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DEVELOPING A NITROGEN MANAGEMENT STRATEGY

Dave Guthrie, Bill Baker, Michael Hickey, Steve Hodges and Jeff Silvertooth

In theory, nitrogen management in cotton is an exercise in arithmetic. With a knowledge of the crop's total requirement, you subtract out the amount of nitrogen available in the soil and apply the difference. In practice, the calculations are more complicated. Crop nitrogen requirements are based on yield expectations that may change year to year. Soil nitrogen availability can be unpredictable, particularly in rain-fed cotton production. Applied nitrogen may not be effectively utilized by the developing crops. Despite these uncertainties, effective nitrogen management strategies can be developed that supply adequate amounts of this required nutrient without sacrificing environmental quality.

One certainty learned early by cotton farmers is that errors in nitrogen (N) management can be costly.

The cost of N mismanagement can be measured in agronomic, economic and environmental terms. Nitrogen fertilization regimes require a balanced approach. Inadequate N limits yields and profits. Excessive N is perhaps more likely and equally troublesome for different reasons. Rank growth, a direct result of over-fertilization, delays maturity, increases attractiveness to insects while complicating insecticide control measures, increases the incidence of boll rot and diminishes the effectiveness of harvest preparation measures.

These problems hamper management and frequently prove costly to yield and quality. In addition to the economic consequences that can result from over-fertilization, there is a real possibility that the environment may suffer if N pollutes ground or surface water or contributes to air quality problems. Nitrogen planning is not the place for snap judgements but for thoughtful deliberations.

To think through this process, start by considering the factors that impact cotton's N requirements, then determine which parts of the fertilization equation create the most uncertainty and devise appropriate management approaches to overcome those obstacles.

Nitrogen Within the Plant

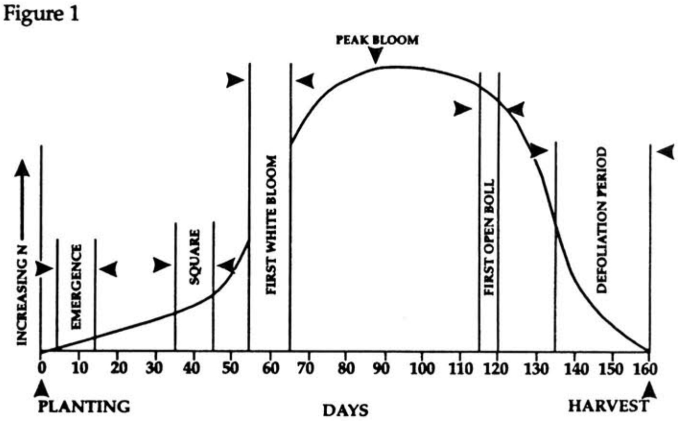
Years of research on the use of N by plants shows that it can be found in a large number of plant compounds, including amino acids used as building blocks for enzymes and other proteins, chlorophyll used in photosynthesis and nucleic acids that are part of the plant's genetic code. A deficiency of N will limit cotton growth through its affects on these critical physiological functions.

Symptoms which are associated with N deficiency include slower growth rate, smaller leaves, premature yellowing and shedding of lower, older leaves, increased fruit shed, and premature cutout. Also two possibly adaptive developmental modifications result from N deficiency, increased root:shoot ratio and increased tolerance to drought stress. When N is overabundant, shoot growth can proliferate relative to roots, which can hinder both drought tolerance and boll retention.

Accumulation Patterns

The cotton plant's N requirements are not constant throughout the season. Early vegetative growth requires only a small amount of N, usually less than 25% of the seasonal total (Figure 1). With the initiation of boll loading, the rate of N uptake increases dramatically. It has been reported that between 25% and 40% of the seasonal N accumulation may occur during the first two weeks of bloom. This translates into a N uptake rate of approximately 4 lbs/acre/day at peak bloom.

Figure 1



The implications of this variation in uptake are significant. Nitrogen must be available to meet these requirements or crop performance suffers. On the other hand, N in the soil that is not used by the plant may — as will be discussed shortly — meet another fate. One of the challenges in N management is determining how best to track and meet crop requirements within an economically and environmentally responsible framework.

Nitrogen in the Environment

Nitrogen is cycled through our environment (Figure 2). The major reservoir of this element is the atmosphere which is comprised of about 80% gaseous N. In this form, N is not directly available to plants. Several natural pathways convert this gas into plant-available forms. Several microorganisms including *Rhizobia* live in a mutually beneficial association (symbiotically) on the roots of leg-

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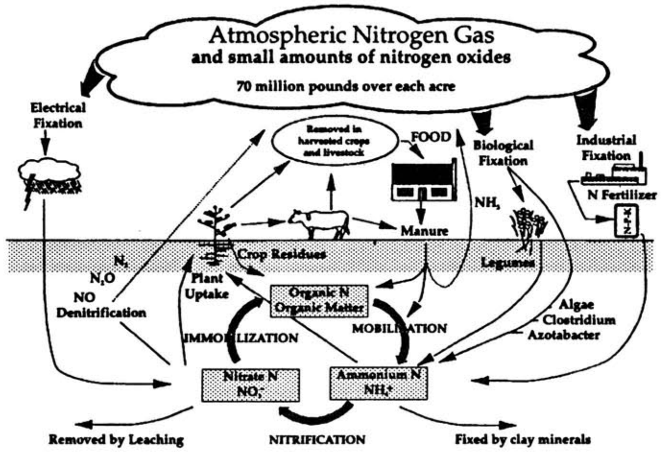
umes, including soybeans. Other microbes, living independently in the soil, are also able to fix gaseous N as ammonium. Thunderstorms also fix atmospheric N that can enter the soil system.

Figure 2



The conversions of the various forms of N are driven by a host of environmental forces. Whether from "natural" or fertilizer sources, these various forms become part of the N cycle and are acted on by the same forces. In a natural ecosystem, N supply is limited and very tightly cycled. Little N leaves the system. In an agricultural ecosystem, large amounts of readily available N are added to enhance plant growth and yield. The use of readily available N improves the ability of a producer to time his applications to correspond with crop requirements. But use of synthetic fertilizers with high availability requires careful management to ensure that the applied N is used by plants rather than lost from the cropping system. When fertilizer moves from the rooting zone, either by leaching, runoff, volatilization or erosion, the producer loses money, and air and water quality may suffer.

Nitrogen in the soil can be found in several forms. Nitrogen is a part of the soil's organic matter and also exists in inorganic forms. The organic matter is commonly found in various stages of decomposition. The inorganic N forms generally include ammonium, nitrate and nitrite. Nitrogen also can be found as a gas in the soil pore spaces.

Several pathways link these forms with various environmental fates. Uptake by the crop is of primary importance to the grower. Both nitrate and ammonium can be taken up by cotton roots for the physiological processes that drive crop development and yield.

There are several alternate pathways that do not lead to yield. One of these is volatile loss of either nitrous oxide or N_2 gas, both products resulting from the **denitrification** of nitrate. Under water-logged conditions, oxygen is depleted in the soil. Certain bacteria grow under these anaerobic (oxygen-free) conditions and utilize the oxygen found in the nitrate molecules to drive their physiological processes. This reaction creates gaseous N-containing molecules that escape into the atmosphere. When nitrous oxide is formed, it contributes to air pollution.

Losses from this process can range as high as 55% of applied inorganic N fertilizer. Denitrification is most likely to occur when temperatures are above 40° and soils are waterlogged, although a significant amount of N can be lost under drier conditions. These conditions are frequently met during the fall, winter and spring in finer-textured clay loams and clays in the Mid-South and Texas regions. This can also happen in finer textured soils following a heavy irrigation in the West.

Nitrates also can be **leached** from the soil profile. This negatively charged molecule is highly soluble and mobile in water. If water percolates down through the soil profile, nitrate in solution can be removed from the root zone and potentially pollute surface water or groundwater. **Leaching** losses of nitrate are more common on coarse-textured soils such as loamy sands or sands which have lower water-holding capacities and rapid internal drainage. Studies have documented that leaching losses can approach 60% of applied N.

Applied N can be lost from the soil through ammonium **volatilization.** Ammonium fertilizers can react with water and be converted to gaseous ammonia which may be lost to the atmosphere. Losses are greatest in high pH soils, warm soils and when the ammonium-containing fertilizer has been surface-applied with little incorporation. Surface-applied urea can undergo a similar fate as it is converted to ammonium, with losses that can exceed 60% of the applied urea N on high pH soils. Simple covering or incorporation by as little as ½ inch of soil can make losses negligible.

Immobilization of soil N is a by-product of microbial metabolism. Soil microflora need N to utilize the constituents of organic matter for their physiological processes. When large amounts of vegetation or organic materials (with a high C:N ratio like wheat straw) are incorporated in the soil, N used by the microbes is unavailable for immediate use by subsequently planted crops. This same phenomenon is seen in backyard compost piles and accounts for the addition of N to speed decomposition.

Mineralization can be thought of as the reverse of immobilization. Although both processes are driven by the resident bacterial population, mineralization has the net effect of releasing organic matter N to the soil environment as inorganic or plant-available forms. The actual conversion is a multi-stepped process that requires the presence of several naturally occurring soil organisms. Some of the immobilized N will be available for crop growth later in the season. In some cases this may pose a problem as rank growth may result as this N becomes available to the crop.

Sustaining a balanced population of soil microbes to perform beneficial processes such as mineralization is one of the benefits of building organic matter through cover crop or other conservation tillage practices.

Mineralization plays a greater role in N management when organic sources of N fertilizer are used or in conservation tillage systems. Researchers speak of N release curves that describe the rate of N mineralization. Ideally, the N release curve would parallel the crop's utilization patterns. Manure and other animal waste is well-suited to cotton production when sufficient N is mineralized to sustain boll loading but not impede harvest preparation. Researchers are currently looking at ways to better predict nitrogen mineralization from organic sources and methods to improve use of these materials in cotton management systems.

Estimating the Soil Reservoir of Nitrogen

Assessing soil N reserves is the most difficult part of N management. This is a complicated process, since N from nitrate, ammoniacal and organic forms may become available to the plant at various times during the growing season. In some areas (AZ, AR, OK, TX), soil nitrate testing procedures have been calibrated against crop response, and these measurements can be used to modify N recommendations. The value of any residual soil N, such as nitrate, can be applied to an estimate of the total N that may be required by the crop. Where rainfall and leaching limit the usefulness of soil nitrate tests, recommendations represent many years of field trials in various locations and various rotations. Nitrogen rates are typically adjusted downward following legumes such as soybeans and peanuts which can supply 20 to 35 pounds of N per acre or alfalfa which can supply over 120 pounds of N per acre.

Fertilization Techniques

The best approach to meeting the N needs of a cotton crop includes: (1) making a realistic estimate on projected yield (consistent fertilization for high yields that don't materialize wastes fertilizer and increases risk of pollution), (2) determining residual N levels from a pre-season soil test, (3) minimizing pre-season N fertilizer applications which are commonly shown to be the least efficient, (4) splitting the fertilizer N applications over the season based on crop conditions, (5) completing all fertilizer N applications before peak bloom and (6) considering past experience in the field with either rank or insufficient growth and adjusting rates accordingly.

Numerous nutrient uptake studies have shown that approximately 60 lbs. of N is required to produce a bale of cotton. So for a field that we would project a 2-bale yield potential (realistically), 60 X 2 = 120 lbs. N/acre are needed from all sources to meet the total N requirements of the crop.

For example, if a realistic yield of 2 bales is projected for the field (2 bales X 60 lbs. N/bale = 120 lbs. N/acre), and we determine that 20 lbs. of residual N are available, we can set an upper limit of 100 lbs. N/acre (120 - 20 = 100) that we may need to apply over the season as fertilizer N. Splitting the applications of fertilizer N over the season offers the best level of control for a farmer in terms of both crop management and fertilizer efficiency.

Applications of fertilizer N should be made from the time of early squaring up to peak bloom, to match the pattern of peak N demand by the crop. Side-dress applications can be very useful in splitting N inputs to the crop before lay-by. In irrigated situations, any additional N applications also can be made to the crop through the irrigation water. Monitoring the crop can help the grower in making in-season decisions about N fertilizer applications. Basically, the greater the fruit load, the greater the N demand. Very little N is needed for early crop development prior to early squaring, and early applications of N can be conservative. In-season applications of N should proceed if the crop is setting fruit normally, which continually increases the N needs of the crop. If the fruit retention levels are dropping, for whatever reason, applications of fertilizer N may need to be withheld or reduced in an attempt to prevent rank vegetative growth. Monitoring tools such as plant mapping (fruit retention, height-to-node ratios, nodes above white flower) when combined with actual N fertility status (analysis of petioles for nitrate-nitrogen) can help a grower in deciding on whether to stay on the scheduled, split applications of N and/or apply foliar N during bloom.

The application of fertilizer N is one of the factors under the grower's control. Use it in a manner that offers the greatest benefit to the crop, which requires following the crop in its development.

Response as Nitrogen Managers

1. Assess the field for potential and limitations: fertility status, yield potential, soil variability, compaction, water supply, weed and disease pressure, environmental hazards — proximity to streams, groundwater.

2. Apply the right rate. This isn't easy to determine because of the factors mentioned. However, there are reasonable guidelines (Table 1.) that include yield expectation, knowledge of soil characteristics, an estimate of soil residual N and the amount of nitrate-nitrogen present in irrigation waters.

Table 1.

Nitrogen Recommendations by State (lbs./acre)

Alabama	60 lbs. (CEC 9.0), 90 lbs. all other soils
Arizona	60 lbs. per bale, adjusted for crop condition and petiole nitrate levels
Arkansas	90 to 120 lbs. irrigated, 60-70 lbs. dryland, adjusted for soil nitrate N, soil texture, soil calcium and crop condition
California	100 to 200 lbs., depending on soil nitrate N level
Georgia	50 to 110 lbs., depending on soil texture and irrigation
Louisiana	60 to 90 lbs. on sandy loams and silt loams; 90 to 120 lbs. on clay loams and clays
Mississippi	80 to 120 lbs., depending on soil type and yield goal or potential
Missouri	60 to 110 lbs., depending on soil texture and irrigation
New Mexico	120 lbs. (60 lbs. at planting and 60 lbs. at 1st square)
North Carolina	50 to 70 lbs.
Oklahoma	60 lbs. per acre (residual + applied) per bale of anticipated yield
South Carolina	70 lbs. per acre dryland; 100 lbs. per acre irrigated
Tennessee	60 to 80 lbs. upland soils; 45 to 60 lbs. bottom soils
Texas	50 lbs. per acre (residual + applied) per bale of anticipated yield

In-season adjustments made based on crop condition and petiole nitrate levels (see **Response as Nitrogen Managers** section).

3. Time the applications. Cotton uses less than one-third of its seasonal N prior to bloom. Carefully consider the potential environmental fates of applied N on your fields. Single pre-plant applications may not be the most agronomically, economically or environmentally sound approaches to N fertilization. Match to correspond with crop uptake, particularly where leaching and movement (runoff, erosion, irrigation erosion) is likely.

4. Placement: Banding increases uptake efficiency. Nitrogen applied in a band near the actively growing root system is more likely to be taken up than N applied broadcast prior to planting.

5. Monitor N status: Petiole monitoring can make you money. By delaying applications, N rate can be adjusted to match the yield potential, taking into account variations in weather, pest pressure and earlier management decisions. When yield expectations improve due to favorable conditions, yield enhancing treatments such as foliar applications can be made based on actual plant demands. Nutrient monitoring can also help detect leaching losses and deficiencies of other nutrients which may limit nitrogen utilization.

6. In-season adjustments: Make corrections as soon as they are needed. Consider soil applications if ammoniacal sources are to be applied. Foliar applications may be better if the soil CEC is above 7. Use soil-applied prior to bloom where possible and foliar applications during bloom. Carefully weigh benefits of late season N applications against potential risks of regrowth and attractiveness to insect pests. Follow state guidelines on foliar N applications.

7. If plant height exceeds 24 inches at early bloom, or the height-to-node ratio (HNR) exceeds 1.7 inches/node, or new internodes are greater than 3 inches long, consider a Pix application to minimize excessive growth.

8. Records: Keep good records to indicate where you made good and bad decisions. These can help in future years.

For further reading on nitrogen and other early-season topics, refer to the following issues of *Cotton Physiology Today*:

- Monitoring Plant Vigor, June 1993, Vol. 4, #5
- Square Retention, June 1992, Vol. 3, #6
- Fertilizer Placement, March/April 1992, Vol. 3, #4
- Physiology of Pix, May 1991, Vol. 2, #6
- Cotton Nutrition — N, P and K, Jan. 1991, Vol 2, #3

To obtain copies of these issues, call or write the National Cotton Council, PO Box 12285, Memphis, TN 38182-0285 (phone 901/274-9030).

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