Chapter 4

# INFLUENCE OF CROP CONDITION ON HARVEST-AID ACTIVITY

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## INTRODUCTION

Cotton is a perennial plant that will shed its mature leaves naturally as the growing season progresses and the crop matures. Stresses such as drought, disease, starvation, or frost may cause natural leaf senescence (Cathey, 1986); however, growers rarely wait for natural defoliation, using harvest aids to remove leaves and hasten boll opening artificially in preparation for harvest. Successful defoliation of cotton requires ideal environmental conditions at the time of – and during the two to three days following – application of defoliants, correct selection of harvest-aid chemicals, and proper condition of the plant at time of harvest-aid application. Of these factors, the influences of weather and condition of the crop at the time of defoliation probably have the most impact on successful defoliation (McCarty, 1995). Obviously, weather is a factor over which the grower has little control; however, with good management decisions throughout the growing season, the grower can have significant impact on the condition of the crop at the end of the season.

# CROP CONDITIONS DURING THE SEASON

## VEGETATIVE VS. REPRODUCTIVE GROWTH

The relationship or balance between vegetative and reproductive growth of a cotton plant during the season is one of the more important factors that affects a crop's response to harvest-aid application (Walhood and Addicott, 1968). Any agronomic practice or environmental factor that promotes vegetative growth, rather than reproductive growth, can lead to problems in harvest preparation and reduced efficacy of harvest aids.

During the early stages of growth, the cotton plant will produce two cotyledonary leaves, followed by five to nine main stem nodes and leaves. After this initial vegetative growth phase, the cotton plant begins its reproductive phase. The auxiliary buds located at the main stem leaf axis begin to differentiate and produce reproductive branches. This process typically begins at the fifth to ninth nodes; once buds along the main stem begin to produce fruiting branches, most of the subsequent nodes also will produce fruiting branches. However, the continuation of flowering is a function of continued vegetative growth, which produces sites for additional fruiting branches, and the formation of additional nodes on existing branches (Mauney, 1986).

The cotton plant has an indeterminate growth habit with the ability to sustain growth, either vegetative or reproductive, as long as weather and nutrients allow. If reproductive growth proceeds normally and first-position bolls – the fruiting structures closest to the main-stem on a fruiting branch – are set, they act as carbohydrate sinks, slowing later vegetative growth. Setting first-position bolls early and retention of these bolls throughout the growing season forces a plant to shift increasingly available carbohydrates from vegetative shoot and root growth to boll (lint and seed) development. If first-position bolls are lost or development of these bolls is delayed, growth will continue and natural senescence will begin later in the season. Therefore, to maximize the performance of harvest-aid chemicals, a grower's production practices should be designed to obtain a balance between vegetative and reproductive growth, to favor early flowering and fruit set, and to retain first-position bolls throughout the growing season, such that physiological maturity coincides with the end of the effective fruiting season.

## VARIETAL DIFFERENCES

Although botanically cotton is considered an indeterminate plant because it flowers and sets fruit over an extended period of time, breeders have developed cultivars that are referred to as "determinate." Determinate cultivars tend to fruit at nodes lower on the plant (Ray, 1972), shed fewer early squares, and require fewer days between fruiting position development on each branch and between successive branches (Namken *et al.*, 1975). These cultivars mature early and fruit heavily during the early growing season. Terminal buds then become dormant, the growth of fruiting branches and rate of flower production decline, and all or most of the late flowers are shed (Tharp, 1960). Indeterminate cultivars continue to flower throughout the growing season and may not develop enough fruit to stop growth later in the season. Over a long growing season, an indeterminate variety most likely will have higher yields than a more determinate variety. However, when the growing season is shortened because of poor weather conditions, an indeterminate variety will be less responsive to harvest aids, because the plant will not have reached natural senescence.

The extent to which different cotton varieties respond to harvest-aid chemicals generally depends on the conditions under which the varieties were developed. Varieties developed under Rain Belt conditions were more susceptible to chemical injury in Arizona than Acala™ varieties developed in the irrigated Far West region (Walhood, 1949). Acala varieties, which have larger and thicker leaves than upland varieties, tend to be more tolerant to harvest-aid chemicals, even when grown in the Rain Belt regions of cotton production.

There does not seem to be evidence that varieties developed for the region under which they are grown have significant impact on performance of harvest aids. Variety selection and how it fits into a management program, however, is an important consideration. For example, plant height and maturity are influenced strongly by plant populations, water management, and use of plant growth regulators.

Transgenic Bt (*Bacillus thuringienesis var. Kurstaki*) varieties with full-season characteristics typically produce rank growth under good growing conditions. A small-statured variety will mature earlier in high planting densities than a tall-statured variety. In order to optimize harvest-aid performance, growers must have knowledge of how a particular variety will interact under their field conditions and what varieties best suit their particular management practices.

## PLANTING DENSITY

Growing a cotton crop for successful use of harvest aids begins at planting with selection of optimum plant populations and establishment of a uniform plant stand. Plant spacing directly influences soil moisture extraction, light interception, humidity, and wind movement. These factors, in turn, influence plant height, branch development, fruit location and size, crop maturity, and, ultimately, yield (Hake *et al.*, 1991a).

Whenever fruit initiation or retention is delayed, crop maturity also is delayed. Ironically, either a very thin or dense crop stand may result in delayed maturity (Hake *et al.*, 1991a). Cotton plants in thin or "skippy" stands grow large vegetative branches to fill the open space. Fruit set on these vegetative branches occurs later in the season; consequently, maturity is delayed. On the other hand, dense stands can result in delayed square initiation, increased fruit shed, and slower nodal development. This is because of poor light penetration into the leaf canopy where leaves do not receive sufficient light to supply assimilates required for boll retention (Johnson, 1969). The relationship between planting densities and maturity depends on the variety. Kerby *et al.* (1990) found that higher plant densities delayed maturity of more indeterminate genotypes but had no effect on shorter, more determinate genotypes. Early maturity was associated with a lower node number of the first fruiting branch, more rapid production of early main-stem nodes, and an increase in retention of early fruiting structures. Optimum plant densities, therefore, generally are related to ultimate size of the plant (Kittock *et al.*, 1986; Kerby *et al.*, 1990), which primarily is controlled by genetics. If plants are small, higher densities can be established without detrimental affect on crop maturity, whereas larger plants perform better under lower plant densities. Recommended planting densities for most picker cotton varieties are three to four plants per foot of row in conventionally spaced (38 to 40 inches) cotton or two to three plants per foot of row in narrow-row (30 inches) cotton. With short-stature stripper varieties, three to four plants per foot of row are recommended.

## CROP STATURE AND THE ROLE OF PLANT GROWTH REGULATORS

Plant stature is affected by many factors, both environmental (nutrient availability, moisture) and cultural (planting density, cultivar, use of mepiquat chloride).

Tall plants with excessive rank growth may have more square and boll abscission due to insect damage and shading of lower leaves. These plants will mature later in the season; the presence of excessive foliage may interfere with penetration of harvest-aid chemicals into the crop canopy.

The plant growth regulator mepiquat chloride is a management tool used by many cotton growers to inhibit plant growth, even when the crop has been affected adversely by other factors. Cotton treated with mepiquat chloride puts less energy into growth of leaves and stems and more into fruit retention and boll development. The benefits of mepiquat chloride use have been well documented. They include reduced plant height and length of fruiting branches (Willard and Kupelian, 1977), improved ratio of fruit dry weight to above-ground dry weight (Wells and Meredith 1984), and improved earliness (Willard and Kupelian, 1977; Briggs, 1981; Kerby *et al.*, 1983; Kerby, 1985). Height reductions vary according to growth conditions (York, 1983, Stuart *et al.*, 1984; Kerby, 1985), with greatest response achieved under conditions that produce taller plants (York, 1983). Conditions that warrant the use of mepiquat chloride to control excessive growth and enhance maturity include late-planted cotton (Cathey and Meredith, 1988), fields that have a history of producing cotton with rank growth due to soil type or water and nutrient availability, and cotton planted in narrow rows (30 inches or less) (Hake *et al.*, 1991b).

## PLANT STRESS EFFECTS

**Water**, in either excessive or insufficient quantities, can affect the plant's response to harvest aids and, depending on when the stress occurs, either can be detrimental or beneficial to harvest-aid efficacy. If moisture is abundant prior to fruit set, vegetative growth and plant height will be excessive. Plants that have been exposed to excessive amounts of moisture during the growing season usually have rank growth and long internode lengths.

If plants are stressed from lack of water, square and boll retention may be reduced, resulting in delayed maturity (Guinn, 1982a). Water stress does not cause major square shedding if it occurs early in the season, prior to flowering

(Bruce and Romkens, 1965; Mauney *et al.* 1980), but will increase square shedding if the stress occurs after flowering has begun (McMichael and Guinn, 1980). The effect of drought stress on fruiting and boll abscission occurs through a number of mechanisms. These include decreased photosynthetic activity due to smaller (Boyer 1973; Marani and Levi, 1973), or the loss of, leaves (McMichael *et al.*, 1973); decrease in translocation of assimilates (Ackerson and Hebert, 1981); and alteration of the hormonal balance within bolls (Guinn 1976). If water then becomes available without the carbohydrate sink of developing bolls, energy will be diverted to vegetative growth and later-maturing bolls.

Cotton plants that are water-stressed during the growing season develop a thick, waxy cuticle that is relatively impenetrable to harvest aids. Oosterhaus *et al.* (1991) concluded that the efficacy of foliar-applied harvest aids was substantially reduced when the cotton had received inadequate rainfall or irrigation during the growing season. Leon and Bukovac (1978) found that the composition of the cuticular wax of water-stressed plants had higher molecular weight waxes than well-watered plants. This trend towards longer-chain waxes results in a greater hydrophobicity of the cuticle contributing to reduced leaf uptake of harvest aids.

Because harvest aids typically do not translocate within the plant, adequate penetration into the plant canopy is essential for activity under water-stress conditions. To maximize canopy penetration, high application gallonage should be used. Five to 10 gallons per acre is recommended for aerial application of harvest aids. By ground, harvest aids should be applied in spray volumes ranging from 10 to 20 gallons per acre. When spraying rank or tall cotton, the top end of the spray ranges are necessary to achieve good penetration and adequate coverage.

If water stress occurs late in the growing season just prior to harvest-aid application, it can be beneficial, because it promotes natural plant senescence. Lack of water during the boll-opening period will hasten boll maturation, stimulate leaf senescence, and retard regrowth. Fields that are depleted of moisture before harvest-aid application generally can be defoliated with lower rates of harvest-aid chemicals (Hake *et al.*, 1996).

**Nitrogen** is an essential nutrient for growth and development of cotton. It plays an important role as a molecular component of chlorophyll, nucleic acids, membrane proteins, enzymes, and plant hormones. Although availability of adequate nitrogen throughout the growing season has significant impact on fruit-set patterns, boll retention, and crop maturity (Kerby *et al.* 1987), excessive levels can negatively affect the efficacy of harvest-aid chemicals.

Unduly high nitrogen levels during the growing season will promote excessive vegetative growth, shifting the available supply of carbohydrates from reproductive growth. Because leaf size is dependent on nitrogen (Jackson and Gerik, 1990) and water availability, leaf size can become very large when nitrogen levels are high. Large leaves that shade lower boll positions cause them either to mature more slowly or to abscise (Guinn, 1982b). Subsequent bolls that are retained will be delayed in opening and the plant will reach senescence later in the season.

If soil nitrogen is not depleted by the time of harvest-aid application and moisture is available, plants will continue to produce healthy, vigorous growth. This late-season, vigorous growth, not having reached the state of senescence required for rapid abscission, is very undesirable (Cathey, 1986). Brown and Rhyne (1954) found that defoliation efficiency was directly related to the age of leaves when plants were in a continuous stage of growth. Addicott (1969) and Thomas (1965) found that leaves on the lower part of the plant and leaves subtending mature bolls are more responsive to most defoliant chemicals than leaves of newer growth. Application of harvest aids therefore most likely would result in poor leaf drop of young, juvenile leaves.

**Diseases**, such as *Verticillium* wilt (*V. dahliae* Kelb.), a fungal disease that infects cotton, blocking the xylem and interfering with translocation of water and nutrients, can affect harvest-aid performance. Mild infections cause leaves to wilt, while more severe infections cause leaf and boll shed (Presley, 1953). If a mild infection of *Verticillium* occurs late in the season, it will trigger the production of ethylene (Wiese and Devay, 1970), which will initiate formation of abscission zones, making the plant more susceptible to defoliation (Hake *et al.*, 1996).

**Insect feeding** can seriously damage cotton by causing leaf malformation or abscission, by increasing the shedding of squares and bolls, by damaging the seed and lint, or by a combination of these. The stimulus for square and boll shedding either may be direct (feeding on the square or boll) or indirect (by withdrawing nutrients from leaves, petioles, or stems, or by causing loss of leaf area due to malformation or abscission) (Guinn, 1982b).

Depending on the extent of the injury and when it occurs during the growing season, insect injury may result in excessive or abnormal vegetative growth and abortion of early-season squares and bolls, resulting in a delay in plant maturity. Good insect control therefore is essential for maintaining the balance between vegetative and reproductive growth and early plant maturity, thus preparing the plant for successful harvest. In addition, disruption in fruiting, leading to nonuniform boll set, can complicate timing of harvest-aid application.

The damage caused by insects can occur at any stage of crop growth. However, because of fruit loss and subsequent compensatory growth, damage that occurs early to mid season is most likely to disrupt normal maturity and senescence and to cause excessive vegetative growth, which will have the greatest impact on harvest-aid performance.

**Plant bugs** (***Lygus spp.***) feed primarily in the terminals of the cotton plant, puncturing developing squares and growing points (Leigh, Kerby and Wynholds, 1988). Feeding on cotton plants prior to fruit development will damage the plant terminal, resulting in an undesirable many-branched, candelabra-shaped plant, commonly referred to as "crazy cotton." When small- to medium-sized squares are fed upon, they will abort in three to four days (Leigh and Goodell, 1996). The critical period for plant bug control and, thus, protection of early fruit set, is during the first to sixth week of squaring.

**Cotton bollworm *(Helicoverpa zea Boddie)* and tobacco budworm *(Heliothis virescens Fabricius)*** cause damage from larvae feeding on leaves, squares, blossoms, and young bolls (Wilson *et al.*, 1980). Their feeding stimulates ethylene production (Guinn, 1982b), triggering shedding of the damaged squares and bolls.

**Pink bollworm *(Pectinophora gossypiella Saunders)*** moths feed on plant nectar and lay eggs on the surface of squares, bolls, or leaves. The larvae burrow into and feed internally on squares or bolls. They normally feed on the immature pollen and anthers within the fruit, rarely causing squares to abscise. However, if the larvae feed on the stigma of squares or on the ovule of young bolls, the boll will abscise soon after anthesis (Guinn, 1982a).

**Boll weevil *(Anthonomus grandis grandis Boheman)*** adults prefer to feed on squares (about one-quarter inch in diameter). Adult weevils also will feed on young bolls when weevil populations are high. The females oviposit in squares and young bolls, where eggs hatch and larvae feed and develop to the adult stage. Oviposition and egg hatch trigger abscission of squares. Feeding-damaged and larval-infested bolls usually remain on the plant but sustain damage to seed and lint.

**Leaf-feeding insects and mites** destroy leaf photosynthetic tissue, depriving the plant of its source of food. Inadequate carbohydrates cause premature cessation of square development and boll growth. Pests causing this type of damage include the cotton leafperforator (*Bucculatrix thurberiella* Busck), beet armyworm (*Spodoptera exigua* Hübner), other foliage-feeding caterpillars, spider mites (*Tetranychus spp.*), and thrips (*Frankliniella* spp.).

## HERBICIDE INJURY

Herbicide use plays an important role in modern cotton production. If applied in accordance with label recommendations, herbicides will not affect the growth and development of cotton negatively. However, misapplication, uneven application, or unfavorable weather, which slows crop growth, may cause injury to the crop such that early growth and fruiting patterns are disrupted, maturity is delayed, and efficacy of harvest-aid chemicals is reduced.

**Cotton herbicides** may cause injury under adverse environmental conditions. Stunting or lack of growth can result from application of pre-plant incorporated or pre-emergence cotton herbicides under adverse conditions. Residues in the soil from these herbicides restrict root growth and development, especially when temperatures are cool and compensatory growth is slowed. Post-emergence herbicide application also may delay maturity, depending on growth stage of the cotton when the exposure occurred. Snipes and Byrd (1994) observed that MSMA and a combination of MSMA and fluometuron, applied post-emergence over the top to cotton in the cotyledon to one-leaf growth stage, elevated the node number of the first fruiting branch by one and 1.5 positions, respectively, indicating a delay in maturity of three to five days.

**Carryover** may occur when cotton is grown in rotation with other crops. Persistence of herbicides used in the previous crops may result in delayed plant development and stunting. Regions of the United States that would be most affected are the Southwest and Far West, where conditions are dry, temperatures are cool, and soil pH is high. The most common offenders are chlorsulfuron and metsulfuron used in wheat; atrazine and propazine used in sorghum or corn; and metribuzin, chlorimuron, imazaquin, and formesafen sodium used in soybeans (Wiese *et al.*, 1992).

**Spray drift** onto cotton may occur in areas where nonselective herbicides are used on crops grown adjacent to cotton fields. This can be a significant problem in regions of the country where cotton is grown next to rice, because some currently registered rice herbicides can injure cotton. In addition, recent introduction of genetically altered cotton varieties tolerant to over-the-top applications of glyphosate or bromoxynil increases the risk of drift further.

The potential for drift or accidental overspray from rice herbicides is significant because of the widespread use of fixed-wing aircraft for application. Smith *et al.* (1977) demonstrated that propanil, the most widely used herbicide in rice, delayed maturity when applied post-emergence to cotton. The extent of injury to cotton is affected by growth stage of the crop when the drift occurs. In general, drift from contact herbicides such as propanil or acifluorfen is more injurious to young cotton than that from systemic herbicides such as triclopyr, 2,4-D, or quinclorac (Snipes *et al.*, 1992). Conversely, when cotton is in the reproductive phase of growth, systemic herbicides have a more profound effect on cotton yield than contact herbicides.

In recent years, cotton varieties have been developed that are resistant to over-the-top application of glyphosate; however timing of application is critical to avoid disruption of fruiting. Presently, over-the-top applications of glyphosate can be made from emergence of the cotton seedling up to the four-leaf (node) stage of growth. Over-the-top applications made after the four-leaf stage of development may result in boll loss, delayed maturity, and yield loss.

## CROP CONDITION DURING HARVEST-AID APPLICATION

### MATURITY AND BOLL LOAD

A heavy boll load prior to harvest-aid application forces the cotton plant to stop vegetative – and reduce further reproductive – growth. This stage of development commonly is referred to as cutout. Cutout is the stage where the harvestable crop is approaching physiological maturity and any further fruit set is of little commercial value. Harvest aids usually perform best when plants have completely reached the cutout stage. During cutout, growth in the immature bolls proceeds and available carbohydrates and nitrogen are partitioned into developing, immature bolls, rather than supporting further vegetative growth. Furthermore, root growth is restricted by the presence of developing bolls (Eaton, 1931; Eaton and Joham, 1944), such that new exploration of soil for moisture and nutrients ceases. Plant senescence therefore is encouraged because of the direct competition by developing bolls for carbohydrates and nitrogen, and the indirect effect of reductions in nutrient and water uptake by roots.

## ENDOGENOUS HORMONE ACTIVITY AND NATURAL SENESCENCE

Plant senescence, whether natural or induced by application of harvest aids, is accompanied by a number of changes in the leaf. These include loss of chlorophyll, a temporary increase in levels of anthocyanin, and a breakdown in leaf proteins and carbohydrates, which then are translocated along with inorganic ions to other parts of the plant (Walhood and Addicott, 1968; Addicot, 1969). In addition, as leaves age, the concentration of auxins, hormones associated with actively growing plant tissue, declines and the levels of ethylene and abscisic acid (ABA) increase. The latter plant hormones are associated with plant senescence and leaf abscission.

The time at which these changes appear and the rate at which they progress can vary because of many factors. The senescence state of development is not always related to chronological age but, more often, is a reflection of the condition under which the plant develops (Cathey, 1986). Leaf senescence can be delayed by the abundant supply of nitrogen or accelerated by drought, frost, mineral deficiencies, and certain toxic chemicals (Addicott, 1969).

## PLANT STRESS AND LEAF ABSORPTION BARRIERS

Plant stresses affect harvest-aid uptake and activity once it has been absorbed into the leaf. Because the internal leaf cells, where enzymatic activity necessary for harvest-aid performance occurs, require a saturated condition to function, it is desirable that leaves have a high moisture content at time of harvest-aid application (National Cotton Council, 1950). Under conditions of prolonged drought, not only do leaf cuticles become thickened, such that uptake of harvest-aid chemicals is reduced (Osborne, 1974), but physiological activity within the leaf also is reduced.

Addicott and Lynch (1957) demonstrated that defoliation is especially enhanced when nitrogen levels are depleted in the soil. The lack of nitrogen promotes senescence and aging, and stimulates the separation zones in leaf petioles and immature boll walls, whereas high nitrogen levels will delay abscission zone formation in both leaf petioles and boll walls.

## CHANGES IN CROP CONDITION AFTER APPLICATION

**Abscission** of leaves is an active physiological process controlled by hormonal interactions within the leaf blade. It involves separation of living tissue from the plant through the breakdown of cells within the separation zone, a restricted band of cells located at the base of the leaf petiole (Webster, 1973; Sexton and Hall, 1974). Hormones within the leaf blade play a major role in this process. They include auxins, such as indole and naphthalene acetic acid (IAA and NAA), abscisic acid (ABA), ethylene, gibberellic acid, and cytokinin (Addicott and Wiatr, 1977). Auxins are strong inhibitors of abscission, while ABA and ethylene are promotive. Gibberellic acid and cytokinin have variable effects depending on concentration, site of application, and tissue involved. (See Chapter 2 for further discussion.)

The auxin gradient theory proposed by Addicott *et al.* (1955) may describe a major factor in the control of the abscission process. The theory is based on the observations that, before leaves abscise, the auxin concentration in leaf blades decreases, whereas the concentration of auxin in the stem remains unchanged. Abscission occurs when the shift in the auxin gradient across the abscission zone favors the stem side. In support of this theory, Addicott and Lynch (1955) demonstrated that, when IAA is applied to the petiole side of the abscission zone, leaf abscission is inhibited, whereas when IAA is applied to the stem side, abscission is stimulated. These observations led Addicott *et al.* (1955) to suggest that the auxin gradient across the abscission zone is more important than absolute concentration of auxin in cotton leaves. As growth and maturation of the cotton plant proceeds, there is a decrease in auxin production by leaf blades. This decrease results in a gradual shift in the auxin gradient across the abscission zone, which initiates abscission in senescent leaves (Cathey, 1986).

Harvest-aid chemicals artificially stress or injure the leaves of a cotton plant, inducing a change in the hormonal balance between the leaf petiole and stem such that leaf abscission will occur. Because respiratory metabolism is essential for abscission to occur, the abscission zone must be alive and fully functional for the process of abscission to take place. Any treatment that is so severe that it damages or kills cells within the abscission zone will prevent abscission. Leaves will be desiccated but remain attached to the stem, contributing to excessive trash in seed cotton. If leaf injury from harvest-aid application is minimal, the hormonal processes required to initiate leaf abscission will not occur, and leaves will remain green and attached to the plant (Roberts *et al.*, 1996).

**Defoliation** may be achieved in two ways: 1) application of a chemical that injures the leaf, resulting in increased concentrations of endogenous hormones (ethylene and ABA) that promote abscission; or 2) application of chemicals that act as plant growth regulators, which directly stimulate ethylene production. Defoliants such as tribufos injure the palisade cells in leaves (Morgan, 1983), while dimethipin causes leaf cells to lose water slowly. Application of both harvest aids caused the leaf to generate ethylene (Hake *et al.*, 1990) and promote leaf abscission. Thidiazuron is a synthetic cytokinin-type hormone that stimulates the production of ethylene relative to auxin in leaf petioles, activating the leaf abscission layer (Suttle, 1985, 1988). Ethephon is a precursor to ethylene, stimulating production of ethylene in the plant, resulting in formation of the abscission zone in immature boll walls and leaf petioles. Although used primarily as a boll-opening chemical, ethylene may enhance defoliation (Snipes and Baskin, 1994; Gwathmey and Hayes, 1997). Hormone-type harvest aids rarely cause desiccation, leaf freezing, or even visual injury but are more dependent on crop condition and environment than contact-type materials.

Though the degree of injury varies with plant condition, defoliant used, concentration of defoliant, and environmental conditions at application, injury usually is visible on the leaf blade within 48 to 72 hours of application (Walhood and Addicott, 1968). The separation layer in the abscission zone can be seen in photomicrographs one to two days later. Within 7 to 14 days, the defoliation process is complete under normal conditions; however, it may take as long as 30 days if conditions are unfavorable.

**Desiccants**, such as paraquat or sodium chlorate applied at high rates, cause rapid water loss from plant cells on contact, killing all aboveground portions of the plant. Unlike defoliation, in which the leaf blade and abscission zone play an active physiological role in leaf shed, desiccants severely injure plant tissues such that plant tissues are killed (Addicott and Carns, 1964; Addicott and Lynch, 1957; Carns, 1966).

Sometimes the plant response to a particular harvest-aid chemical may not be so clear-cut. High doses of defoliants under ideal environmental conditions will result in desiccation of plant parts. On the other hand, low rates of desiccants, especially paraquat, may result in defoliation, if only the leaf blade is injured, but petioles remain uninjured.

### CARBOHYDRATE RESERVES AND REGROWTH

When maturing bolls are not present to act as carbohydrate sinks, undesirable regrowth may occur if temperatures remain warm and water and nitrogen are available in the soil. Terminal (growth from the tips of stems or branches in the upper portion of the plant) or basal (growth from auxiliary buds at the base of the plant) regrowth can occur prior to or after leaves have been removed by harvest aids. Regrowth occurring prior to leaf removal generally is referred to as juvenile growth, whereas regrowth occurring after leaf removal is either terminal or basal regrowth.

The level of auxin in young leaves tends to be higher than in mature leaves. This makes younger leaves highly resistant to chemical removal. Application of harvest aids generally will remove mature leaves more easily than younger leaves. Though highly resistant to defoliation, young leaves that still are expanding have thin cuticles and are very sensitive to desiccation.

## SUMMARY

The condition of the cotton crop throughout the growing season has a significant impact on the efficacy of harvest-aid chemicals. The "ideal" crop condition for optimal harvest-aid performance includes an early and uniformly maturing crop, a heavy boll load, adequate but not excessive moisture availability throughout the growing season, nitrogen levels that have been depleted, a crop that has stopped vegetative and reproductive growth (reached cutout), and a crop that is senescing naturally. Though all these conditions rarely are met, a grower's agronomic practices should be designed through fertility and water management, insect control, plant stand establishment, use of plant growth regulators, and other practices to prepare the crop for the best possible harvest-aid performance.

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