FERTILIZATION

As fertilizer and lime costs continue to rise, getting the most from your 'fertilizer dollar" is even more important. Soil testing also becomes more important since this is the best way to guide your fertilizer and lime needs. Other tools such as tissue and petiole testing should also be considered so that fertilization and liming are not the weak link in the overall management package.

There are numerous ways to fertilize and lime a cotton crop. However, an overall strategy that combines the best materials, rates, timing, and application methods to produce the highest economical yield is the ultimate goal. This is especially true for nitrogen fertilizers since nitrogen is usually the essential plant nutrient needed most by cotton. In addition, a good program must allow for in-season adjustments that account for specific site and weather situations. Both under-fertilization and over-fertilization should be avoided in order to make good yields and profitable returns.

Lime

The official UGA recommendation or "target" pH (water) for cotton is 6.0. However, a field with an average pH of 6.0 may very well have large areas measuring below this target pH. Recent precision soil sampling techniques have indicated that this happens frequently. Therefore, growers using standard soil sampling techniques are encouraged to maintain their soil pH for cotton between 6.0 and 6.3. Liming to pH values above 6.3 may cause manganese deficiency problems in the Flatwoods soil region. However, this problem can be handled easily with applications of foliar Mn during the growing season. Liming soils 6.0 to 6.3 for all soil regions in Georgia is critical for proper uptake and utilization of nutrients that are essential for plant growth. Fertilizer use efficiency is also best in this range. In addition, toxic elements such as aluminum (Al) are kept unavailable when pH is above 5.5.

There are many factors that affect the soil pH reading obtained form soil testing. Possible reasons for seeing abrupt changes in soil pH include 1) sampling variability (spatial and depth), 2) rainfall amounts and 3) nitrogen fertilizer usage. Even so, changes of more than 0.5 in soil pH in one year should be considered suspect and called for resampling.

Dolomitic lime is the most common liming material used on Georgia cotton which provides magnesium (Mg) as well as calcium (Ca) and a pH adjustment. Calcitic lime may be used in cases where high soil Mg levels occur. A good liming program should supply all the Ca and Mg cotton needs. Calcium deficiency in cotton is very rare, and the need for foliar Ca applications or small doses of supplemental Ca applied to soil should be considered unnecessary.

Phosphorous and Potassium

Phosphorous (P) and potassium (K) levels in soil should be maintained in the upper medium range as determined by soil testing. All of the P requirements should be applied preplant since it is relatively immobile in soil and is important to seedling growth. All of the K requirements should also be applied preplant on all soil types including Piedmont, Coastal Plain, and Deep Sand soils. Widespread K uptake and deficiency problems in recent years have lead to investigations into ways to combat this problem. Split applications, especially half the recommended rate at planting and half at sidedress, have not proven to be effective. In fact, in some cases this approach may lead to potassium deficiency before sidedress applications are made. Recent field trials conducted in Georgia have focused on additional soil-applied K during

N sidedressing versus foliar K applications during peak bloom (first 4 weeks of bloom). Preliminary results from studies conducted on Coastal Plain soils indicate that foliar K may be more effective than sidedress K in improving yields. Research on Deep Sands is still needed to determine which approach is more effective. Currently, foliar K applications should automatically be considered on deep sands (more than 18 inches to subsoil clay), low K soils, high Mg soils, high-yielding conditions, short season varieties and especially, where severe K deficiencies have been observed in the past.

Nitrogen Management

Nitrogen is probably the most important fertilizer used on cotton, yet it is the most difficult to manage. Low N rates can reduce yield and quality while excessive N rates can cause rank growth, boll rot, delayed maturity, difficult defoliation, and poor quality and yield. Total N rates for cotton should be based on soil type, previous crop, growth history, and yield potential. Base N rates recommended by the UGA Soil Testing Lab according to yield goals are listed below.

Yield Goal (lb lint/A)	Recommended N Rate (lb N/A)
750	60
1000	75
1250	90
1500	105

These N rates should then be adjusted according to other factors. For example:

Increase N rate by 25% if:
- Deep sandy soil
- Cotton following cotton
- History of inadequate stalk growth

Decrease N rate by 25% if:
- Cotton following peanuts or soybeans
- Cotton following good stands of winter legumes such as clover or vetch
- History of rank or excessive vegetative growth

Yield goals should always be realistic, preferably based on past production records. For N rates above 100 lb/A, cotton should be highly managed in terms of insect control, plant height, and boron fertilization. Total N rates above 120 lb/A should only be needed on deep sands or in special cases of history of inadequate stalk growth or where excessive leaching has occurred. The N rates for the 1250 and 1500 lb lint/A yield goals assume irrigation.

The total N rate should always be applied in split applications. Apply 1/4 to 1/3 of the recommended N at planting and the remainder at sidedress. The preplant or at planting N application is critical for getting the crop off to a good start and ensuring adequate N nutrition prior to side-dressing. Sidedress N between first square and first bloom depending on growth and color (toward first square if slow growing and pale green, toward first bloom if rapid growth and dark green). A portion of the sidedress N can also be applied as foliar treatments or through irrigation systems.

There are a number of nitrogen fertilizer materials that can be used on cotton including UAN solutions, ammonium nitrate and urea. UAN solutions are made up of urea and ammonium

nitrate and often contain sulfur (e.g. 28-0-0-5). Ammonium nitrate is losing favor as a sidedress N source for cotton due to higher cost and burn potential. Urea is being considered as an alternative to ammonium nitrate but is known to be prone to volatilization losses. Volatilization losses can be minimized however by irrigating after a urea application or by use of a urease inhibitor such as Agrotain. Feed grade urea is still the product of choice for foliar N applications later in the growing season. Controlled release nitrogen foliar products are also available but usually contain potassium and boron and are less concentrated in N.

Sulfur

The official UGA fertilizer recommendation for sulfur is 10 lb/A. Sulfur can be applied either with preplant fertilizer or with sidedress N materials such as 28-0-0-5 or ammonium sulfate. Sulfur fertilization is most important on sandy, low organic matter Coastal Plain soils. With less S input from cleaned ("scrubbed") power plant smokestack emissions and the recent trend toward high-analysis (S-free) fertilizers, including S in a cotton fertilizer program is currently very critical. Adequate S fertilization is also important where higher rates of fertilizer N are used. Since S deficiency symptoms are similar to N deficiency (yellowing) and the N:S ratio in plant tissue is a good indicator of S nutrition, a plant tissue sample greatly aids in diagnosis when low S is suspected.

Boron

Boron (B) is an essential micronutrient that is important to flowering, pollination, and fruiting of the cotton plant. The standard recommendation of 0.5 lb B/A, applied in two 0.25 lb/A foliar applications between first square and first bloom, fulfills the base requirement for B. Single applications of 0.5 lb B/A can be used but include a greater risk of foliar burn. Foliar applications above the base recommendation of 0.5 lb B/a and up to 2 lb B/A (applied in increments of no greater than 0.5 lb B/A per application) may help move nitrogen and carbohydrates from leaves into developing fruit. Cumulative applications totaling above 2 lb B/A, however, may reduce yields and quality. The need for additional B above the 0.5 lb/A rate is best determined by tissue or petiole testing. Since B leaches readily through sandy soils, foliar applications have always been considered the most effective and efficient application method. However, on a typical Coastal Plain soil like the Tifton series, with normal rainfall and irrigation, preplant, starter, and sidedress soil applications are also be considered effective. If no B is included in preplant, starter, or sidedress soil-applied fertilizer applications, is foliar B alone (with no insecticide or growth regulator) worth the trip? Yes, especially on sandier soils and with irrigation or adequate rainfall.

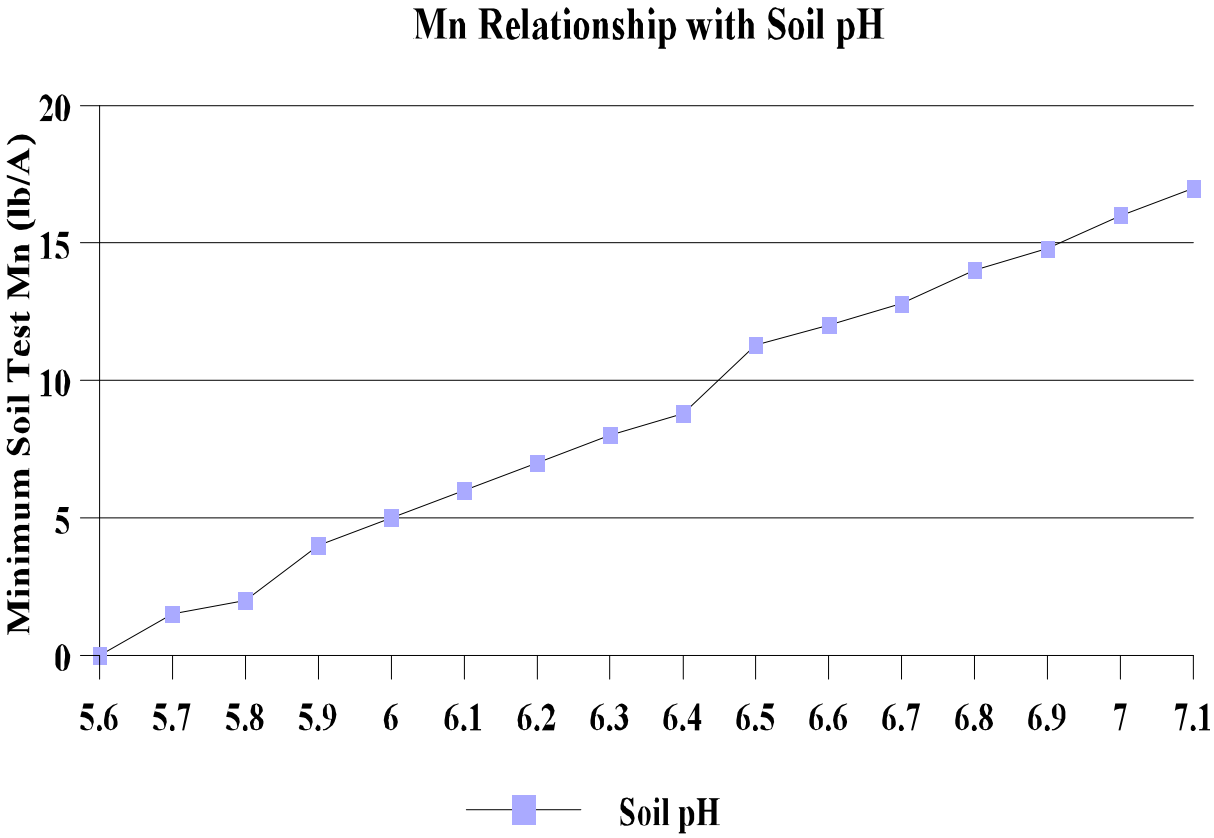
Numerous B fertilizer materials are currently available. Most are either derived from boric acid or sodium borate and can be either in the liquid or wettable powder form. There are many "additives" used with these base B materials such as nitrogen and complexing agents designed to improve efficiency of uptake. However, extensive field testing over recent years has proven that all of the B fertilizers currently on the market are equally effective in terms of plant nutrition. Therefore, choice of B fertilizers should be made on price per pound of B.

In addition, at least one boron fertilizer currently sold in Georgia is recommended at application rates well below the recommended 0.5 lb B/a rate. As far as fulfilling the 0.5 lb B/a base recommendation, any application rate below 0.25 lb B/a should be considered "uneconomical." Again, since all boron fertilizer materials are thought to be similarly effective, rates should be based on actual B delivered.

Manganese and Zinc

Manganese (Mn) and zinc (Zn) are two essential micronutrients that are routinely measured in soil testing at UGA and can sometimes be deficient in cotton. Both Mn and Zn are less available for plant uptake at higher soil pHs. Therefore, soil test results should be examined closely for the combination of low levels of Mn or Zn and high soil pH.

In order to minimize the chance of Mn deficiency on cotton, minimum levels of soil test manganese should be maintained with varying pH levels as shown in the following graph.



Notice on the graph, that if soil pH is at the recommended target of 6.0, soil test level of Mn should be at least 5 lb/A. At soil pH of 6.5 the soil test level of Mn should be at least 11 lb/A.

Even when the soil test level of Mn falls below the recommended level for a given pH, the result is not an automatic recommendation to apply Mn fertilizer. Instead, the crop should be monitored using tissue testing between first square and first bloom and foliar Mn can be applied if a deficiency is confirmed. Small amounts of Mn can also be added to starter fertilizer applications. Be sure to read and apply Mn and other micronutrients starter packages according to label to avoid burn and stand loss.

Large amounts of soil applied Mn (above 5 lb/A) are not considered to be economical. Therefore, in situations where soil test levels of Mn need to be built up, do so slowly and monitor the crop for deficiency using tissue testing. In essence, if a grower likes to maintain soil pH near the UGA target pH of 6.0, then soil test Mn should be built to and maintained around 5 lb Mn/A. If the grower likes to maintain soil pH at a higher level, say around 6.5, then the soil test level of Mn needs to be built to and maintained around 11 lb/A.

Cotton growers in the Flatwoods soil region are cautioned not to maintain soil pH above 6.3 to minimize the chance of Mn deficiency (peanuts are also susceptible to Mn deficiency at this pH on these soils). If soil pH is maintained above 6.3 on these soils, tissue testing is recommended regardless of soil test Mn levels in order to avoid deficiencies. If a deficiency is detected in this situation, it can be corrected by foliar feeding Mn.

Soil test levels of zinc should be maintained between 2 and 8 lb/A. Unlike Mn, if soil test Zn falls below this range, it is considered low and an application of zinc fertilizer will be recommended. The recommended Zn fertilizer can be applied with broadcast preplant fertilizer or more efficiently, with a starter fertilizer application. In the event that no zinc is applied to the soil even though recommended by soil testing, a foliar application of zinc can be made. Tissue testing in both cases, whether Zn was applied to soil or applied foliar, is recommended. The tissue sample should be taken between first square and first bloom. Tissue sampling at first square is better than at first bloom in order to correct the deficiency before the crop experiences any possible reduction in yield.

Deficiencies of the other essential micronutrients including copper, iron, chlorine, and molybdenum in cotton are extremely rare.

Petiole and Tissue Testing

The University of Georgia currently offers a 10-week petiole testing program for monitoring the N and K status and for making N, K, and B foliar applications. Leaf stems (petioles) are sampled weekly from the same field starting the week before first bloom and analyzed for N, P, and K. Depending on the relationship between N and P, along with other information such as soil moisture and fruit load, foliar N and/or B will be recommended. Potassium levels are also monitored and in the case of K deficiency, soil-applied or foliar K applications will be recommended. A valuable feature of petiole testing programs is that weekly sampling tracks nutrient level trends and allows the detection of deficiencies or excesses up to 2 weeks in advance. Most importantly, petiole testing allows in-season correction of problems. Unfortunately, due to cost and labor, petiole testing is a severely under used tool.

Tissue testing (the leaf blade without the petiole) is also available through the University of Georgia lab and can be especially helpful to detect deficiencies of nutrients not included in petiole testing. Tissue testing is used differently than petiole testing in that it does not track nutrient level trends, but instead gauges nutrient levels in the leaf blade at certain growth stages. Magnesium, S, Mn, and Zn can all be measured and deficiencies can be detected and corrected. The most common growth stage when cotton leaf tissue is sampled is early bloom, the same time as the first petiole sampling. However, tissue sampling can be helpful earlier during the "vegetative" stage to detect and correct early nutrient problems. Tissue sampling can also be used

any time during the growing season when trouble shooting if samples are taken from both normal ("good") and affected ("bad") areas of a field.

Since petiole and tissue samples tell different things, it is recommended that both are taken during troubleshooting (especially when past the first bloom stage). For example, petiole samples appear to be a better indicator for N and K deficiency than tissue samples when troubleshooting, but tissue samples are useful for detecting S deficiency (based on the N:S ratio) and micronutrient deficiencies. Also, petiole samples analyzed as tissue samples and vice versa will result in useless information. For example, measuring the nitrate level in a tissue sample or total N in a petiole cannot be interpreted since no data are available for these measurements.

Private labs in the state also offer petiole testing programs and tissue testing services. In recent years, reduced-frequency petiole sampling programs (3 or 6 weeks) and combination packages (petiole and tissue tests) have been offered by private labs. These programs (for example, sampling at the vegetative, early bloom, and late bloom stages) can be attractive due to less sampling and the opportunity to automatically check on secondary and micronutrients with an early tissue test. Timing is even more important with the less-frequently sampled programs since results are based on critical stages of nutrient demand by the cotton plant.

Consistent soil moisture increases the reliability of petiole testing results. Representative samples are more critical for petiole testing than with soil testing. Growers and scouts are urged to closely follow sampling instructions and to provide exact information requested for each sample. Apart from good sampling techniques and consistent soil moisture, petiole results can be unreliable and confusing.

Foliar Fertilization

Foliar fertilization of cotton should be used to supplement a good soil-applied fertilizer program. The most likely nutrients needed for foliar applications are N, B, and K. Foliar N applications can be made as part of an overall N management strategy or as determined by petiole testing. Urea is the most reliable, economical, and proven foliar N material. The standard recommendation is for 4.5 lb N/A as urea in 5 gal or more of water (5gal/A assumes aerial application). Both liquid (23 % N) and granular urea (46 % N dissolved into water) can be used. Applying all the recommended K to soil preplant or at-planting should provide sufficient K for Georgia cotton in most cases. Again, due to recent K problems, foliar K applications should be considered on deep sands (more than 18 inches to subsoil clay), low K soils, high Mg soils, high-yielding or short season varieties, or any fields where K deficiencies have been a problem in the past. Potassium nitrate is the most common material used for foliar K applications. The standard recommendation is for 4.4 lb K_2O/A in 5 gal or more of water. Again, 5 gal/A assumes aerial application and both liquid and granular KNO_3 can be used.

Starter Fertilizers

Although starter fertilizers do not consistently increase cotton yields, they are an effective way of providing early N and P as part of an overall fertility program. Yield responses have been most consistent where soil P levels are low or when planting in cool, wet soils. The use of starter fertilizer is strongly encouraged for conservation tillage systems and in high yield situations. Even though yield responses may not be realized, other advantages include the development of

strong root systems and the encouragement of early rapid growth for weed control with directed herbicide sprays.

Ten gal/A of 10-34-0 is probably the most common starter fertilizer treatment used on Georgia cotton. Nitrogen solutions (with or without S) and complete (N-P-K with micronutrients) dry fertilizer materials can also give good results. Recent research conducted in Georgia showed that the choice of starter fertilizer should depend on soil type and conditions. For example, on "red dirt" such as the Greenville series that has a high affinity for P, P-containing materials such as 10-34-0 should be used. On "stiffer" Coastal Plain soils such as the Tifton series that have medium to high soil test P, N-only materials such as 32 % N liquid can be used. On sandy Coastal Plain soils with histories of S problems, N+S materials such as 28-0-0-5S should be considered. An economic evaluation of this same research showed that in 23 out of 30 comparisons, starter fertilizer gave greater economic returns compared to the untreated check. Adding liquid micronutrient packages to liquid starter materials is also gaining in popularity. This may be a good way of providing recommended B, Zn, and Mn in an overall fertilization program.

The recommended placement for any starter fertilizer is 2 inches below and 2 inches to the side of the row (also referred to as "2-by-2"). **No starter fertilizer materials should be placed in direct contact with the seed in the furrow**. "Dribbling" liquid starter fertilizers on the soil surface, 2 inches to the side of the furrow (to avoid possible leaching into the seed zone) has proven effective on sandy soils but does not work on "stiffer" soils. **Avoid using starter fertilizer rates greater than 15 lb N/A**, even in the 2-by-2 placement, in order to reduce the risk of "starter burn." Under certain conditions -- namely dry, sandy soil -- even 15 lb N/A can burn cotton seedlings if not placed properly.

Starter fertilizers can also be applied in conjunction with herbicide applications by spraying narrow bands (3 to 4 inches) directly over the row behind the press wheel. Mixing liquids containing both N and P with preemergence herbicides can result in clogging of spray nozzles and can decrease the fertilizer effect (or benefit) by spreading the material in a wider band. However, this may supply some needed N when no other preplant N has been applied. Rates should not exceed 20 lb N/A when this method is used.

Poultry Litter

Managed properly, poultry litter (manure mixed with wood shavings) can be a valuable source of plant nutrients for Georgia cotton. The fertilizer value of poultry litter varies depending on a number of factors including moisture, temperature, feed rations, number of batches before clean-out, storage, and handling. However, broiler litter has an approximate analysis equivalent to 3-3-2 (%N – % P_2O - % K_2O). Based on this average, one ton of broiler litter contains 60 lb/A of N, 60 lb/A of P_2O and 40 lb/A of K_2O. Based on current fertilizer prices for N, P, and K, poultry litter is valued at approximately $25/ton. Due to variability, it is recommended that litter be analyzed for nutrients by a reputable laboratory before application rates are determined.

Poultry litter on cotton should be managed to provide preplant P and K and a portion of the total N requirement. The remainder of the N requirement should be applied as commercial fertilizer at sidedressing. For example, 2 tons/A of poultry litter preplant incorporated followed by 30 to 60 lb/A of sidedress N (depending on soil type) is a good, basic strategy.

This approach should avoid unnecessary P buildup and should not cause rank growth, boll rot, or defoliation problems typically associated with excess N. In addition, the availability of N from poultry litter, because it is an organic material, is less predictable than from commercial fertilizer. Therefore, side-dressing with commercial fertilizer N assures adequate N availability when the crop needs it the most. The amount and timing of N released from litter depends on a number of factors, including soil pH, temperature, sand content, and available moisture. As a rule of thumb, 60% (or 36 lb N/ton of litter) is made available for crop uptake during the season if the manure is incorporated into the soil prior to planting. Most of the remaining N in the litter (about 40%) is either lost or "tied up" during the growing season and should not be considered for carryover to the next crop. Since N availability from poultry litter can be highly variable, petiole testing is strongly recommended. Build up of soil P and Zn are long-term concerns for using poultry litter as fertilizer. However, at the 2 ton/A rate, there are no short-term concerns for poultry litter use in cotton.

The only situation where poultry litter rates above 2 ton/A should be considered is where problems with "black root" are suspected. Black root is isolated to poorly-drained Flatwoods soils. Rates of 3 to 4 tons of poultry litter per acre have been shown to alleviate this problem dramatically. However, at the 4 ton/A rate excess soil P will build rapidly. Therefore, this solution should only be considered a short-term fix and not a long-term strategy.

Other By-Products

As landfill costs and regulations increase, more by-products are becoming available for land application on row crops such as cotton. These by-products are not only from the agricultural sector (such as poultry litter), but also from municipalities and industry. Examples include gin trash, mushroom compost, yard waste, biosolids, composts, fly ash, and wood ash. These materials may have some value as fertilizers, soil amendments, or liming materials. They may be free or available at very low cost. However, great caution is needed when considering the use of any by-product to ensure it can be used, safely, effectively, and economically.

Before considering the use of any by-product material on cotton, investigate the properties of the material. Find out what value it has (as either lime, fertilizer, soil amendment, or a combination), if it is safe (for example, low in heavy metal content and free of any toxins), how much it costs, and if it will handle and spread easily. Fortunately, any by-product material to be used as a fertilizer, lime, or soil amendment in Georgia must first be approved by the Department of Agriculture. Since by-products are unique, they should be investigated on a case-by-case basis.