12. COTTON DEFOLIATION

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Defoliation is the application of chemicals to encourage or force cotton leaves to drop from the plant in order to harvest the crop in a timely manner. Defoliation is a balancing act between killing the leaves and not affecting the leaf. For successful defoliation, the leaf must stay alive long enough to begin the formation of an abscission zone that results in leaf drop. If the leaf is killed too rapidly, the chemical signals are not sent from the leaf to the abscission zone. The result is a leaf that is frozen or "stuck" to the plant, creating unnecessary trash.

Proper defoliation is a profitable part of a total cotton management system. Benefits include:

1. Elimination of the main source of stain and trash, resulting in better grades.
2. Faster and more efficient picker operation.
3. Quicker drying of dew, allowing picking to begin earlier in the day.
4. Straightening of lodged plants for more efficient picking.
5. Retardation of boll rot.
6. Potential stimulation of boll opening, which can increase earliness, yield, and profit.

DEFOLIATION DECISIONS

Harvest-aid application decisions are made based on crop maturity, crop condition, weather conditions, and desired harvest schedule. Once producers decide that defoliation is needed, they must determine when the chemical should be applied, what material(s) will be applied, and how much of each material to apply. Crop condition and air temperatures will largely determine the selection of defoliation materials and rates. Still, desired defoliation materials and rates of application often change during the season with changes in crop condition and weather. In the end, the two most important factors in determining when to defoliate are crop maturity and desired harvest schedule.

When to defoliate?

Poor defoliation can be economically costly. Defoliating too early lowers yield and fiber quality or micronaire. Defoliating too late increases the likelihood of boll rot and lint damaged or lost due to weathering. Defoliating too late also increases the possibility that defoliant activity may be inhibited by lower temperatures.

It is generally safe to defoliate when about 60 percent of the bolls are open. But this strategy may not work well in situations where the crop is set faster or slower than normal. Example

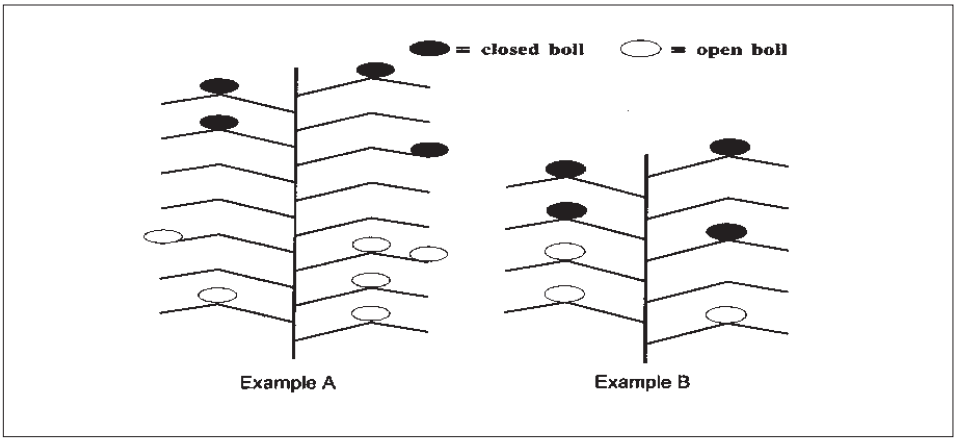

Figure 12-1. Examples of when to defoliate.

A in Figure 12-1 illustrates that a crop set over a long period may have a fruiting "gap" due to fruit loss associated with stress or insect pressure at peak bloom. This type of crop may have a high proportion of immature bolls at 60 percent open. Defoliation at 60 percent open would cut short the development of the top bolls and reduce yield and micronaire. On the other hand, Example B illustrates that a crop set in a short period of time, such as three weeks, could safely be defoliated at 40 to 50 percent open boll, as unopened bolls may be sufficiently mature and thereby safe for defoliation to occur.

Another method that is often used to time defoliation is counting the nodes above cracked boll (NACB). This is done by selecting plants with a first-position cracked boll (cracked enough that lint is visible) and counting the nodes above the cracked boll up to the highest node that has a harvestable boll. This technique places more emphasis on the unopened portion of the crop than the percent open. A count of four NACB is usually safe for defoliation. If you have low plant populations (less than two plants per foot of row), a count of three NACB would be safer. Low plant population results in a less mature crop because of the number of bolls set on vegetative branches and outer positions of the fruiting branches.

No matter which technique is used, producers should also cut and examine unopened bolls to ensure that harvestable bolls are mature. Bolls need 40 to 60 days to mature, depending on temperature. In cool weather, bolls will need extra time to mature. A boll that is set in July or early August will mature in about 40 to 45 days, whereas a boll set in mid August through early September may require about 50 to 60 days to mature. In North Carolina, bolls set (white bloom) after August 20 to 25 are likely to never mature, depending on heat unit accumulation during the fall. Producers should walk each field, decide which bolls they intend to harvest, and examine these bolls to determine whether they are mature. The younger bolls in question will be the bolls toward the top and outer portions of the plant. Bolls will be mature enough for defoliation when the following conditions occur:

1. Bolls are hard and difficult to slice into cross sections with a sharp knife. The fibers should string out when the boll is cut. If the fibers do not string out, the boll is not mature. Mature bolls should be firm when pressed, with little moisture remaining inside.

2. The seed coat is light-brown, and the kernel completely fills the seed cavity with no jelly in the center. The seed coat is a pearly-white in young bolls and turns from white to black as the boll matures. When the seed coat becomes light-brown, the boll is mature enough not to be adversely affected by harvest-aid chemicals.

Defoliation should be coordinated with picker availability. Applications should be timed so that harvesting can keep up with defoliation. In general, defoliate only as much acreage as can be harvested in about 12 to 14 days. Early defoliation of excess acreage can decrease yields, expose lint to weather more than necessary, and increase the likelihood of significant regrowth. When harvesting capacity is low for the acreage involved, consider abandoning the "once-over" strategy and plan to "scrap" or "second-pick" the acreage picked during the first week. Doing so may improve grades and prevent losses should unfavorable weather shorten the harvest season.

Defoliants work best on mature cotton under warm, humid, sunny conditions. Cool temperatures at the time of application and for the three to five days afterward can retard the activity of defoliants and cause less than desirable defoliation. If possible, defoliants should not be applied during cool snaps or cloudy weather, or when both occur. Better defoliation will occur if you can wait for a sunny, warm spell that is predicted to last for at least three to four days.

HERBICIDAL VERSUS HORMONAL DEFOLIANTS

Defoliants can be categorized as having either herbicidal or hormonal activity. Aim, Blizzard, Def, ET, Harvade, and Quickpick are herbicidal-type defoliants that injure the plant, causing it to produce ethylene in response to this injury. The ethylene promotes abscission and leaf drop. If these defoliants are applied at rates too high for the temperature, they kill the leaf too quickly before ethylene can be produced. This lack of ethylene production results in desiccation or "leaf stick" instead of the desired defoliation (leaf drop).

Dropp, FreeFall, Klean-Pik, Finish, CottonQuik, and Prep are hormonal defoliants that result in increased ethylene synthesis by the plant. Prep releases ethylene, which stimulates further ethylene synthesis in the plant, resulting in abscission zone formation in the boll walls and leaf petioles. Thidiazuron (Dropp, FreeFall, Klean-Pik, and other generics) is a type of hormone called a cytokinin. Although cytokinins promote leaf health in most plant species, in cotton and related species such as velvetleaf, cytokinins promote ethylene synthesis and act as a defoliant. Because these hormonal-type defoliants bypass herbicidal injury, they are not as likely to cause desiccation (leaf stick) as herbicidal defoliants.

DEFOLIATION MATERIALS

Sodium chlorate. Sodium chlorate is generally not used as a defoliant on spindle-type picked cotton in North Carolina. Leaf sticking may occur with high application rates, and at normal rates, sodium chlorate is usually not as effective as other defoliants. It is not a strong inhibitor of terminal regrowth and is not very effective on young, immature leaves. It is probably used most in the rainbelt to defoliate older, mature leaves. **Do not mix sodium chlorate with surfactants, oils, insecticides, or other defoliants.**

Aim. Aim is a PPO-inhibitor herbicidal type defoliant that appears to be similar to Def 6 and Harvade and is probably most similar to Harvade as it does not appear to be as rate dependent as Def 6. It appears that Aim could be used to replace any of these defoliants in defoliation mixtures. Aim has excellent desiccation activity on juvenile growth. But, like other herbicidal defoliants, Aim does not prevent regrowth. As Aim appears to be fairly hot in early research, growers may need to be careful in fields with conditions that are prone to desiccation, such as rank juvenile growth or high temperatures. The label states that Aim should be applied with a 1 percent by volume crop oil. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation. Aim appears to have good activity on morningglories.

Blizzard. Blizzard is a PPO-inhibitor herbicidal-type defoliant similar to Aim, ET, and Resource. Blizzard has excellent desiccation activity on juvenile growth. But, like other herbicidal defoliants, Blizzard does not prevent regrowth. Blizzard can be tank-mixed with ethephon-based products. Similar to other PPO-inhibitor defoliants, Blizzard should be very useful in desiccating juvenile foliage and as a second application prior to harvest. A crop coil concentrate or surfactant should be added to tank mixes containing Blizzard.

CottonQuik/FirstPick. CottonQuik and FirstPick contain the boll opener ethephon, plus urea sulfate that acts as a synergist to improve the defoliation characteristics of ethephon. CottonQuik and FirstPick will provide defoliation of mature leaves and have excellent boll-opening activity, especially compared to other products when temperatures are cool. CottonQuik can be tank-mixed with Dropp or FreeFall if regrowth is expected. Acceptable defoliation with CottonQuik alone requires cutout cotton with mature leaves. Under adverse conditions, with rank growth or with juvenile growth, a tank mixture with another defoliant will improve defoliation with CottonQuik.

Def 6 or Folex. This phosphate-type material has been a standard defoliant for several years in North Carolina. It provides effective, economical defoliation over a wide range of environmental conditions. Def or Folex is very effective in removing mature leaves but does not inhibit regrowth. It is more effective on young, immature leaves than sodium chlorate but is less effective than Ginstar, Dropp, or FreeFall. Leaf removal is rapid, and a rain-free period of two hours is sufficient for phosphate-type defoliants. The use of surfactants or crop oil has only enhanced the performance of these materials under very adverse conditions.

Dropp, FreeFall, Klean-Pik, other generics. These products contain the active ingredient thidiazuron, which candefoliates mature leaves essentially as well as the phosphate-type defoliants, especially in warm temperatures. However, thidiazuron products also provide excellent removal of juvenile growth and strong regrowth inhibition. A minimum of 0.05 lb active ingredient per acre is needed for 10 to 14 days of regrowth inhibition. Higher rates (0.1 lb a.i./A) will result in longer periods (up to 21 days) of regrowth inhibition. Thidiazuron products are slower-acting than the phosphate materials and are more sensitive to cool weather. The labels state that when nighttime temperatures fall below 60°F, less than desirable defoliation can result. Tank-mixing thidiazuron plus adjuvants such as petroleum-based crop oils has been shown to improve performance during low nighttime temperatures (60°F to 65°F). Also, tank-mixing Dropp or FreeFall plus the phosphate defoliants or Prep will enhance defoliation during cool conditions. A crop-oil concentrate should not be used when a phosphate insecticide or Def, Folex, or Prep is tank-mixed with Dropp or FreeFall.

Products containing thidiazuron require a 24-hour rain-free period. The addition of 2 to 4 ounces of Def will reduce the rain-free period required by Dropp or FreeFall alone. Make sure to follow the label instructions for tank cleanup when using Dropp or FreeFall. Failure to follow label tank-cleaning instructions may cause premature defoliation of cotton when the sprayer is used the following year. When tank-mixing thidiazuron with organophosphates (phosphate insecticides, Def, Folex), the use of 0.5 percent nonionic surfactant is recommended by the manufacturers to improve tank cleanout.

A minimum of 0.05 pound active ingredient per acre of thidiazuron will provide regrowth control for a short period (10 to 14 days). Higher rates such as 0.1 pound active ingredient per acre are needed for longer periods of control.

Thidiazuron is produced in dry and liquid formulations. At equivalent rates of active ingredient per acre, defoliation and regrowth control activity of liquid and dry formulations are similar. Limited research has indicated that the liquid formulations may be more prone to low levels of leaf desiccation when applied in combination with higher rates of Def and/or crop oil concentrate. Table 12-1 can be used to determine equivalent rates of thidiazuron in liquid and dry formulations.

Table 12-1. Equivalent rates of thidiazuron in liquid and dry formulations

Active ingredient (lb/acre)	Liquid Formulations (oz product/acre)	Dry Formulations (lb product/acre)
0.05	1.6	0.10
0.075	2.4	0.15
0.10	3.2	0.20

ET. ET is a herbicidal defoliant that is similar to Aim, Def, or Harvade. ET appears to be rather hot and may cause desiccation, especially in rank cotton. The label states that ET should be applied

with a crop oil. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation. ET appears to have good activity on morningglories.

Finish. Finish contains the boll opener ethephon, plus cyclanilide that acts as a synergist to improve the defoliation characteristics of ethephon. This synergist is different from the one found in CottonQuik/FirstPick. Finish will provide defoliation of mature leaves and has excellent boll-opening activity. Finish also displays a level of regrowth control. Finish provides good terminal regrowth control, but basal regrowth control is not comparable to products that contain thidiazuron.

Ginstar, Adios, Cutout, Redi-Pik, other generics. These products include thidiazuron (active ingredient in Dropp) and the herbicidal defoliant Diuron. Defoliation is faster than with Dropp alone, especially in cooler temperatures. Adjuvants should not be added to this formulation. Do not exceed 10 ounces per acre unless under extremely cool conditions. The label does not allow this defoliant to be tank-mixed with Def. Prep or other forms of ethephon can be added to enhance defoliation and boll opening. The addition of 6 ounces of Ginstar per acre provides the equivalent of 0.05 pounds active ingredient per acre of thidiazuron.

Harvade 5F. Harvade has generally provided defoliation equivalent to that of the phosphate-type materials and is also not a strong inhibitor of terminal regrowth. Harvade has been reported to have better activity at low temperatures. Harvade provides excellent desiccation of mature morningglory in cotton, especially in mixtures with Prep. The addition of 1 pint per acre of crop oil is necessary for acceptable defoliation. Rainfall within six hours may reduce the effectiveness of Harvade.

Leafless. Leafless is a mixture of Dropp and Harvade. Research with Leafless is limited in North Carolina. The recommended rate of 10 to 12 ounces per acre provides 0.125 to 0.15 pounds of Dropp per acre and 6.4 to 7.7 ounces of Harvade per acre. Growers may want to add Harvade to bring the Harvade rate up to 8 ounces per acre along with Prep where morningglory desiccation is desired. The addition of 0.5 to 1 pint per acre of crop oil is necessary for acceptable defoliation.

Resource. Resource is a PPO-inhibitor herbicidal-type defoliant. Similar to Aim and ET, Resource should provide acceptable defoliation of mature leaves and desiccation of juvenile regrowth. The Resource label suggests the addition of 1 to 2 pints of COC or a nonionic surfactant in hotter weather.

BOLL-OPENING MATERIALS

Boll-opening materials are often used in combination with defoliation materials to increase the percentage of the crop harvested during first picking or possibly to eliminate the need for a second picking. Boll maturity is very important when using a boll-opening material. Lint micronaire and strength can be adversely affected if immature bolls are opened. In certain years

cotton micronaire is improved by mixing higher micronaire cotton from the bottom of the cotton plant with lower micronaire cotton from the top. Picking capacity, the number of unopened bolls, and the cost of second picking determine whether boll opening is economical.

The application of boll-opening materials may be justified at any time during the harvest season, but they are often used on only part of the crop. For example, because of time constraints, the first third of the acreage to be harvested is often defoliated early when a large number of bolls have not opened. This portion of the crop may not benefit from boll-opening materials because the number of unopened bolls on these plants may justify a second picking even if a boll-opening material is used. In this case the farmer may want to avoid using boll openers and plan to use a second harvest on this portion of the crop. The second third of the crop to be harvested is most likely to benefit from boll-opening materials because it is less likely that a second picking will be justified. The use of a boll opener in this situation may well make the difference in the need to make a second picking. The final third of the crop to be harvested is usually the least likely portion of the crop to justify the application of a boll-opening material because most of the bolls there are more likely to have opened naturally. Also, the farmer has fewer time constraints at this point, and under cool temperatures Prep does not work as well (see Table 12-5 for boll-opening chemicals and instructions).

Prep 6, SuperBoll, Ethephon 6, other generics. Prep stimulates boll opening by increasing ethylene synthesis that normally occurs at boll opening. Mature bolls will usually open 10 to 14 days after application. However, boll opening is very rare and temperature-dependent, and best results are obtained when Prep is applied when night temperatures are above 60°F. Day temperatures between 65°F and 75°F will require twice the rate of Prep to produce the same speed and degree of boll opening as will be achieved if application is made when temperatures are 85°F to 95°F.

Deciding whether to use Prep for boll-opening purposes is often difficult. When making such a decision, it is helpful to consider that Prep plus defoliant mixtures usually give sufficient defoliation for harvest after 7 to 10 days. In addition, Prep usually doubles the number of green bolls that will open within 10 to 14 days after treatment. If harvest is delayed longer than 14 days after treatment, the advantage of Prep is often reduced.

Prep can be applied with other defoliants or in a second treatment after leaf drop has occurred. If the bolls you wish to open are under a canopy of leaves, it is better to apply the Prep after defoliation to ensure coverage of the bolls you want to open. Although Prep is not labeled as a defoliant, it does have some defoliant activity. Prep has provided satisfactory defoliation at a high rate of application (2 lb active ingredient/acre) under optimum conditions on well-matured cotton. The addition of Prep at lower rates with other defoliants has been reported to increase the degree of defoliation and hasten leaf drop under adverse conditions. Prep is compatible with Aim, Blizzard, Def, ET, Harvade, Dropp or FreeFall, Ginstar, and Resource, but it should never be mixed with sodium chlorate.

Paraquat (Gramoxone Max, Gramoxone Super Tres, Gramoxone Inteon). Paraquat has been used to open mature bolls by causing outside boll injury, which leads to drying of the carpal walls, boll cracking, and boll opening. Paraquat is generally used when weather conditions are cool and bolls are fully mature. Paraquat at lower rates (3 to 6 oz/acre) in addition to conventional defoliants may increase defoliation of juvenile growth and stimulate boll opening. Higher rates have been shown to actually cause bolls to "freeze" and not open under certain conditions; therefore, at least 80 percent of the bolls should be open before application. Development of immature bolls will be inhibited. Paraquat can also be used to "clean up" regrowth or otherwise missed leaves if harvest is delayed beyond 21 days after defoliation. However, growers can expect desiccation of these leaves, especially during warmer temperatures.

ADDITIVES

Accelerate (0.52 lb/gal of endothal concentrate) can be added to Def at 1.5 pints per acre to increase leaf drop by approximately 25 percent during the first few days of defoliant activity. This practice may allow an earlier application of Prep to open bolls where early harvest is important. Because total leaf drop after 7 to 10 days has generally not been improved with Accelerate, the use of the defoliant alone may be preferred if early harvest is not important.

According to labels, diesel oil can be added to Def to improve performance in cool weather or under drought-stress conditions. This effect has not been verified under North Carolina conditions. Be careful with diesel oil because of drift problems.

DESICCANTS

Sodium chlorate, Starfire. Desiccants are generally not used as harvest aids for cotton harvested with spindle-type pickers. If desiccation is necessary due to regrowth or weeds, it is best to apply a defoliant, wait until leaf drop occurs, and then apply the desiccant. Desiccants can kill the entire plant and burn immature bolls. Therefore, 90 percent of the crop should be open before applying a desiccant, and you should anticipate picking within seven days to avoid possible bark contamination (Table 12-6).

DEFOLIANT COMBINATIONS

The application of a single defoliant may be more economical than defoliant mixtures and can result in satisfactory defoliation. However, under less than desirable defoliation conditions, mixtures are likely to provide better results. Aim, Blizzard, Def, ET, Harvade, and Resource can be used in combination with Dropp/FreeFall or Prep. There is some indication that the activity of the PPO-inhibitor herbicidal defoliants (Aim, Blizzard, ET, and Resource) is so rapid that less thidiazuron makes it into the plant and may result in a shorter period of regrowth control when these materials are mixed with thidiazuron-containing defoliants. Defoliant selection should be based on whether juvenile growth needs to be defoliated, the need for regrowth control or

boll opening, and the temperature at and following application. One defoliant may not provide all of the desired characteristics, so defoliant mixtures may be preferable. A list of the common defoliants and their characteristics is shown in Table 12-7.

DEFOLIATING RANK COTTON

Deciding how to defoliate rank cotton is always difficult. Producers often have to decide whether they will defoliate early in an effort to save the bottom crop (and lose the top crop) or wait for the top crop to develop before defoliating. Producers who wait for rank cotton to finish a top crop may very well lose much of their bottom crop to boll rot, especially if wet weather occurs and continues.

A common tendency when defoliating rank cotton is to use high rates of defoliants in an effort to cover and defoliate the entire plant. The Def label does suggest high rates for defoliating rank cotton. The problem with this approach is that the high rates of defoliants will tend to stick the leaves, especially on the top of the plant where most of the defoliant is intercepted. The safest approach is to apply the same rate of defoliants that you would if the cotton were not rank under the same crop and weather conditions, realizing that you may have to make a second application to defoliate the bottom portion of the crop.

You may consider bottom defoliation to decrease loss to boll rot in extremely rank cotton. Defoliate as high on the plant as possible until immature bolls are found. The idea is to remove enough leaves from the middles to allow air movement and light penetration. The lower labeled rates are usually used for bottom defoliation unless otherwise specified. Some research indicates that bottom defoliation can do more harm than good by mechanically injuring bolls and stems, resulting in increased chances for boll rot.

DEFOLIATING WEEDY COTTON

A weedy cotton field can present unique problems that standard defoliation practices won't handle. Weeds not only interfere with harvest options, but can stain lint and almost certainly increase the trash content of harvested bolls. For detailed information on defoliating weedy cotton, see the section on "Preharvest Herbicide Application" in chapter 10, "Weed Management in Cotton."

DEFOLIATION OF DROUGHT-STRESSED COTTON

Drought-stressed cotton often has thick and leathery leaves, and this condition may affect the plant's ability to take up the defoliant. However, growers are advised not to use high rates of defoliants or complex mixtures. Still, the uptake of thidiazuron products does appear to be reduced on drought-stressed cotton. Therefore, higher rates of thidiazuron may be needed on drought-stressed cotton. Mixtures of Def/Folex and thidiazuron have worked well in the past under these conditions. Recent research in other states suggests that the addition of either a

silicone surfactant or crop oil plus ammonium sulfate increases thidiazuron uptake on drought-stressed cotton. However, these additives also increased the likelihood of leaf desiccation, and their general use is not recommended at this time in North Carolina.

REGROWTH CONTROL

Regrowth is most likely to be a problem on cotton that reaches cutout quickly, has a small or early maturing boll load, and has adequate heat and moisture and excess nitrogen. Controlling potential regrowth with thidiazuron is more effective than reapplying defoliants after regrowth has occurred. Reapplication of defoliants is permitted, but reapplication often provides less than desirable results because of poor coverage of small leaves and continuing emergence of new leaves. Desiccants can be used to eliminate unwanted regrowth. They should be applied at the earliest possible date to avoid new leaves reaching enough size to decrease grade.

DEFOLIANT APPLICATION

Defoliants should be applied in the late afternoon or early morning when humidity usually is high and winds are calm. Coverage is very important because each leaf that is to be removed must receive some defoliant. Defoliants can be successfully applied by airplane or ground machines.

Defoliation by aircraft. Successful defoliation by airplanes requires a uniform swath width and coverage of each leaf. The use of well-trained flagmen, permanent markers, or GPS will keep uniform swath widths and result in more uniform defoliation. Typical swath widths for popular agricultural aircraft are listed in Table 12-2.

Table 12-2. Typical Aircraft Swath Widths

Aircraft	Span	Wing (feet)	Swath Width (feet)
		5 GPA	10 GPA
Air Tractor	45 feet 5 inches	55 to 65	50 to 60
Ag Cat A	39 feet 1 inch	40 to 50	40 to 50
Ag Cat B	42 feet 3 inches	45 to 55	45 to 55
Cessna	42 feet 8 inches	45 to 55	45 to 55
Thrush 600	44 feet 5 inches	55 to 65	50 to 60

Thorough coverage by air requires a finished spray volume of 4 to 12 gallons per acre. Coverage depends on spray droplet size, atmospheric conditions, and the amount of foliage. In general, smaller spray droplets provide better coverage and canopy penetration but are more likely to drift in windy conditions or evaporate in high-temperature, low-humidity conditions. Larger spray droplets reduce drift and evaporation but provide less coverage and canopy penetration. Medium-sized droplets by disk and core-type hollow cone nozzles with number 8, 10, and 12 disks or number 46 and 56 cores are recommended. These nozzles should be turned down and 45 degrees back on 100- to 120-mph aircraft and straight back on 120-mph to 150-mph aircraft. Removing nozzles from at least the outer 20 percent of the aircraft wing is recommended to

reduce drift. Higher finished spray volumes improve coverage and give more thorough defoliation, especially on large plants with lush foliage.

Defoliation by ground machines. Research indicates that cone-type nozzles are superior to flat fan or flood nozzles for foliar coverage. Two equally spaced hollow cone nozzles per row should give adequate coverage. Spray pressure, ground speed, and nozzles should be matched to apply a finished rate of 15 to 20 gallons per acre.

FROST DEFOLIATION

Some producers like to wait and let frost defoliate cotton. This delay is generally not desirable because of the loss of quality and yield that can occur while waiting for a frost. A light frost can defoliate cotton fairly well, but a hard frost (below about 28° F) can stick leaves and rot bolls. Less mature leaves and bolls are more likely to be negatively affected by frost because of their higher water content. It is common for a frost to take off the top leaves, leaving enough bottom leaves to require chemical defoliation following the frost.

Producers should wait several days following a frost to make defoliation decisions. Boll-opening materials usually do not work following a frost that was strong enough to turn bolls brown. If you can thump leaves and they fall off a week following a frost, those leaves will probably drop off. If the leaves do not drop, they are stuck. See Table 12-5 for defoliants.

ROTATIONAL CROPS RESTRICTIONS

Table 12-3. Label Restrictions for Planting Small Grains Following Application as a Harvest Aid in Cotton

Material	Recrop Interval Following Application for Planting Small Grains
Def/Folex	None
Thidiazuron	14 days
Harvade	6 months
Ginstar	1 month
Leafless	6 months
Aim	None
ET	None
Blizzard	None
Resource	30 days
Prep/SuperBoll, others	30 days
CottonQuik/FirstPick	30 days
Finish	1 month
Glyphosate	None
Sodium Chlorate	None
Paraquat	None

With increased interest in double-cropping wheat following cotton, some consideration should be given to label restrictions of harvest aides for rotational crops. Table 12-3 summarizes harvest aid label restrictions for planting wheat following cotton.

DEFOLIATION AND BOLL-OPENING SCENARIOS

The following are some defoliation situations typically encountered in North Carolina. Defoliation rates and materials are suggested as guides to use under different weather situations. Other combinations may work equally well, but these are some more commonly used combinations.

Ginstar can be used as a stand-alone treatment under all the scenarios presented below. Ginstar should not be used in combination with other herbicidal defoliants unless the rates of one or both are reduced. Ginstar can be used in combination with ethephon-containing, boll-opening materials. Rates can be reduced in combination with Finish or CottonQuik. The new defoliants Aim and ET could be substituted for Def in the situations listed below. Their activity is not very temperature-dependent, so the rates would tend to stay the same for the scenarios listed below.

Drought Stress, High Temperatures (90s °F), Lows (70s °F)

Drought-stressed cotton leaves have thickened cuticles that often reduce penetration of defoliant materials. High temperatures usually will enhance leaf burn and can increase leaf sticking. Under these conditions, combinations of three or more materials often result in leaf sticking. Regrowth is usually a problem when rainfall occurs. Lower rates of the herbicidal defoliants should be used to reduce leaf burn, while higher rates of defoliants controlling regrowth may be needed because of reduced penetration into the cotton plant. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation.

1. Def (1.3 pt) (defoliation)
2. Dropp or FreeFall (0.075 to 0.1. lb ai) (defoliation or regrowth control)
3. Def (0.5 to 1 pt) + Dropp or FreeFall (0.05 to 0.1 lb ai) (defoliation or regrowth)
4. Dropp or FreeFall (0.05 to 0.1 lb ai) + Prep (5.33 oz) (defoliation or regrowth control)
5. Dropp or FreeFall (0.05 to 0.1 lb ai) + Prep (1.33 to 2 pt) (defoliation or regrowth/boll opening)
6. Def (0.1 to 1.3 pt) + Prep (1.33 to 2 pt) (defoliation or boll opening)
7. Sodium chlorate (3 lb active ingredient) (defoliation, less effective)
8. Finish (1.3 to 2 pt) (defoliation and boll opening) (Add Dropp or FreeFall [0.05 to 0.1 lb ai] or Def [0.5 pt] if rank growth or regrowth is present.)

9. Aim, Blizzard, ET or Resource (recommended rates) + Dropp or FreeFall (0.1 ai to 0.15 lb ai) (defoliation or regrowth)

10. Aim, Blizzard, ET or Resource (recommended rates) + Prep (1.33 to 2 pt) (defoliation or boll opening)

11. CottonQuik/FirstPick (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (0.5 pt)

Normal Cutout, High Temperatures (90s °F), Lows (70s °F)

Cotton with a good boll load, normal cutout, and warm day and night temperatures generally defoliates well. Regrowth is often a problem, depending on boll load, soil moisture, and night temperatures after defoliation. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation.

1. Def (0.75 to 1.0 pt) (defoliation)

2. Dropp or FreeFall (0.05. to 0.1 lb ai) + Def (0.5 to 1.0 pt) (defoliation or regrowth control)

3. Dropp or FreeFall (0.05 to 0.1 lb ai) + Prep (5.33 oz) (defoliation or regrowth control)

4. Dropp or FreeFall (0.05 to 0.1 lb ai) + Def (0.25 to 0.50 pt) +Prep (1.33 to 2 pt) (defoliation or regrowth control/boll opening)

5. Def (0.75 to 1.25 pt) + Prep (1.33 to 2 pt) (defoliation and boll opening)

6. Sodium chlorate (3 lb active ingredient) (defoliation, less effective)

7. Aim, Blizzard, ET or Resource (recommended rates) + Dropp or FreeFall (0.05 to 0.1 lb ai) (defoliation or regrowth)

8. Aim, Blizzard, ET or Resource (recommended rates) + Prep (1.33 to 2 pt) (defoliation or boll opening) (Finish or FirstPick can be substituted for Prep, but both are used at different rates.)

9. Finish (1.3 to 2 pt) (defoliation and boll opening) (Add Dropp or FreeFall [0.05 to 0.1 lb ai] or Def [0.5 pt] if rank growth or regrowth is present.)

10. CottonQuik/FirstPick (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (0.5 pt)

11. Ginstar (4 to 6 oz) (defoliation or regrowth control) (Add boll opener if needed.)

Normal Cutout, High Temperatures (80s °F), Lows (60s °F)

Cotton with a good boll load, normal cutout, and warm day and night temperatures generally defoliates well. Good coverage is important, and higher rates of herbicidal defoliant can generally be used. Regrowth may or may not be a problem, depending on boll load and night

temperatures after defoliation. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates.

1. Def (1 to 1.5 pt) (defoliation)
2. Dropp or FreeFall (0.125 to 0.2 lb) + Def (1 pt) (defoliation or regrowth)
3. Dropp or FreeFall (0.125 to 0.2 lb) + Prep (5.33 oz) (defoliation enhancement)
4. Dropp or FreeFall (0.1 to 0.125 lb) + Def (0.25 to 0.50 pt) + Prep (1.33 to 2 pt) (defoliation or regrowth/boll opening)
5. Def (1 to 1.5 pt) + Prep (1.33 to 2 pt) (defoliation and boll opening)
6. Harvade (0.5 pt) + crop oil (1 pt) (defoliation)
7. Harvade (0.5 pt) + crop oil (1 pt) + Prep (1.33 pt) (defoliation or boll opening or weed desiccation)
8. Sodium chlorate (3.5 to 4 lb active ingredient) (defoliation or weed desiccation) (less effective)
9. Aim, Blizzard, ET, or Resource (recommended rates) + Dropp or FreeFall (0.125 to 0.20 lb) (defoliation or regrowth)
10. Aim, Blizzard, ET, or Resource (recommended rates) + Prep (1.33 pt) (defoliation or boll opening) (Finish or FirstPick can be substituted for Prep, but both are used at different rates.)
11. Aim, Blizzard, ET, or Resource (recommended rates) + Def (1 to 1.25 pt) (defoliation)
12. Finish (1.3 to 1.5 pt) (defoliation and boll opening) (Add Dropp or FreeFall [0.05 to 0.1 lb] or Def [0.5 pt] if rank growth or regrowth is present.)
13. CottonQuik (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (0.5 pt) (defoliation and boll opening)
14. Finish (1.3 to 1.5 pt) or CottonQuik (2 qt) + Harvade (0.5 pt) + crop oil (1 pt)(defoliation, boll opening, and weed desiccation)
15. Ginstar (6 to 8 oz) (defoliation or regrowth control) (Add boll opener if needed.)

Late Season, High Temperatures (60s to 70s °F), Lows (50s °F)

For best results, defoliation should be delayed until warmer weather occurs, if possible. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates.

1. Def (1.5 to 2.5 pt) (defoliation)
2. Dropp or FreeFall 50 WP (0.1 to 0.125 lb) + Def (2 pt) (defoliation or regrowth)
3. Harvade (0.5 pt) + crop oil (1 pt) (defoliation)
4. Harvade (0.5 pt) + crop oil (1 pt) + Prep (1.33 to 2 pt) (defoliation or boll opening at higher rates of Prep or weed desiccation)
5. Harvade (0.5 pt) + crop oil (1 pt) + Def (1 pt) (defoliation)
6. Sodium chlorate (4 lb active ingredient) (defoliation, less effective/weed desiccation)
7. Aim, Blizzard, ET, or Resource (recommended rates) + Dropp or FreeFall (0.125 to 0.2 lb) (defoliation or regrowth)
8. Aim, Blizzard, ET, or Resource (recommended rates) + Prep (1.33 to 2 pt) (defoliation/boll opening at higher Prep rates)
9. Aim, Blizzard, ET, or Resource (recommended rates) + Harvade (0.5 pt) + crop oil (1 pt) (defoliation)
10. Aim, Blizzard, ET, or Resource (recommended rates) + Def (1 to 1.5 pt) (defoliation)
11. Finish (1.5 to 2 pt) (defoliation and boll opening) (Add thidiazuronl [0.05 to 0.1 lb] or Def [1 to 1.5 pt] if rank growth or regrowth is present.)
12. CottonQuik (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (1 to 1.5 pt) (defoliation and boll opening)
13. Finish (1.3 to 2 pt) or CottonQuik (2 qt) + Harvade (0.5 pt) + crop oil (1 pt)(defoliation, boll opening, and weed desiccation)
14. Ginstar (8 to 10 oz) (defoliation or regrowth control) (Add boll opener if needed.)

Table 12-4. Harvest Aid Performance

Material	Estimated minimum temperature	Expected activity			
		Mature leaves	Juvenile growth	Regrowth prevention	Boll opening
Def/Folex	60°F	Excellent	Fair	Poor	None
Thidiazuron	65°F	Excellent	Excellent	Excellent	None
Harvade	55°F	Excellent	Fair	Poor	None
Ginstar	60°F	Excellent	Excellent	Excellent	None
Aim	55°F	Excellent	Excellent	Poor	None
ET	55°F	Excellent	Excellent	Poor	None
Resource	55°F	Excellent	Excellent	Poor	None
Blizzard	55°F	Excellent	Excellent	Poor	None
Prep/SuperBoll, others	60°F	Fair	Poor	Poor	Excellent
Finish	60°F	Excellent	Poor	Fair	Excellent
CottonQuik/FirstPick	60°F	Excellent	Poor	Poor to Fair	Excellent
Glyphosate	55°F	Fair	Fair	Excellent	None
Sodium Chlorate	55°F	Fair	Fair	Poor	None
Paraquat	55°F	Desiccation	Excellent	Poor	Fair

Table 12-5. Boll Opening Rates

It may be desirable to accelerate the opening of mature cotton bolls for earlier harvest or for a once-over harvest operation. Prep (ethephon) has been shown to accelerate the opening of bolls and enhance defoliation. Immature bolls also will be affected and, depending on the stage of maturity, fiber may be immature, seed quality lower, and yield reduced. Application should not be made until enough mature, unopened bolls have developed to produce the desired yield of cotton. Cool, damp conditions occurring within 48 hours before or after treatment may severely inhibit the effectiveness of Prep.

Trade Name (product/a)	Common Name (rate a.i./a)	Application Instructions
Prep 6 (1.33–2.66 pt)	ethephon (1–2 lb)	Apply in 5 to 50 gal/acre of water when 40 to 60 percent of the bolls are open and when there are sufficient mature, unopened bolls to produce the desired yield. Prep can be used four to seven days before application of defoliants as a preconditioning agent, tank-mixed with defoliants, or applied after defoliation. Rank cotton will often require defoliation before Prep application in order to obtain good spray coverage of bolls. DO NOT harvest cotton sooner than seven days after Prep application. DO NOT mix Prep with sodium chlorate products because toxic chlorine gas fumes will be produced.
Finish (1.3–1.5 pt)	ethephon (1–1.5 lb) + Cyclanilide (0.5–0.75 lb)	
CottonQuik FirstPick (2 qt)	ethephon (1.14 lb) + AMADS (7.3 lb)	

Table 12-6. Desiccant Rates

Desiccants primarily dry plant tissue. These chemicals usually act so rapidly that leaves are killed and stick to the stalk, and defoliation does not occur. Desiccants are generally recommended in areas where cotton is harvested by strippers. In North Carolina, desiccants should be used only as a last resort to eliminate second growth, especially on ultra narrow row stripper cotton.

Trade Name	Common Name	Application Instructions
(product/a)	(rate a.i./a)	For use as a desiccant, apply when 80 percent or more of the bolls are open and the remaining bolls to be harvested are mature. DO NOT apply within three days before harvest. Paraquat may also be applied at 3 to 6 oz/acre with defoliants to hasten boll opening. Paraquat is a Restricted Use pesticide.
Paraquat (various brand names) (1.5–2.5 pt)	paraquat (0.25–0.5 lb)	

Table 12-7. Defoliants

The chemicals below are labeled for use as defoliants. They will defoliate cotton but will not kill the stalk under normal usage. Some regrowth will occur with all of these products.

Trade Name (products/a)	Common Name	Application Instructions
Accelerate 0.52 lb/gal (1–1.5 pt.)	endothal	Accelerate may be added to Def at 1.5 pt/acre to speed leaf drop by approximately 25% during the first few days of defoliant activity. The rate of leaf drop after 7 to 10 days has generally not been improved with Accelerate. Always add Accelerate to organic phosphates (Def) previously tank-mixed with water.
Aim 40 DF (0.66–1 oz)	carfentrazone-ethyl	Aim can be used in place of other herbicidal defoliants. Growers should be careful about using Aim in conditions that are subject to causing desiccation until more research is conducted. Aim does appear to desiccate morning glory. The label states that Aim should be applied with a 1% by volume crop oil.
Blizzard 0.91 lb/gal (0.5–0.66 fl. oz.)	Fluthiacetmethyl	Blizzard is a PPO-inhibitor herbicidal-type defoliant. Experience with Blizzard in North Carolina has been limited. Blizzard can be tankmixed with ethephon-based products. Similar to other PPO-inhibitor defoliants, Blizzard should be very useful in desiccating juvenile foliage and as a second application prior to harvest. A crop oil concentrate or surfactant should be added to tank mixes containing Blizzard according to label directions.
sodium chlorate (several name brands) Read label for rates.	sodium chlorate with fire suppressant	Apply to mature cotton plants after the youngest bolls expected to make cotton are at least 30 days old. DO NOT apply later than seven days before harvest. With ground equipment, use 10 to 20 gal of spray solution per acre, and by air use 5 to 10 gal/acre.
CottonQuik/ FirstPick (1.7–3 qt)	ethephon + synergist	Use higher rates only during cool weather. Limited experience suggests that CottonQuik will provide defoliation of mature leaves and has boll-opening activity. CottonQuik can be tank-mixed with Dropp or FreeFall if regrowth is expected. In adverse conditions, with rank growth or juvenile growth, a tank mixture with another defoliant will improve defoliation.
Def 6 (1–2 pt)	tribufos	Def should be applied when 50% or more of the bolls are open and 7 to 10 days before anticipated picking. Use the low rate when the crop is mature and the weather is warm. When plants are still green and actively growing, the temperature is cool, or the weather is dry, use higher rates or a tank mix with another defoliant. A spray mix of 5 to 25 gal/acre should be applied.

(continued)

Table 12-7. Defoliants

The chemicals below are labeled for use as defoliants. They will defoliate cotton but will not kill the stalk under normal usage. Some regrowth will occur with all of these products.

Trade Name (products/a)	Common Name	Application Instructions
Dropp or FreeFall (0.2–0.4 lb)	thidiazuron	Dropp or FreeFall should be applied to plants ONLY when 60 to 70% of the bolls are open. Apply in 10 to 25 gal of water per acre by ground equipment and in 2 to 10 gal/acre by air. Use higher rates during periods of low temperatures. Apply at least five days before picking. May be tank-mixed with Def or Prep. Dropp or FreeFall rates as low as 0.1 lb of product per acre may be used in tank mixes. Spray tanks should be cleaned immediately after using Dropp or FreeFall. A nonionic surfactant or compatibility agent is recommended when using tank mixes of Dropp or FreeFall plus Def to facilitate cleanup. See label for more information.
ET (1.5–2 oz).	pyraflufen ethyl	ET should be applied in 20–30 gpa by ground (1.5 or at least 5 gpa if applied by air). ET can be applied using one or two applications, but do not exceed a total of 5.5 fl oz of product per acre. Crop oil at a rate of 1% should be used with ET and defoliant mixtures with ET. Do not use crop oil when mixed with CottonQuik. No surfactant or a nonionic surfactant should be used in mixtures with CottonQuik. A 2% rate of crop oil should be used if applied by air. There is little experience in North Carolina with ET applications in high temperature. Some states recommend that crop oil rates be reduced or eliminated in high temperatures to avoid desiccation.
Ginstar 1.5 EC (6.5–10 oz)	thidazuron + diuron	Do not exceed 10 oz/acre unless under extremely cool conditions. Ginstar is similar to Dropp Ultra but contains an enhancing agent, and thereforre an adjuvant should be used.
Finish 6 4 Pro 6 EC (1.3–2.7 pt.)	ethephon +cyclanalide	Use higher rates in cool weather. Finish is a defoliant and boll opener. Finish also provides some regrowth control. Terminal regrowth control is stronger than basal regrowth control. Finish will provide acceptable regrowth control in many situations. In situations where extended regrowth control is needed (in the 20- to 28-day range), Dropp/FreeFall would provide more acceptable regrowth control. Finish performance may benefit from the addition of a low rate of a standard defoliant in situations where cotton is actively growing with juvenile growth, especially under cooler conditions.
Harvade-5F (0.5 pt.) + Crop oil concentrate (1 pt)	dimethipin + crop oil concentrate	Harvade is a harvest growth regulant that affects certain plant processes that lead to defoliation. Complete coverage is essential. Harvade should be applied to mature cotton plants when 70% or more bolls are open. A mixture of Harvade plus 1 1/3 pt of Prep has been effective in drying annual morning glory vines entangling cotton.
Resource 0.86 lb gal (4–6 oz)	Flumiclorac-pentyl	Under ideal defoliation conditions (warm sunny days), add a NIS at 1 qt per 100 gal of spray solution. Under dry or cool weather, a methylated seed oil (MSO) or organosilcone adjuvant may be used. Apply in a minimum of 10 gal per acre for ground applications and a minimum of 5 gal per acre for aerial applications. Do not use flood jet or air induction nozzles. Resource can be tank-mixed with other products if boll opening or regrowth control is desired. Resource only needs a 1-hr rain-free period. Preharvest interval (PHI) is seven days.