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Foliar Feeding Cotton

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There seems to be conflicting information about foliar fertilizers and their timing of application to cotton. Much of the confusion lies in the variety of fertilizer products available. A cotton farmer now has a choice of applying foliar fertilizers (according to fertilizer labels) beginning at the first true leaf stage and continuing until defoliation. This newsletter will focus on available information about foliar fertilizers: when and how they may be best used to maximize economic returns.

Unfortunately, many foliar fertilizers are used by farmers when the cotton crop encounters stress conditions such as drought, hail damage, sand blasting or flooded soils. Uptake of fertilizers through cotton leaves is often decreased drastically under stress conditions. Additionally, there has been an increase in the use of foliar fertilizers on seedling and young cotton. There is very little scientific data to support the use of these early season foliar fertilizers unless a known deficiency has been diagnosed. Several problems associated with these early season foliar applications are:

- Small leaf area for nutrient absorption,
- Minimal demand for nutrients at this stage and
- Low amounts of nutrients being applied.

Soil applied starter fertilizers may be a better choice for farmers wanting an early season growth response until more data on early season foliar fertilizers becomes available.

The best use of foliar fertilizers would be to supplement a good soil based fertilizer program. If environmental conditions are favorable for a large boll set, the crop will need and utilize significantly more nutrients than if boll set is limited. Under these favorable conditions, in-season foliar fertilization to supplement a soil applied program may be necessary for maximum yield and quality.

(continued on page 4)

In this issue

Leaf Feeding Insects and Mites

L. Ted Wilson and Frank Carter

Although entomologists have reported in excess of 1,000 species of insects and mites inhabiting cotton, only a handful cause economic loss. Several mechanisms give cotton this high degree of natural resistance to many insects. First of all, cotton has the capacity to rapidly produce leaves and fruit when temperatures are warm and water available. This capacity for rapid leaf growth probably derives from cotton's origin in dry climates. Cotton developed the capacity to sustain life during prolonged drought and then explode with growth following summer rains. This rapid leaf growth minimizes the impact of insect leaf feeding. Secondly, cotton is well known for its production of compounds such as gossypol and tannins, which are highly toxic to pests. Even in the absence of mortality from natural enemies and pesticides, less than 40-60% of those pests which are well adapted to cotton will survive. When mortality due to predation and parasitism is added, 12% to less than 1% will survive to the more damaging latter instar stages. Unfortunately, insects and mites also have evolved to utilize cotton as a host; and although only a small percentage survive, their reproductive rates are sufficient to insure that their population will increase on cotton if conditions are favorable.

Yield Loss from Insect Damage

Cotton's yield loss from insect damage depends on the stage of crop growth, the type and intensity of the damage, and in some cases the prevailing weather conditions. Fruit feeding pests are far more important economically than leaf feeders. In the Beltwide Insect Crop Loss Report, entomologists ranked the various insect and mite pests on cotton, based on the percent of the U.S. cotton crop lost. The top 3 pests, averaged over the last 5 years, were fruit feeders (boll/bud worms - 1.9%, boll weevil - 1.8% and lygus bugs - 1%) while the top 3 leaf feeders caused only one third the yield loss (spider mites - 0.7%, aphids - 0.6% and thrips - 0.4%). Damage by leaf feeding pests can be divided into four general categories: (1) chewing, (2) piercing-sucking, (3) tunneling and (4) lint contamination.

	Type of Damage	Impact on		
		Yield	Quality	Maturity
Aphids	Piercing, Contamination	2*	1*	minimal
Armyworms	Chewing	1	2	delay
Leaf Perforator	Tunnelling	1	2	minimal
Spider Mites	Piercing	1	2	earlier
Thrips	Piercing	1	2	delay
Whiteflies	Piercing, Contamination	2	1	minimal

* Potential for severe loss = 1, minimal loss potential = 2.

Chewing Insects

Chewing pests which feed on leaves include: the various armyworms (Spodoptera spp.), cabbage looper (Trichoplusia ni), salt marsh caterpillars (Estigmene acrea) and occasionally other larvae of nocturnal moths.

Armyworms and Salt Marsh Caterpillars

Armyworm and salt marsh caterpillar eggs are laid in masses of up to 2 or 3 hundred eggs per mass, with each female moth capable of producing several masses. Although the females may place the masses practically anywhere on the plant, they are often found on the under side of leaves in the middle of the canopy. Upon hatching, armyworm and salt marsh caterpillar larvae skeltonize the leaves until the end of the third instar. By the time larvae begin to disperse during the fourth, fifth, and sometimes sixth instars, they no longer skeletonize leaves. Damage during these later stages appears as open holes in the leaves. Many of the armyworms also feed on fruit, although most of the species in the U.S. prefer to feed on leaves. Fourth and fifth instar stages feed on the outside of bolls, while the fifth instar larvae generally can feed inside bolls that are less than 13 days old.

Cabbage Looper

The cabbage looper in contrast lays its eggs singly, but again most often on the lower surface of leaves in the middle of the canopy. Leaf damage is similar to that for the previous pests except that the larvae do not cluster and as a result skeletonization by younger larvae is not as obvious.

Chewing Insect Damage

Damage by chewing insects can occur at practically any stage of crop growth. Research in Australia, China, Mexico, and the U.S. has shown that damage to cotton by leaf chewing insects can decrease yield but that the amount of leaf area that must be consumed to cause an economic loss is often considerably higher than what most growers consider to be acceptable. If damage is restricted to leaves, cotton can tolerate up to 75% loss in leaf area prior to square initiation with no effect on crop maturity or yield. When high levels of leaf feeding occur later in the season or when stress restricts leaf development, cotton may not tolerate this level of injury. From square initiation until the majority of bolls have matured, the crop is only able to tolerate as little as 25% leaf loss without affecting yield.

Early season armyworm damage, when it occurs, also can delay crop maturity when larvae feed on cotton terminals. On hundred percent terminal damage prior to squaring can delay the crop maturity by up to 14 days. Damage to terminals later in the season will not affect yield or maturity, unless the leaf injury levels above are exceeded. Under extremely high late-season leaf feeding pressure, lint quality may be reduced when the larval feeding is followed by heavy rainfall which washes larval frass and leaf fragments into open bolls.

Piercing-Sucking Insects and Mites

The majority of cotton leaf feeders either pierce the leaf surface with their mouthparts to suck the cell contents (aphids and whiteflies), or rasp and suck the contents from the cells (spider mites and thrips).

Aphids and Whiteflies

Aphids and whiteflies, although considered to be less important pests than spider mites and thrips, are nevertheless a major concern to the textile industry due to their copious production of honeydew and the subsequent discoloration from sooty molds. The resulting sticky and stained cotton not only reduces lint quality, it also has the potential to develop reluctance by textile mills to buy cotton from areas having a sticky cotton problem. Therefore populations of aphids and whiteflies during boll opening should be monitored closely to avoid honeydew contamination of the lint.

Aphids and whiteflies are both primarily late season pests. In the West where aphids and whiteflies have been a greater problem, damage is less when early season insecticide applications can be avoided. Early season insecticide sprays contribute to aphid resistance and apparently destroy or suppress a complex of parasitoids which normally keep these pests in check. Prior to the broad scale use of calcium arsenate in the early 1940s, neither of these pests were a significant problem to cotton production. Even in fields previously treated with broad spectrum insecticides, aphid populations often collapse prior to boll opening if predators and parasites are allowed to rebuild or if pathogenic fungi develops.

Both pests also have an incredible ability to multiply rapidly, as well as the ability to rapidly develop resistance to insecticides, factors which can promote their pest status. Based on research in California's lower desert valleys, it appears that whiteflies are less severe in short season cotton.

Spider Mites

Spider mites undoubtedly are the most severe leaf feeding pest on cotton. Studies have shown that their damage may result in up to a 70% loss in yield. In addition to removing the contents of leaf cells during feeding, spider mites inject a toxin which causes destruction of surrounding cells. Their story is somewhat complicated by the different spider mite species (at least four feed on cotton in the U.S.) which differ in the amount or type of toxin injected into the leaves.

In regions other than the Far West, growers do not experience a consistent mite problem. In the Far West, spider mites thrive in the low humidity and a moderate percentage of fields may require treatment. Humid weather promotes specialized fungi that weaken spider mites.

Spider mites have become an increasing problem during the last several years where pyrethroids are used. In many cotton growing states researchers have found that a pyrethroid application can result in a spider mite outbreak capable of drastically reducing yields. Although the mechanism is not fully understood, pyrethroids appear to disrupt the complex of predators, increase the dispersal of the spider mites and possibly increase their reproductive rate. Research has shown that spider mites reproduce faster on leaves with high N levels. However, well fertilized cotton often is more vigorous and cooler than N deficient cotton, and since temperature is more important than nutrition to spider mite development, vigorous well fertilized cotton tends to develop fewer mites than cotton under stress.

Thrips

A complex of thrips species feed on cotton. All produce damage which is nearly indistinguishable. Their feeding is similar to that caused by spider mites, except that thrips do not produce webbing and they do not appear to inject a significant level of toxins while feeding. Thrips can cause pronounced damage to leaves, particularly during the early stages of crop growth. When the plants are small, a high percentage of the adults and larvae can be found feeding in meristem tissue in the terminal. Under conditions of slow growth, such as cool or cloudy spring weather, developing meristematic tissue will suffer severe tissue damage that only becomes evident after the leaf starts to expand. If the weather remains cool, crop maturity can be delayed and under extreme conditions, severe stand loss has been reported. Stand loss may be due to the thrips and soil pathogens.

During most years, except in the northern part of the Cotton Belt, the springs are usually sufficiently warm for seedlings to grow rapidly and although the expanding leaves will show obvious symptoms of damage, yield and crop maturity may not be affected. In the northern part of the cotton belt thrips damage to leaves and growing points can retard plant development (shoots and roots). This retarded growth and development can interfere with cultural practices such as cultivation and directed weed sprays, shift the boll opening later into the season and reduce yield and fiber maturity (micronaire).

In the West, thrips have been shown to be an extremely important predator of spider mites, and probably are responsible for limiting mite outbreaks in a region which is otherwise ideal for spider mites.

Tunneling Pests

The cotton leafperforator is an occasional problem to cotton in the southern desert valleys of Arizona and California. The earlier larval stages tunnel in the leaves, while the latter stages feed on the leaf surface. Under extremely heavy pressures, lint may be contaminated by leaf fragments and by larval excrement.

Breeding for Host Plant Resistance

Many chemical and physical traits of the cotton plant have been identified that contribute to host plant resistance to insects. No single trait provides adequate resistance to all pests, and in fact some resistance factors increase susceptibility to other insects. The nectariless trait provides resistance to various plant bugs, the pink bollworm and leaf perforator. These insects prefer to feed and lay eggs on cotton with extra-floral nectaries (the ones at the base of the square or boll).

Leaf pubescence (hairiness) affects many insects. Cotton without hairs, true smooth leaf or glabrous, is more susceptible to aphids, loopers and thrips. The greater susceptibility to thrips, however, increases mite predation in the San Joaquin Valley. The glabrous trait offers resistance to whiteflies and reduces the trash content of seed cotton and baled cotton. Even so called "smooth leaf" cottons have some hairs and are not glabrous. At the other extreme of hairiness, pilose cotton is resistant to thrips, loopers and the leaf perforator, but susceptible to white flies. The hirsute cotton is intermediate in leaf hairiness and neutral in effect on most insects. Okra-leaf has 40% less foliage and permits 70% more light to penetrate into the canopy, depending on stage of growth. This open canopy causes an increase in mortality of boll weevils and whiteflies because of an increase in temperature and a decrease in relative humidity.

High levels of gossypol in cotton glands is important to the plant's resistance to bollworms, budworms and loopers. Unfortunately, high gossypol levels also confer susceptibility to thrips and whiteflies. High tannin concentration in cotton leaves confers resistance to spider mites.

Potential Host Plant Resistance to Leaf Feeding Insects

Trait	Thrips	Aphids	Loopers	Perforators	Whiteflies	Mites
Nectariless	N	?	N	R	N	N
Glabrous (hairless)	S	S	S	N	R	N
Hirsute (hairy)	N	S/?	N	N	N	N
Pilose (very hairy)	R	S	R	R	S	N
Okra-leaf	N	?	N	?	R	N
Red Color	N	R	N	S	N	N
High Gossypol	S	?	N/R	?	S	N
High Tannin	?	?	?	?	?	R

(IPM Systems for Cotton, ed. Frisbie, El-Zik and Wilson 1989)

* R, resistant; S, susceptible; N, no effect; ?, conflicting evidence.

WRAP-UP

The appearance of leaf damage during fruit development can be a valid concern to growers. Leaf damage prior to squaring or after boll maturation is generally much less deleterious. When economically damaging populations develop, appropriate control actions should be taken. The decision to control a leaf feeding pest should not be taken lightly. Not only are the pesticide sprays costly, they can trigger the development of other pests, some of which may be fruit feeders. As with any other management decision, action should be based on sound sampling information taken at least weekly throughout the season.

Foliar Feeding (Continued)

Nitrogen

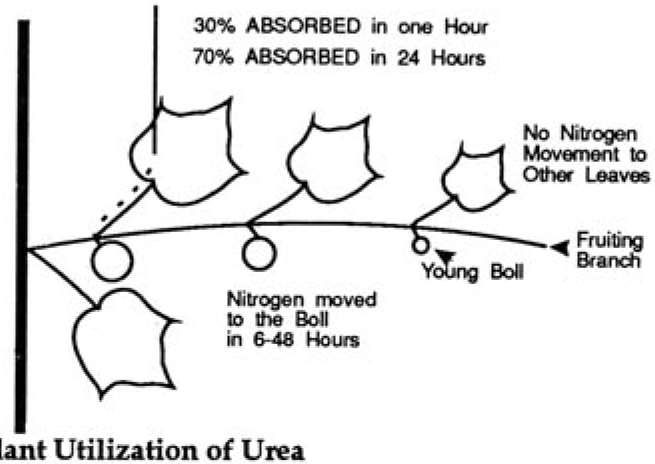
Foliar feeding nitrogen (N) to the cotton plant allows producers to address several difficulties presented by soil applied N:

- Soil uptake of N is excellent in the early and mid season; however, as the root system declines under competition for carbohydrates with developing bolls, the ability ob roots to absorb N from the soil is reduced. Fields with the greatest boll load and thus the highest demand for N are unfortunately also the fields with the greatest restraint placed on the root system.
- Soil applications of N made late in the bloom period increase the risk of excess soil N available during the boll opening period. High soil N sustains leaf production and thus the shading of bolls. Bolls that are shaded suffer delayed opening and boll rot under humid conditions. Additionally, higher N maintains the healthy non-senescent status of the leaves, which inhibits defoliation.

Uptake of Foliar Urea

Urea is the most common foliar N material applied to cotton, due to its low cost, ready uptake into the leaf and low salt hazard. The uptake of urea into the leaf is dependent on rate, temperature and condition of the leaf cuticle. Since urea enters the leaf by diffusion, if the concentration on the leaf surface is increased then diffusion into the leaf will be also increased. Temperature has a strong influence on uptake. Warm temperatures increase diffusion and soften the cuticle. The leaf cuticle is a waxy layer on the outside of leaves that protects the leaf from evaporation losses and adverse environmental conditions. This layer will be thick and composed of harder waxes (more resistant to diffusion) when leaves expand during hot, dry or water stress conditions. Cuticles on these leaves can be 33% thicker, reducing uptake by ⅓rd even after stress is relieved. The leaf cuticle retains the thickness and changed waxy condition that was developed in response to environmental conditions during leaf expansion.

Urea is readily absorbed across the waxy cuticle into the watery leaf because it is a neutral molecule, soluble in both oil and water. Research at the University of Arkansas has shown that under good conditions 30% of the foliar-applied urea can be absorbed during the first hour after application. Within 6 hours the 15N could be detected in the bolls and within 24 hours most of the labeled N that the leaf had taken up moved into the bolls. Based on tagged ^{15}N (stable isotope) studies, the efficiency of foliar urea is high, with 50 to 70% of the applied tagged N recovered inside the plant. This compares to typical recoveries for soil applied tagged N of 50%.



Plant Utilization of Urea

Once urea is absorbed into the plant it is rapidly converted into ammonium and carbon dioxide by the widespread enzyme urease. During this conversion, 2 hydrogen ions (H^+) are consumed raising the pH (more basic, less acidic). Even when urea breaks down in the spray solution or in the soil, the pH is raised. If the pH rises above 7 ammonium is converted to toxic ammonia. Inside the plant, ammonium is incorporated into amino acids if the leaves have sufficient carbohydrates to complete the reaction.

Cotton that is drought stressed or treated with too high a rate of urea will not be able to incorporate the ammonium, leading to ammonia toxicity. At moderately toxic levels urea disrupts the internal pH of the cell, thereby reducing the leafs photosynthetic activity. Under more severe toxicity, cells are killed causing leaf tissue to desiccate and burn in blotches. Occasionally the leaf margins will burn due to movement of urea into the outer edges prior to leaf injury.

If the ammonium from foliar urea is successfully incorporated into amino acids, these are then exported out of the leaf into nearby developing bolls. Since urea is not converted to nitrate in the plant, an increase in petiole nitrate levels should not be expected. A delay in the drawdown of leaf and petiole nitrate may be observed. Never-the-less, petiole nitrate levels provide a strong guide for the need for foliar urea late in the season.

Petiole Sampling and Crop Monitoring

The University of Arkansas Extension Service developed a computer program to aid in recommendations for foliar urea and potassium based on the current status of the crop and field along with a recent petiole sample. Many other State Extension Services recommend petiole sampling to determine the need for supplemental fertilization.

The following conditions will increase the likelihood of a positive response to foliar urea in a field with low petiole levels.

- High (greater than 60%) retention of 1st position bolls.
- Adequate soil moisture.
- Insects under control.
- Warm, favorable temperatures, but not too hot and dry.
- No rain or overhead irrigation within 24 hours.

Field Usage of Foliar Urea

Optimum timing of foliar urea occurs when: (1) the need for supplemental N exists (i.e. a boll load set on the plant that exceeds the ability of the roots to supply N), (2) the plant can still utilize the urea and (3) when it is too late in the season for soil-applied N.

In the rain-belt, boll rot can severely reduce yield, when late-season rainfall promotes leaf and stem growth. Allowing the plant to run out of N reduces late-season growth, but also risks limiting yield if the weather allows a heavy boll set. Producers often will apply a limited amount of N to the soil in multiple applications to minimize the risk of leaching and supplement with foliar urea during late July and early August if petiole levels and crop development indicate a need for additional N.

In the irrigated-West, foliar urea is used in much the same way as in the rain-Belt, except the ability to stop plant growth by curtailing irrigation allows producers to put more of the total N supply in the soil. As a result, where a 3 bale crop in the rain-belt may receive 100 to 130 lbs of N soil-applied and then 30 to 50 lbs of N foliar-applied, in the irrigated-West that same 3 bale crop might receive 175 lbs of soil-applied N and minimal if any foliar N.

When N deficiency is anticipated prior to boll opening, applications of foliar urea need to begin prior to the development of a severe deficiency. There is a window of opportunity for application of foliar urea. To avoid unnecessary expense, it should be applied after a potential deficiency has been identified but prior to the deficiency reaching such a severe level that photosynthesis and fruit retention are restricted. Examination of both boll load and petiole levels aids in identifying this window of opportunity for foliar urea.

Typical rates of foliar urea range from 10 to 15 lbs of urea or 5 to 7 lbs of N. One pound of dry urea can be easily dissolved in 1 gallon of water. Extreme care should be taken to avoid letting urea solutions stand for more than a few hours prior to application because urea will break down releasing ammonium. The ammonium will convert to toxic ammonia as the pH of the solution raises. Applications of urea solutions with high pH (greater than 7) pose a severe hazard for ammonia burn to the leaves. Either buffer the pH down to 6.5 or utilize urea solutions within several hours after mixing from the dry state.

Urea can burn leaf tissue. Applications should be made either early in the day or late in the evening to avoid burn. Even at these cooler times, foliar urea can still injure leaf tissue if applied to drought stressed cotton or applied at too high a rate for the temperature.

Biuret contaminant in urea does not appear to alter the response to foliar urea. Biuret is produced from two urea molecules and contaminates most fertilizer grade urea. Biuret is not metabolized or broken down in the plant and thus accumulates in leaf tissue. In plants with persistent leaves (citrus leaves stay on the tree for up to 18 months) multiple applications of regular urea can accumulate biuret to toxic levels. Where low biuret urea has been compared with fertilizer grade urea, no differences in the degree of leaf injury to cotton were measured even when rates as high as 25 lbs of N were applied during the hot part of the day. Where dry urea is mixed with water for foliar application, care should be taken to avoid urea sources with particulate contaminants that may clog nozzles. "Feed" grade urea is often used, for its lower level of particulate contaminants.

Other N sources are available for foliar feeding cotton, although cost and availability make urea the most common material.

Potassium

Potassium (K), like N, is an essential element required in large amounts for normal plant growth and fiber development.

Uptake and Utilization

Potassium is taken into the leaf as the ion K^+. Like urea, it diffuses across the leaf cuticle, and uptake is decreased into leaves that expanded during a period of water stress. Likewise, applications of K should be made either early in the day or late in the evening to avoid any possible injury. Once inside the leaf, K is highly mobile within the plant.

Cotton bolls are heavy consumers of K during the entire boll development stage. If the soil's ability to supply K is not sufficient, the boll will pull K from nearby leaves leading to their breakdown. If leaves drop below 2% K their ability to function declines. At 1% K they have essentially shut down. Leaves shed when the level drops to 0.2%K. When leaves breakdown, boll development is halted, resulting in late set bolls with immature fiber and low micronaire. In addition to low yield and micronaire, K deficient cotton suffers reduced length and strength. Apparently, K nutrition is important for many aspects of fiber quality. Incidentally, planting seed from K deficient fields has inferior germination.

Field Usage of Foliar K

Foliar K has been developed as a tool to correct K deficiency discovered during the growing season. Where sufficient time allows for an application of soil K to correct deficiencies, this is the preferred method. Plants roots evolved to take in nutrients and leaves evolved to reduce leaching of nutrients. If we can supply nutrients to the roots via the soil, this is the preferred route. However, research in Arkansas and California has shown that K deficiencies can develop even when soil K levels are more than adequate. This is due to the use of higher-yielding faster fruiting varieties, coupled with the decline in root growth during boll filling.

Many deficiencies are not detected until cotton is starting to bloom. Petiole levels reveal a potential deficiency at first bloom if K levels are below 4%. A field that tests moderate for K may be insufficient if weather allows a heavy early boll set on the plant. This year more fields are testing low in petiole K than last year, possibly due to the restricted rooting in the early planted cotton and the reduced uptake from the prolonged drought.

Recent research in Arkansas has shown that supplemental KNO_3 partially offset K deficiencies as well as increased yield and improved fiber quality. The increased yield and quality occurred on soils that were low in K (158 lbs K/acre soil test) as well as on soils that tested high in K (350 lbs K/acre).

Many commercial products are available to correct K deficiencies. To avoid salt burn to the leaves, select a material developed and tested for use as a foliar product on cotton. Where potassium nitrate is used (KNO_3), rates of 10 lbs of material dissolved in 10 gallons of water, applied 3 to 4 times starting after first bloom, have been the most effective. Visual symptoms of foliar burn were not observed following the application of up to 20 lbs/acre KNO_3 to well-watered cotton.

Zinc

Although only small amounts of zinc are removed from the field by a cotton crop (0.5 ounces per bale), zinc is critical for several key enzymes in the plant. Most notable are the enzymes that: convert carbon dioxide with bicarbonate, allow respiration in root tips during anaerobic conditions (lack of oxygen) and build proteins. Historically Zn has been associated with low levels of IAA the hormone responsible for mainstem growth. Although Zn deficient plants are generally stunted, the relationship between Zn and IAA, is not clear.

Zinc deficiency is observed in cotton growing on high pH soils, particularly where the topsoil has been removed to alter the field slope for irrigation, exposing the Zn deficient subsoil. In addition, Zn deficiencies have occurred where high rates of phosphorus are applied, or when cool weather and waterlogging limit root growth and Zn uptake during the spring. High rates of phosphorus in the plant interfere with the utilization of zinc.

Zinc deficiency symptoms include: small leaves with interveinal whitening or chlorosis, shortened internodes giving the plant a stunted appearance, reduced boll set and small bolls with a "ping-pong ball" size and shape.

Foliar Zinc

With the exception of molybdenum, micronutrients have reduced availability in high pH soils. Both iron and zinc can be limiting to cotton in soils with a pH greater than 7.5. And boron deficiency is aggravated when sandy soils low in boron are limed, thereby reducing its availability.

Zinc is relatively immobile in the plant and thus complete coverage with foliar zinc is necessary to correct severe deficiencies. Foliar applications of zinc have been used extensively in the irrigated-West where desert soils are natively deficient in zinc and the high pH limits availability. Although, precise guidelines are not available for petiole zinc, when levels drop below 20 ppm Zn a yield limiting deficiency may occur. Zinc is highly immobile in the soil and thus correction requires either thorough incorporation of soil Zn prior to planting or foliar zinc applications applied several times to the leaves.

Repeated applications of a dilute solution of zinc sulfate (0.5% or 4 lbs of 36% zinc sulfate in 100 gallons of water) applied at 15 to 30 gallons has been used to correct deficiencies. Additionally, commercial formulations of chelated zinc and organically bound zinc are available.

Boron

Of all the essential nutrients to plants, the role of boron in the plant is the least understood. Boron is only essential for vascular plants, but not fungi or algae. A common feature of boron deficiency is the disturbance of metabolic tissue, such as in the terminal or the developing squares. Boron deficient plants also suffer from poor translocation or movement of sugar out of the leaves.

Boron deficiencies occur in sandy acidic soils with low organic matter. These soils leach boron readily. The high solubility in acid soils of micronutrients (other than molybdenum) increases micronutrient plant availability and the leachability. If sandy acid soils are limed, severe micronutrient deficiencies can result, especially boron. Although boron is applied extensively in the Mid-South and South-East to sandy soils and clear deficiencies have been observed, few guidelines or critical levels exist to identify deficient fields.

Boron is mobile only in the xylem, the system that moves water from the roots to the leaves. As a result, when temporary soil deficiencies occur, for example due to drought, symptoms occur in the young tissue and meristems. Drought can aggravate boron deficiency because much of the available boron is in the organic matter near the soil surface. When the surface soil dries, the lower water content reduces nutrient uptake and release of nutrients from the organic matter. When needed, applications of 0.1 to 0.2 lbs of boron per acre, should be made no closer than weekly intervals to correct B deficiency. This will require 0.5 to 1 pound of 20.5% material (Solubor).

Boron deficient plants often have dark rings on the petioles, distorted squares and flowers and can be stunted. Under severe conditions, squares will shed and the terminal meristem may die, resulting in release of the lateral vegetative branches and the appearance of candelabra or "crazy cotton". However, insect feeding in the terminal is thought to be the primary cause of terminal injury.

Sulfur

The reduction in use of high sulfur coal in the southern states has been suggested as a reason for the increased appearance of S deficiency in cotton. Additionally, the high analysis fertilizers used today contain little to no sulfur. Sulfur is absorbed by the plant as sulfate (SO_4^{2-}). Once in the plant it is bound and reduced to sulphydryl (-SH) in two essential amino acids (cysteine and methionine). Sulfur in these amino acids is not reused within the plant, unlike the N in amino acids. Thus sulfur is considered immobile in the plant, and the light green to white deficiency symptoms appear first in young tissue. Other symptoms include stunted plants with reduced boll set.

A warm season deep- rooted crop such as cotton is less likely to suffer a S deficiency than cooler season crops such as corn and wheat, because the S content in the soil organic matter is released when the warm soil allows vigorous microbial degradation. However, sporadic incidences of S deficiency have been reported on cotton. These have usually been limited to deep sandy soils or sandy surface soils with hardpans in the subsoil. Excessive winter rainfall often increases leaching of sulfate-S and may create S deficient conditions the next spring. Sulfur deficiencies on cotton are usually seen early in the growing season and can be corrected with soil applied S containing fertilizers. Foliar sprays of S also can be used, but since S is immobile in the plant, multiple applications may be required to correct the S deficiency. Two applications of magnesium sulfate (epsom salts, $MgSO_4$) have corrected deficiencies when applied at 4 lbs of S per acre.

Nodes Above the White Bloom

The Nodes Above the White Bloom (NAWB) is a technique that many producers and consultants are using to chart cotton's growth during the bloom period. NAWB indicates the amount of reserve horsepower a plant has in excess of that required to fill bolls. NAWB reflects this reserve horsepower because excess energy is channeled into additional terminal growth. The amount of terminal growth that has occurred during the time period from the first appearance of a pinhead square in the terminal until that fruit reaches bloom is simply the number of nodes above the white bloom. If the boll load consumes almost all of the nutrients provided by the roots and leaves, or if stress reduces the nutrient supply, then little excess supply will be available for continued terminal growth. Under these conditions, the NAWB will lessen as the squares in the top of the plant develop into bloom. On the other hand, if the boll load is slight and the plant amply fed with water and nutrients, then the excess supply of nutrients for production of new nodes in the terminal will be large. Under these conditions, the NAWB will stay large or even increase.

Measuring NAWB

Plants can be examined for NAWB starting at first bloom until cutout, when the plant blooms out the top. Select plants with 1st position white blooms, those closest to the mainstem. Starting with this node as zero, count the nodes above, up to the terminal. When counting nodes near the terminal it is easier to count mainstem leaves, because the nodes have not yet expanded. Near the terminal, count the mainstem leaves as they get progressively smaller until the mainstem leaf is less than a quarter dollar size (1 inch diameter). Do not count nodes with a main stem leaf smaller than 1 inch diameter. For further information of measuring NAWB, a plant mapping instructional video is now available from the National Cotton Council in Memphis.

Utilizing NAWB in the Field

The NAWB technique is easy and fast. Walk into at least 4 parts of the field that are representative of the entire field and count the NAWB on at least 5 plants. Average each set of 5 plants. Use the average NAWB to adjust management inputs, such as irrigation, PIX, foliar feeding.

Using NAWB in Cotton Management

At 1st bloom, the NAWB should be 8 to 10 depending on variety and prior stress. Fast fruiting varieties that develop blooms rapidly will have fewer NAWB, even when non-stressed. Water stress will reduce NAWB. For this reason, the first few plants to bloom usually have a smaller NAWB, because they have come into bloom faster often due to water stress. Once half the plants reach first bloom, if the NAWB is 8 or less and the variety is full to medium season, then this field has most likely suffered from stress. The cause of which should be identified rapidly and corrected prior to a premature cutout.

At Mid-Bloom, the NAWB should decline as bolls are set on the plant. Some of the irrigated Mid-South fields are experiencing a rapid and heavy boll set due to the near ideal irrigation weather, warm and dry. In these fields, the white bloom is approaching the top rapidly as the plant enters cutout from the heavy fruit set. Some Mid-South non-irrigated fields are also blooming near the top, NAWB 5 or less, due to the severe water stress. Since these fields do not have a heavy boll load, they may turnaround and set a late crop if the rainfall permits. In the South-East, the high rainfall this year has promoted lush vegetation in some fields, with a NAWB that is remaining above 8. These fields should be scrutinized closely for possible causes of poor fruit set or small bolls and may require additional growth regulation to avoid excessively tall plants and late season boll rot.

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The National Cotton Council (NCC) is the central organization representing all seven sectors of the U.S. cotton industry: producers, ginners, warehousemen, merchants, cottonseed crushers, cooperatives and manufacturers. A majority of elected delegates from each sector must approve all NCC policies, thus assuring unity of purpose adn action.

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