COTTON PHYSIOLOGY TODAY

Newsletter of the Cotton Physiology Education Program -- NATIONAL COTTON COUNCIL

March/April 1992, Volume 3, Number 5

Fertilizer Placement

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For many soil types, broadcasting and incorporating phosphorus (P) - potassium (K) fertilizer has been a convenient method of supplying these 2 essential plant nutrients. Nitrogen (N) is commonly applied as a band. However, certain soil limitations such as compaction, fixation, leaching, shallow rooting can limit plant utilization of nutrients. So, producers may need to apply fertilizer with greater precision to minimize loss and maximize uptake. In this issue, specific examples will be used to illustrate principles of fertilizer placement:

- As the volume of soil treated with a fertilizer increases, the following also increase: root interception, uniformity of soil test levels **and** potential for nutrient fixation.
- Fertilize to maximize nutrient availability during peak nutrient demand, the first 6 weeks after bloom.
- Place nutrients in the soil zone where roots will be active during peak demand.
- Unbalanced combinations of certain chemicals (P-Zn, K-Mg, Na-Ca, lime-B) may interfere with nutrient uptake from the soil, while others (NH_4-P, NO_3-K) enhance uptake.

Volume of Soil Treated

Band or Broadcast?

Traditionally, fertilizers are either broadcast or applied as a concentrated band. Broadcast applications typically precede incorporation into a uniform soil volume, 6 to 8 inches deep. Broadcasting is generally less expensive and allows higher rates of fertilizer to be applied safely without salt damage to the plant. Band applications place concentrated fertilizer close to the seed row, but not in it. Band applications reduce fertilizer fixation. At low soil test levels banding also gives a greater crop response per pound of fertilizer than does broadcasting. In these tight economic times, on soils that have been under fertilized over the last several years, banding lower rates can be more efficient and economic than broadcasting the same or higher rates of fertilizer.

Fixation vs Root Interception

Fixation by the soil refers to reactions which severely limit plant availability of nutrients such as P and K. Phosphorus fixation is common on highly weathered acid soils, such as the hill country of the Mid-South and Southeast. Potassium fixation occurs on soils with a high illite or vermiculite clay content, such as soils in the San Joaquin Valley and some Mid-South soils. Under fixation conditions, band application is preferred because fertilizer to soil contact is minimized which helps control fixation. If fertilizers are strictly broadcast on high fixation soils, higher rates are necessary to insure that some nutrients are available to the plant after fixation has reduced the supply. Where the cost of applying high rates of broadcast fertilizer to overcome soil fixation is prohibitive, applying fertilizer as a combination of band and broadcast can be highly efficient. Treating too small a volume of soil without fixation problems reduces the ability of the root system to intercept nutrients. Only certain soil and nutrient combinations show strong fixation. Most sandy soils, especially coastal plain soils, generally do not show severe fixation problems. Instead these sandy soils generally have high P and K availability and greater movement of K, resulting in less K stratification problems.

Nutrient &	Soil Types with Strong Fixation
Potash	Medium to fine textured soils, esp. with high illite or vermiculite clay content
Phosphate	Either low or high soil pH
Boron (B)	Recently limed fields
Molybdenum (Mo)	Low soil pH (a problem for soybeans)
Micronutrients	Soil pH 7.5 and above (except Mo)

Supply Peak Daily Demand

Another concern is the soil's ability to supply sufficient nutrients during peak demand periods. Potash uptake can reach 4 lbs per day per acre during the 3rd to 5th week after bloom. The many developing bolls creates a large "sink" for K. Fertilizing a small soil volume with K may restrict uptake. If that volume of soil happens to be too wet or too dry for optimum root activity, uptake can be severely reduced. This is exactly what happens to dryland cotton entering a drought when the K supply is located in the top few inches of soil — uptake is restricted. As a result, responses to deep placement of fertilizer are most obvious in dry years.

Transport

Transport of nutrients to the root should be considered when determining the optimum volume of soil to fertilize. Highly mobile nutrients such as N, B and sulfur (S) move easily with the soil water throughout the soil profile even when band applied.

Producing cotton on beds further complicates movement of mobile nutrients and salts. As the water evaporates from the top of the bed, salts carried with the water accumulate in this zone. In addition, when water is ponded or flowing in the furrows, it can sub or seep into the beds, sweeping nutrients and salts along with it. This concentrates mobile nutrients in the center and top of the bed. Obviously, N applied to the top of the bed would not move into the root zone, if furrow irrigated; however, N applied to the side of the bed would move into the root zone. To determine where best to place mobile nutrients, consider water movement through the soil.

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Potassium has limited mobility in most soils except the coastal plains where mobility is high due to the low clay content and the sandy loam soils of the Southwest where K movement is intermediate. On other soils, K movement can be treated like immobile nutrients (zinc (Zn) and P). Immobile nutrients move very little in the water stream and must diffuse over short distances to nearby root hairs. Surface applied zinc remains in the top 6 inches of soil despite years of ripping, discing and bedding along with irrigation and rain. If fixation is **not** a problem, immobile nutrients should be applied to maximize soil incorporation and mixing, i.e. prior to deep tillage. Where fixation of immobile nutrients does occur, band applications in close proximity to the seedling allows roots to intercept this zone early in the growing season and proliferate in the treated zone.

Methods to Overcome Nutrient Transport and Fixation Problems

Several innovative methods have been developed to increase nutrient availability in problem soils. Each producer must consider their own soil conditions to determine whether any of these methods are appropriate, because not all of them will work on every farm.

- **Deep Placement:** Deep placement equipment is used in Texas to place liquid P fertilizer and in the Mid-South to place dry K or lime-K blends into the subsoil. Untreated soil may however, become depleted if broadcast applications are not also used.
- **Combination Band and Broadcast:** Band and broadcast combinations allow part of the applied fertilizer to be concentrated so that fixation is minimized, and part broadcast so that root interception is maximized. In trials, the broadcast component was more effective at promoting luxury consumption of K early in the season, which is reused during the period of peak demand. Broadcast in combination with banded fertilizer K has resulted in the greatest yield increases.
- **3 Inch Band Starter Fertilizer:** As a cost saving measure, the 3 inch band treatment was developed in the Mid-South. Twelve gallons of 11-37-0 or 10-34-0 are applied at planting in a 3 inch band to the soil surface after the drill row has been closed. Rainfall then moves the fertilizer 1 to 3 inches into a soil **without** fixation potential, effectively treating the zone of early root growth.
- **Band Applications:** The traditional band applications minimize soil fixation, if applications are early enough to minimize root injury yet allow placement in the expanding root zone. Liquid formulations of P or K also can be placed 8 to 10 inches deep to increase deep uptake.
- **Foliar:** Is best used to correct a nutrient deficiency that is not correctable by soil applications. This method is normally used with N, K, B or Zn.

Timing Of Application

"Maximize availability during peak demand" should be the goal for timing application of nutrients. This is easier said than done because of the time required for fertilizers to be activated. "Activated" is a general term that refers to the interval between the time of application and the time a nutrient is available to the plant. This interval includes the time required for any chemical transformation to occur and for movement into the active root zone. In the Southwest, 10 days may be required, after a rain or irrigation, before much plant uptake occurs from a fertilizer such as urea that must undergo both chemical transformation and movement into the root zone.

Plant Nutrient Needs

Nutrient uptake parallels plant growth. When temperatures are warm and the plant is growing rapidly, more nutrients are needed than when either the temperature is cool or growth is slow. Since seeds and bolls are major sinks for nitrogen and potassium, their peak demand starts at first bloom and continues for the next 6 weeks. Cotton plants can take up significant amount of N and K during squaring which is stored for later reuse. After late bloom, most of the bolls have slowed their growth and nutrient demands slacken. Phosphorus is taken into seeds, but because its uptake is limited in the spring by cold soils and small root systems, availability of P needs to be high at planting and during boll filling. Starter fertilizer applications (N and P) are designed to increase P uptake in cool soils. Micronutrients are taken up in small amounts during the entire season in proportion to plant growth.

Activation on Nutrients

Nutrients can only be taken up by plants in specific forms. Fortunately, nutrients contained in most commercial fertilizers are in the proper form. The exception is organic fertilizers. Soil micro-organisms must break down the large organic molecules before nitrogen and phosphorus can be taken up. Potassium in organic fertilizers is already in the available inorganic form, and no further transformation is required. Nitrogen is primarily taken up by the cotton plant as nitrate (NO_3) since this is the dominant form in warm soils, however plants can utilize ammonium (NH_4).

The major component of activation is dissolution into soil water and movement into the root zone. This must occur prior to plant uptake. When fertilizer is applied into dry soil or the zone of application promptly dries after application, subsequent rainfall or irrigation is required to initiate uptake or chemical conversion. Once a fertilizer comes into solution in the root zone, it is immediately available to the plant and can be taken up during the day as soil water is absorbed by the plant. During cloudy or rainy days when the evaporative demand is low water uptake is reduced to less than a quarter of that for a full sun day. As a result, nutrient uptake also is reduced to the same degree.

End of Season Requirements

Where late season rains can promote continued leaf and shoot growth, depleting the soil of Nat the end of the season is critical to boll opening, leaf shedding and curtailment of regrowth. In the irrigated West, control over water allows higher levels of N to be safely applied. However, where the chance of significant rain during late bloom to harvest exists, N fertilizer levels should be reduced and applied earlier. In the Rainbelt, N fertilizer applications to the soil are avoided after the 2nd to 3rd week of bloom because potential delays in activation (drought followed by rain) could stimulate undesirable second growth.

This need to maintain adequate fertility during the first 6 weeks of bloom followed by a rapid decline in soil available N creates a management challenge for producers in the Rainbelt that is met through several mechanisms.

- Fortunately, the cotton plant has a mechanism to store Nand P for future use. This storage, often called "luxury consumption," allows high levels of N and K to be taken up during squaring and reused during the bloom period and is a critical component of short season cotton's N management. Since nutrient demand prior to bloom is low, applications made at or prior to squaring usually result in luxury consumption. Luxury consumption is evidenced in high N and K concentrations of early bloom petiole samples.
- Careful adjustments of N rates to match yield potential will minimize excessive N levels late in the season. Most producers have developed optimum N rates applied prior to bloom which will allow full boll development in most years. For those few high yield years, such as 1991 in the Mid-South, supplemental nitrogen during bloom either applied in irrigation water or foliarly, can support the increased number of bolls and seeds.

Placement In Relation To Roots

Movement to Roots and Root Injury

Nutrients need to be placed where roots can absorb them during peak demand. Since nitrate is mobile in the soil water, it can be moved from any place in the root zone with water. The immobile nutrients (P, K and Zn) require more planning in terms of placement to avoid root injury and still maintain availability. For example, if mid-season drought is the norm, then placement of immobile nutrients early in the season, below the surface soil, will increase their uptake during periods of moderate drought when the surface soil drys but moisture is still available deeper in the profile. On the other hand, no-till cotton growing where subsoils are acidic may have very shallow roots and placement on the surface is highly effective.

In the Mid-South and Southeast, shallow root injury (less than 4 inches) such as from early cultivation, appears to have little deleterious effect (Snipes 1992). However, root injury can be damaging during the bloom period when the roots' capacity to regrow is reduced or if the injury results in plant wilting.

Salt and Ammonia Hazard

The cotton plant's high tolerance of salts minimizes the chance of injury from fertilizer salts, however, cotton seedlings are highly sensitive to ammonia and salts. When fertilizers are placed close to the seed, low salt forms such as 8-24-0, 10-34-0 and 11-37-0 should be used, and then only at previously tested rates and no closer than 2 inches to the side and below the drill row. When fertilizer is applied at bedding directly below the seed zone it can later wick up into the seed zone. A rain pattern of alternately wet and dry increases this upward movement of fertilizers and can result in salt injury.

Pop-up fertilizers are applied to the seed row at very low rates, in dilute solutions. These can damage the stand if applied in high rates, greater than 1.5 gals per acre of 11-37-0. Preliminary results show some yield benefit to this low rate of fertilizer applied in 5 gals of mix per acre. Unfortunately, supplemental fungicides do not appear compatible with these pop-up fertilizers.

Ammonia toxicity kills root tips and roots when soil pH is high and soil temperature warm. Sandy soils are particularly susceptible to ammonia toxicity due to their low clay content. Clay has a high capacity to absorb ammonium, thus reducing the likelihood of ammonia toxicity. Cotton growing on sandy soils is often fertilized in at least 2 applications to minimize leaching loss of nitrogen and avoid ammonia toxicity. When applying high rates of ammonia fertilizers (urea, anhydrous ammonia, UAN32 and 18-46-0) to soils with a pH over 7.5, insure that placement is away from existing roots or the seed furrow (drill row).

Soil Water Movement

- Since soil water movement is the major route for nitrogen movement into the plant, an understanding of the conditions that promote water movement is important. In general, arid environments experience excellent water movement to the roots anytime the soil is moist, but not saturated. At typical plant densities, up to a quart of water per plant per day can move from the soil through the plant and into the atmosphere. Even in a dilute solution of nitrogen (50 ppm Nitrate-N) sufficient N will move to the plant to meet maximum demand (4 lbs of N per day per acre). The following conditions reduce water movement to the roots and thus reduce uptake of nitrogen:
- Slow root growth due to a heavy boll load.
- Soil flooding reduces the soil oxygen necessary for root uptake of nutrients, water and microbial conversion of ammonium to nitrate. Foliar urea applications have been used in South Texas and Australia to supply N to yellowing plants during brief periods of soil saturation.
- Drought can reduce nutrient uptake as water movement through the plant is reduced.
- Humid, overcast weather slows water movement because evaporation out of stomates is reduced. Temporary N deficiencies can be induced by humid, overcast weather even though the soil is adequately fertilized. If these conditions occur during early to mid bloom, foliar feeding may be beneficial.

Placement With Other Nutrients

The soil solution from which plants draw their nutrients is a complex soup of chemicals. For the most part the presence or absence of any nutrient has little effect on uptake of other nutrients. Several exceptions are important in cotton production where specific nutrients enhance or limit uptake of other nutrients.

P or K with N: When N is mixed with either P or K, uptake is enhanced due to the root growth stimulation of nitrogen. For this and formulation reasons, starter fertilizers contain both N and P.

Lime: Lime has a positive effect on uptake of most nutrients when applied to acid soils. Soils with a pH below 5.5 can suffer from low calcium availability and aluminum-manganese toxicity. Both of these conditions restrict root exploration into low pH soil. For continued root extension, pH and calcium levels must be favorable because the root tip can only get this essential element directly from the surrounding soil. High applications of lime can have a detrimental effect on uptake of B and Zn. Availability of these 2 nutrients is lessened in high pH soil.

Elemental Sulfur: Elemental S acidulates the soil and can increase the availability of micronutrients in high pH soils. For highly calcareous soils that would be prohibitively expensive to completely neutralize, applications of S or sulfuric acid can provide localized zones of low pH that are more suitable for nutrient uptake.

Magnesium and Potassium: Several nutrients are so similar in size and charge that one can interfere with root uptake of the other. Some Delta and Western soils are natively high in magnesium that interferes with the uptake of K. However, fertilizers containing both magnesium and K do not appear to create problems for K uptake.

Zinc and Phosphorus: Some nutrients interfere with utilization in the plant. If applications of either Zn or P are excessive, then utilization of the other can be reduced. Applications of either in excess of recommended rates should be avoided. Several negative relationships between yield and soil P have been attributed to this interference with Zn utilization. Especially avoid excess P in soils with a pH above 7.8 where zinc availability is already very low. Just as with magnesium and K, fertilizer combinations of Zn and P appear to successfully increase the uptake of both. Applications of Zn should be limited to regions where yield responses have been documented.

Fertilizer Placement in No-till Cotton

No-till cotton relies on surface applications of nutrients with only limited subsurface placement of banded and starter fertilizers. This results in a highly stratified soil condition. The organic matter content, nutrients and pH, all can change dramatically with each inch of depth. Fortunately, this enriched soil surface also is highly favorable for root proliferation because cultivation doesn't disturb the surface roots or moisture, and the protective layer of organic matter cools the soil and retains soil moisture during summer heat.Nutrients become enriched in the high organic surface soil of no-till cotton and thus traditional soil tests that focus on inorganic nutrients may underestimate soil nutrient supply. Producers can test the need for nutrients themselves by treating strips through a field. Use of a starter fertilizer has been found to increase no-till cotton yields. This practice has been beneficial during years when the soils tend to remain cooler than normal during the first month after planting.

Soil test levels should be considered when fertilizing any field, no-till or conventional. Response from a fertilizer is less likely if the soil tests levels are high for that nutrient. By the same token, yields are more likely to be enhanced by fertilization if the soil test is medium or low. Soil tests reflect the best technology available but should be supplemented with experience, local trials and tissue analysis.