PHYSIOLOGY AND NUTRITION OF HIGH YIELDING COTTON IN THE USA

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INTRODUCTION

Cotton is a major row crop grown primarily for fiber and oil seed. The cotton plant is unique because it is a perennial with an indeterminate growth habit and has perhaps the most complex structure of any major field crop. Associated with this complex growth habit is an extreme sensitivity to adverse environmental conditions which is reflected in excess fruit abscission. A better understanding of cotton (*Gossypium hirsutum* L.) growth and development in commercial production is important in the continuing efforts of growers to produce lint and seed yield more efficiently and profitably.

GROWTH AND DEVELOPMENT OF THE COTTON PLANT

The growth and development of the cotton plant proceeding through a number of stages, which for productions management, may be divided into four main growth stages (OOSTERHUIS, 1990):

(1) germination, emergence and seedling establishment,

(2) leaf area-canopy development,

(3) flowering and boll development, and

(4) maturation (Figure 1).

The overall growth and development of the cotton plant follows a typical sigmoid curve with a relatively slow start during emergence and root growth (Figure 2), followed by an exponential increase in growth rate during canopy formation, flowering and boll development, and finally by a slowing down during the boll maturation phase (Figure 1). The transitions between these successive stages are subtle and not always clearly distinguishable.

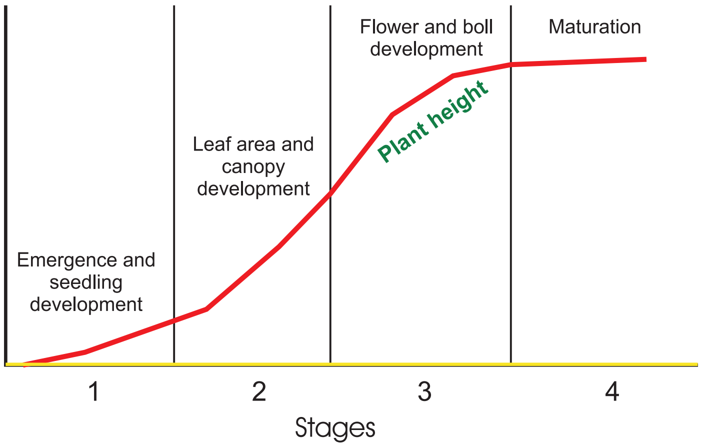

Figure 2. Cotton germination and seedling development. Emphasis is on early root establishment.

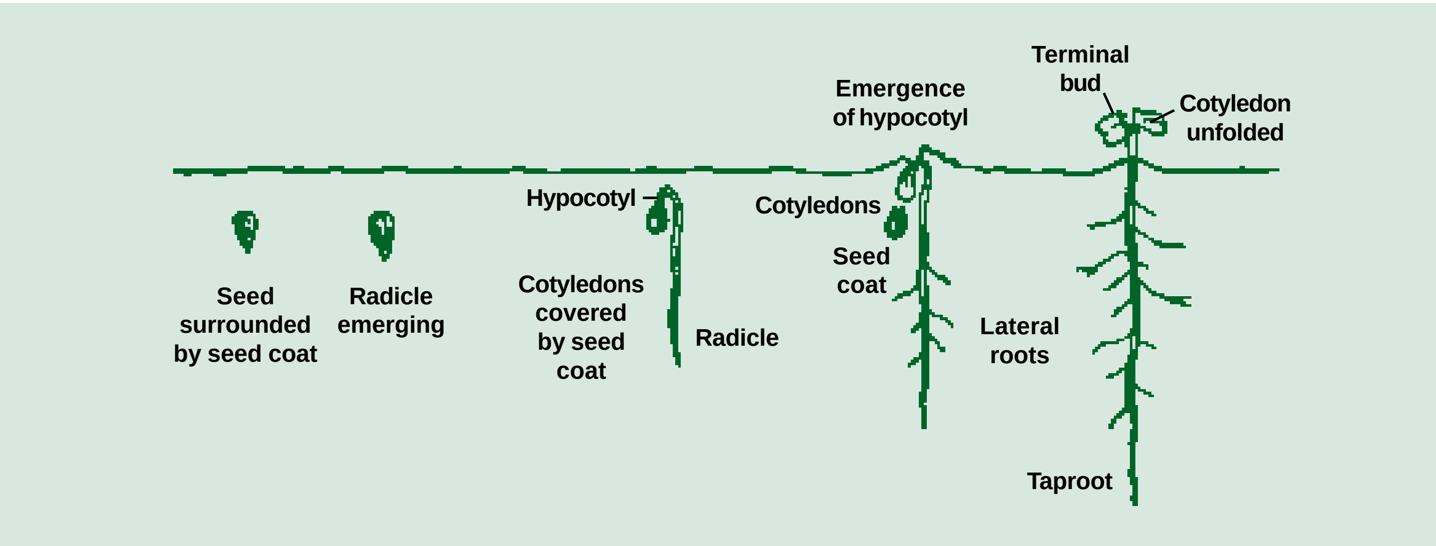

Figure 1. Developmental pattern of the cotton plant showing the main stages of development.

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Each stage may have different physiological processes operating with specific requirements. If growers are aware of these stage-dependent differences in cotton growth and requirements (e.g. for fertilizer), then many problems in crop management can be avoided resulting in increased yields and profits. Furthermore, management practices should be flexible to cater for changing environmental conditions.

YIELD DEVELOPMENT

How is Yield Formed?

Yield is essentially controlled by the genetics of the plant and the environment. These in turn are further modified by cultural practices. At a more agronomic level, yield may be considered in terms of its major components: boll number per unit area times the average boll weight. The growth of the plant and development of bolls depends on the production of dry matter by photosynthesis, and therefore the production of dry matter is the fundamental process of yield. The carbohydrate products of photosynthesis need to be translocated to the developing fruits which in turn need to be protected from pests. These processes require sunlight, water and adequate plant nutrition. Maximizing these processes through good cultural practices requires careful attention to the factors that we can control, mainly water and plant nutrition.

Not all Bolls are of Equal Value

The distribution of the bolls on the plant varies due to shedding from physiological/environmental and insect causes. Plant diagrams and crop monitoring are used to "map" the position of bolls and are useful management tools to follow square and boll retention, assess the success of production inputs, and detect stress. A large portion of the total yield is derived from the central portion of the canopy, between main-stem nodes 6 and 14, which coincides with the distribution of leaf area within the canopy. Fewer bolls are produced above these nodes and they tend to take longer to mature and are smaller in size. Furthermore the *value* and *quality* of bolls decreases along the fruiting branches away from the main stem (Figure 3).

While managing the cotton crop, attention should be paid to the position in the canopy where harvestable bolls are produced (Figure 4) to the monetary value of these bolls (Figure 5) so as to determine when to apply inputs, and more importantly, when to stop inputs.

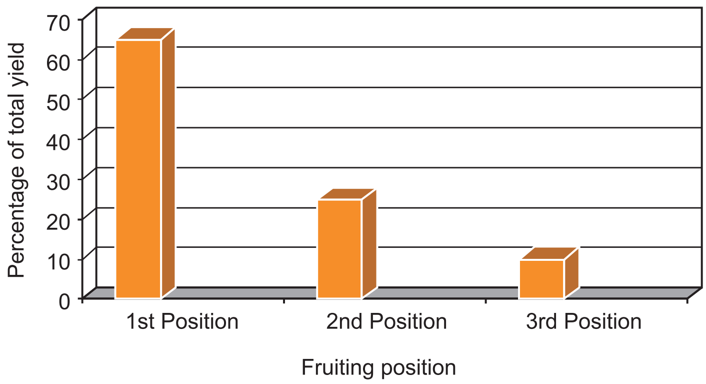

Figure 4. Percentage of yield formed at each fruiting position away from the main stem.

Vegetative -Reproductive Balance

Since cotton plants continue to grow vegetatively after fruiting is initiated, the vegetative to fruiting balance of the plant is

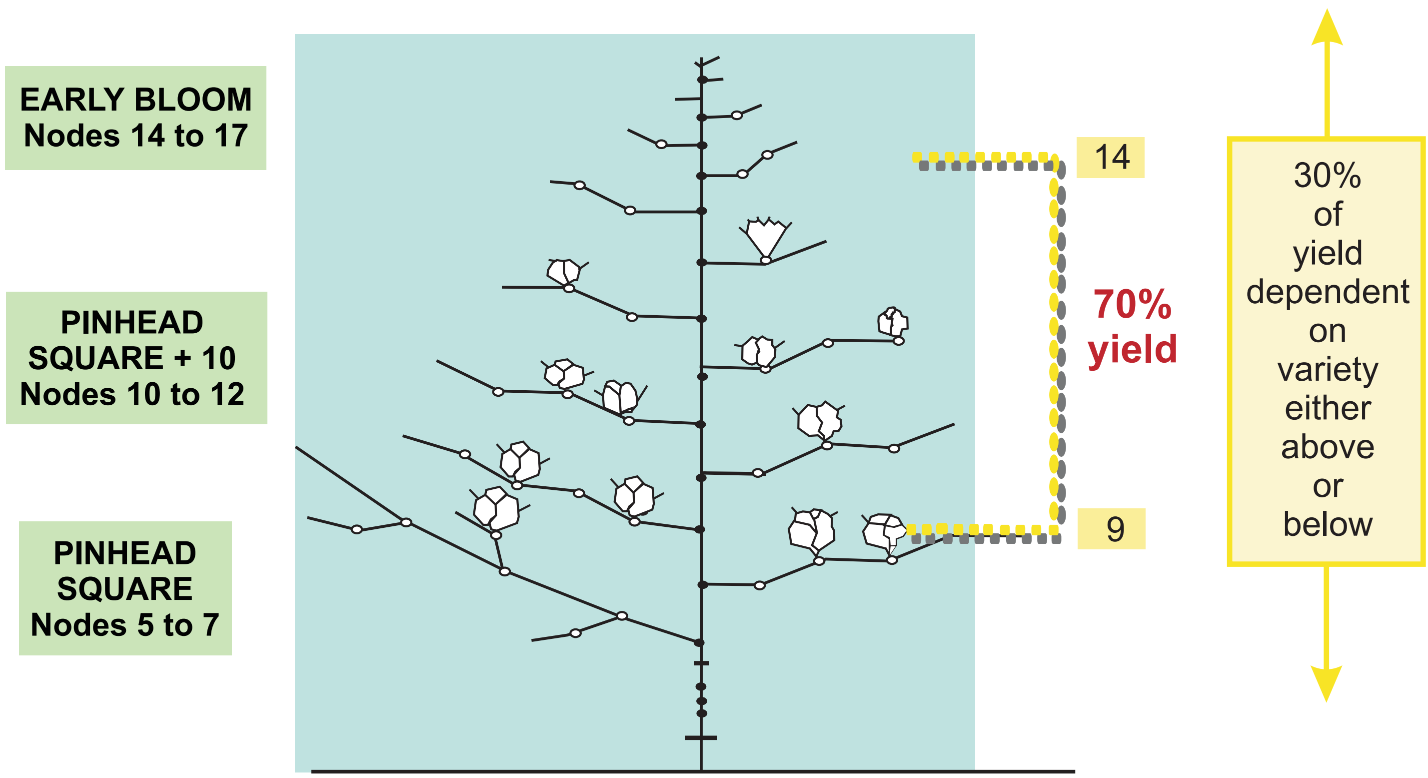

Figure 3. Fruiting zones of the cotton plant and their contribution to yield.

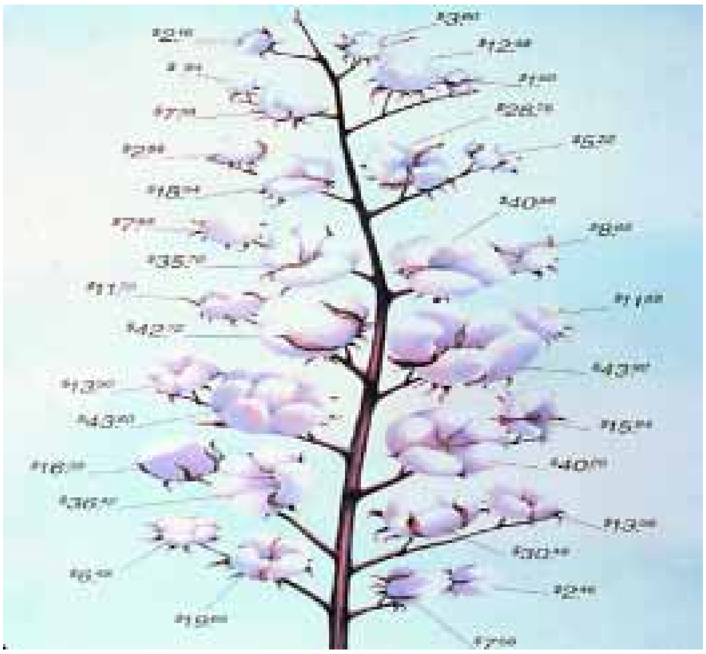

Figure 5. Dollar value of individual bolls by position on the plant. (From JENKINS, 1995).

critical. This balance can be influenced by management and environment. Excess vegetative growth from abundant fertility and water, can delay maturity and increase problems with insects and boll rot. Excess fruiting, on the other hand, may cause early cutout with associated fruit shed and lessen yield potential.

Plant growth regulators such as mepiquat chloride are widely used to control excessive vegetative growth, but the best control of excess vegetative growth is through the development and retention of a big fruit load. This necessitates adequate attention to soil fertility and subsequent plant growth and tissue nutrient levels.

Square and Boll Shedding/Retention

Cotton square and boll shedding (or retention) has received much attention and generated much controversy during the past 50 years. The attention derives from the concern that lost squares and bolls represent lost yield, such that if shedding were decreased, then productivity would be increased.

On the other hand, there is evidence that boll shedding may be an important natural process by which the plant adjusts its fruit load to match the supply of inorganic and organic nutrients, suggesting that a limited amount of shedding is therefore normal and necessary for good yields. A cotton plant commonly sheds about 60% of its squares and young 5- to 8-day-old bolls. The shedding or abscission of squares and young bolls is a natural occurrence in cotton that is accentuated by adverse environmental conditions including extended overcast weather, extreme temperatures, water stress, *nutrient deficiencies*, and insect damage. Under typical environmental stress, the plant will shed only small bolls and small to medium size squares. Actually, nutritional stresses alter the hormone balance which in turn causes fruit abscission. There are a number of synthetic compounds on the market today which supposedly aid in boll retention including Pix, Cytokin and PGR-IV.

NUTRITION OF THE COTTON CROP

Pattern of Nutrient Uptake

The pattern of nutrient uptake generally follows that of dry matter increase by the crop (Figure 6) as would be expected. This means that nutrient uptake is low during early season when the cotton seedling is developing, and increases dramatically after flowering during early boll development. Peak uptake rates usually occur a few weeks after flowering and total uptake reaches a maximum as the bolls begin to mature.

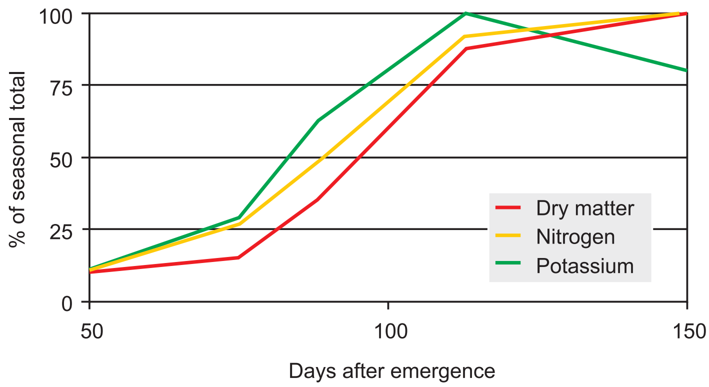

Figure 6. Pattern of nutrient uptake by the cotton crop in relation to the development of dry matter.

Soil and Tissue Diagnoses for Fertilization

Analyses of soil and plant samples offer a means of determining the nutrient status of a crop. ***Soil sampling*** and analytical methods of assessing nutrient availability in the soil are available and well documented and provide the standard method of determining crop fertilizer requirements. Knowledge of the soil being used is important because the mineralogy, organic matter, and level of nutrient depletion for a specific soil can significantly affect the fate and availability of applied fertilizer. ***Tissue tests*** complement a sound soil testing program and can help identify opportunities for more efficient nutrient use. Plant tissue analysis is the determination of essential nutrient concentrations in sampled plant tissue.

In cotton, tissue tests have become a valuable diagnostic tool for assessing crop nutrient status, for determining fertilizer recommendations during the growing season, and for detecting potential deficiencies. When a nutrient deficiency is detected, this can be corrected by fertilizer applications to the soil during the first half of the season, and later by foliar fertilizer applications. Where soil moisture and rainfall are adequate, many crops can still respond to applications of potassium, sulfur, nitrogen, and micronutrients as late as mid boll-filling in cotton. However, the objective should be to prevent deficiencies before the rapid vegetative growth and reproductive stages.

Foliar fertilization is usually only appropriate when a nutrient deficiency is observed or detected by tissue analysis. The petiole is generally considered more indicative of cotton plant N and K status than the leaf blade. For K, this is partly because of the more rapid decline in K concentration in the petiole, compared to the leaf, during the boll development period. Critical or threshold levels for the major nutrients have been studied and documented although some uncertainty exists about sufficiency levels in the leaf or petiole for certain elements, i.e. boron, as these values may be appreciably altered by the environment, plant genetics, and sampling procedure.

The patterns of nutrient uptake and use by the cotton plant have been well documented and soil and plant sampling techniques have been established to check if crop nutrient status is adequate for the particular soil, environment and yield level. Nutrient levels in plants vary with stage of maturity, plant part sampled, variety, and environmental conditions. However, there is always an element of uncertainty because of changes in the environment and plant demand, the ability of the soil to meet this demand, declines in root growth during boll development, increases in nematode populations, and other production problems.

The results of plant analysis alone should not be used to make fertilizer recommendations. Most diagnosticians prefer to consider plant tissue analysis along with soil test results, a record of lime and nutrient or manure applications, cropping history, crop soil moisture condition, and yield potential. The cost varies from $ 3 to $ 20/sample, depending on the number of nutrients analyzed. Mid-season tissue diagnoses and foliar fertilization provides a mechanism of supplying timely inputs of needed nutrients. Accurate soil analysis coupled with mid-season plant tissue analysis are needed to formulate and manage a suitable fertilizer program.

Advantages and Disadvantages of Foliar Fertilization

The advantages of using foliar feeding include low cost, a quick plant response (i.e. increased tissue K concentration and fewer new deficiency symptoms), use of only a small quantity of the nutrient, quick grower response to plant conditions, no soil fixation problems, independence of root uptake problems, increased yields and possible improved fiber quality.

On the other hand, the disadvantages are that only a limited amount of nutrient can be applied in the case of severe deficiencies, and the cost of multiple applications can be prohibitive unless incorporated with other foliar applications such as pesticides. Other disadvantages when using high concentrations of a nutrient include the possibility of foliar burn, compatibility problems with certain pesticides, and low solubility of certain fertilizers (e.g. KNO_3), especially in cold water. Another restraint is the lack of a full understanding of this technology, specifically the optimum rate and timing, tissue threshold levels to predict the need for foliar fertilizer, the exact mechanism of absorption, and the effect of plant condition and environmental factors on absorption.

NITROGEN NUTRITION

The growth and yield of cotton depend strongly upon the availability of N and water during the season, and management of these two inputs has received much attention. Nitrogen fertilization is a critical practice in cotton production because soils on which cotton is grown are more often deficient in N than any other plant nutrient, and N fertilization represents a significant cost in cotton production.

Importance of Nitrogen and Nitrogen Deficiency

Nitrogen (N) is the element needed in the greatest amount and is often limiting. N is involved in numerous fundamental processes such as protein synthesis, photosynthesis, carbon partitioning, as well as enzyme and hormonal activity. Nitrogen deficiencies result in short, stunted plants, with pale green leaves which may hang vertically or fold inward. Lower leaves may develop a red coloration. Leaf symptoms generally appear first on older leaves because N is highly mobile in the plant. With progression of the deficiency, the older leaves turn very pale and begin to show necrosis and leaf death, and premature senescence.

Cotton N Requirements

Total seasonal N requirement ranges from 50-300 kg N/ha (Table 1) depending on the growing season and yield potential. N removed in the lint and seed accounts for 43-60% of total plant N. During fruit development the fruit becomes the dominant sink for N in the plant and redistribution within the plant occurs. Peak daily uptake rates 0.6-5.7 kg N/ha/day (dryland) and 1.5-4.6 kg N/ha/day (irrigated).

Table 1. Cotton nutrient requirements for high yields. Extracted from the literature, particularly Mulliuns and Burmester, 1998.

	N	P	K	B
Seasonal needs (kg/ha)	300	70	200	66-200 (g/100 kg)
Amount removed (lint + seed) as %	50	35	40	9 (g/100 kg)
Peak daily uptake (kg/day)	5.0	0.5	4.0	3 (g/day)

* Dryland requirements are about half.

N Fertilization of Cotton

The timing and method of N fertilization in the US Cotton Belt differs greatly among regions. Nitrogen fertilizer was typically applied in a split application with about half the total amount applied before planting and the remainder applied before flowering. However, less than 10% of the US cotton acreage presently receives N at planting and less than 5% of the acreage receives N as a foliar treatment. The total soil applied N varies across the US Cottonbelt and ranges from about 90-140 kg N/ha for irrigated cotton and about half that for dryland cotton.

Foliar Fertilization with N

The practice of applying mid-season N to cotton as a foliar application varies widely in the US Cottonbelt from single applications to multiple applications, and is usually applied in combination with other foliar applications of agrochemicals. A recent e-mail survey indicated that the use of foliar fertilization with N varies from as much as 50% in certain counties in California, 45% in Arkansas, 15% in Georgia, 10% in Arizona, Louisiana and North Carolina, and 5% or less in Alabama and Tennessee. Foliar-applied

N is used mainly on irrigated cotton. In west Texas, foliar fertilization with N only occurs on dryland cotton when adequate rainfall occurs. The practice of foliar fertilization with N is not used much in other cotton growing countries, except for Greece where about 15% of the cotton area receives foliar-applied N. In Australia, foliar N fertilization has proved beneficial when applied before waterlogging. In some regions, such as Arizona and Greece, N is often applied with the irrigation water, i.e. fertigation, which for overhead irrigation is a form of foliar fertilizer.

Although foliar feeding with N is widely used, the effectiveness of foliar N fertilization in cotton has been questioned due to inconsistencies in yield response. Studies in Arkansas have demonstrated the absorption of foliar-applied ^{15}N-urea by the leaves and its translocation to the developing bolls, with 30% of the N absorbed in the first hour, and a total of 60-70% within 48 hours (Figure 7). The majority of the absorbed N from foliar-applied ^{15}N moved directly to the closest boll. Furthermore, absorption of foliar-applied ^{15}N by the cotton canopy was highest at flowering (60% uptake) and then declined markedly to 40% during the first three weeks after flowering, and then further still thereafter to less than 30% with progression of the season. The decline was associated with the increase in average leaf age in the canopy and the increasing waxiness of the older leaves. This partly explains the lower response to foliar feeding three weeks after flowering. Recent research has demonstrated that the size of the developing boll load had a major affect on petiole N and plant response to foliar-applied N.

POTASSIUM NUTRITION

Potassium (K) deficiency has occurred widely but sporadically across the US Cotton Belt in recent years. This has prompted a large number of agronomic and physiological research to explain this phenomenon. These studies have shown that the onset of K deficiency is related to the use of higher-yielding, quicker-maturing, varieties with less K being stored in prior to flowering, and decreased root activity during boll development. Obviously low soil K status, soil K fixation, and inadequate root growth are also involved.

Importance of K to Cotton Growth

Potassium is integrally involved in metabolism and plant water relations, although it is not a constituent of any known plant components. Its primary role is as an enzyme activator. It has been implicated in over 60 enzymatic reactions, which are involved in many processes in the plant such as photosynthesis, respiration, carbohydrate metabolism, translocation and protein synthesis. Potassium balances charges of anions and influences their uptake and transport. Another important function is the maintenance of osmotic potential and water uptake. These two functions of K are manifest in its role in stomatal opening when stomatal conductance and turgor are coupled. Another major role of K is in photosynthesis by directly increasing leaf growth and leaf area index, and therefore, CO_2 assimilation. Potassium increases the outward translocation of photosynthate from the leaf. In cotton, K plays a particularly important role in fiber development and a shortage will result in poorer fiber quality and lowered yields.

K Deficiency in Cotton

Potassium deficiency occurs more frequently and with greater intensity on cotton than for most other agronomic crops. Typical K deficiency symptoms consist of yellowish-white mottling of the leaves that changes to numerous brown specks at the leaf tips, around margins and between veins. The leaf tip and margin curl downwards as the tissue breakdown continues. Finally the whole leaf becomes rust colored, brittle and drops prematurely, stopping boll development which results in dwarfed and immature fruit, some of which may not open. These small bolls are a typical symptom of severe K deficiency in cotton. Many of these symptoms are related to the disturbance of tissue water balance resulting in tip drying, leaf edge curling, and early senescence. Potassium deficiency

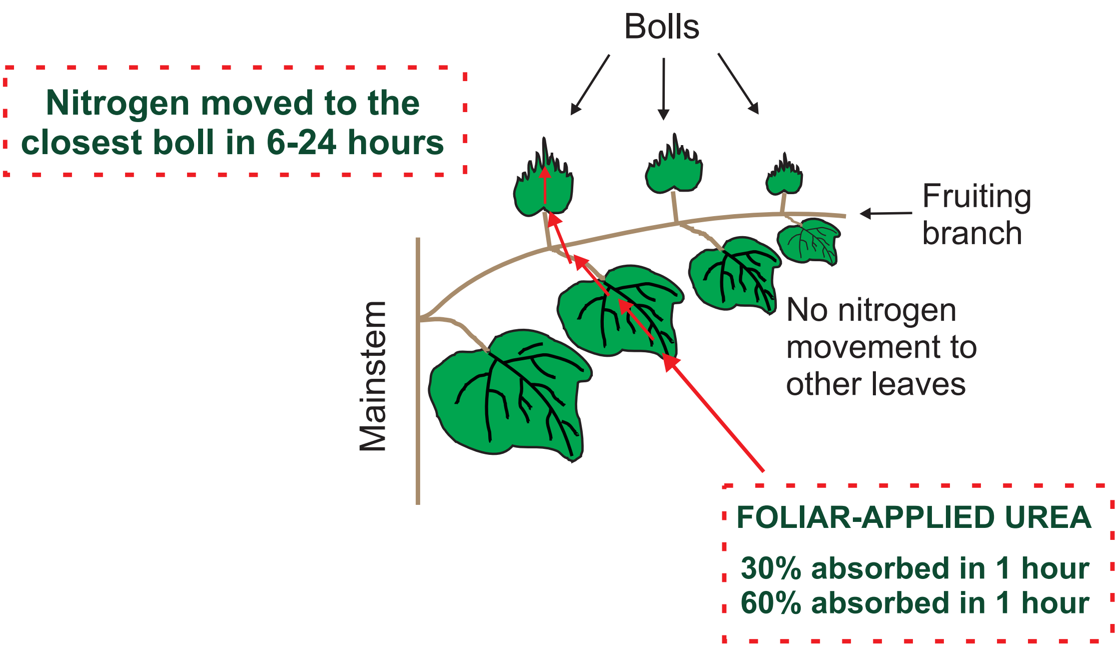

Figure 7. Uptake of foliar-applied ^{15}N by cotton leaves and movement to the bolls (From Miley and Oosterhuis, 1990).

symptoms in cotton are quite distinctive and, due to the characteristic bronzing that occurs, were once termed *cotton rust* before the true cause was known. The symptoms of K deficiency have been mistaken for *Verticillium* wilt symptoms as they seem to occur under similar environmental conditions. Furthermore, the growth and yield of cotton varieties less susceptible to *Verticillium* wilt are often less affected by late-season K deficiency.

Potassium deficiency has occurred widely across the US Cotton Belt in recent years. The occurrence of these outbreaks of K deficiency have been somewhat unpredictable and the explanations not clear. The K-deficiency syndrome appears to be a complex anomaly related to low soil K status, K fixation in the soil, a greater demand for K by modern cultivars, less storage of K prior to flowering by modern cultivars, the inability of the root system to supply the needed K during boll development, and possible relationships with diseases such as *Verticillium* wilt.

Cotton K Requirements

Total seasonal K requirement ranges from 52-112 kg N/ha for dryland cotton, and 53-393 kg K/ha for irrigated cotton. K removed in the lint and seed accounts for 7.5-46% of total plant K. Peak daily uptake rates 2.1-4.6 kg K/ha/day (dryland) and 1.5-4.6 kg N/ha/day irrigated. Most goes into developing fruit the boll wall (55-60% at maturity) in particular (40%).

K Fertilization of Cotton

Most fertilizer applications of K are surface applied or shallowly incorporated into the topsoil. Applications are usually made in Fall of immediately prior to planting. Quantities vary from zero to about 90 kg K/ha. Research in California has shown that cotton root systems fail to exploit available K in the topsoil adequately. Work in Alabama suggested that cotton may respond to deep placement of K fertilizer at a depth of 15-30 cm. Yield increases from deep placement of fertilizer K have not consistently resulted in yield increases and additional research is needed. Soils exhibiting the greatest response to deep placement of K generally have subsoils with low to very low soil K. Foliar applications of K are made when tissue tests or leaf symptoms call for it, although the practice is probably only applied on 2-3% of the acreage.

Foliar Fertilization with K

Potassium deficiencies can be corrected through preplant soil applications or partially corrected using mid-season sidedress applications of K. The requirement for foliar-applied K varies greatly with geographical area and even within a single field, and it is difficult to provide a standard recommendation for the practice, mainly because the explanation for the K deficiency syndrome is still not clear. Foliar application of K during boll development may be beneficial when the soil K level is inadequate, either from K fixation, low soil test K status, or poor root growth, and when petiole analysis indicates a pending shortage of K. Foliar applications of K may offer the opportunity of correcting these deficiencies more quickly and efficiently, especially late in the season when soil application of K may not be effective or possible. Foliar applications have the advantage of allowing producers to add the necessary K when tissue analysis indicates a pending shortage, and thereby correct the deficiency and prevent yield loss. It is of interest that foliar feeding of a nutrient may actually promote root absorption of the same nutrient. The petiole threshold level of K will decrease from about 5.0% at first flower to about 2.0% near open boll. Three to four foliar applications of K should be made during the first five weeks of boll development at 7 to 10 day intervals starting at the commencement of flowering. A minimum rate of approximately 4.5 kg/ha of K should be used at each application. The recommended source of K for foliar fertilization is KNO_3, although K_2SO_4 or $K_2S_2O_4$ appear to work almost as well. Attention should be given to possible solubility problems in cold water. The use of an adjuvant with the foliar spray will increase leaf K uptake but may not necessary result in increased yields, although it may permit the use of a lower rate of K per application.

A three-year Beltwide study from 1991 to 1993 at twelve sites from North Carolina to California evaluated the effect of foliar-applied KNO_3 compared to soil-applied KCl on cotton yield and fiber quality, and showed significant yield increases from foliar K recorded about 40% of the time. It has been shown, using $^{42}KNO_3$ applied to cotton leaves that foliar-applied K moved into the leaf and to the boll within 20 hours. Other studies in Arkansas using Rubidium, indicated that K first entered the leaf within 6 hours and then in greater quantities between 6-48 hours after application and was translocated to the developing bolls with little delay during the same period. Foliar K has been shown to increase the K content and dry weight of the fibers.

BORON

Boron (B) has long been known as an essential micro nutrient element required for optimal growth and development of cotton (*Gossypium hirsutum* L.) plants.

Importance of B

Boron is required for cell wall synthesis, integrity of plasma membranes and pollen tube growth. The important role of B in pollen germination and pollen tube growth for successful fruit set of higher plants suggests that B deficit during flowering and fruiting may significantly reduce boll retention, resulting in lower yields. A deficiency of B can also affect fiber quality presumably because of the role of B in cell wall growth.

B Deficiency in Cotton

Because B is important in pollen germination and pollen tube growth, deficiencies result in reduced boll retention, lower yield and poor fiber quality. Boron deficiency is common in highly leached and acidic sandy soils of cotton growing regions in the world. B deficiency in cotton is characteristically manifested as black rings on the petioles as well as with deformed flowers, stunted growth, fruit shedding and decreased yield. Physiologically, a deficiency of B results in decreased stomatal conductance and net photosynthetic rate, and depressed plant growth and dry matter accumulation, resulting in increased fruit abscission and a change in dry matter partitioning to the developing bolls after squaring. Therefore, in B deficient areas, soil or foliar application of boron may improve cotton plant growth and lint yield. Although B deficiency reduced total dry matter production, plant height and number of reproductive structures under the greenhouse conditions, foliar application of B may not avoid the deficiency because the mobility of B in cotton is limited.

Cotton B Requirements

Total seasonal B requirement averages about 66-200 g B/ha for irrigated cotton (Table 1). B removed in the lint and seed accounts for 9.3 g B for every 100 kg lint. In past thirty years, there were many reports on growth and yield responses of cotton to soil or foliar application of B. The narrow concentration range between B deficiency and toxicity requires special care in the application of B fertilizers.

B Fertilization of Cotton

B is routinely applied in commercial cotton production in the USA as soil- and foliar-applications irrespective of soil B status. However, this recommendation was based largely on research conducted 30 years ago, and recent work in Arkansas has shown no response to added B fertilizer. Current production recommendations in Arkansas call for initial preplant soil applications of 1.0 lb to 2.0 lb B/acre or two up to six foliar applications of 0.1 lb to 0.2 lb B/acre. Reports of yield response to soil or foliar applications of boron have been inconsistent, with some researchers reporting no yield response to B utilizing non-buffered spray solutions, and others reporting yield responses using B spray solutions buffered to pH 4.0. Recent work in Arkansas has shown no yield response to soil or foliar applications of B irrespective of soil N status. These contrasting results may be associated with soil texture, soil pH, soil fertility, soil B level, and yield potential because all these factors influence B uptake by plants and crop yield response to supplemental B application.

The critical soil B concentration affecting yield in cotton was reported to be 0.4 to 0.55 mg/kg. The critical B levels in plant tissues is reported to be 103, 61 and 78 mg/kg for roots, young leaves and stems of cotton, respectively. However, recent work has indicated even lower critical leaf B values for diagnostic purposes of 30 mg/kg in the upper fully-expanded main-stem leaf located four nodes from the terminal.

DROUGHT STRESS AND PLANT NUTRITION

Plant nutrition depends on an adequate supply of water for uptake, translocation and metabolic functions for growth. Therefore drought stress, and irrigation, strongly affect the efficiency of fertilization and the resulting growth and yield. Cotton exhibits a large degree of drought tolerance compared to other crops (Figure 8) because of various mechanisms including root growth, osmotic adjustment and selective fruit shedding.

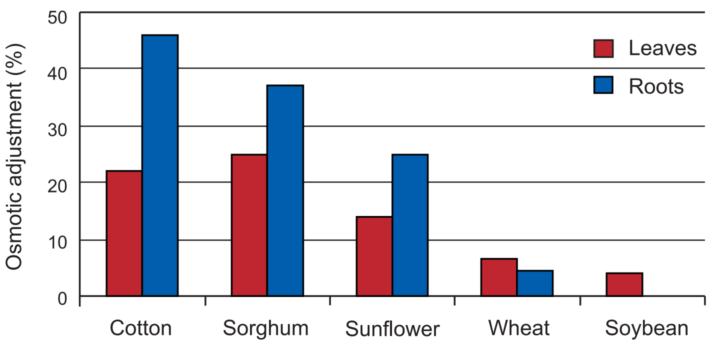

Figure 8. Drought tolerance of cotton compared to other major row crops.

Drought decreases growth (smaller leaves, roots, and plant height) and yield (increased shedding, smaller bolls, less seed, etc). Drought amplifies the effects of high temperature. Because the plant uses water to cool itself very effectively by evaporative water loss from the leaves, such that crop leaves are usually a few degrees below air temperature. Under drought crops heat up and growth is detrimentally effected. The water use pattern of cotton closely follows that of dry matter production as may be expected given that growth depends largely on an adequate supply of nutrients and water. Current research in the USA in this area is focused on selecting drought resistant varieties, more efficient water application systems, and the use of biotechnology to introduce appropriate genes into existing agronomically adapted varieties.

CROP MONITORING

The use of crop monitoring has become very popular and widely used in the USA for improved crop management.

Crop monitoring allows us to closely follow crop development, detect stress or problems, and more importantly, to act on a timely basis before yield reduction. Current crop monitoring programs, such as COTMAN, follow crop growth weekly by comparing with a standard (optimum) crop target development curve. In this way it is easy to detect if crop growth is not on schedule. The most important aspects of modern crop monitoring programs is that they are easy to perform, sensitive, reliable and permit management inputs on a timely basis before yield is lost. A recent innovation in the COTMAN crop monitoring program has been the testing of a new “stress index”. This is a ratio of the change in square shedding over the change in main-stem nodes, i.e. the balance between square abscission and plant growth. The stress index utilizes two measurements that already are recorded in COTMAN. Current research is aimed at testing and refining the use of this stress index for detecting shifts in the balance between square abscission and plant growth, and determining if detection of the shifts could be used to improve management decisions. Crop monitoring also involves attention to changes in the nutrient status of the crop by observations of growth in relation to tissue sampling diagnosis.

CONCLUDING STATEMENT

The production of dry matter is the basis of yield development and therefore the cornerstone of agriculture. Dry matter production is a result of light interception by crops and the utilization of the energy derived to fix carbon dioxide into carbohydrates in the green tissues of plants, i.e. photosynthesis. This is controlled by genetics and environmental conditions.

Crop management is a means by which we attempt to control and harness this overall process for food, feed and fiber. The success of this process depends upon the seasonal conditions and our ability to successfully manage the cultural practices. Fertilization is one of the cultural practices which we understand and control and therefore careful attention is needed to the judicious and timely application of plant nutrients for optimum yields. There is no magic formula for fertilizing cotton. However, a sound fertilizer plan involving soil testing, mid-season tissue analysis, and consideration of the yield potential and production practices used, should ensure the optimization of yields.