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## Causes of Nitrogen Shortages

Circumstances leading to deficiencies may develop even though a producer has properly fertilized. Excessive rainfall or irrigation may have caused leaching of N from the rootzone or denitrification if the soil remains waterlogged. On the other hand, too-wet or too-dry field conditions may have delayed initial fertilization or side-dress applications.

Timely rains, particularly at peak bloom, may provide a producer the opportunity for greater lint yields. As the yield goal increases, the N requirement also increases. These and other diverse situations may cause a shortfall in N supply. If a grower could accurately predict the plant’s N needs, application of additional N might provide increased yields on a cost-effective basis.

### Nitrogen Balance Is Essential

Nitrogen management of cotton requires a balanced approach. Inadequate N leads to reduced yields and profits. Excessive levels of N can also reduce profits and may result in environmental problems. Excessive N fertilization can lead to rank growth that delays maturity, increases insect problems, and decreases the effectiveness of harvest-aid chemicals. Environmental problems can occur if N pollutes ground or surface waters.

Cotton is a perennial plant with an indeterminate growth habit. As such, it exhibits a dynamic response to the environment and to management. Cotton stores N in the leaves when N is easily available to the plant, for later use during the peak demand of boll setting. Cotton seed are very high in protein and represent a strong “sink” (place where N is being stored). Urea-based foliar products can be used when cotton is large and will be damaged by soil application equipment or for late-season applications when timing is critical. Foliar N products are more expensive than soil-applied products, and the amount that can be applied in a single application is limited, to prevent leaf burn. Without testing quantitatively how much actual N to apply, foliar applications can be expensive and largely a matter of guessing at the N shortages.

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### Most Nitrogen Deficiencies Occur Late in Season

Understanding cotton’s seasonal demand for N is important in order to implement sound fertilizer N management strategies. The cotton plant’s average N requirement is 0.1 pounds N for every pound of lint produced. Uptake of soil N, primarily as nitrate, is excellent in the early and mid-season because of the healthy young root system. The variation in N demand through the season poses a burden to the plant’s physiological systems. Competition for carbohydrates during boll filling results in decreased N uptake efficiency by the roots, which can cause problems. Nitrogen deficiency is more likely to occur late in the season, particularly at peak bloom, when the plant’s demand for N is highest.
occurs later in the season as the N requirement is great and leaves may be stripped of stored proteins to meet boll feeding demands. Reduced N supply to the plant results in a decline in the total leaf area, which in effect sets an upper limit on the number of bolls that can be filled. The plant sheds small bolls as a means of adjusting the fruit load to match its leaf area. Clearly, N must be readily available in the soil and sufficient levels must be stored in leaf tissue to meet the demands of the crop, or lint yields will be lower.

**Fine-Tuning Nitrogen Fertilization**

Adjusting the N supply to production potential is a strategy that leads to maximum yield and profit. Several techniques or predictive tools are useful for producers to successfully meet crop N needs. During the pre-season, producers need to:

1. make a realistic yield goal estimate.
2. determine residual nitrate-N levels through a soil test.

Pre-season fertilizer needs are best determined through soil test analysis for nitrate-N, with fertilizer recommendations coupled to yield goal. Choosing a realistic yield goal is important, because consistent fertilization for unattainable yields wastes capital. Producers who irrigate and have excellent water should base their yield goals on the amount of available water. Producers depending on limited irrigation or rainfall should average the yield for the top three out of the last six years. Over time, this will represent an average growing rate that will include changes in management, varieties, and environment.

The petiole monitoring program offers producers a means of tracking in-season N needs of the crop. The program is best suited for irrigated producers with center-pivot or drip irrigation systems, but it also has practical application for growers in high rainfall areas where water supply is consistently adequate for high yields.

The magnitude of crop response to applied fertilizer N often changes with environmental conditions. Applications of supplemental N during fruiting and boll filling are often appropriate and profitable. Monitoring nitrate-N in the petiole provides a way to compensate for seasonal variation.

The aim of the monitoring program is to provide a tool that allows a grower to adjust N supply to the production potential dictated by the environment. Under normal conditions, petiole analysis will indicate N needs about 7 to 10 days before the onset of N stress.

**When and How to Sample**

The petiole analysis program starts one week prior to first bloom. To make successful interpretations using petiole analysis, consider previous fertilizer history, management practices, precipitation and/or irrigation amount, and plant monitoring data. Coupling petiole analysis with plant monitoring (height-to-node ratio, percent fruit retention, and nodes above white flower) provides producers with a set of complementary dynamic management tools.

About 20 petioles are adequate for analysis. The petiole is the leaf stalk, connecting the leaf blade to the mainstem (Figure 1). For producers using plant mapping, petiole samples should be gathered at the same time and should come from the same plants. Others should collect samples from randomly selected plants from uniform areas of the field.

**Petiole Analysis**

Petiole analysis is based on analyzing petioles from leaves that are physiologically the same age throughout the season. This means that selecting the correct petiole is important. Take the petiole from the first fully expanded main stem leaf from the top of the plant. You can find the top leaf by identifying the quarter-sized main stem leaf in the terminal. Call this leaf number one; then count down two and three; and collect leaf number four. When in doubt, it is better to err by collecting a slightly older leaf than one too young.

Petioles should be placed into a paper envelope (not plastic) and sent to an appropriate laboratory. Include as much information as you can: soil moisture rating, insect control rating, fruiting rate, average internode length, nodes above white flower, fertilizer applied, and rain or irrigation received. Try to get the samples to the laboratory by Thursdays of each week. This will expedite getting your results back in a timely manner.

**Using the Analyses**

Nitrate-N in cotton petioles will be high (provided soil N is adequate) during the squaring stage. The shift to bloom starts a general decline in petiole nitrate-N that continues through boll maturation. In other words, as the plant shifts to developing and filling bolls, less nitrate-N is moved to the terminal for vegetative development.

Desirable levels of petiole nitrate-N during the cotton bloom period are shown in Figure 2. The area between the dotted lines in Figure 2 indicates the desirable range for petiole-N through the monitoring period. Nitrate-N values in the lower range generally merit N fertilizer application unless the soil contains high levels of organic N. High or excessive levels of N are to be avoided, particularly late in the season, to avoid defoliation problems.

Three scenarios are plotted in Figure 2: N at optimum, N too low, and N too high. A crop with optimum N will often experience a substantial drop in petiole nitrate-N from the week prior to bloom to one week after bloom, but the nitrate-N levels should not fall below the desirable range.

Note that for the N-too-low scenario (Figure 2), petiole nitrate-N dropped below the optimum range at bloom plus one week and never recovered. An N fertilizer application should have been made just following one week after bloom (“+1” in Figure 2), and no yield loss would be expected.

For the N-too-high scenario (Figure 2), no additional fertilizer would be recommended. Any application of N would be a waste of money and would further enhance the potential for regrowth and delayed maturity. Cotton growing under those conditions would probably be rank, and the producer would be faced with a difficult harvest aid situation.

**Interpreting Results**

Before a N fertilizer management decision is made, the change in petiole phosphorus (P) must also be considered. Environmental factors can influence petiole nitrate-N levels. This includes: drought, excess moisture, and pest-related fruit loss. These effects are the reason it is so important to provide those making recommendations with as much weekly data as possible.

The interpretive relationships between petiole nitrate-N and petiole-P are shown in Figure 3 (page 4). In part A, nitrate-N is decreasing nicely and petiole-P is increasing, dropped between periods 2 and 3. Petiole-P, which is increasing, dropped between periods 2 and 3. This drop in P is generally indicative of a drought response, and management...
occurs later in the season as the N requirement is great and leaves may be stripped of stored proteins to meet boll feeding demands.

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Using Petiole Analysis for Nitrogen Management in Cotton

M. G. Hickey, C. R. Stichler, and S. D. Livingston*

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*Associate Professor and Professor, Soil Chemist and Agronomists, respectively, Texas A&M University.