the nitrogen carryover from earlier years.

Nitrogen carryover on nitrogen-treated coarse-textured soils is usually negligible. There is a measure for carryover nitrogen by soil testing for nitrate-nitrogen. The test should be performed on a sample taken from the surface to a depth of 2 to 3 feet.

Nitrogen losses

Nitrogen can be lost from the soil in several ways: plant uptake, water run-off, leaching, and denitrification (volatilization). Losses due to run-off water can be held to a minimum if nitrogen is incorporated, and soil erosion is prevented. The amount of nitrogen leached through the soil profile is largely related to uptake, soil texture, precipitation, and the nitrogen rates applied.

Table 2 shows the nitrogen movement through the soil profile after 11 years of application in two areas of Minnesota: one low in rainfall, one high in rainfall. The greatest

Table 2. Pounds of nitrate-nitrogen to a depth of 32 feet at two locations in Minnesota after annual nitrogen treatments*

	Pounds of nitrogen added annually (11 years)**					
	Waseca			Morris		
Soil depth feet	0	40	240	0	40	240
	Pounds per acre NO_3-N					
0-1	29	27	121	31	46	205
1-2	8	4	65	9	10	124
2-3	4	3	26	9	10	111
3-4	3	5	26	7	12	72
4-5	3	6	10	--	--	--
5-6	3	4	7	--	--	--
6-7	4	4	6	--	--	--
7-8	4	3	6	9	18	146
11-12	3	3	2	17	23	48
15-16	2	2	2	20	24	43
19-20	2	2	2	19	16	23
23-24	2	2	2	11	14	14
27-28	2	2	2	13	12	17
31-32	3	3	2	13	12	13

*Data by MacGregor, University of Minnesota.
**Adequate P and K added each year.

nitrogen might be expected in the high rainfall area of Waseca rather than the relatively low rainfall area of Morris, but this is not true. At Waseca, the yields were nearly three times higher than those at Morris; thus nitrogen uptake was considerably greater. Based on the rates used and the most economical yields obtained, 40 pounds of fertilizer nitrogen was adequate at Morris while between 80 and 240, probably about 160 pounds, proved to be the best rate at Waseca. Thus greater uptake at Waseca would at least in part explain the low rate of leaching. Additionally, the high rainfall at Waseca probably resulted in greater loss due to denitrification. Denitrification is the loss of nitrogen due to action of soil bacteria which convert nitrate-nitrogen into a gaseous form which can be lost from the soil. This usually takes place when soils are extremely wet and the soil oxygen supply is low. Nitrogen lost due to denitrification would reduce the amount of nitrate leached. Absence of denitrification and low yield allows greater loss downward. Table 2 data indicate that excess nitrogen rates should be avoided to prevent nitrogen movement to the watertable. Normally when recommended rates of nitrogen are followed closely, very little leaching beyond the root zone occurs on fine-textured soils. Losses on coarse-textured soils, however, can be serious.

Nitrogen from organic matter

Releases of nitrogen from organic sources is variable. It depends on moisture, temperature, aeration, pH, and soil texture. These are the factors that affect soil bacteria that bring about decomposition and subsequent nitrogen release. Fine-textured soils may warm slowly in the spring to restrict nitrogen availability and yield, especially of early harvested crops, such as small grains.

An estimate of the soil's total organic nitrogen is 1,000 pounds for each percent organic matter. Coarse-textured soils usually have quite low organic matter, but because of the good aeration, nitrogen is released rapidly. But the quantity is small. Fine-textured soils may release nitrogen slowly or rapidly, depending on weather conditions. A soil with 7 percent organic matter may release about 70 pounds of nitrogen per acre during a cold, wet spring and approximately 140 pounds of nitrogen when soil conditions are ideal for bacterial activity. An extreme case at Lamberton, Minnesota in 1977 (after the drought of 1976 where there was little uptake of nitrogen) showed corn yields of 141 bushels per acre on land receiving no supplemental nitrogen for 18 years. Corn apparently obtained large amounts of nitrogen released from organic matter the past 2 years.

Nitrogen forms

There are several forms of nitrogen fertilizer on the market. One, anhydrous ammonia (NH_3), is basic in the production of most other commercial nitrogen fertilizers. Natural gas (methane) is the source now for hydrogen. The nitrogen source is from the limitless supply in the atmosphere. A shortage of natural gas in the future could result in more expensive nitrogen fertilizer. To date, no low cost source of hydrogen other than methane for nitrogen fertilizer manufacture has been developed.

The most common forms of nitrogen fertilizer are anhydrous ammonia 82% N, urea 46% N, ammonium nitrate 34% N, and nitrogen solutions 28 to 32% N.

When various nitrogen forms are applied according to individual specifications, all are equally effective.

Manure

The average manure contains about 0.5 percent nitrogen or 10 pounds per ton. About half the nitrogen becomes available during the year it is applied. If manure is used, commercial nitrogen rates should be reduced about 5 pounds per ton of manure applied.

Time of application

Generally ammonia or urea, which becomes an ammonium material when applied to the soil, can be applied successfully in the fall on medium- and fine-textured soils. Best results are obtained if the application is made late enough so that bacterial action is slowed by cool soil temperatures. There is evidence that materials containing nitrate forms of nitrogen are less effective when applied in fall. This includes ammonium-nitrate of which half is in the nitrate form. If ammonia or urea are applied after soil temperature at a 4 inch depth is below 50° F, only a very limited amount is converted to the mobile nitrate form.

Care should be taken at planting time when certain forms of nitrogen such as ammonia or any of the solutions are applied in shallow bands (5 inches or less). Nitrogen and the seed should be kept apart. If the planter row coincides with the nitrogen band, seed germination could be seriously reduced. The damage becomes less with time. Planting a week after application greatly reduces germination problems. Damage is less when planting in a moist rather than a dry soil. There is no damage with immediate planting if ammonia is applied greater than 6 inches deep.

On coarse-textured soils, nitrogen should be applied as a split application when a crop is grown under irrigation. A portion can be applied at or before planting; the remainder added in irrigation water, or applied as a sidedressing or topdressing close to the period of greatest need. This varies with crops but the period of rapid growth or the reproductive stage are times of great nitrogen need. Fall applications on sandy loams or coarser are not recommended.

Inhibitors

There are inhibitors on the market that reduce activity of organisms converting the positively charged ammonium to the negatively charged and mobile nitrate form. A reduction in the conversion rate of nitrogen in the ammonium form to the nitrate form is generally desirable because nitrate is the form most susceptible to leaching or gaseous loss. There have been varying degrees of success with inhibitors on different soil types, but there are specific instances, especially on coarse-textured soils, where benefits from inhibitors are obtained frequently.

Soil analysis

Checking out soil nitrogen by a chemical test is fairly new. The Minnesota test, adapted from North Dakota research, is a measurement of nitrate-nitrogen to the 2-foot depth. It has been a valuable tool for western Minnesota where there is less fluctuation from very wet to very dry. These fluctuations create considerable variation in nitrogen availability. Predictions for nitrogen additions in western Minnesota are being used for small grains, sugar beets, potatoes, and sunflowers. Research is promising on corn, although current recommendations for nitrogen are still based on previous cropping history.

Plant analysis

Nitrogen in plant tissue is an excellent indicator of nitrogen supply to the plant. The stage of plant growth at sampling must be known for best interpretation of sufficiency levels. The younger the plant, the more nitrogen it usually contains. Most nutrients in tissue are analyzed by an emission spectrograph, but a special procedure (Kjeldahl) must be run to determine nitrogen. Table 3 shows interpretation of nitrogen content at the recommended time of sampling.

Table 3. Plant part, time of sampling, and relative nitrogen levels*

Crop	Plant part and sampling stage	Threshold levels: deficient	low	sufficient	high
		----------	---------- % N	----------	----------
Corn	Ear leaf, silking	<1.7	1.7	2.7	>3.7
	Whole plant, 12-inch height			3.5	>5.0
Small grain	Top leaves, boot stage	<1.5	1.5	2.0	>3.0
Sunflowers**	5th leaf, flowering	<2.5	2.5	2.7	>3.2

*Adapted from soil testing and plant analysis, SSSA '73.
**Values subject to modification as research develops.

Predicting nitrogen needs

Nitrogen needs vary with weather conditions, past cropping history, and the production potential of a specific soil. Nitrogen recommendations are made by research oriented soil scientists and are based on research results obtained from nitrogen trials on specific soils.

As a "rule-of-thumb," nitrogen needs can be estimated by farmers on the basis of yield potential:

corn: 1 pound N for each bushel expected
wheat: 1.5 pounds N for each bushel expected

Adjustments downward are necessary based on whether alfalfa was the preceding crop, manure was spread, or if nitrogen buildup has occurred because of low yields.

On coarse-textured soils the buildup of soil nitrogen in the profile does not occur. Nitrogen use on these soils must be based on meeting the crop needs on an annual basis. Nitrogen levels can build up in the soil profile from unused nitrogen if soils are other than sandy. On finer-textured soils if a large carryover results from lower than expected yields, the nitrogen rate the following year can be reduced. This utilizes the nitrogen carryover for crop production and lessens the possibility of ground water pollution.

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