Nitrogen Management in Cotton

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Nitrogen (N) is the most heavily applied and one of the most expensive nutrients used for cotton production in Texas, and is also the most difficult to properly manage because of its reactivity and mobility in the soil environment. Inadequate N reduces the number of fruiting sites and potential yield, whereas excessive N can create rank growth, actually lower yields and quality, delay maturity, increase problems with disease, insects, and defoliation, and pollute ground and surface water resources. Recommended N rates are based on the N required to produce a crop at a realistic yield goal, and should be reduced by credits for residual nitrate nitrogen (NO_3-N) in the soil, as well as by any NO_3-N applied in irrigation water. Crediting soil and water NO_3-N requires collection and submission of samples to a laboratory for proper analysis.

The amount of N cotton requires depends on the yield potential of a given field. Texas AgriLife Extension Service recommends 50 pounds of N per acre (from all sources) be available for each bale produced (Table 1).

Table 1. Nitrogen Recommendations for Various Yields of Cotton in Texas.

Yield (bales/acre)	Nitrogen Recommendation[1] (lbs/acre)
0.5	25
1.0	50
1.5	75
2.0	100
2.5	125
3.0	150
3.5	175

[1] Recommended amount should be reduced by the amount of residual NO_3-N in the soil and credits for NO_3-N from irrigation water.

Accurately predicting the amount of supplemental fertilizer N needed by a crop is difficult because N can undergo chemical changes that influence its mobility and retention in the soil, as well as its availability to plants. Nitrogen leaching, denitrification, ammonia volatilization, and mineralization/immobilization (tie-up and later release of N by soil microbes involved in decomposition of organic residues) are processes that can quickly alter the amount of N available to plants.

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Crops obtain N from applied fertilizer, residual fertilizer in the soil (primarily NO_3), and N released (mineralized) from decaying organic residues. But of these sources, only the amount of N applied as fertilizer is generally accurately known. Residual N in the soil is highly dynamic, and the amount of N released from organic residues varies depending on soil and climatic factors. **Thus, soil should be tested each year for NO_3-N as near planting time as possible because a soil test gives only a point-in-time estimate of the amount of N available.**

The price of N fertilizers has risen dramatically over the past few years. For example, urea ammonium nitrate (32-0-0) was $180/ton in 2003 and in 2008 the price was $560/ton, representing a 211% increase. Due to very high fertilizer input costs, producers can no longer afford unnecessary applications. The return per pound of N will only be as good as the overall efficiency of the production system. Following established best management practices for proper variety selection, plant density, weed, insect, and disease management, irrigation management, etc. are all components of an effective N management strategy. Additionally, establishing a realistic yield goal and then applying the amount of N needed to meet that goal are imperative. Setting too high a yield goal can lead to over-application of N, excessive input costs, crop management problems, and increase pollution potential.

Soil Sampling

The foundation for a sound fertility program is soil testing. The only way to properly estimate how much of a nutrient is needed is through the soil testing process. As mentioned previously, N is very dynamic in the soil system so sampling for N determination should be performed as close to planting as possible.

Sampling Procedure

Sampling is generally done by hand with a soil probe. These can be purchased online from a number of sources. Hand probes cost from $25 to $150, depending on the type of probe, but good quality probes generally can be purchased for less than $100. For deeper sampling, hand probes may not suffice and it may be necessary to acquire a mechanical soil probe. A small shovel can also be used. With a shovel dig a V-shaped hole to the desired depth (usually 6 inches), take a 1-inch slice from the smooth side of the hole, and then take a 1 x 1 x 6 inch core from the middle of the slice and place it in a clean plastic bucket.

The soil analysis will only be as good as the soil sample collected. It is important that the soil sample be as representative of the field as possible. This means that the more subsamples collected within a given field, the better the overall composite sample will be. It is particularly important that separate soil samples be collected from those areas of the field with known soil differences or a history of production and/or management differences. In each area that is identified, collect 12 to 15 subsamples, place these in a clean plastic bucket to form a composite sample, thoroughly mix this sample, and then use the amount needed to fill the soil sampling bag. Bags can be obtained from most soil testing laboratories.

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Depth of Sampling

Historically, soil samples for fertilizer recommendations have been collected from a depth of 6 inches (commonly termed an “acre-furrow slice”). This “surface” sample is not only important for measuring N, but also to test for other essential plant nutrients such as phosphorus, potassium and micronutrients. However, because it is so mobile in the soil, plant available N (as NO_3) can many times be found deeper in the soil profile.

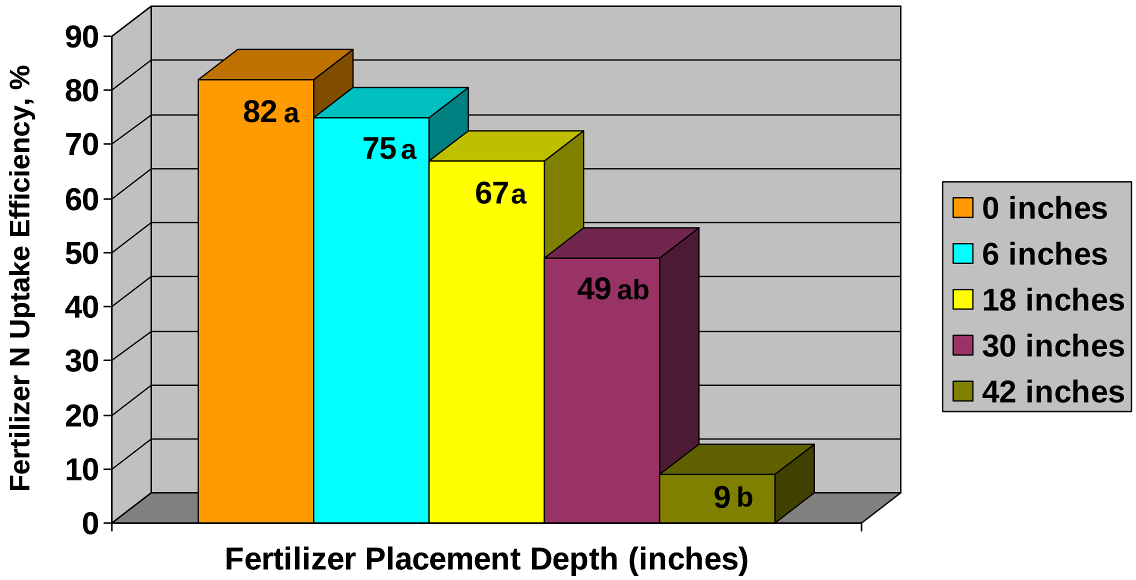
Research conducted over a seven-year period across Texas’ major cotton production regions indicated that most fields contain some level of residual N in the soil profile (Table 2). Residual soil NO_3-N, measured to a depth of four feet, exceeded 100 lbs/acre at 33 sites (61%) and supplied the N necessary for optimum yields at those locations. The long-term study showed that residual NO_3-N was present in about two-thirds of fields tested (note that the majority of these field sites were commercial fields and not Texas AgriLife Extension Service or Texas AgriLife Research properties). In addition, recent research has shown that the cotton plant is very efficient at utilizing N down to a depth of 24 inches (Figure 1). **Consequently, any NO_3-N measured by soil testing to a depth of 24 inches can be subtracted directly from the amount of N fertilizer needed, based on the yield goal.**

Table 2. Nitrogen Management Study - Seven Year Summary.

	Locations		
Year	**Total**	**Profile NO_3-N > 100 lbs. N/acre[1]**	**Response to Applied Fertilizer N**
1998	6	1	3
1999	7	5	1
2000	7	5	0
2001	10	6	2
2002	9	5	2
2003	7	5	3
2004	8	6	2
Total	**54**	**33**	**13**
		61% of Locations	**24% of Locations**

[1] Samples collected to a depth of 36 or 48 inches.

Figure 1. Uptake efficiency of cotton for ^{15}N-labeled fertilizer placed at various depths (sampled at early bloom).



These studies clearly demonstrate the need to account for residual NO_3-N when determining fertilizer requirements, and support the recommendation for soil sampling to greater depths. Samples can be collected from several depths (0-6 inches, 6-12 inches, and 12-18 or 12-24 inches) to better define the residual N that may be present.

A good approach is to collect a 0-6 inch sample plus an additional sample to a greater depth. The 0-6 inch sample can be used to determine the amount of residual NO_3-N in that depth, the amounts of other essential plant nutrients, and provide a general fertilizer recommendation. An additional sampling depth below 6 inches can be used to determine residual NO_3-N only. This depth of sampling could be from 6 inches down to 12 inches or deeper, depending upon the soil and the sampling equipment used. The condition of the soil will largely determine the ease with which deeper soil samples can be collected using a hand probe. The 0-6 inch depth is generally obtained fairly easily using a hand probe, but 6-12 inch or deeper samples can be difficult in hard, dry soils or in fine-textured soils. When sampling under these conditions, it is acceptable to apply penetrating oil (such as WD-40) to the probe. When possible, a 6-18 inch or even a 6-24 inch sample is desirable, but this will likely require some additional sampling equipment.

Regardless of how deep the soil sample is collected, be sure to note the sampling depth for your records so you can calculate the amount of residual N in that field based on the soil test results. **Many laboratories will assume that each sample submitted is from a 0-6 inch depth. If this occurs for a 6-18 or 6-24 inch sample, the amount of residual NO_3-N will be significantly underestimated. For proper correction factors see the <u>Interpreting Soil Analysis section and Table 3</u> in this publication.**

Sample Handling Prior to Analysis

If soil samples are wet and cannot be delivered to the soil testing laboratory within two days, they should be refrigerated or air dried. Do not allow soil samples to be exposed to temperatures above 75^{o}F for any significant period of time. Be sure that all samples are properly labeled and soil forms are clearly filled out expressing the desired soil analysis.

Interpreting the Soil Analysis

A soil sample analysis will report nutrient concentration, including N, in parts per million (ppm). The ppm value is then converted to pounds of nutrient per acre using established mathematical relationships. Nitrogen is usually reported as NO_3 because this is the most plant available form. The conversion formula from ppm NO_3-N to pounds of N per acre is dependent upon the bulk density of the soil. An acre-furrow-slice of soil is considered 6 inches deep and is assumed to weigh 2 million pounds. Therefore, if the soil is sampled to a 6-inch depth and the NO_3-N test indicates 15 ppm, then the appropriate factor to multiply by to obtain pounds of NO_3-N per acre is 2. Some soil testing laboratories will assume a different bulk density which in turn results in a slightly different weight for the soil. This is why the same ppm value reported by two laboratories may give slightly different pounds of N per acre.

Using the assumption that an acre-furrow-slice of soil weighs 2 million pounds and is consistent with depth, Table 3 provides conversion factors for different possible soil sampling depths. By multiplying laboratory NO_3-N values given in ppm times the appropriate conversion factor based on the depth of the sample, the estimated pounds/acre of plant available nitrogen in the sample can be determined.

Table 3. Calculating NO_3-N per acre based on the depth of soil sample submitted (using 15 ppm NO_3-N as an example).

Sampling Depth (inches)	NO_3-N ppm	Multiply ppm by	NO_3-N lb/acre
6	15	2.00	30
8	15	2.66	40
10	15	3.33	50
12	15	4.00	60
14	15	4.66	70
16	15	5.33	80
18	15	6.00	90
20	15	6.66	100
22	15	7.33	110
24	15	8.00	120

Example calculations:

1. A sample was taken with a hand probe to a depth of 12 inches. This sample was submitted to a laboratory which does not allow you to specify the depth of sampling on the form. This laboratory will assume it is a 0-6 inch sample. The amount of residual NO_3-N was determined to be 15 ppm. The actual sampling depth is 12 inches, therefore, the conversion factor is 4. The total amount of residual NO_3-N in this sample would be 60 lbs N/acre. .

2. A sample was taken with a hydraulic probe to a depth of 18 inches. The sampler did not partition this sample into 0-6 and 6-18 inch increments. Therefore, this sample represents the entire 18 inch depth. The amount of residual NO_3-N was determined to be 15 ppm. The actual sampling depth is 18 inches, therefore, the conversion factor is 6. The total amount of residual NO_3-N in this sample would be 90 lbs N/acre. Also, results and fertilizer recommendations for other plant nutrients typically would not be considered accurate due to the depth of sampling.

3. A sample was taken with a hydraulic probe to a depth of 18 inches. The sampler did partition this sample into 0-6 and 6-18 inch increments. Therefore, these samples represent 2 distinct sampling depths. The results for the 0-6 inch increment indicated 15 ppm residual NO_3-N. The factor for this increment is 2, therefore, a total of 30 lbs NO_3-N/acre were found. The results for the 6-18 inch increment indicated 15 ppm residual NO_3-N. The factor for this increment is 4 (18 inches - 6 inches = 12 inches), therefore the amount of residual NO_3-N is 60 lbs N/acre. If we total the amount in the entire sampling depth, we have 90 lbs N/acre. Also, in this case results and fertilizer recommendations for other nutrients based on the 0-6 inch sample could be used.

Credits for NO_3-N from Irrigation Water

In some areas of Texas (for example in the High Plains and Rolling Plains), irrigation water contains enough NO_3-N that it should be credited toward the cotton N requirement. In order to determine if irrigation water contains significant NO3-N, a water sample must be collected and submitted to a testing laboratory (such as the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory). For every one ppm of NO_3-N in irrigation water, 0.23 lbs/acre of N will be added to the soil with each inch of water applied. Thus, one acre-foot (12 inches) of 10 ppm NO_3-N irrigation water would supply about 27 pounds of N per acre. This can be calculated using the following:

ppm of NO_3-N in water x 0.23 x inches of water applied = lbs of N/acre added.

As an example, suppose 15 inches of irrigation water are applied and the water test indicates 10 ppm for NO_3-N. Based on the above formula, an additional 34.5 lbs of N per acre will be applied during the growing season (10 ppm x 0.23 x 15 inches = 34.5 lbs N/acre). Table 4 provides a quick reference for other irrigation amounts and irrigation water NO_3-N concentrations. The pounds of N added in irrigation water should be subtracted from the overall amount needed by the crop for a specific yield goal.

Table 4. Plant Available N in Irrigation Water

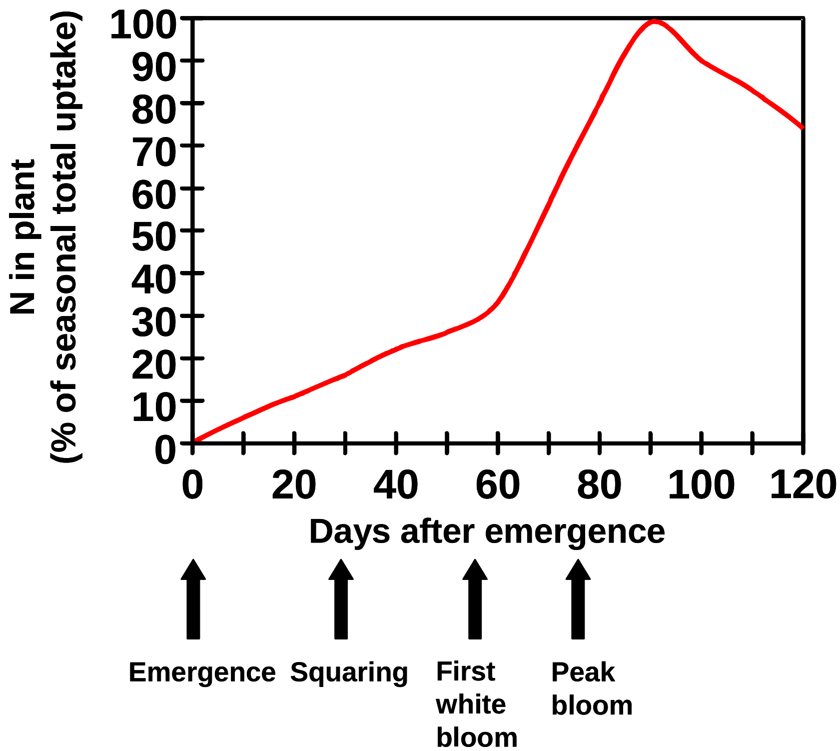
Water Applied (inches)	NO_3-N in Irrigation Water (ppm)			
	10	20	30	40
	lbs N added/acre			
9	20	41	61	82
12	27	55	83	110
15	34	68	102	136

Nitrogen Application

Once residual soil N and possible irrigation water N contributions have been determined, an effective fertilization strategy can be developed. Cotton requires minimal amounts of N during the early growth stages (Figure 2). All of the N needed for a specific yield goal can be applied in a single preplant application, or in split applications. Splitting N applications generally results in greater N use efficiency. Split N applications should be made with one-third to one-half applied preplant and the remainder sidedressed during squaring. Knifing or injecting fertilizer into the soil will result in less N fertilizer loss compared to broadcast application, especially if considerable crop residue is present.

Fertigation (N fertilizer such as urea-ammonium nitrate - UAN, 32-0-0 applied through center pivot irrigation systems) is a practice that is gaining in popularity in many areas due to reduced application costs. The preferred fertigation method is to apply 20% of the total N required in a preplant application. Apply an additional 50% through the squaring stage, with the remaining 30% by early bloom.

Figure 2. Relationship between N in cotton plants (expressed as a percentage of total seasonal uptake) and days after emergence.



When N fertilizer is applied, the following can reduce its effectiveness:

1. Denitrification (volatilization) – NO_3-N is converted to a gaseous form of N. This occurs when oxygen levels in the soil are low, such as when water ponds or stands in a field after a rainfall event.
2. Immobilization (tie-up) – This can occur when a large amount of crop residue is present, and can require the use of higher N rates to feed microbial populations that decompose the crop residue. When planting into terminated small grains cover, or perhaps with large amounts of residue from a previous sorghum crop, additional N will be required.
3. Leaching NO_3-N out of the root zone – This is generally a problem only in sandy soils or when a significant amount of rainfall or irrigation occurs after N has been applied.
4. Ammonia Volatilization - This can occur when urea-based fertilizers such as urea, and urea ammonium nitrate (UAN) are broadcast surface applied. Factors favoring ammonia volatilization include:

1. High soil pH
2. Low cation exchange capacity (such as in low organic matter, sandy soils)
3. Large amounts of plant residues (urease enzyme present)
4. High temperatures
5. Moist conditions followed by rapid drying

In order to reduce ammonia loss from urea-based materials (this would also apply to broadcast or "dribbled" fluid UAN), the following strategies are suggested:

1. Incorporate into the soil by cultivation or at least by rotary hoeing after application – depths of 2 inches or more are adequate.
2. Time applications immediately before a center pivot irrigation event. Use spray mode immediately following a broadcast application if other soil incorporation is not used.

Summary

Research in Texas has shown that deep soil sampling for N management in cotton production systems is effective. Crediting residual soil N to a depths as great as 24 inches can substantially reduce fertilizer N requirements, and may reduce other related input costs (growth regulators, defoliants). Together, soil and irrigation water testing for nitrogen are important management practices that can enhance both production economics and environmental stewardship.

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Edward G. Smith, Director, Texas AgriLife Extension Service, The Texas A&M University System.