PHYSIOLOGY TODAY

Newsletter of the Cotton Physiology Education Program — NATIONAL COTTON COUNCIL

August 1990, Volume 1, Number 11

Cotton Defoliation

Kater Hake, George Cathey and Jeff Suttle

Contributors: Claude Bonner, Tom Burch and Johnny Crawford

When to defoliate and what materials/rates to use are two important decisions that give most cotton growers grief. These decisions are frustrating because they must be made without knowledge of the most important factor, the fall weather. A fall that is hot or cold, wet or dry, can turn even the most carefully considered defoliation decision into the "wrong choice". Because of the overwhelming influence of weather on defoliation, producers must understand the basics about defoliation and boll opening to minimize the risks associated with uncooperative fall weather.

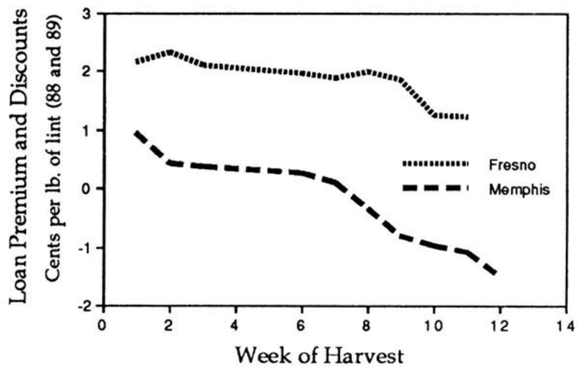
Irrigated West vs Rainbelt

Strategies for defoliation timing in the rainbelt differ markedly from the irrigated west. In the west, where whiteflies and aphids threaten the quality of open bolls, producers defoliate as soon as the crop matures to remove insect-infested leaves (the source of honeydew) and to utilize the warm temperatures for defoliation and boll opening.On the other hand, rainbelt growers prefer to delay defoliation until just before the field can be picked. This keeps as many bolls as possible closed and protected from thunderstorms.

Harvest Aid Timing

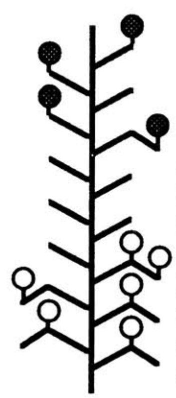
Optimum timing of harvest aids must strike a balance between further boll development and potential crop loss from adverse weather. Each producer must examine his harvesting capacity, regional weather patterns and crop development. The easiest decision occurs when the bolls are fully mature and no advantage exists in leaving the crop in the field. Most likely, some of the bolls are still immature when traditional fall weather threatens.The figure above shows the average loan value for each week based on grade for the Lubbock, Memphis and Fresno classing offices over the last 3 years. Since classing lags 1 to 3 weeks behind harvesting in most areas, the price decrease during the season reflects the deterioration of cotton quality with delayed harvesting.

The easiest determination of boll maturity is cutting with a sharp knife. A boll is mature when the lint is difficult to cut with a sharp knife and close inspection of the seed reveals folded cotyledons that are firm and without jelly. When 98% or more of the crop is mature, based on the sharp knife technique, defoliant application should allow full maturity.

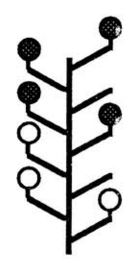


Techniques such as the seed coat color change are very subjective. The seed coat turns dark only when the boll actually opens and air gets into the seed.

Percent open boll has historically been the method to determine optimum defoliation timing and is still useful when the crop is set over the traditional number of weeks. Recent research in the Mid-South collaborates work done in the 50's, that defoliation prior to 60% open boll can decrease yield. The percent open boll technique falls apart when the crop is set faster or slower than traditionally as demonstrated by the following figure. If the crop is set over 6 weeks, say due to small boll shed associated with high temperatures at peak bloom, then defoliation at the customary 60 to 65% open would prematurely cut short the development of many bolls. Under these conditions, the crop might not be mature until 75 to 80% open bolls. The percent open technique may also inaccurately time defoliation of low density or skippy fields, because many of the bolls may be set late on vegetative branches. On the other hand, we could safely defoliate a crop set in only three weeks at 40 to 50% open boll because all the bolls are maturing at approximately the same time.



At 60% open boll, this crop would not be fully mature and safe to defoliate.



Mature enough to defoliate even at 45% open boll.

Application Method

The first part of the defoliation process is chemical application, that is, getting the product to the leaves. The leaves most susceptible to defoliation are older leaves, depleted of N by a heavy boll load. Leaves stressed or injured by foliar or wilt diseases also are susceptible to defoliation. Older leaves, such as mainstem leaves at the base of the plant senesce, turn yellow/red due to aging and shading and require less chemical than those in the middle of the plant. Aerial applications apply more product to leaves at the top of the plant which are younger and less able to initiate abscission. Where the terminal is still growing, due to either regrowth or lack of cutout, the young, tender leaves on the top of the plant will be likely to freeze on the plant if high rates of defoliants are applied under warm weather. Application with ground rigs allows concentration of material in the top half of the plant if the leaves are mature. If top leaves are still young and expanding, smaller nozzles can be used to apply less material and avoid desiccation.

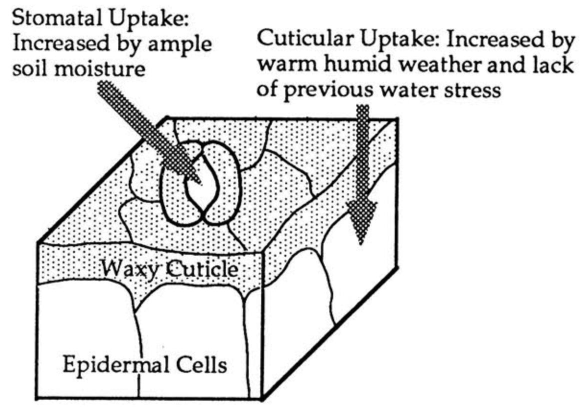
High N Effects on Leaf Drop and Boll Opening

High nitrogen delays abscission zone formation in both leaf petioles and boll walls. Growers often observe the delayed boll opening where excess N fertilizer has been applied. Excess nitrogen promotes sustained leaf growth that delays crop maturity partially due to reduced boll retention from shade induced shed. Also, bolls set on the plant can suffer delayed boll opening due to cooling and shading from excess leaves. Nitrogen deficiency promotes senescence and aging, and stimulates the separation zones in petioles and boll walls.

Uptake into the Leaf

Once the chemical is applied to the leaf it follows two routes into the plant, through the stomates (the minor route) and across the cuticle (the major route). The following diagram displays these two routes and emphasizes the various factors that decrease uptake.

- Water stress prior to harvest-aid application increases the waxiness and thickness of the cuticle. Uptake into water-stressed leaves can be reduced by up to 35% (Oosterhuis, 1990) compared to well-watered plants. Water stress in the irrigated west can increase defoliation in the absence of fall rains, because water-stressed plants produce fewer young leaves and the existing leaves age or senesce prematurely. But water-stressed cotton in the rainbelt often requires higher rates of material or wetting agents to increase uptake.
- Low humidity during application decreases uptake because chemicals dry rapidly on the leaf. Additionally, cotton grown in low humidity environments is generally under more water stress and has a thicker cuticle. Wetting agents or spray adjuvants are added to some harvest aids under low humidity conditions to delay chemical drying and speed uptake.
- Cool temperatures during and after application decrease uptake due to hardening of the waxy cuticle and the slower diffusion rate of chemicals. Once a chemical is taken into the leaf, cool temperatures further delay leaf drop because the growth processes of abscission are slowed by cool temperatures.



Abscission Zone Formation

All defoliants have a common mode of action; they alter the balance of hormones in the leaf triggering separation in the abscission zone at the base of the petiole (leaf stalk). One hormone (the auxin, IAA) is produced at high rates in leaves of healty, vigorous cotton inhibiting abscission after it moves into the petiole. Other hormones in the leaf (absciscic acid and ethylene) retard the movement of IAA and promote enzymes that loosen the cells in the abscission zone. Cotton defoliants fall into two categories of action. One is the herbicide-defoliants (Chlorate, DEF/Folex and Harvade). These products slowly injure or stress the leaf, stimulating ethylene synthesis. This stress-ethylene response not only occurs when leaves are slowly injured by defoliants but also occurs with many other types of injury such as drought, waterlogging, disease, insect damage and mechanical wounding. Producers are well aware of the cruel trick that stress-ethylene plays on harvest timing. Within a week after picking, all those stubborn bolls in the top of the plant pop open due to injury from spindles and the resulting stress-ethylene response.

Chlorate and its metabolite, chlorite, are strong oxidizers that injure the leaf. The relationship between chlorate and nitrate is interesting. Cotton leaves store nitrate in the blade and petiole. That's because the enzyme nitrate reductase, which converts nitrate to nitrite and then on to amino acids, is located in the leaves. Small grains (barley and wheat) have this enzyme in the roots and thus do not store nitrate in the leaves. While chlorate acts as a foliar herbicide on cotton, it acts as a soil-applied herbicide damaging plants such as wheat and barley and causes nitrogen deficiency from the destruction of nitrate reductase.

Two other herbicide defoliants are DEF/Folex and Harvade. Harvade causes surface cells to lose water, stimulating the stress-ethylene response, while DEF/Folex are slow contact herbicides. If the herbicide defoliants are applied at too high a rate for the temperature, they kill the plant quickly before ethylene can be produced and the abscission zone formed. This results in desiccation instead of defoliation.

The other two defoliants (Dropp and Prep) are hormone defoliants. Prep releases ethylene in the plant stimulating further ethylene synthesis and abscission zone formation in both the boll walls and leaf petioles. Although Prep is considered a boll opener, it can defoliate cotton at high rates. Dropp is in a different class of hormones called cytokinins. Cytokinins act most unusually when applied to cotton and related species such as okra and velvetleaf. When applied to cotton, cytokinins such as Dropp stimulate a massive increase in ethylene synthesis and thus act as a defoliant. In other species, cytokinins actually promote leaf health and not defoliation. Since these two hormone defoliants (Prep and Dropp) bypass the herbicide route, they rarely cause desiccation, leaf freezing or even visual injury.

Because leaf drop requires production of cell-loosening enzymes in the separation zone, the speed with which leaves drop after any defoliant application is highly dependent on temperature. Additionally, if cells in the separation zone are damaged by a desiccant, a high rate of herbicide defoliant or frost, then leaves dry up and freeze on the plant. This is why high rates of defoliants can freeze leaves under hot weather, and low rates of desiccants occasionally defoliate cotton. While hormone defoliant's activity (Dropp and Prep) dramatically increases when temperatures are above 80°F, the herbicide defoliants remain active at much lower temperatures. The following table lists the estimated minimum temperature for optimum defoliant performance.

Min. Temp. for Optimum Defoliant Performance

Dropp	65°F
PREP	60°F
DEF/Folex	55-60°F
Harvade	55-60°F
Chlorate	50°F

(Tom Burch, 1990)

Leaf Drop and Boll Opening

The formation of an abscission zone does not always ensure leaf drop because the vascular bundles that pipe water and nutrients in and out of the leaf are not separated by the abscission zone. It usually takes a little wind to break these vascular strands and cause the leaves to drop. PREP and Dropp permit the leaves to stay green. This added weight appears to cause leaf fall even in the wind's absence.

Boll opening is accelerated by defoliation. Shaded bolls are 7 to 9°F cooler than sun-exposed boll. Bolls that are warmer and drier due to sunlight and enhanced air movement speed through the last stage of boll opening. During this stage, abscission zones form between the burs which then dry and bend backwards as fibrous strands inside the bur shrink and contort.

Timing Prep Applications

The boll opener Prep is a strong formulation of the fruit ripening chemical, ethephon, which releases the plant hormone ethylene once it is absorbed into the plant. The multitude of ethephon uses reflects the widespread need to control crop maturation in many crops: pineapple, tobacco, apples, grapes, tomatoes, walnuts, lemons, berries and others. Ethephon moves only short distances in the plant stimulating ripening responses, notably the production of enzymes that loosen cell walls. When these enzymes are produced in mature fruit they soften and ripen, while in cotton they loosen the cells in the abscission zones between burs and at the base of the petiole and boll. Prep is used as a tank mix with defoliants (not chlorate) at low rates to increase defoliation and stimulate some boll opening. Prep is applied at higher rates to open mature bolls. Optimum timing for both of these two common uses is the same as a normal defoliant application, when the bolls to be harvested are mature. The optimum rate of Prep is heavily dependent on temperature after application. Cool temperatures (65 to 75 max °F) require twice the rate of Prep to accomplish the same speed and degree of boll opening compared to warmer temperatures (85 to 95 max °F). If Prep is applied prior to boll maturation, especially if temperatures are warm or top of label rate is used, then some immature bolls will shed and decrease yield. Even the immature bolls that are forced open will also reduce yield and quality. Low rates of Prep (1/3 pint) occasionally are applied prior to defoliation on vigorous and healthy cotton. This preconditioning effect allows subsequent use of lower defoliant rates along with the reduced risk of desiccation if temperatures suddenly turn warm.

Combinations/Multiple Applications

Many producers use combinations and multiple applications of harvest aids to enhance defoliation. This approach is supported by research in many states. Because of the difficulty of predicting what materials will work best each year on each field, combinations with different modes of action increase reliability and allow greater defoliation stimulation with less desiccation compared to a high rate of one chemical. Multiple applications are beneficial because leaves deep in the canopy can be covered fully with the second shot and the hormonal stimulation for defoliation maintained longer.

Harvest Aids for Maximum Quality

A cadillac system to deliver the highest grades would include a field with a high percent set (70 to 80%) of the first position bolls during a short 3 to 4 week bloom period, and then an abrupt cutout due to the boll load and judicious N applications. A field such as this could be treated with a defoliant or high rate of boll opener when most of the bolls were mature but still un-open, minimizing the lint exposure to weathering. Because of the abrupt cutout, this field would have few young leaves and mainly older stressed leaves from the rapid heavy boll set. Leaves such as these have a good probability of shedding and not freezing on the plant. A once over harvest in 7 to 14 days, depending on temperature, should pick a clean white cotton that would need only one lint cleaner to produce excellent grades with minimal lint cleaner loss or fiber damage. Few fields achieve this fairy tale, but the take home message is that high quality cotton is determined all season long, with variety selection, fruit retention, irrigation, fertilization and finally harvest aid application all contributing to lint quality.

What and How Much to Apply ?

Producers can only decide when and what harvest aid to apply. The weather and plant condition will determine when and if the leaves actually fall. Since shed is a temperature driven growth response it proceeds twice as fast at 95°F max air temperature than at 77°F. And whether a harvest aid works at all is heavily influenced by the plant's readiness for defoliation. Because of the weather and plant influence on defoliation, a better understanding of the mechanisms of defoliation and boll opening prepares us to look at a field, read a weather forecast and then make the best possible defoliation decision.

About the Authors

George Cathey is a Cotton Physiologist retired from the USDA research station in Greenville, Mississippi. He has worked extensively on defoliants and plant growth regulators and recently authored the chapter on Physiology of Defoliation in the Cotton Physiology text published by the Cotton Foundation with support from the BASF corporation.

Jeff Suttle is a Plant Physiologist with the USDA in Fargo, North Dakota, who has specialized in biochemcial mechanisms of defoliants. Besides the benefits to our understanding of cotton growth and defoliation, his research has yielded rapid methods to identify promising new chemicals for use as cotton defoliants. For those of you who question cotton in North Dakota, Jeff's cotton is all greenhouse grown.

Claude Bonner, Tom Burch and Johnny Crawford are the Cotton Specialist for Arkansas, Louisiana and Georgia, respectively. These Specialist have recently produced publications on defoliation, which were used extensively in the preparation of this newsletter

Cotton Physiology Today
Edited by Kater Hake, Manager, Cotton Physiology Education Program,
Electronically published by
NATIONAL COTTON COUNCIL Prod. A/V