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Management of Fertilizer Nitrogen in Arizona Cotton Production

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Nitrogen (N) is the nutrient that is required most consistently and in larger amounts than other nutrients for cotton production. Common rates of fertilizer N applied in Arizona cotton production systems range from 50 to over 300 lbs N/acre. The management of fertilizer N is critical, both for insuring optimum cotton yields, and minimizing the potential for environmental contamination.

Soil N Reactions and Availability

Soil N is composed of both organic and mineral forms but organic forms often comprise 80% - 90+% of the total soil N. Organic N is not immediately available for plant use but may be decomposed to available mineral forms (ammonium, NH_4^+; and nitrate NO_3^-) that are available through naturally occurring soil reactions. This decomposition process is generally referred to as mineralization. However, in most Arizona soils, the native organic matter (O.M.) levels are inherently low, and therefore, contributions of soil N for cotton production are usually negligible. As a result, most of the N needs of the cotton crop are supplied from crop residues and fertilizer. This includes N fertilizers applied to a crop plus residual N that remains in the soil from preceding crops. Some crops, particularly leguminous crops such as alfalfa, may leave relatively high amounts of residual N that are available for subsequent crops. Otherwise, N nutritional needs of the cotton crop must be supplied in fertilizer form. Common sources of fertilizer N used in Arizona are shown in the following table.

Table 1. Common nitrogen fertilizer

Material	Form	%N
Anhydrous Ammonia	Gas	82
Urea	Solid	45
UAN-32	Liquid	32
Ammonium Nitrate	Liquid/Solid	20/35
Ammonium Sulfate	Solid	21

Important Soil Nitrogen Reactions

Any fertilizer N applied as NO_3^- - N is readily available to the plant. Ammoniacal forms (NH_4^+- N) of fertilizer N may be slightly available for plant uptake initially, but after conversion through a two-step biological process, become completely available as NO_3^- - N. The two-step reaction is referred to collectively as "nitrification" and occurs as follows:

1.) $2\,NH_4^+ + 3O_2 \longrightarrow 2\,NO_2 + 2\,H_2O + 4H^+$

2.) $2\,NO_2^- + O_2 \longrightarrow 2\,NO_3^-$

The bacterial organisms responsible for carrying out these important transformations are *Nitrosomonas* and *Nitrobacter*, for the two reactions, respectively. Both organisms are naturally occurring and collectively referred to as *Nitrobacteria*. There are several factors which affect the activity of these organisms and resulting rates of nitrification. Some of these factors include: soil reaction (pH), soil temperatures, as well as soil moisture and aeration. When soils are not saturated due to recent irrigation (contributing to temporary conditions of poor aeration), the conditions in most agricultural soils of Arizona are conducive to nitrification. As a result, most fertilizer N applied to a cotton crop any time during the growing season is converted rapidly to a form readily available to the plant (nitrate).

N Uptake

Nitrate - N is the most available form of N to the plant because it is mobile in soil systems. Therefore, NO_3^- - N moves readily with soil moisture and is available to the plant within the entire range of the root system.

Uptake of nutrients and water occur near the young root tips, particularly the young root hairs. The NO_3^- - N present in the soil water moves to the roots and is taken up with the soil water into the roots. An unfortunate aspect of this phenomenon is that NO_3^- laden soil water will also carry this N form below the root system if a wetting front pushes the soil water below the active plant root system.

N Movement in the Plant

Once NO_3^- is taken up by the roots, it moves in the transpirational stream to the leaves. In the leaves, NO_3^- may either be stored in the petiole or leaf cells (within the vacuoles) or reduced and converted into amino acids. The amino acids are then exported out of the leaves to other organs (roots, stems, bolls, and young leaves) where they are used as building blocks for proteins needed for growth.

In older leaf structures, proteins may be broken down into amino acid components and translocated within the plant to points of new growth and development. The N in older, lower leaves on the plant is exported first and will develop yellow or red coloration prior to abscising and falling from the plant. This is a characteristic symptom of N deficiency.

N Movement in the Plant

The use of N in amino acids and protein formation is an important function of N in the plant physiologically. Nitrogen is also an important component of nucleic acids, which serve in information and control systems in the plant. Enzymes represent an important class of proteins that are used in many of the plants' biochemical systems. An enzyme responsible for converting CO_2 from the atmosphere to carbohydrates is a major constituent of leaves and a major N^- containing compound. If N deficiencies become severe, a resultant disruption of photosynthesis will follow, with a reduction in growth.

N Use Patterns

Maximum N demand by the cotton plant takes place during boll development. Sufficient levels of N also must be present prior to boll filling to prevent fruit abscission and abortion. Research results indicate that approximately 55 to 60 pounds of N/bale of cotton lint is required for production.

Only a small amount of N is needed early in the season. Root systems are small and recovery of fertilizer N applied early or preplant is probably low, until plants develop a more extensive root system and begin to fruit (figure 1 and 2).

Defoliation and N Management

At the end of the cotton production season, Upland cotton plants lend themselves best to chemical defoliation when petiole NO_3^- - N levels have declined to levels below 2,000 ppm. A lowered N level in the plant enhances maturity by promoting senescence and leaf abscission, and reducing growth-stimulating hormones, all of which contribute to more complete defoliation. It is important to manage N nutrition to lower petiole NO_3^- - N levels late in the season without driving the plant into a N deficiency that will diminish yield. Most Arizona cotton farmers have learned that this can be done by reducing N inputs to the crop after peak bloom periods.

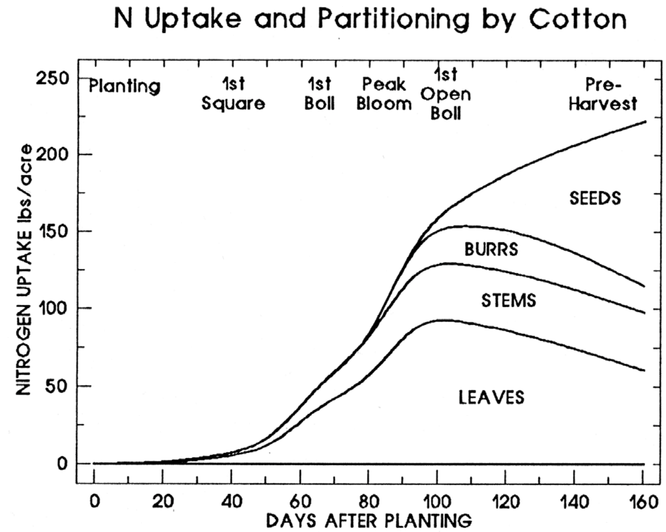

Figure 1.Pattern of N.uptake and partitioning by cotton.

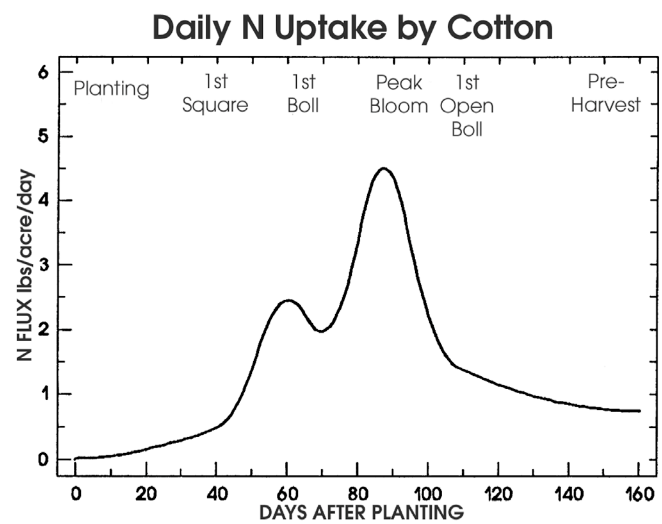

Figure 2. Pattern of daily N uptake by cotton (N flux).

Fertilizer N Management

The actual fertilization program for any cotton crop is not always a simple matter, depending heavily on the experience and skill of the grower, which can be assisted through the use of several basic principles and N management tools.

The cotton plant has a distinctive growth pattern that is often characterized in terms of the flowering pattern or "flowering curve". This curve is typified as being sigmoid or bell-shaped. The peak of the flowering curve is followed by an event called "cutout," which is a temporary reduction in the flower production of the crop. The N requirements and uptake patterns for cotton, closely resemble the growth pattern expressed by the flowering curve.

The total N uptake pattern is shown in Figure 1, and the daily uptake pattern for N is shown in Figure 2. Review of these N uptake diagrams taken from an Upland cotton research experiment in Arizona, reveals that most of the total N needs of the crop are met approximately 100 days after planting (Figure1), which coincides very closely to the peak daily uptake rate (Figure 2). If one were to overlay either of these N uptake plots with a dry matter accumulation curve or a flowering curve, the pattern and relationships in terms of rates and peaks would be very similar. Figure 1 also illustrates the partitioning of N in the plant into various plant parts over the course of the growing season. Of particular interest here is that it can be shown how the cotton plant typically allocates the largest portion of its total N to the seeds late in the season (past 100 days after planting). This is obviously at the expense of N in the leaves, which declines over time simultaneously as N in the seeds increases. This is largely due to translocation and reallocation of N within the plant to the seeds during boll development, which become the strongest sink for N after peak bloom.

The patterns of N use and needs by the cotton plant can be of specific value in managing the N fertilization of a crop. It is obviously very important to supply adequate, but not excessive amounts of N to the crop at all times, but especially in the growth period prior to peak bloom, when the demand is greatest. A deficiency during this period may have a greater impact on yield than a deficiency at any other time. To manage and plan for N fertilization at the beginning of the season, one should obtain a soil sample from each field (preseason) and have it analyzed for residual NO_3^- - N left in the soil form the previous crop. The information provided in Table 2 can be referenced for interpretation of these soil test results in terms of early season fertilizer N management. To minimize the leaching potential of the NO_3^- - N forms by early irrigations, it is important to consider early season fertilizer N management in terms of the needs of an active rooting system of the young plants. This important consideration helps to improve the efficiency of N management and fertilizer N recovery, but also helps in minimizing the potential movement of NO_3^- - N below the active rooting zone of the crop.

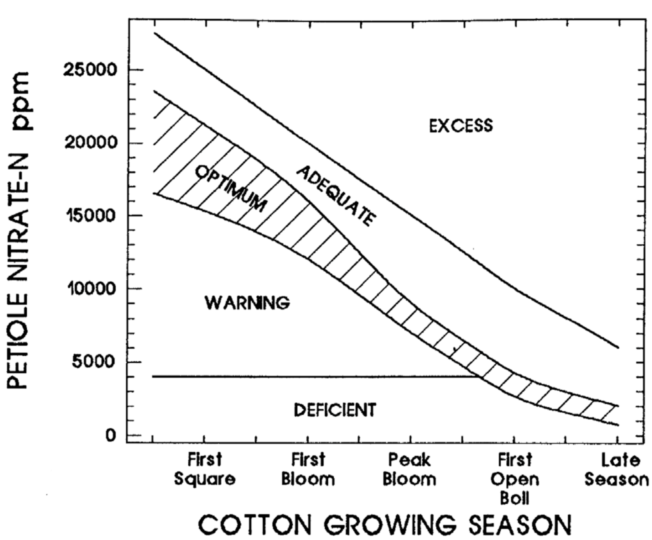

Figure 3. General guidelines for NO_3^- - N concentrations in petioles at various stages of crop development (Upland cotton).

Table 2. Preplant fertilization guidelines based upon preseason soil NO_3^- - N levels.

Preplant Soil Test Level	Preplant N Fertilizer Rate
ppm NO_3^- - N	*lbs N/acre*
0-5	30 - 50
5 - 10	20 - 30
10 - 15	0 - 20
> 15	0

Table 3. Interpretation of irrigation wate nitrates.

Water applied during one growing season	Total nitrate-N applied in irrigation water			
	Nitrate-N content in irrigation water			
	2ppm	5ppm	10ppm	20ppm
acre-feet	*lbs NO_3^- - N applied/acre*			
2	11	27	55	109
4	22	55	109	218
6	33	82	164	328

It is recommended that split applications, by use of side-dress and/or water-run applications of fertilizer N prior to peak bloom periods in the crop, serve to improve fertilizer N efficiency, supply crop needs of N, and reduce losses of NO_3^- - N due to leaching. Use of split applications in-season can be managed by considering the NO_3^- - N contributions from the irrigation water, as shown in Table 3, and by use of regular sampling and analysis of cotton leaf petioles for NO_3^- - N (Figure 3).

Interpretive and management guidelines for the N fertility of a cotton crop based upon petiole analysis have been in place for Arizona cotton production since the mid 1960's (Ray, Tucker and Amburgey, *Soil and Petiole Analyses Can Pinpoint Cotton's Nitrogen Needs*, Folder 97, The University of Arizona, College of Agriculture, 1964). More recent guidelines are available for Upland and Pima cotton in Arizona as shown in Figure 3 and Table 4 (Pennington and Tucker, *The Cotton Petiole, A Nitrogen Fertilization Guide*, Bulletin No. 8373, The University of Arizona, College of Agriculture, 1984).

Analysis of cotton petioles—the stem tissue connectingthe leaf blade to the main stalk—for NO_3^- - N helps determine the N status of cotton at any time during the season. The petiole is selected from the most recently fully-expanded leaves, usually a petiole of the third to the fifth leaf from the terminal. Selection of the correct petiole can substantially influence test results. Petioles from leaves which are younger than the first fully-expanded mature leaf will have NO_3^- - N values lower than those from the mature leaves. In general,

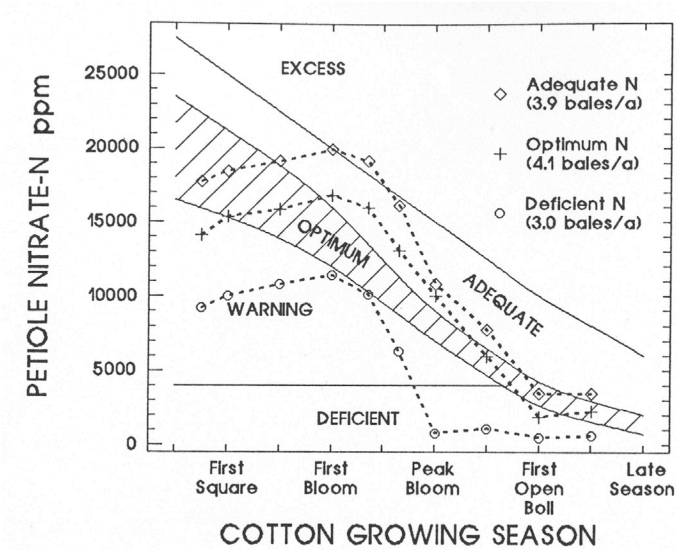

Figure 4. Examples of three N management regimes illustrating petiole NO_3^- - N levels at various stages of growth, and corresponding lint yields (Upland cotton).

Table 4. General guidelines for desirable NO_3^- - N concentrations in petioles at various stages of crop development for American Pima and Upland cotton.

COTTON	Desired Petiole Nitrate Levels	
Growth Stage	American Pima	Upland
	ppm NO_3^- - N	
Early Squaring	10,000+	18,000+
Early Bloom	8,000+	14,000+
First Bolls	4,000+	8,000+
First Open Bolls	2,000+	4,000+

if any doubt exists about which petioles to use, collecting petioles slightly older than the first mature fully-expanded leaf is better than collecting younger petioles.

About 25 to 30 petioles per sample are adequate for analysis. The number of samples tested from each field depends on uniformity of the field. Samples should be collected from uniform areas representing the largest part of a field that can be treated separately. Samplings should be made at one-to-two-week intervals through July.

Nitrogen Management Using Petiole Nitrate Levels

In Figure 4, three N management programs were employed in an experiment with Upland cotton in Arizona. In the treatment designated as "deficient N," petiole NO_3^- - N levels were never brought above the warning and deficient zones, resulting in comparatively lower yields. The "optimum N" treatment provided adequate levels of N according to the N management guideline chart, that were maintained through the peak bloom stage of development. After peak bloom the petiole levels of NO_3^- - N were allowed to decline, and no further N fertilization was applied. This management strategy provided adequate N for excellent yield (4.1 bales/acre), and allowed for a desirable N use pattern of the crop as previously described. This strategy also allows for the natural senescence of the plant's vegetative structure, which accommodates late-season defoliation management, without diminishing yield potential.

The "adequate N" treatment in Figure 4 resulted in somewhat excessive levels of N in the petioles in midseason. The ultimate result of this treatment regime was a slightly more vegetative plant, and consequently a slightly lower yield (3.9 bales/acre).

Whenever petiole NO_3^- - N analysis is being used to manage the N fertilization program for a crop, one must also incorporate a "feel" and understanding for growth patterns, vegetative/reproductive balance, and the overall fruit load of the crop. Other management factors such as irrigation and insect, weed, and disease control must be properly practiced before N management will be completely effective. This will assist in developing a plant of N fertilization that is potentially more efficient, but also more complementary to the production potential of the crop.

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