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THE ART AND SCIENCE OF DEFOLIATION

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Producers recognize that success in defoliation depends on a little science and a lot of luck. Fortunately, that view is slowly changing as some of the art of defoliation is replaced by science. This newsletter will revisit some of the principles responsible for defoliation success and highlight a new technique to schedule harvest preparation — nodes above cracked boll (NACB).

The Challenge - The Cooperative Plant

Successful defoliation is dependent on a cooperative plant. Without that cooperation, inadequate leaf drop on one hand or leaf desiccation (leaves that dry and do not drop) on the other hand are likely to result. Cotton leaves need to be persuaded or coaxed off. A heavy-handed or sledge hammer approach is not desirable.

Experience as Guide

Experience usually is an excellent instructor. That may not be the case when it comes to defoliation. Treatments that worked on a field last year may or may not be effective this year. The inconsistency in cotton response to defoliation treatments leads to no small amount of frustration. Common responses to this problem include a reliance upon the experiences of fellow growers, a decision to increase the rate of a particular defoliant, a decision to tank mix a little or a lot of several products, or a decision to not decide and let the frost kill the leaves on the plant. While each of these techniques works occasionally, consistently satisfactory results elude most practitioners. To understand why defoliation is so uncertain, the physiology of leaf aging (senescence) must be explored.

Leaf Senescence

Defoliation (leaf abscission) is the normal conclusion in the life of a leaf. As a perennial, cotton is programmed to enter dormant periods while awaiting the return of favorable conditions. During active growth, leaves are initiated at growth points and initially sustained by the products from working mature leaves. These young leaves reach functional maturity in about 20 days and begin to support other growth points including bolls. This support can be maintained by a leaf up to 40 days or more depending on many factors including location on the plant, presence of nearby bolls and available mineral nutrition. During this time, the aging (senescence) process gradually diminishes the net productivity of the leaf leading to recognizable symptoms that conclude with leaf drop.

Complex physiological alterations are associated with leaf aging. One of the first changes can be observed in the behavior of the membranes that enclose and divide the compartments of the cell. These membranes normally permit the orderly function of the cell's machinery and transport of material from one compartment to another. With continued aging, these membranes begin to leak with serious consequences. Powerful enzymes capable of dismantling the cell are activated.

Several crucial physiological processes are quickly upset in this upheaval. The chlorophyll molecules that harvest the sun's energy begin to break down. The photosynthetic machinery that transfers this captured energy to the chemical bonds of plant sugars (carbohydrates) is destroyed. The cell's ability to repair damage also is short-circuited. Interestingly, the cell's ability to convert stored energy into quickly usable forms (respiration) does not decrease until very late in the process. This fact is important and will be mentioned again later.

Plant hormones play a central role in this process. Ethylene is partially responsible for the leaky membranes that unleash the dismantling enzymes. This injury cycle spurs further ethylene production (stress ethylene) creating a snowball effect that accelerates the cellular disorganization. Changes in ratios of auxin hormone to ethylene across the separation layer initiate the abscission process. Auxin plays a role in leaf aging and death by stimulating growth only on the stem side of the abscission zone of the leaf petiole. Ethylene complements auxin's action by promoting the activity of enzymes responsible for the degradation of cell walls. The unequal growth at this zone completes the sealing off process that precedes leaf drop. Physical separation and drop result when the weight of the leaf combined with mechanical forces such as rain or wind are sufficient to break the few remaining connections in the vascular tissue.

While leaf senescence may look like destruction, it is not random or wasteful. The dismantling process is more accurately viewed as recycling. Once the useful function of a leaf has ended, it dismantles itself and ships the reusable parts back through the petiole to the stem for relocation to growing points or storage organs.

It is no mistake that cellular respiration continues

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throughout the senescence process and actually increases in many instances. The recycling process requires the expenditure of energy to dismantle and move the cellular contents out of the leaf prior to final separation and leaf drop. Difficulties associated with defoliation revolve around this need for metabolic expenditure.

Recycling also is apparent during leaf senescence caused by nutrient deficiency, drought stress, etc. The leaf dismantles itself to maintain the younger growth points such as bolls. In more intensive crop management systems, recapture of previously used nutrients from senescent leaves is less important to overall productivity. Our decreased reliance on these previously used building blocks does not diminish the biological importance of the programmed senescence process. Defoliation strategies must be developed in accordance with the natural senescent processes to avoid genuinely disruptive disorganization, which leads to rapid leaf death without abscission (stuck leaves).

Defoliation treatments impose their own aging schedule on cotton leaves. Contact-type products including Def, Folex, Harvade and Chlorate induce abscission by stimulating the production of naturally occurring stress ethylene. Dropp is a defoliant related to the naturally occurring hormone cytokinin. Dropp stimulates ethylene production without pronounced herbicidal effects. The boll opener Prep is converted to ethylene in the plant, resulting in defoliation in some instances.

Young Leaves

Young, vigorous leaves are normally more difficult to remove than older leaves. The leaf aging process that concludes with abscission is really a series of related events. Older leaves have proceeded toward developmental conclusion of their life. They are frequently referred to as "conditioned" for defoliation. Young leaves, on the other hand, are not conditioned for early termination. They are still a physiological sink and are in a growth mode, not a senescent mode. Signals for senescence are not guiding the metabolism of young leaves. As a result, defoliation treatments may be largely ineffective when applied at rates that readily remove older leaves. Alternatively, when rates are increased, leaf and stem death or desiccation may occur prior to completion of the abscission process. This quick kill without defoliation "sticks" the desiccated leaves. The situation resembles the frozen leaves that accompany a first killing frost.

Environmental Considerations - Temperature

Environmental conditions that favor growth favor defoliation. Temperatures during and immediately following defoliation treatment will largely determine the success of a given treatment. Defoliant activity roughly doubles with every 10 degree rise in temperature. The hormone-type materials Dropp and Prep are dependent on sustained cellular metabolism. These 2 materials appear to be the most sensitive to temperatures below 60 degrees. The contact-type defoliants' activity also decreases with temperature, but retains marginal activity at slightly lower temperatures.

Desiccation poses a greater risk when employing contact-type defoliants. When temperatures are high, the activity of these materials may kill the leaf and adjoining stem before the abscission zone can develop. Care must be exercised when using these defoliants to match the rate with the temperature to avoid rapid leaf kill and leaf/stem desiccation.

Moisture

Well-watered cotton is more responsive to defoliants for several reasons. Drought stress decreases overall metabolism and inhibits abscission. The leaf cuticle thickens in response to more limited water availability resulting in less uptake through this route. Finally, arid conditions cause more rapid drying which impedes defoliant diffusion through the cuticle.

Nitrogen

Nitrogen availability can also interact with defoliant performance. High nitrogen can support continued vegetative growth of young unconditioned leaves, particularly if the boll load is low or cutout was not sharp. This late season second growth shades and cools the lower plant parts, delaying boll opening while adding to the plant mass, complicating efforts to achieve good defoliant coverage.

Timing Crop Termination

Timing harvest preparation is not an exact science. The physiology of the cotton plant prevents that. The plant produces bolls over an extended time period. Some will be ready to pick sooner than others. The dilemma is when to stop waiting on the latecomers, pull the plug and terminate the crop.

Decisions on crop termination demand thoughtful compromise. A balance must be struck. Delaying defoliation until all the bolls have opened exposes the earliest and most valuable bolls to potential weathering. Delay can reduce yield and quality. Early crop defoliation impacts yield and quality of the later produced bolls by removing the predominant source of nutrients. There is no one correct answer on timing, only a range of acceptable settlements.

Decision aids can help growers with this timing uncertainty. The most widely used technique relies on the percent open bolls. The desired minimum threshold ranges from 50-80% open. This procedure is straightforward, simple and well-researched.

It does have some drawbacks. It does not separate out those phantom bolls that are unharvestable. Full boll size is achieved within 30 days of bloom.

Late maturing bolls may require 70 days to reach full development. Many of those bolls will not find their way into the picker basket and should not be included in the percent open determination.

The second drawback also involves unopened bolls. Percent open bolls provides little information about the maturity and quality of the bolls that have not opened. The effective bloom period may range from 3 to 6 weeks and over 7 to 20 fruiting branches. Crops set over a long time period have a wider range in boll maturity and require a very conservative boll opening threshold to avoid premature termination of late boll development. Conversely, compact boll loading periods produce bolls of similar maturity and may in certain situations be acceptably defoliated when boll opening is less than 50%. Producers may also elect to defoliate selected fields when boll opening is less than 50% in order to begin harvesting sooner. Unopened bolls must be sufficiently mature or this strategy may backfire.

Percent boll opening is usually practiced in conjunction with techniques that assess the maturity of the unopened bolls. These techniques require time and a sharp knife. Unopened bolls are sliced and examined. Mature bolls are difficult to slice, have lint that strings out, dark seed coats (in absence of damage) and fully developed embryo inside seed. These are excellent measures of maturity but are time consuming.

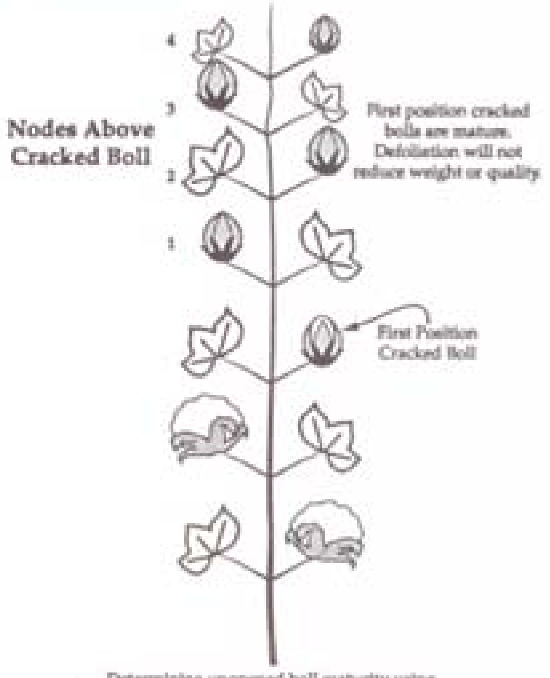
Nodes Above Cracked Boll (NACB)

Nodes Above Cracked Boll (NACB), a new technique that utilizes plant mapping information, can increase the reliability of crop termination decisions. The method is based on the fact that the maturity of unopened bolls is related to their closeness (developmentally and spatially) to open bolls.

Square initiation and flowering occurs up the main stem approximately every 3 days. A flower on the first position of the second fruiting branch is expected to bloom 3 days after the first position on the first fruiting branch, and so on. Then, in principle, this same relationship holds true throughout boll development. If the first position boll at a given fruiting branch has just cracked (lint visible but not machine pickable), then the first position boll the next branch up is only about 3 days from also cracking open, and so on.

As the spatial distance from the cracked boll increases, both up the stem and out the branches, the developmental similarity decreases. If the bolls under consideration are above (or outside) and therefore later, they are less mature. Research trials from California, Texas, Oklahoma and Mississippi indicate that any first position bolls on the 4 fruiting branches above the fruiting branch with a first position cracked boll are mature. Defoliant or boll opening treatments should not significantly reduce their potential weight or quality. The accompanying drawing illustrates this relationship.

This system is quick and offers an excellent supplement to boll opening determination and boll slicing techniques. Fields that lend themselves well to this technique would be uniform with few skips and moderate-to-high plant populations. NACB is not well suited to crops with high portions of bolls on vegetative branches or second position bolls close to the terminal or plants with major gaps in fruit retention along the stem.

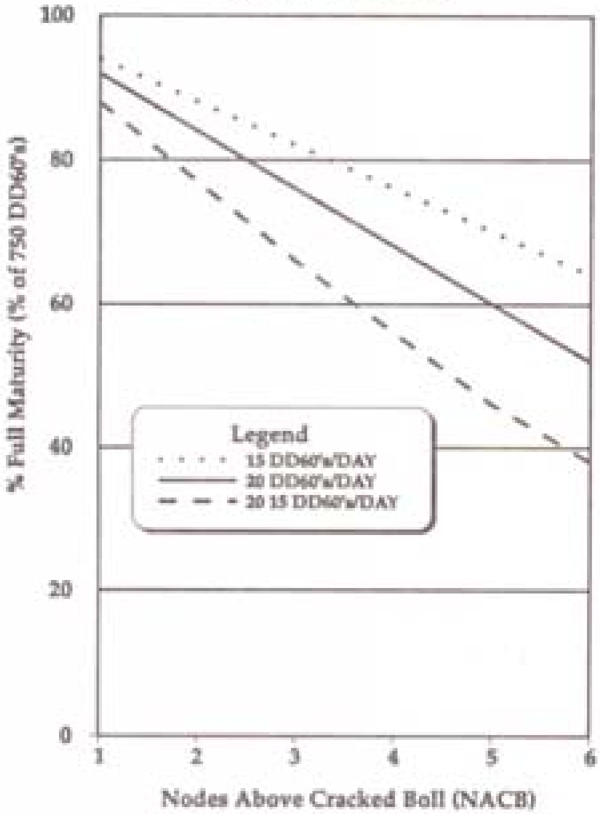


Determining unopened boll maturity using Nodes Above Cracked Boll (NACB) technique.

As additional experience is gained with NACB, the technique will be refined. For instance, in a trial where the fruit load was set in 10 fruiting branches or less with ample and consistent day-to-day DD60 accumulations, bolls 5-6 or more NACB were fully mature. On the other hand, in late-planted cotton or in regions where the onset of cooling weather is abrupt, 2 or 3 NACB may need to be used as a threshold. The figure demonstrating relative boll maturity charts the calculated DD60 accumulation for first position unopened bolls relative to a cracked boll. Published reports suggest that maximum lint weight and micronaire are achieved after roughly 600 DD60s (80% of 750). Note that when older bolls develop under warmer conditions than younger bolls, the developmental lead of the older bolls increases as the growth rate of the younger bolls slows. This is related to the increased time needed under cooler conditions to accumulate the same 750 DD60s required for full maturity.

However, it should be noted that the yield contribution of the top fruiting branches is relatively minor compared to those found lower on the plant. Therefore, applications that prematurely terminate the development of these last bolls has a small negative impact on yield. This is frequently more than

Temperature Influence on Boll Maturity



balanced by a more timely harvest and improved lint quality.

Wrap Up

The indeterminate growth habit of cotton and the unpredictability of weather team up to prevent guaranteed success with any of the defoliant treatments currently available. Growers must use good judgement to select the right time and treatment combination to convince the cotton plant to abandon its schedule and adopt theirs. Understanding the complexity of the process may not make defoliation easier, but it does underline the need for thoughtful consideration before pulling out the sledge hammer.

Nodes Above Cracked Boll Video

A new video, entitled Nodes Above Cracked Boll, is available to assist producers making decisions on crop termination. The 17-minute tape outlines an objective, science-based tool that can improve the reliability of harvest-aid timing determinations. This Cotton Foundation project, sponsored by Rhône-Poulenc Ag Company, can be obtained by calling 1-800-334-9745.

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