2014 Cotton Information

North Carolina Cooperative Extension Service
College of Agriculture and Life Sciences
North Carolina State University

2014 Cotton Information is meant to help growers plan for the coming year and make management decisions based on the unique opportunities and challenges the year might bring. Web-based resources are available to supplement the information found here. These resources allow our specialists to make updated recommendations during the season.

Extension cotton portal—Timely production information updates, links to cotton information and Calendar of upcoming cotton events. **cotton.ces.ncsu.edu**

Facebook page—Join our cotton Facebook group for short cotton production updates and information. You can post pictures, experiences, and questions. **www.facebook.com/groups/344058599029946/?bookmark_t=group**

Twitter notifications—Follow @NCCotton to receive notifications on your phone or computer when new information is added to these sites. You can set up a Twitter account at **twitter.com**.

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COUNTY EXTENSION PERSONNEL
WORKING WITH COTTON

The following are the county Cooperative Extension Service personnel with cotton responsibilities as of January 1, 2014. In some cases where a vacancy exists, the county Extension director's name is given.

COUNTY	NAME	CITY	TELEPHONE
Anson	Jessica Anderson	Wadesboro	704/694-2415
Beaufort	Rod Gurganus	Washington	252/946-0111
Bertie	Richard Rhodes	Windsor	252/794-5317
Bladen	Ryan Harrelson	Elizabethtown	910/862-4591
Camden	Mark Powell	Camden	252/338-0171
Carteret	Anne Edwards	Beaufort	252/222-6352
Chowan	Katy Shook	Edenton	252/482-6585
Cleveland	Greg Traywick	Shelby	704/482-4365
Columbus	Michael Shaw	Whiteville	910/640-6605
Craven	Mike Carroll	New Bern	252/633-1477
Cumberland	Colby Lambert	Fayetteville	910/321-6875
Davidson	Troy Coggins	Lexington	336/242-2080
Duplin	Curtis Fountain	Kenansville	910/296-2143
Edgecombe	Art Bradley	Tarboro	252/641-7815
Gates	Paul Smith	Gatesville	252/357-1400
Greene	Roy Thagard	Snow Hill	252/747-5831
Halifax	Arthur Whitehead	Halifax	252/583-5161
Harnett	Brian Parrish	Lillington	910/893-7530
Hertford	Wendy Burgess	Winton	252/358-7822
Hoke	Keith Walters	Raeford	910/875-3461
Hyde	Malcolm Gibbs	Swan Quarter	252/926-4486
Iredell	Mike Miller	Statesville	704/873-0507
Johnston	Tim Britton	Smithfield	919/989-5380
Jones	Jacob Morgan	Trenton	252/448-9621
Lee	Susan Condlin	Sanford	919/775-5624
Lenoir	Mark Keene	Kinston	252/527-2191
Martin	Al Cochran	Williamston	252/789-4370
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Nash	Charles Tyson	Nashville	252/459-9810

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COUNTY	NAME	CITY	TELEPHONE
Northampton	Craig Ellison	Jackson	252/534-2831
Onslow	Melissa Huffman	Jacksonville	910/455-5873
Pamlico	Bill Ellers	Bayboro	252/745-4121
Pasquotank	Alton Wood, Jr.	Elizabeth City	252/338-3954
Pender	Mark Seitz	Burgaw	910/259-1235
Perquimans	Lewis Smith	Hertford	252/426-5428
Pitt	Adam Lassiter	Greenville	252/902-1704
Richmond	Paige Burns	Rockingham	910/997-8255
Robeson	Mac Malloy	Lumberton	910/671-3276
Rowan	Jim Cowden	Salisbury	704/633-0571
Rutherford	Janice McGuinn	Rutherfordton	828/287-6010
Sampson	Kent Wooten	Clinton	910/592-7161
Scotland	Randy Wood	Laurinburg	910/277-2422
Stanly	Andrew Baucom	Albemarle	704/983-3987
Tyrrell	Frank Winslow	Columbia	252/796-1581
Union	Andrew Baucom	Monroe	704/283-3801
Warren	Paul McKenzie	Warrenton	252/257-3640
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Wilson	Norman Harrell	Wilson	252/237-0111

2014 Cotton Information

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North Carolina State University

1. 2014 COTTON COST OF PRODUCTION

S. Gary Bullen
Extension Associate

Cotton Budgets

Information and Web links on the cotton program, outlook and situation, budgets, farm management, and more are available at the North Carolina State University Department of Agricultural and Resource Economics website:

http://www.ag-econ.ncsu.edu/extension/Ag_budgets.html

The budgets in Table 1-2 represent costs and returns that are achieved by many growers in different regions of North Carolina using different production technologies. The budgets do not represent average costs and returns. Budgets are intended to be used as guides for calculating individual costs and returns.

Budget 1-1. COTTON — TIDEWATER — 2014

ESTIMATED COSTS AND RETURNS PER ACRE, 2014
950 POUND YIELD

	UNIT	QUANTITY	PRICE OR COST/UNIT	TOTAL/ ACRE	YOUR FARM
1. GROSS RECEIPTS					
COTTON LINT	lb	950.00	$0.74	$703.00	_____
COTTON SEED	lb	1587.00	$0.13	$206.31	_____
TOTAL RECEIPTS:				**$909.44**	
2. VARIABLE COSTS					
SEED	lbs	8.00	$9.71	$77.68	_____
FERTILIZER					
10-26-0	lb	227.00	$0.36	$81.72	_____
0-0-60	lb	135.00	$0.40	$54.00	_____
30% N Sol.	lb	183.00	$0.20	$36.60	_____
Boron	lb	3.00	$4.25	$12.75	_____
Sulfur	lb	15.00	$.30	$4.50	_____
LIME (Prorated)	ton	0.33	$55.75	$18.40	_____
HERBICIDES	acre	1.00	$42.31	$42.31	_____
INSECTICIDES	acre	1.00	$25.28	$25.28	_____
GROWTH REGULATORS & DEFOLIANTS	acre	1.00	$16.82	$16.82	_____
GINNING	lb	950.00	$0.105	$99.75	_____
CROP INSURANCE	acre	1.00	$35.00	$35.00	_____
TRACTOR, ADDITIONAL MACHINERY	acre	1.00	$123.71	$123.71	_____
LABOR	hr	1.55	$9.98	$15.47	_____
INTEREST ON OPERATING CAPITAL	$	$246.89	5.00%	$12.34	
TOTAL VARIABLE COSTS:				**$656.33**	
3. INCOME ABOVE VARIABLE COSTS				**$253.11**	
4. FIXED COSTS					
TRACTOR, ADDITIONAL MACHINERY	acre	1.00	$93.53	$93.53	
TOTAL FIXED COSTS:				**$93.53**	
5. TOTAL COSTS				**$749.86**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT				**$159.58**	

BREAK-EVEN YIELD

VARIABLE COSTS:683 LBS
TOTAL COSTS:1,699 LBS

BREAK-EVEN PRICE

VARIABLE COSTS: $0.51
TOTAL COSTS: $0.61

NOTE: THIS BUDGET IS FOR PLANNING PURPOSES ONLY.

Prepared by Gary Bullen, North Carolina State University, Department of Agricultural and Resource Economics

Budget 1-2. COTTON — CONVENTIONAL TILLAGE — 2014

ESTIMATED COSTS AND RETURNS PER ACRE, 2014
770 POUND YIELD

	UNIT	QUANTITY	PRICE OR COST/UNIT	TOTAL/ACRE	YOUR FARM
1. GROSS RECEIPTS					
COTTON LINT	lb	770.00	$0.74	$569.80	_____
COTTON SEED	lb	1286.00	$0.13	$167.18	_____
TOTAL RECEIPTS:				**$737.02**	
2. VARIABLE COSTS					
SEED	lb	8.00	$9.71	$77.68	_____
FERTILIZER:					
18-46-0	lb	227.00	$0.19	$43.13	_____
0-0-60	lb	135.00	$0.40	$54.00	_____
30% N. Sol.	lb	183.00	$0.20	$36.60	_____
SULFUR	lb	10.00	$0.30	$3.00	_____
BORON	lb	3.00	$4.25	$12.75	_____
LIME (Prorated)	ton	0.33	$55.75	$18.40	_____
HERBICIDES	acre	1.00	$44.62	$44.62	_____
INSECTICIDES	acre	1.00	$25.28	$25.28	_____
GROWTH REGULATORS & DEFOLIANTS	acre	1.00	$16.82	$16.82	_____
GINNING	lb	770.00	$0.105	$80.85	_____
CROP INSURANCE	acre	1.00	$10.05	$10.05	_____
TRACTOR, ADDITIONAL MACHINERY	acre	1.00	$91.68	$91.68	_____
LABOR	hr	1.80	$9.98	$17.96	_____
INTEREST ON OPERATING CAPITAL	$	$211.98	5.00%	$10.60	
TOTAL VARIABLE COSTS:				**$543.42**	_____
3. INCOME ABOVE VARIABLE COSTS				**$193.60**	
4. FIXED COSTS					
TRACTOR, ADDITIONAL MACHINERY	acre	1.00	$70.17	$70.17	
TOTAL FIXED COSTS:				**$70.17**	
5. TOTAL COSTS				**$613.59**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT				**$123.43**	

BREAK-EVEN YIELD

VARIABLE COSTS:567 LBS
TOTAL COSTS: 1,401 LBS

BREAK-EVEN PRICE

VARIABLE COSTS: $0.53
TOTAL COSTS: $0.63

NOTE: THIS BUDGET IS FOR PLANNING PURPOSES ONLY.

Prepared by Gary Bullen, North Carolina State University, Department of Agricultural and Resource Economics

Budget 1-3. COTTON — STRIP TILLAGE — 2014

ESTIMATED COSTS AND RETURNS PER ACRE, 2014
770 POUND YIELD

	UNIT	QUANTITY	PRICE OR COST/UNIT	TOTAL/ACRE	YOUR FARM
1. GROSS RECEIPTS					
COTTON LINT	lb	770.00	$0.74	$569.80	_____
COTTON SEED	lb	1286.00	$0.13	$167.18	_____
TOTAL RECEIPTS:				**$736.98**	
2. VARIABLE COSTS					
SEED	LBS	8.00	$9.71	$77.68	_____
FERTILIZER:					
18-36-0	lb	227.00	$0.36	$81.72	_____
0-0-60	lb	135.00	$.40	$54.00	_____
30% N Sol.	lb	183.00	$0.20	$36.60	_____
Boron	lb	3.00	$4.25	$12.75	_____
Sulfur	lb	10.00	$0.30	$3.00	_____
LIME (Prorated)	ton	0.33	$55.75	$18.40	_____
HERBICIDES	acre	1.00	$42.93	$42.93	_____
INSECTICIDES	acre	1.00	$25.28	$25.28	_____
GROWTH REGULATORS & DEFOLIANTS	acre	1.00	$16.82	$16.82	_____
GINNING	lb	770.00	$0.105	$80.85	_____
CROP INSURANCE	acre	1.00	$10.05	$10.05	_____
TRACTOR, ADDITIONAL MACHINERY	acre	1.00	$76.98	$76.98	_____
LABOR	hr	1.44	$9.98	$14.37	_____
INTEREST ON OPERATING CAPITAL	$	$223.08	5.00%	$11.15	
TOTAL VARIABLE COSTS:				**562.58**	
3. INCOME ABOVE VARIABLE COSTS				**$174.40**	
4. FIXED COSTS					
TRACTOR, ADDITIONAL MACHINERY	acre	1.00	$59.65	$59.65	
TOTAL FIXED COSTS:				**59.65**	
5. TOTAL COSTS				**$622.23**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT				**$114.75**	

BREAK-EVEN YIELD

VARIABLE COSTS: 591 LBS
TOTAL COSTS: 1,440 LBS

BREAK-EVEN PRICE

VARIABLE COSTS: $0.55
TOTAL COSTS: $0.63

NOTE: THIS BUDGET IS FOR PLANNING PURPOSES ONLY.

Prepared by Gary Bullen, North Carolina State University, Department of Agricultural and Resource Economics

2. THE COTTON PLANT

Keith Edmisten
Crop Science Extension Specialist—Cotton

Successful cotton production depends on an integrated management strategy that recognizes and adapts to the unique characteristics of the crop. The development of vegetative growth and fruiting forms is highly related to temperature if adequate moisture is available. The relationship between cotton development and temperature is best described by DD-60s. The equation for determining DD-60s is:

(°F Max + °F Min Temp)/2 - 60 = DD-60s

For example, if today's high and low temperatures were 80° F and 60° F, then the formula would give this answer: (80° F + 60° F)/2-60 = 10 DD-60s.

Perennial Growth Habit

In its native habitat, cotton is a perennial that does not die in the fall. Instead, the plant becomes dormant during periods of drought and resumes growth with the return of favorable rainfall. This characteristic is partially responsible for cotton's reputation of being a dry-weather crop. During periods of drought in North Carolina, a cotton plant will continue to grow the most mature bolls and abscise (or drop) the remaining boll load. This trait enables cotton to produce some yield even during severe drought years.

Along with this favorable drought-avoidance trait comes the undesirable feature of regrowth and the harvesting problems this may create. Unlike annual crops that die following seed production, cotton will continue growing until environmental conditions become unfavorable. This trait is shown when cotton continues adding leaves and unharvestable bolls until a killing frost occurs. This second growth presents some producers with defoliation challenges while inducing others to delay harvest in the hopes of realizing additional yield. The consistent and reliable heat needed to continue to contribute significantly to yield rarely occurs past the middle of October in North Carolina.

Fruiting

Another growth characteristic associated with cotton's perennial nature is its indeterminate fruiting habit. Rather than flowering during a distinct period following vegetative growth, cotton simultaneously produces vegetation and fruiting structures. A cotton

fruit begins as a small flower bud or "square" that flowers about 21 days after it reaches the size of a pinhead (just visible to the naked eye). The new bloom is white the first day (pollination occurs on the first day) and turns red by the second day. Cotton normally will flower for up to 8 weeks in North Carolina. This characteristic allows the crop to compensate partially for earlier periods of unfavorable conditions. However, this longer fruiting period requires continued attention to pest management and complicates harvest timing decisions.

Squares that bloom by around August 15 in the northern part of the state and around August 20 in the southern part of the state should have a reasonable chance of maturing. These bolls should be full-sized by around mid- to late-September if we have a reasonable chance to harvest them. A boll needs about 2 weeks of decent weather after it becomes full-sized to mature (increase in micronaire). It takes at least 6 weeks or 750 DD-60s after the last harvestable bolls are set before the crop can be terminated without reducing overall lint yield and quality. Nine hundred DD-60s are usually needed from white bloom until a boll is fully mature. Although maturity is minimum at 750 DD-60s, overall lint quality is not seriously affected because the relative proportion of bolls set last is usually small.

Tropical Origins

The third distinguishing characteristic of cotton results from its tropical origins. Cotton is adapted to regions where temperatures range from warm to hot. Grown as an annual crop in the United States, it is often necessary to plant cotton before the onset of consistently favorable temperatures. While cotton struggles to emerge from the soil and grow, diseases, weeds, and insects adapted to our environment can damage the crop. When several pests are present simultaneously, especially when accompanied by chemical stress, crop development may be severely retarded. Earliness, normally our best indicator of high yields, strongly depends on favorable environmental conditions during the early season. Cool and wet conditions during the early part of the growing season adversely affect cotton development.

Lint Quality

The price received by cotton producers is determined by both the quantity and quality of the harvested lint. While the nonfood nature of cotton may persuade newcomers of the crop's tolerance of harvesting delays, experienced growers recognize the value of timely harvests that preserve the maximum lint quality. Lint exposed to wet weather will become discolored, a reason to discount the ginned lint. Because of cotton's prolonged fruiting habit, some weathering of lint exposed to the elements is unavoidable. Green leaves resulting from incomplete defoliation or excessive regrowth also can cause grade discounts. Growers should concentrate on developing a harvest preparation strategy that retains as much lint quality as possible. This strategy can increase a grower's net return several cents per pound.

Summary of Plant Development

Seedling leaves, or cotyledons, appear on the day of cotton emergence. True leaves will appear 7 to 10 days later. After 30 to 35 days of vegetative growth, the first square (flower bud) will be formed on a fruiting branch arising from the axil (node) of the fifth to seventh true leaf. This important event marks the visible beginning of reproductive growth. The plant will normally continue to produce additional fruiting branches in an orderly manner up the main stem. Fruiting branches are distinguished by their zigzag appearance where a leaf and flower bud are formed at each angle. Each fruiting branch may produce several squares. However, over 90 percent of the harvestable bolls will be found at either the first or second position on a fruiting branch. When plant populations are high, 90 percent of the harvestable bolls may be found at the first position on the fruiting branch.

North Carolina cotton normally produces between 12 and 15 of these fruiting branches. Research in North Carolina indicates that bolls produced at the first position of fruiting branches arising from nodes 6 through 10 have a 50 to 70 percent chance of becoming harvestable bolls (assuming protection from insects). Boll-set at position one declines at higher fruiting branches. Bolls produced on fruiting branches arising from nodes 18 or higher have less than a 10 percent chance of finding their way into the picker basket. The same trend is followed at position two except that boll-set peaks at 20 to 30 percent at nodes 6 to 10 and then declines.

The progression of cotton fruiting can be followed by estimating the interval between the appearance of cotton flowers up the main stalk and out each fruiting branch. The vertical fruiting interval, or VFI (the interval between appearance of white flowers at position one on adjacent fruiting branches), is approximately three days (50 DD-60s). The horizontal fruiting interval, or HFI (the interval between appearance of white flowers at positions one and two on the same fruiting branch), is approximately six days (100 DD-60s). For example, in Figure 2-1, the boll closest to the stalk on the lower branch is about 9 days older than the white bloom on the second position of the upper branch (3 days up and 6 days out). The same principle can be used throughout most of the plant to map when and where boll loading occurs. Due to boll load, this relationship can begin to break down for nodes and fruiting sites developed following peak bloom.

This process can be used to record and frequently identify the causes of fruit loss, such as water stress, insect damage, rank growth, cloudy weather, and prolonged periods of rain. Growers can then use this information in refining their management strategies.

Plant Monitoring

Plant monitoring techniques, such as monitoring nodes above white bloom and plant mapping, have received a great deal of attention in the past few years. These techniques require a certain amount of time and energy but can tell us a lot about our cotton crop and how the crop should be managed. This section is divided into three subsections called prebloom, the bloom period, and the boll-opening period (postcutout).

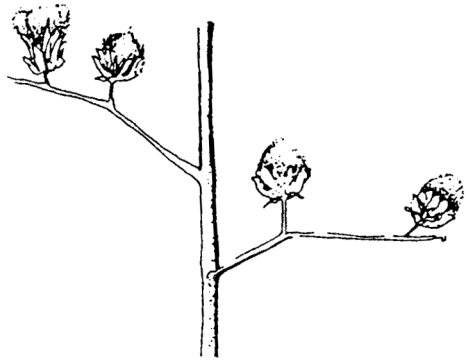

Figure 2.1. section of omain stem showing two adjacent branches.

Tables 2-1, 2-2, and 2-3 (at the end of this chapter) are examples of mapping sheets for use during prebloom, the bloom period, and the boll-opening period (postcutout), respectively. This plant monitoring method involves mapping only first positions of fruiting branches. Fruiting sites on vegetative branches and second or higher positions of fruiting branches are ignored.

Prebloom

Determining the Onset of Fruiting (Node of First Fruiting Branch)When the cotton plant has about 5 or 6 true leaves, you should be able to detect pinhead squares in the terminal (top of the plant). By counting the number of mainstem true leaves (ignore cotyledons) when a majority of the plants have a pinhead square, you can determine the node of the first fruiting branch. Well-managed early season varieties should begin fruiting on node 5 or 6 with an occasional plant fruiting at node 4. Full-season varieties usually start fruiting about a node higher. As the plant grows larger, the leaves below the first fruiting branch will shed, and vegetative branches may develop from these lower nodes.

When determining the first fruiting node of older cotton, you will have to count the "notches" if the lower leaves have been shed. Do not count the cotyledon notches. The shedding of cotyledons will leave two notches directly across from each other just above the soil surface. The notches you are interested in are those that were formed by true leaves above the cotyledons.

Factors Affecting the Onset of Fruiting

Several factors alone or combined can influence the onset of fruiting. Low plant populations can lower the node of the first fruiting branch by as much as one node. High plant populations, cool temperatures (night temperatures below 60° F) during the weeks after emergence, thrips damage, or unusually high temperatures (nights remaining above 80° F) can raise the node of the first fruiting branch by as much as 3 nodes. Nitrogen stress also can raise the node of the first fruiting branch, although this is rare because nitrogen requirements are low prior to fruiting, and preplant nitrogen applications almost always

supply enough nitrogen to avoid delaying fruiting. If one or more of these factors have delayed squaring, then no visible square scar should be present. If visible square scars or black squares are present at nodes 5 or 6, then the cotton is not delayed in squaring but is shedding squares.

In 1992, cool temperatures following planting raised the node of the first fruiting branch about 1.5 nodes. This corresponded to about a 5-day delay in maturity that resulted from slow growth during the cool period. Scout for pinhead square initiation to determine if the crop is developing on time.

Implications of Delayed Fruiting

Cotton that begins fruiting higher on the plant is more likely to grow rank, particularly if early squares are not retained. Retaining early squares and bolls is of increased importance when cotton begins to fruit higher on the plant than normal. These fields should be monitored closely for fruit retention and the potential need for Pix applications to control plant height. Delayed fruiting increases the likelihood of a positive response to Pix. In addition, in-season nitrogen applications should be weighed carefully. Nitrogen application above recommended rates may further delay the crop and add to the potential for a rank crop.

Determining Fruit Retention

When the cotton plant has about 5 or 6 true leaves, you should be able to detect pinhead squares in the terminal (top of the plant). From this time through first bloom, it may be helpful to determine fruit retention using plant-mapping techniques. You should map plants from several areas of the field and map at least 20 plants per field. The more plants you can map per field, the more accurately your mapping program will reflect the true fruiting pattern of the field. The percentage of fruit retention is determined by dividing the number of fruit by the number of fruiting sites. The resulting number is then multiplied by 100. For example, if you mapped 20 plants and came up with 75 fruit and 90 fruiting sites, the fruit retention would be 83 percent.

$$\% \text{ fruit retention} = \frac{\text{(number of fruit)}}{\text{(number of fruiting sites)}} \times 100$$

Example: $\% \text{ fruit retention} = \frac{75}{90} \times 100 = 83\%$

Causes of Early Square Shed

When squares are formed but then shed, a visible scar remains. Square shed prior to bloom can be caused by several factors, including insect damage; cloudy, cool weather; or water-saturated soils. However, it is often difficult to distinguish early season square shed due to insect damage from square shed due to weather conditions. Because weevils have been eradicated in North Carolina and plant bug damage is rare in our state, our fruit retention prior to bloom is usually very high. When square retention is lower than desired (below 80 to 90 percent), try to determine the possible cause. But don't be too quick to blame poor retention on plant bugs. Unnecessary spraying for plant bugs is not

only a waste of money, but will also kill beneficial insects that in turn may result in a higher likelihood that the cotton will need to be treated for (June) tobacco budworms. Unnecessary spraying also can cause aphid resistance.

Cool, cloudy weather (below 55°F at night) has been observed to cause square shed because of decreased photosynthesis. Water-saturated soils (often combined with cloudy weather) can cause square shed. Although drought conditions can cause shedding of small-to-medium-sized squares later in the season, square shed before bloom caused by drought stress is fairly rare. Other insects, including second-generation (June) tobacco budworms, can cause square loss, especially in the southern parts of the state. Never assume early square shed is entirely caused by weather conditions without first closely examining the insect situation in the field.

Significance of Early Fruit Retention

Square retention before bloom can have an effect on how the plant grows for the remainder of the season and on how the field should be managed. Fields with low early square retention are more likely to grow rank and have delayed maturity. Therefore, fields with low early square retention are more likely to respond to Pix applications. Because fields with low early square retention tend to grow rank, use nitrogen judiciously to minimize rank growth and the potential for boll rot. Scouting for insects should be intensified to avoid further excessive fruiting losses.

The Bloom Period

Cotton normally blooms for 7 or 8 weeks. Stresses associated with drought, nematodes, and fertility can shorten the bloom period significantly. The bloom period also can be lengthened by poor fruit retention or excess nitrogen (with adequate rainfall). Plant mapping, as discussed under preblooming, can be beneficial during the bloom period. In addition, monitoring the movement of first-position white blooms up the stalk during the bloom period gives us some insight into the condition of the crop.

Nodes Above White Bloom (NAWB)

Counting the nodes above white bloom (NAWB) is relatively easy during the bloom period. This technique involves locating the highest first-position white bloom on a plant and counting the nodes above that bloom. Each node above the highest first-position white bloom should be counted if the main stem leaf associated with the node is larger than a quarter. You will have to look for plants with a white bloom in the first position because not all plants have one at any given time.

Implications of NAWB

NAWB should be eight to ten at first bloom, depending on variety and growing conditions. NAWB at first bloom for short-season varieties that fruit on the fifth to sixth node normally will be at the lower end of this range, while full-season varieties usually will be at the higher end of the range. Environmental stress, such as drought, cool temperatures, or nitrogen deficiency, can result in a lower NAWB at first bloom. Poor fruit retention or excess nitrogen may result in a higher NAWB at first bloom. NAWB should begin

to decrease after 2 weeks of bloom because of fruit load. If NAWB does not begin to decrease during the third week of bloom, fruit retention should be evaluated. An increase in NAWB during the season is usually caused by insect damage. Crops with a large NAWB may be suffering from poor fruit retention caused by insect damage. Under these situations the crop will grow rank and be late maturing if ample moisture and nutrients are available. In crops with higher than normal NAWB at first bloom or crops in which NAWB does not begin to decrease during the third week of bloom, one can expect a strong response to Mepiquat. On the other hand, Mepiquat may not be needed in crops with low NAWB at first bloom or in crops in which NAWB decreases rapidly during the bloom period.

NAWB should continue to decrease through the remainder of the bloom period as the plant moves toward "flowering out the top." If NAWB is decreasing too rapidly, one should attempt to identify stresses and alleviate them if possible. The most common stresses that will cause a rapid decrease in NAWB are drought and nitrogen deficiency. When NAWB is lower than normal at first bloom or decreases more rapidly during bloom than desired because of drought stress, increasing the frequency of irrigation may be beneficial. Foliar urea applications have been shown to increase NAWB and yield when NAWB is lower than desired because of nitrogen deficiency.

When NAWB has reached five, the terminal has essentially ceased growth and cutout is imminent. Less than 2 percent of the yield is set after NAWB reaches four. Cutout occurs when NAWB reaches three or fewer.

When NAWB is higher than normal, look hard at insect-related fruit shed and consider Mepiquat to control plant height.

When NAWB is lower than desired, avoid Mepiquat use and attempt to alleviate any drought stress or nutrient deficiencies.

The Boll Opening Period (Postcutout)

Percent Open

Plant monitoring during the boll-opening period can help you schedule defoliations and determine whether boll openers are justified. Table 2-3 can be used to determine the percentage of open bolls. Cotton is almost always safe to defoliate at 60 percent open, but often can be defoliated earlier if fruiting is compact (see Chapter 12, "Cotton Defoliation"). Percent open is determined by counting the number of open and closed harvestable bolls on several plants in a field. The number of open bolls is divided by the total number of bolls (both open and unopen). For example, if you mapped 20 plants and came up with 195 open bolls and 105 closed bolls (300 total bolls), the percent open would be 65.

$$\% \text{ open} = \frac{\text{(number of open bolls)}}{\text{(total number of bolls)}} \times 100$$

Example: $\% \text{ open} = \frac{195}{300} \times 100 = 65\%$

Nodes Above Cracked Boll (NACB)

Bolls within 4 nodes above a cracked boll should be mature enough for defoliation in most fields. Counting the nodes above cracked boll (NACB) is a good technique to help schedule defoliation. This technique involves counting the nodes from the highest first-position boll that has cracked open enough that lint is visible up to the highest first-position boll you plan to harvest. This technique gives more focus to the unopened portion of the crop and is less likely to result in premature defoliation. When NACB reaches four, there will be essentially no yield loss due to defoliation in fields with normal plant densities. A yield loss of about 1 percent would be expected when defoliated at an NACB of five, and a yield loss of about 2 percent would be expected when defoliated at an NACB of six with normal planting densities. Fields with low plant populations (less than two plants per foot of row) will set more fruit on vegetative branches and outer positions of fruiting branches, and these fruit will be less mature. In these type fields, an NACB count of three might be a better estimate for timing defoliation.

Green Boll Counts

Deciding whether Prep is needed for boll-opening is often difficult. Counting the number of mature green bolls per foot of row is helpful in making this decision. In-depth information on the number of green bolls needed to justify Prep application is given in Chapter 12, “Cotton Defoliation.”

Table 2-1. Prebloom Plant-Monitoring Form

Field _____

Date _____

Plant #	Height (inches)	Total Nodes	Node of First Fruiting Branch	Number of Fruiting Branches	First Position Squares Retained
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Average					

Table 2-2. Bloom Plant-Monitoring Form

Field _____

Date _____

Plant #	Height (inches)	Nodes Above White Bloom	First Position Bolls Retained	Fruiting Branches Below White Bloom	First Position Squares Retained
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Average					

Table 2-3. Postcutout Plant-Monitoring Form

Field _____

Date _____

Plant #	Height (inches)	Node Above Cracked Boll	First Position Unopened Bolls	Fruiting Branches Below Cracked Boll	First Position Open Bolls
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Average					

3. DEVELOPING A MANAGEMENT STRATEGY: SHORT-SEASON TIMELINESS

Keith Edmisten
Crop Science Extension Specialist—Cotton

The key to successful cotton production in North Carolina is the adoption of a short-season management strategy. Cotton growers may equate a short-season management strategy with the recently overworked "earliness" philosophy. While in principle earliness is a worthwhile goal, particularly in a short-season management system, earliness alone may lead producers to adopt practices that unnecessarily limit yield and profit. Even at the northern margins of the cotton belt, there is sufficient time to consistently produce yields in excess of two bales per acre. "Timeliness" is the key component of a management strategy that is fluid enough to accomplish this yield level.

Earliness and timeliness frequently mean the same thing in North Carolina, although not always. There are few production practices that do not require some season-to-season and within-season modification to improve their effectiveness within a production system. For example, nitrogen fertilization must be adjusted for residue left by the preceding crop, as well as for the unique characteristics of the soil and environment currently encountered. Variety selection depends on soil type, planting date, and harvest scheduling, as well as yield and quality potential. The earliest variety may or may not be appropriate in a specific field. Plant-growth regulators help a producer achieve earlier harvest, but sometimes that earlier harvest is not possible due to time constraints, picker availability, or harvest schedule. The key to successful cotton management is adapting the strategy to the specific situation.

There are five specific goals important to producing a profitable crop in a short-season production system.

1. Maximum Early Season Growth

Cotton farmers and researchers alike recognize the yield benefits that result from rapid early season development. Strong emergence of healthy seedlings that establish a uniform stand is the foundation enabling maximum early season growth. Once a stand is established, vegetative growth should be promoted through the judicious use of cultivation, fertilizers, and agrichemicals.

2. Stimulate Early Flowering

Early flowering follows maximum early season growth. Commercially desirable varieties raised in North Carolina normally produce their first fruiting branch when the plants have between 5 and 7 true leaves. A fruiting branch produces squares, or flower buds, that may become harvestable bolls. Flowering is delayed when physiological, chemical, or insect-related stress retards square formation or causes square abscision (shed).

Examine cotton plants with 5 to 7 true leaves and note whether small squares, sometimes referred to as pinhead or matchhead squares, are present on the plant. If they are, then your cotton is developing properly. If they are not, then you may need to alter your management plans to increase square formation and retention. This may require you to apply Pix to reduce the likelihood of rank growth, delay nitrogen sidedressing, increase insect scouting and treatments to avoid further loss, and avoid overtop treatments with fluometuron (Cotoran or Meturon) or MSMA/DSMA. Over-the-top applications of Roundup to Roundup Ready cotton after the four-leaf stage can cause early fruit loss and delay maturity. Post-directed applications of Roundup to Roundup Ready cotton also can cause fruit loss if the application is made too high on the plant. Growers should carefully follow the Roundup label to avoid delays in maturity caused by Roundup applications.

3. Prevent Rank Growth

Excessive vegetative or rank growth historically has been a common problem for cotton farmers, particularly in a rainbelt like North Carolina. Problems associated with rank growth include (1) delayed maturity, (2) increased insect damage, (3) increased boll rot, (4) more difficult defoliation, and (5) decreased harvest efficiency. The indeterminate, perennial growth habit of cotton is partially responsible for this undesirable trait. Unlike determinate, annual crops such as corn and small grains, cotton will support vegetative and reproductive growth simultaneously. Early season growth is dominated by vegetative growth. Once flowering and boll loading begin, vegetative growth slows because bolls have preference over leaves and stems for available energy and nutrients. When cutout occurs or cotton blooms out the top, the plant's energy and nutrients from the leaves have been entirely directed to the bolls. Vegetative growth ceases until a sufficient number of bolls have matured enough to allow vegetative growth to resume. The development of cotton is a changing balancing act.

Rank growth occurs when this balancing act is disturbed and vegetative growth predominates over boll loading. The imbalance can happen in several ways. Abundant water and nitrogen accompanied by warm weather will support vigorous growth before bloom. As plant vigor and leaf area increase, sunlight available for photosynthesis lower in the plant canopy decreases. Individual bolls are supported by leaves growing nearby. The earliest squares and bolls that form at nodes 5 through 7 are fed by leaves that may not photosynthesize sufficient energy to support fruit growth. The result of this increased shading and decreased available energy is square and boll shed. Square and boll shed also may result from insect damage and pesticide damage or other environmental stress, such as drought or nutrient deficiencies. Rank growth also can begin after the flowering starts. Whatever

the cause, rank growth can snowball by reducing boll load and thereby increasing the potential energy available for further vegetative growth.

In the past, farmers were ill-equipped to control rank growth. The available solutions were to (1) plant on the sandiest drought-prone land, (2) withhold nitrogen, (3) avoid irrigation, and (4) chop the tops out of rank cotton. Fortunately, with the availability of mepiquat chloride or Pix, the judicious use of nitrogen, and timely insect control, we can largely avoid rank growth.

4. Protect Investments from Pests

To produce cotton profitably, pest control must be viewed as a wise investment, not another cost. Typically, a new grower may see the weed, insect, and disease management costs comprise a large and seemingly excessive part of the production expenses. Therefore, a new producer may delay or avoid timely pest management. This is a serious mistake.

The tools available to minimize economic damage from pests are limited. Timeliness is the essence of effective pest management in cotton. Timely crop development is the first defense against pest damage. Perform those agronomic practices that promote cotton fruiting development. Cotton can better compete with pests if it is healthy and actively growing. Some pesticide applications are inevitable because of the poor competitiveness of this tropical crop during the early part of the season and the attractiveness of cotton to insects. The effectiveness of cotton pesticides is entirely dependent on timely application in a technically appropriate manner.
Veteran cotton producers can speak with experience about the field or crop that was lost because weeds, insects, or diseases overran the cotton.

5. Harvest Quality Cotton

North Carolina cotton producers can expect some harvest delays because of rain and high humidity. In addition to delaying harvest, these environmental conditions can reduce lint quality and yield. Harvest delays also may result from the harvesting of other crops, particularly peanuts. Growers need to remember that these delays can, and frequently do, reduce the value of their cotton. Timely harvest will increase or maintain the value of an investment in cotton.

In many years there is a temptation for growers to delay defoliation in the hopes of increasing yields. Growers in North Carolina need to remember that we seldom have the type of weather needed to increase yields after the first week or two in October. Cotton left in the field not only suffers losses in reduced quality but also in reduced yield because lint falls off the plant. Losses exceeding 100 pounds of lint per acre over a six-week period have been observed in North Carolina, particularly in varieties with poor storm-proof characteristics. In addition, days and hours suitable for harvest generally decline in the fall. As a result, gaining a week for potential added growth in late September or early October may delay the final harvest of the season by a much longer period.

4. PLANTING DECISIONS

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Planting Date

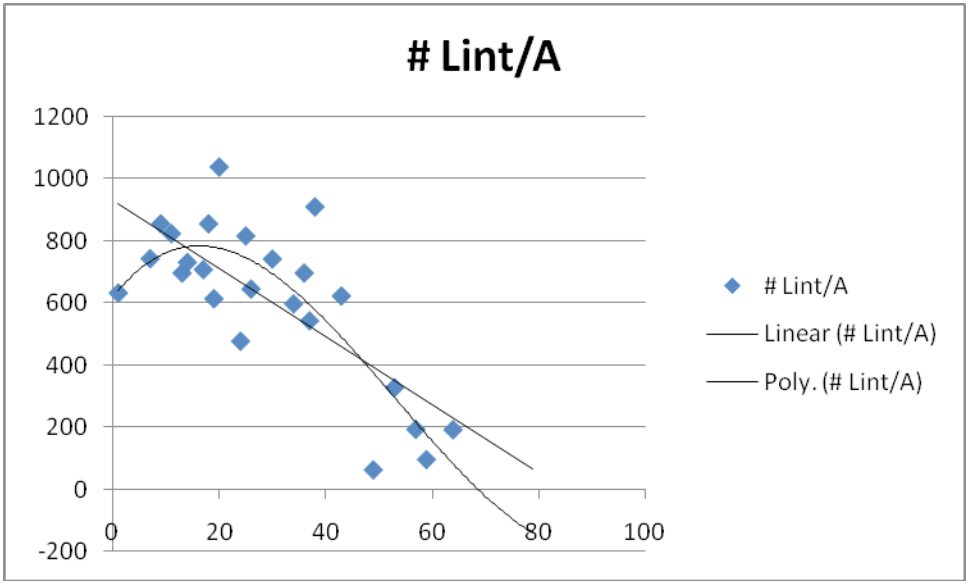
In a short-season cotton production region, planting date has a large, direct effect on development, maturity, and harvested yield. Planting date also influences insect control, plant growth regulator, and defoliation strategies indirectly. Decisions on planting date should not be taken lightly.

Although cotton planting used to start as early as March in North Carolina in the past, there have been many developments that have caused us to shift the optimum planting dates to later in the year. These include varieties bred to be earlier, boll weevil eradication, Bt cotton, the loss of Temik for thrips control, improved seed treatments, and the availability of growth regulators to manage maturity. In addition, the high cost of seed due to the technology delivered through the seed has made replanting less desirable. Fig-ure 4-1 shows the effect of planting date on cotton yields over a five-year period.

Careful analysis of the data presented in Figure 4-1 shows that yield response to planting date is not linear but strongly polynomial and that yields begin to drop to below early planting levels around 40 days after April 29, which would be after June 10. These data suggest the optimum planting date should be shifted later rather than earlier. Planning to complete planting by May 31 should provide a long planting period and an “insurance” period should replanting be needed. Cotton planting should be completed by June 10 if full yield potential is desired.

While planting date is important, soil temperature during the first 5 to 10 days after planting also influences early season cotton health and development. Research conducted in other states has established a relationship between temperature during stand establishment and subsequent stand yield. These findings indicate that temperatures below 50°F in the seed zone can cause chilling injury. The cooler the temperature, the more severe the damage, and the damage is cumulative.

There are two distinct, sensitive periods during seedling emergence. First, the cotton seed is sensitive to temperatures below 50°F when it is absorbing water to begin germination. The cotton seed can die if temperatures dip to 41°F. The second period of sensitivity is normally reached about two days after planting and may occur as the cotton seedling begins to grow. Temperatures below 50°F may either kill the seedling or cause growth retardation for weeks into the season. Many veteran cotton growers have observed the poor growth that occurs when recently planted cotton is subjected to cold temperatures.



Suggested Planting Dates

Ideally, planting should proceed after April 15 when (1) the soil temperature has reached 65°F by 10 a.m. in a 3-inch-deep, moist, prepared seedbed and (2) when warm, dry weather is predicted for the next 5 to 7 days. Unfortunately, it is not always possible to plant cotton in a timely fashion following this guideline. Temperatures above 70°F result in rapid germination; germination is very slow at temperatures below 60°F. The risk associated with planting in cold soils is exacerbated under wet conditions. The relationship between predicted DD-60 accumulation for the 5 days following planting and planting conditions is shown in Table 4-1.

Table 4-1. Relationship Between Predicted DD-60s and Planting Conditions

Predicted DD-60 accumulation for 5 days following planting	Planting conditions
10 or fewer	Very poor
11 to 15	Marginal
16 to 25	Adequate
25 to 50	Very good
More than 50	Excellent

Avoid planting cotton if the low temperature is predicted to be below 50°F for either of the 2 nights following planting.

Normally, emergence will occur after 50 DD-60s have accumulated. Calculation of DD-60s is described in Chapter 2, "The Cotton Plant."

Plant Population

Plant population has a profound influence on crop development. High plant populations (greater than three plants per foot on 38-inch rows) increase the percentage of the crop set at the first position of fruiting branches while reducing the total number of fruiting branches. This tends to shorten the boll-loading period compared to planting lower populations. Unfortunately, high plant populations decrease the cotton crop's ability to withstand drought stress.

The effect of plant population on final yield depends on rainfall patterns and crop/moisture relations. During those years when July and August rainfall exceeds 5 inches per month and the crop does not undergo prolonged drought stress, optimum yields can be achieved with plant populations varying from 2 to 4 plants per foot (28,000 to 55,000 plants per acre on 38-inch rows). However, in years when drought stress is pronounced, higher yields are achieved with plant populations of less than 2 plants per foot.

Choosing an appropriate cotton seeding rate is further complicated by an inherent weak-ness in cotton. Cotton cannot emerge through a thick soil crust. When cotton is planted deeper than ¾-inch and a surface crust forms following a packing rain, seedling emergence can be severely reduced. One response is to increase seedling rate, expecting normal seedling mortality. This strategy may backfire if seedling emergence is not hindered by a surface crust. A high emergence rate results in a plant population that cannot withstand drought stress.

A balance must be struck to achieve optimum yields, regardless of soil crusting characteristics and crop/moisture relations.

Seeding Rate and Depth Guideline

Calibrate the planter to place 4 to 6 seeds per foot. Set the planter to place the seeds ½- to 1-inch deep depending on soil type, crusting potential, and moisture levels. Under most conditions, you will have an adequate plant population. If germination and emergence are excellent, your cotton will still have some ability to rebound following drought stress.

Replanting Decisions

Nonuniform "skippy" cotton stands may be caused by poor seedling emergence, postemergence damping-off, hail damage, or insect damage. Growers are rightfully concerned that these stands may not be adequate to sustain high lint yields. The question, "Should I replant?" rises from this concern. There is no simple answer to this question. However, several points should be considered before making a decision.

The effects of planting date on yield are well known. The advantages of a more uniform stand must be weighed against the delay in maturity that results from cotton planted later. Additionally, there is no guarantee that replanted cotton will emerge satisfactorily. Finally, if the skippy cotton was planted before May 5, it frequently can compensate with larger, more heavily fruited plants. This is particularly true if midseason drought occurs.

No satisfactory rules have been set to guide you in replanting decisions. Experienced growers will attempt to work with a skippy stand rather than replant. If there are sufficient plants, work with what you have rather than replant. If the stand is unacceptable in many areas, try to replant only those areas.

If you are totally at a loss, ask for assistance from your county Cooperative Extension agent.

Finally, remember that a skippy cotton stand looks better at the end of the season than at the beginning.

5. Variety Selection

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Variety selection is one of the most important decisions a grower makes at the beginning of the crop year. There are several criteria for variety selection that may be important to a grower. How these criteria rank may vary from one grower to another, and the criteria may vary for the same grower from one field to the next depending on various factors such as weed pressure, soil types, planting date, and anticipated harvest schedules. Several criteria for variety selection are discussed below.

VARIETY SELECTION CRITERIA

Transgenic Traits

Most cotton produced in North Carolina has been genetically engineered to have an insect control package and an herbicide resistance package. The herbicide resistance package is the one of most concern to growers in variety selection. Glyphosate-tolerant varieties have been very popular in North Carolina, but now glyphosate-resistant weeds have emerged in many areas of the state. Glyphosate-resistant Palmer amaranth—and, to a lesser extent, glyphosate-resistant horseweed—have led many growers to select varieties with gene packages that allow the application of Liberty herbicide to help control these glyphosate-resistant weeds. LibertyLink cotton varieties and Widestrike cotton varieties are both tolerant to Liberty herbicide. Tolerance of varieties with the WideStrike trait to Liberty is not complete. In contrast to LibertyLink cotton, which is highly tolerant of Liberty, some injury can be expected when Liberty is applied to WideStrike cotton. The injury is basically leaf burn and can range from very minor to rather significant. However, the injury is contact in nature, and the crop generally recovers. More information about weed control systems and varieties is available in chapter 10, "Weed Management in Cotton."

Varieties in the tables presented in this chapter with the designation "RF" are Roundup Flex varieties that allow over-the-top applications of glyphosate. Varieties with the designation "GL" allow over-the-top applications of Liberty and glyphosate. Varieties with the designation "WRF" allow over-the-top applications of Liberty and glyphosate. The W in "WRF" also indicates that the variety has *Cry1A(2)* and *Cry1F* genes to produce Bt endotoxins that have high activity against all pest caterpillar species other than cutworm. The abbreviation B2 in a variety name indicates that the variety has *Cry1A(2)* and *Cry2A(b)*

genes to produce to Bt endotoxins that have high activity against all pest caterpillar species other than cutworm.

Yield Stability
Yield stability is the ability of a variety to perform well across various environments. Although it is tempting for a grower to put a lot of emphasis on the variety test nearest to their farm, this is not the best practice. We have consistently seen that the best predictor of how a variety will perform in the upcoming year is not how well it did at that particular location in the past year but how it performed compared to other varieties **averaged across all locations** in prior years. Some varieties tend to rank well only in good environments, while others tend to rank highly across all environments. In the absence of irrigation, growers need to select varieties that have performed well in good environments as well as under stress.

Maturity
Maturity is an indication of how long it will take from planting until harvest for a variety. Cotton variety maturity is often classified as early, medium, late, or full season. The cotton varieties we grow are day-neutral plants in that flowering is not initiated based on photoperiodism. Soybeans are day-length sensitive, and this is why later varieties of soybeans are recommended for late plantings. The opposite is true for cotton. Early varieties start fruiting at a lower node on the plant than later varieties. The typical first fruiting node for an early variety is node 5, while a late- or full-season variety might not start fruiting until node 8 or 9. For this reason, plantings after the middle of May should be devoted to early varieties in North Carolina.

Late-season varieties do offer some advantages compared to early-season varieties. Later varieties tend to not be negatively affected by stress as much as early varieties. Growers may want to lean toward mid- to late-season varieties when planting on sandy soils that are prone to drought stress if the cotton can be planted early. In general, later-season varieties tend to have better fiber quality than earlier varieties.

Fiber Quality
The price a grower receives can be positively or negatively affected by fiber quality. Fiber quality is discussed in more detail in chapter 17, "Cotton Classification." Fiber length, strength, and uniformity are heavily influenced by genetics and to a much lesser extent by environment. Of these, fiber length is the factor of concern most often with growers in North Carolina. Growers can usually avoid discounts for fiber length by selecting varieties with longer fiber length. Micronaire is influenced by a combination of or interaction between environment and genetics. High mike is most likely in cotton produced under stress, primarily drought stress. Growers should particularly avoid planting varieties that tend to have higher micronaire in fields that have a history of drought stress.

Stormproof
"Stormproof" is a term that indicates how tightly a variety holds lint over time. Research in North Carolina has shown that high winds and rainfall can cause losses, especially

when high winds and rainfall occur simultaneously. Stormproof characteristics of a variety are usually expressed as poor, fair, good, or excellent. Varieties that are considered to have poor or fair stormproof ratings should be planted in fields that can be harvested in a timely manner. Fields that a grower expects to be harvested in a less timely manner should be devoted to varieties with good stormproof ratings. The flip side of the coin is that varieties with poor stormproof ratings tend to pick cleaner; therefore, growers may want to plant a portion of their acreage to these varieties if they can be harvested quickly. The important factor is to consider harvest schedule with variety selection and placement with regard to stormproof characteristics.

Leaf Hair

Varieties have different amounts of hairs (tricomes) on the plant. The leaf hair typical for a variety is often classified as smooth, semismooth, and hairy. Smooth leaf varieties tend to have better leaf grades when the cotton is classed (chapter 17). Desiccating cotton during defoliation can also lead to high (bad) leaf grades. It is particularly important to try to avoid desiccation of hairy leaf varieties, as the desiccated leaves will tend to adhere to the lint, resulting in poor leaf grades.

OFFICIAL VARIETY TESTING DATA

There was a tremendous amount of rainfall this past growing season, especially in the first half of the growing season. The Rocky Mount location was dropped due to variability associated with excess rain. The 2013 locations used for the data presented here are from the research stations at Lewiston, Clayton, and Plymouth, and from an on-farm location in Scotland county.

Every variety has both strengths and weaknesses. The more experience we have with a variety, the better we can place it on the farm and manage it. The best way to manage risk on the farm associated with variety selection is to follow these principles:

- Use as much variety testing information as you can.
- Do not plant too much acreage to any one variety, especially varieties with only one year of data available.
- Use multiple varieties, to avoid putting too many eggs in one basket.

TABLE 5-1. Three-Year Statewide (North Carolina) Average Performance of OVT Cotton Varieties - 2011-2013

VARIETY OR BRAND VARIETY	LINT YIELD LB/ ACRE	LINT %	PLANT HEIGHT INCHES	PERCENT BOLLS OPENED	UHM S.L. (IN.)	UNIFORMITY INDEX	T1 (G/TEX)	MIKE	ELONGATION
PHY499WRF	1179**	44.8	34	52	1.14	83.7	30.7	4.9	6.3
DP0912B2RF	1166*	42.6	32	52	1.13	83.1	29.8	4.9	5.7
DP1028B2RF	1139*	45.0	33	49	1.14	83.4	28.9	4.8	6.2
Americot NG-1511B2RF	1132*	44.9	34	47	1.15	83.1	29.9	4.8	5.9
DP1137B2RF	1102*	44.1	36	53	1.13	83.6	28.7	4.8	6.0
Americot AM-1550B2RF	1087	42.9	31	59	1.12	82.8	28.3	4.7	5.6
+DP1252B2RF	1080	45.6	36	42	1.13	83.4	29.0	4.7	6.2
Dyna-Gro-2610B2RF	1074	43.9	37	47	1.15	83.4	29.3	4.6	6.2
DP1034B2RF	1046	44.4	34	51	1.16	83.5	29.4	4.6	6.4
PHY375WRF	1042	43.6	34	54	1.14	83.1	29.6	4.6	5.4
MEAN	**1105**	**44.2**	**34**	**51**	**1.14**	**83.3**	**29.4**	**4.7**	**6.0**
Adj R2 (%)	93								
C.V. (%)	9								
BLSD (K-50)	91								
S.E.	14								
Error d.f.	72								

**Highest yielder. *Not significantly different from highest yielder.

Nine locations

+Experimental

TABLE 5-2. Two-Year Statewide (North Carolina) Average Performance of OVT Cotton Varieties - 2012 - 2013

VARIETY OR BRAND VARIETY	LINT YIELD LB/ ACRE	LINT %	PLANT HEIGHT INCHES	PERCENT BOLLS OPENED	UHM S.L. (IN.)	UNIFOR-MITY INDEX	T1 (G/TEX)	MIKE	ELON-GATION
DP0912B2RF	1297**	42.6	32	53	1.14	83.4	29.8	4.7	5.8
PHY499WRF	1283*	44.7	34	57	1.17	84.3	30.7	4.8	6.2
Americot NG-1511B2RF	1278*	44.7	34	48	1.17	83.4	30.4	4.6	5.7
DP1321B2RF	1271*	43.8	34	53	1.16	83.3	30.5	4.6	6.1
Americot AM-1550B2RF	1231*	43.0	32	63	1.15	83.3	28.6	4.6	6.0
ST 4946GLB2	1225*	42.9	30	51	1.15	83.7	30.2	4.9	6.0
DP1028B2RF	1225*	44.6	33	54	1.16	83.9	29.3	4.7	6.1
DP1137B2RF	1193*	43.6	37	55	1.16	84.0	29.3	4.7	6.0
Croplan CG-3787B2RF	1191*	44.2	36	48	1.17	83.9	29.0	4.8	6.1
Dyna-Gro-2285B2RF	1186*	42.6	33	51	1.18	83.8	29.8	4.6	5.9
ST 6448GLB2	1173	41.8	33	52	1.18	83.2	29.8	4.6	5.2
PHY339WRF	1172	42.5	38	56	1.18	83.8	30.0	4.5	5.8
DP1048B2RF	1170	44.1	34	54	1.17	84.0	29.3	4.5	6.3
PHY375WRF	1169	43.4	35	58	1.15	83.3	29.8	4.5	5.7
DP1311B2RF	1162	44.1	33	53	1.17	83.5	28.9	4.5	6.0
+DP1252B2RF	1159	45.0	37	42	1.15	83.5	29.2	4.6	6.0
Dyna-Gro-2610B2RF	1158	43.6	37	49	1.16	83.5	29.8	4.6	6.2
DP1050B2RF	1153	44.8	37	53	1.17	83.9	29.2	4.5	6.2
DP1034B2RF	1137	44.1	33	52	1.18	84.2	29.9	4.5	6.4
Croplan CG-3428B2RF	1090	42.9	35	51	1.18	84.0	29.2	4.6	5.9
MEAN	**1155**	**43.7**	**34**	**52**	**1.16**	**83.7**	**29.6**	**4.6**	**6.0**
Adj R2 (%)	92								
C.V. (%)	8								
BLSD (K-50)	122								
S.E.	17								
Error d.f.	90								

**Highest yielder. *Not significantly different from highest yielder.

Six locations

+Experimental

TABLE 5-3. Statewide (North Carolina) Average Performance of OVT Cotton Varieties Across Locations - 2013

VARIETY OR BRAND VARIETY	LINT YIELD LB/ ACRE	LINT %	PLANT HEIGHT INCHES	PERCENT BOLLS OPENED	UHM S.L (IN.)	UNIFOR-MITY INDEX	T1 (G/TEX)	MIKE	ELON-GATION
PHY 333WRF	1216**	45.0	35	55	1.17	83.5	29.9	4.2	5.8
+PHY PX-553840WRF	1205*	43.4	39	47	1.16	83.7	29.1	4.3	6.3
Americot NG-1511B2RF	1167*	45.5	33	47	1.17	83.5	30.0	4.3	5.6
DP 0912B2RF	1162*	43.1	32	55	1.17	83.0	29.9	4.2	5.6
PHY 417WRF	1156*	44.0	36	52	1.18	83.4	29.7	4.4	6.4
PHY 339WRF	1131*	42.7	38	55	1.15	83.2	29.4	4.5	5.3
PHY 375WRF	1128*	44.4	35	50	1.16	83.6	29.6	4.6	6.2
DP 1321B2RF	1128*	44.4	34	54	1.15	82.9	30.4	4.3	5.8
+MON 12R242B2R2	1111*	44.3	34	51	1.16	83.0	29.4	4.6	6.0
ST 4747GLB2	1108*	43.6	31	60	1.18	83.8	29.9	4.2	5.8
+PHY PX-444414WRF	1096*	45.0	35	56	1.15	83.3	29.2	4.3	5.9
PHY 499WRF	1095*	45.6	34	51	1.15	83.4	30.2	4.7	6.0
ST 4946GLB2	1094*	42.8	32	46	1.15	83.3	29.2	4.7	6.0
+MON 12R224B2R2	1093*	43.0	35	58	1.18	83.5	29.7	4.6	5.7
FM 1944GLB2	1084*	41.2	37	40	1.18	84.2	30.0	4.6	5.9
Dyna-Gro 2285B2RF	1084*	43.0	33	54	1.17	83.5	29.4	4.3	5.9
+PHY PX30031WRF	1083*	44.3	33	52	1.16	83.6	29.5	4.4	5.9
+MON 13R352B2R2	1080*	45.6	35	39	1.17	83.3	29.4	4.4	5.9
Americot AM-1550B2RF	1079*	43.4	34	56	1.15	83.0	29.0	4.3	5.9
DP 1044B2RF	1069	42.2	32	50	1.17	84.0	29.6	4.5	6.0
PHY 427WRF	1062	42.0	36	57	1.17	83.5	28.8	4.4	6.3
+DG CT13125B2RF	1054	44.5	34	50	1.17	83.5	29.0	4.5	6.3
ST 6448GLB2	1030	41.9	33	44	1.15	82.8	29.1	4.5	5.9
DP 1028B2RF	1002	44.5	32	42	1.18	83.9	29.9	4.4	5.8
Croplan CG-3787B2RF	998	44.5	36	43	1.18	83.7	29.1	4.7	5.7
DP 1311B2RF	988	44.5	34	49	1.17	83.5	29.0	4.3	5.6
+Dyna-Gro CT13414	985	45.4	33	40	1.16	83.7	28.6	4.6	6.1
DP 1048B2RF	963	43.9	35	47	1.16	83.7	29.7	4.3	6.1
DP 1034B2RF	950	44.2	34	37	1.18	84.0	30.4	4.4	6.4

continued

TABLE 5-3. Statewide (North Carolina) Average Performance of OVT Cotton Varieties Across Locations - 2013 (continued)

VARIETY OR BRAND VARIETY	LINT YIELD LB/ ACRE	LINT %	PLANT HEIGHT INCHES	PERCENT BOLLS OPENED	UHM S.L (IN.)	UNIFOR-MITY INDEX	T1 (G/TEX)	MIKE	ELON-GATION
DP 1137B2RF	945	43.9	35	51	1.15	83.6	30.3	4.5	5.8
Dyna-Gro 2610B2RF	937	44.0	37	41	1.15	83.1	29.4	4.5	6.1
DP 1050B2RF	935	44.7	34	49	1.15	83.3	29.2	4.5	6.1
Croplan CG-3428B2RF	906	43.1	34	51	1.15	83.5	28.6	4.6	5.9
Americot NG-5315B2RF	898	44.0	36	37	1.18	83.9	30.0	4.5	5.7
+DP 1252B2RF	888	45.1	40	36	1.15	83.3	29.5	4.3	5.6
PHY 599WRF	873	42.6	39	28	1.17	83.5	29.4	4.4	5.8
Seed Source HQ210CT	801	42.1	30	45	1.16	83.0	30.0	4.6	5.8
Seed Source Genetics UA222	744	42.2	31	51	1.17	83.0	29.5	4.5	6.0
+LA 35RS	578	39.6	28	29	1.17	83.4	29.6	4.4	5.7
+LA 17	442	39.2	34	23	1.14	82.6	29.6	4.4	6.0
MEAN	**1009**	**43.6**	**34**	**47**	**1.16**	**83.4**	**29.5**	**4.4**	**5.9**
Adj R2 (%)	93								
C.V. (%)	12								
BLSD (K-50)	143								
S.E.	27								
Error d.f.	117								

**Highest yielder. *Not significantly different from highest yielder.

+Experimental

Four locations

TABLE 5-4. Relative Ranking of OVT Cotton Cultivars for Yield, Fiber Length, and Micronaire - 2013

VARIETY OR BRAND VARIETY	LINT YIELD LB/ ACRE	VARIETY OR BRAND VARIETY	UHM S.L. (IN.)	VARIETY OR BRAND VARIETY	MIKE
PHY 333WRF	1216	Bayer BX1347GLB2	1.18	Bayer BX1347GLB2	4.2
PHY PX553840WRF	1205	Americot NG-5315B2RF	1.18	PHY 333WRF	4.2
Americot NG-1511B2RF	1167	PHY 417WRF	1.18	DP 0912B2RF	4.2
DP 0912B2RF	1162	DP 1034B2RF	1.18	DP 1252B2RF	4.3
PHY 417WRF	1156	Croplan CG-3787B2RF	1.18	Dyna-Gro 2285B2RF	4.3
PHY 339WRF	1131	MON 12R224B2R2	1.18	Americot NG-1511B2RF	4.3
PHY 375WRF	1128	FM 1944GLB2	1.18	DP 1321B2RF	4.3
DP 1321B2RF	1128	DP 1028B2RF	1.18	PHY PX-553840WRF	4.3
MON 12R242B2R2	1111	PHY 333WRF	1.17	DP 1048B2RF	4.3
Bayer BX1347GLB2	1108	Americot NG-1511B2RF	1.17	PHY PX-444414WRF	4.3
PHY PX444414WRF	1096	Dyna-Gro 2285B2RF	1.17	Americot AM-1550B2RF	4.3
PHY 499WRF	1095	LA 35RS	1.17	DP 1311B2RF	4.3
ST 4946GLB2	1094	MON 13R352B2R2	1.17	DP 1028B2RF	4.4
MON 12R224B2R2	1093	PHY 599WRF	1.17	PHY 417WRF	4.4
FM 1944GLB2	1084	Seed Source Genetics UA222	1.17	LA 17	4.4
Dyna-Gro 2285B2RF	1084	DG CT13125B2RF	1.17	PHY 427WRF	4.4
PHY PX30031WRF	1083	DP 1311B2RF	1.17	PHY 599WRF	4.4
MON 13R352B2R2	1080	DP 0912B2RF	1.17	LA 35RS	4.4
Americot AM-1550B2RF	1079	DP 1044B2RF	1.17	PHY PX30031WRF	4.4
DP 1044B2RF	1069	PHY 427WRF	1.17	MON 13R352B2R2	4.4
PHY 427WRF	1062	Dyna-Gro CT13414	1.16	DP 1034B2RF	4.4
DG CT13125B2RF	1054	PHY 375WRF	1.16	Americot NG-5315B2RF	4.5
ST 6448GLB2	1030	DP 1048B2RF	1.16	Dyna-Gro 2610B2RF	4.5
DP 1028B2RF	1002	Seed Source HQ210CT	1.16	DP 1050B2RF	4.5
Croplan CG-3787B2RF	998	PHY PX30031WRF	1.16	DP 1137B2RF	4.5

TABLE 5-4. Relative Ranking of OVT Cotton Cultivars for Yield, Fiber Length, and Micronaire - 2013 (continued)

VARIETY OR BRAND VARIETY	LINT YIELD LB/ ACRE	VARIETY OR BRAND VARIETY	UHM S.L. (IN.)	VARIETY OR BRAND VARIETY	MIKE
DP 1311B2RF	988	PHY PX553840WRF	1.16	DP 1044B2RF	4.5
Dyna-Gro CT13414	985	MON 12R242B2R2	1.16	DG CT13125B2RF	4.5
DP 1048B2RF	963	Americot AM-1550B2RF	1.16	ST 6448GLB2	4.5
DP 1034B2RF	950	DP 1137B2RF	1.16	PHY 339WRF	4.5
DP 1137B2RF	945	PHY PX444414WRF	1.15	Seed Source Genetics UA222	4.5
Dyna-Gro 2610B2RF	937	DP 1050B2RF	1.15	MON 12R224B2R2	4.6
DP 1050B2RF	935	Croplan CG-3428B2RF	1.15	Seed Source HQ210CT	4.6
Croplan CG-3428B2RF	906	ST 6448GLB2	1.15	MON 12R242B2R2	4.6
Americot NG-5315B2RF	898	Dyna-Gro 2610B2RF	1.15	Dyna-Gro CT13414	4.6
DP 1252B2RF	888	DP 1252B2RF	1.15	PHY 375WRF	4.6
PHY 599WRF	873	DP 1321B2RF	1.15	Croplan CG-3428B2RF	4.6
Seed Source HQ210CT	801	PHY 499WRF	1.15	FM 1944GLB2	4.6
Seed Source Genetics UA222	744	PHY 339WRF	1.15	ST 4946GLB2	4.7
LA 35RS	578	ST 4946GLB2	1.15	Croplan CG-3787B2RF	4.7
LA 17	442	LA 17	1.14	PHY 499WRF	4.7

6. COTTON SEED QUALITY AND PLANTING DECISIONS

Keith Edmisten
Crop Science Extension Specialist—Cotton

A uniform stand of healthy, vigorous seedlings is essential if growers are to achieve the yields and quality needed for profitable crop production. It is important for growers to plant high quality seed of varieties adapted to their farm situations, management styles, and intended market uses.

Cotton yield and quality depend upon the seedlings established in the spring; therefore, timely and uniform emergence is critical. However, obtaining adequate stands is not always easy. The failure of seeds to germinate or the failure of seedlings to survive the initial few weeks of growth can be caused by a number of factors, many of which can be managed by cotton producers.

Planting Conditions

Cotton seeds are extremely sensitive to cool, wet soils during the early phases of germination and seedling growth. If the stress is severe, germination can be delayed or may not occur. Young, tender seedlings also may be damaged or killed if exposed to prolonged periods of cool, wet conditions.

Growers should not be tempted to plant cotton when cool, wet weather is expected. Planting under these conditions can lead to poor stands and may result in the need to replant. Chilling injury is most likely from the time the seed imbibes water and for the next 2 days as the radical emerges. Growers may want to cease planting 2 days prior to a prediceted wet and cool spell. Chilling injury can result seedling death, poor seedling development, J-rooting, tap root abortion. The abortion of the tap root can decrease the ability of the plant to perform well in dry periods later in the season.

Seed Quality and the Cotton Cool Test

High quality cotton seeds are those seed lots with high germination and vigor potential. Most growers are familiar with standard germination, which is a measure of the seed's ability to produce a normal, healthy seedling when conditions are ideal. For cotton seed, standard gerination tests are conducted under ideal germinating conditions at approximately 86^{o} F. However, most North Carolina growers plant cotton long before soils warm

to 86°F. This standard germination is the germination percentage you will find on the seed bag.

The potential of a cotton seed to germinate in cool, wet soils depends upon the vigor level of the seed. Seed vigor is a measure of the seed's ability to produce a normal, healthy seedling under a wide range of conditions. Several laboratory stress tests have been developed to estimate the vigor level and field performance potential of seed lots planted under less than ideal conditions. For cotton, there is a test known as the cool-germination test or cool test. In this test, instead of planting the seeds in ideal germinating conditions (86°F), the seeds are planted and evaluated for growth at 64.5° F. This cool temperature places stress on the seed, and only high-vigor seeds will germinate and produce seedlings with normal growth patterns.

The cool conditions used in this test are usually more closely related to field conditions than the standard warm germination test. This is especially true when planting early in the season or planting no-till. Studies have shown that high-vigor seeds germinate faster and seedlings develop more rapidly, thus avoiding many of the pathogens that cause seedling diseases.

The results of the cool test are not printed on the seed tag. However, this information is often available from the seed dealer. You can also check for this information with the seed company if the dealer does not have the information using the lot number. Small differences in cool-test results from one company to another may not be very meaningful. Company procedures for performing the cool test may vary slightly.

Interpreting Cotton Cool-Test Values

It is the responsibility of the grower to understand what the cool-test values mean. There is a significant vigor difference between seed lots with 85 percent and 60 percent cool-germination test results. But this does not mean that an 85 percent stand and a 60 percent stand will result from these two seed lots. It means the seed lot with an 85 percent cool-test result is likely to perform better in the field if stress conditions occur than is the lot with a 60 percent cool-test result. The low-vigor lot may do just as well as the high-vigor lot if both are planted when there is little or no stress. Likewise, if the lot with 85 percent cool germination is planted and soil temperatures immediately become extremely cool and wet, germination and seedling survival may never get near the 85 percent mark.

If growers have several seed lots, but the lots differ in cool-test results, growers should take care that the seed lots with lower cool-test readings should be planted under conditions as possible.

Seed Treatments

Planting cotton seed in early spring when temperatures can vary dramatically is one reason cotton seedling emergence fluctuates during any given season and from year to year. Seed companies know that one way to maximize emergence of cotton seedlings is to treat the seeds with both protective and systemic fungicides. Seed treatment chemistry

has improved dramatically in recent years. Growers should refer to the "Seed and Seedling Disease" section in Chapter 9, "Disease Management in Cotton," for informatio about additional fingicide treatment at planting.

Seed Performance Complaints

The North Carolina General Assembly passed a law in 1998 to help resolve seed performance complaints outside court. Growers who purchase seeds that fail to perform as labeled (for example, poor germination, weed seeds present, or mislabeled variety) may file a complaint with the Commissioner of Agriculture to have his or her seed compliant investigated by the Seed Board. Details on filing a complaint can be found in *Handling Seed Complaints,* AG-596, available from county Cooperative Extension centers or from the North Carolina Department of Agriculture and Consumer Services (NCDA&CS).

7. FERTILIZATION

Carl R. Crozier, Soil Science Extension Specialist; and David H. Hardy and Brenda R. Cleveland, NCDA&CS Agronomic Division

A good cotton-fertilization program begins with regular soil testing. Soil-test results are the most accurate and economical way to determine the fertilizer and lime needs of cotton. Although small amounts of nutrients are removed from the field at harvest, cotton requires high availability of nutrients, particularly late in the season. A good liming program usually supplies adequate calcium (Ca) and magnesium (Mg); many soils can meet the demand for phosphorus (P) and most micronutrients without annual fertilizer applications. Soil-test results can let you know when additions of these nutrients are required and when they are not.

For example, 85 percent of the more than 64,000 soil samples submitted to the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) laboratory in FY 2011for cotton were either high or very high in phosphorus. These fields would very likely not need additional phosphorus for 5 to 8 years. In addition, 75 percent of the samples were also high or very high in potassium (K).

Cotton is very sensitive to deficiencies of nitrogen (N), potassium (K), sulfur (S), and boron (B). These nutrients can be removed by leaching rains, especially in sandy soils. Of these elements, potassium is least subject to leaching, and its availability can be determined from a routine soil-test sample. Sulfur levels are included in NCDA&CS soil test reports, but while the presence of sufficient S in a sample indicates response to additional S inputs are unlikely, a low S soil test merits further consideration. Sulfur typically leaches downward from a sandy topsoil and accumulates in underlying layers with more clay. Sufficient S for adequate plant growth could still be present if this underlying clay layer is within 18 inches of the surface; however, this subsoil layer is rarely sampled. Recommended rates of nitrogen, sulfur, and boron are based on long-term field trials over a wide range of conditions. Annual applications of these nutrients are usually recommended for most soils. On soils subject to leaching, two or more applications may be required to improve fertilizer efficiency and ensure adequate availability throughout the growing season. Typical nutrient deficiency symptoms can be seen at the following website, although actual problem diagnosis should be based on soil and plant laboratory analyses (http://www.soil.ncsu.edu/nmp/deficiency/).

Fall or early winter is the best time to collect soil samples (September to November if you are sampling for nematodes at the same time). This allows plenty of time to get the

soil-test report back and to plan your fertilization and liming program before the busy planting season. In the coastal plain, sample every 2 to 3 years. In the piedmont, sampling every 3 to 4 years is adequate. Consult your county Cooperative Extension Service center, NCDA&CS agronomist, or local fertilizer dealer for details on sampling procedures.

Soil Acidity and Liming

Of the crops grown in North Carolina, cotton is among the most sensitive to soil acidity. Marked growth and yield increases have repeatedly occurred when fields are properly limed. When the soil pH drops below 5.5, aluminum and manganese dissolve from soil clays and can severely decrease root elongation, as well as reduce plant growth. Such a condition puts additional stress on cotton because stunted roots don't reach as much water or nutrients. Look for "J-shaped" taproots, and collect separate subsoil samples to confirm this. Acidity also interferes with the availability and uptake of phosphorus, potassium, calcium, and magnesium. Poor nutrient uptake results in fewer and smaller bolls with poor lint quality.

The optimum pH for cotton ranges from 6.2 to 6.5. We have paid too little attention to this requirement. In recent years, soil pH has become a major yield-limiting factor for cotton production in North Carolina. In FY 2011, approximately half of the NCDA&CS soil-test results for cotton fields were below the target pH of 6.2. Many of these fields will be limed, and others were organic or mineral-organic soils with target pH less than 6.0, but excess soil acidity continues to be one of our largest yield-limiting factors.

The amount of lime required for optimum cotton production varies with soil texture, pH, organic matter content, soil minerals, and animal waste application history. Lime rate can be determined only through periodic soil testing to document both soil pH and residual soil acidity ("Ac" on the NCDA&CS soil test.) The recommended amount of lime should be applied several months before planting to allow time for it to dissolve and react with the acidic components of the soil. However, lime applied just before planting is much more effective than no lime applied at all. If possible, mix lime thoroughly with the soil to speed the reaction. For more information on soil acidity and liming, see SoilFacts publication AGW-439-50, Soil Acidity and Liming for Agricultural Soils (http://www.soil.ncsu.edu/publications/Soilfacts/AGW-439-50/SoilAcidity_12-3.pdf). This publication also describes how to evaluate alternative lime sources such as industrial slags.

Nitrogen Fertilization

Nitrogen fertilization practices strongly affect growth and lint yield of cotton. Apply too little nitrogen, and yields drop sharply. On the other hand, apply too much nitrogen, or apply it at the wrong time, and plants will be rank, slow to fruit, more attractive to insect pests, late to mature, more difficult to cover with crop-protection chemicals, quick to develop boll rot, more troublesome and expensive to defoliate and control regrowth, and more likely to have grade reductions from bark.

Nitrogen Rate

The recommended rate of nitrogen ranges from 30 to 80 pounds per acre for rain fed crops (20 to 25 percent higher for irrigated crops). The best rate for a particular field depends on soil texture, the previous crop, expected rainfall patterns or irrigation, and grower experience in that field. Without knowledge of the field and of the specific management practices used, it is difficult to give specific recommendations, but some guidelines are available.

Uptake studies across the cotton belt suggest that cotton needs about 60 pounds of nitrogen per acre per bale of lint produced. Why are the recommended rates so much lower? Numerous on-farm nitrogen-rate studies throughout North Carolina show that unfertilized soils can supply 40 to 100 pounds of available nitrogen from organic matter, subsoil storage, and rainfall. Soil nitrogen reserves are generally highest on organic or mineral-organic soils and lowest on deep, well-drained sands. A good crop of soybeans or peanuts will supply an additional 20 to 30 pounds of nitrogen per acre. When soil nitrogen reserves are included, the recommended rates are consistent with a range of total available nitrogen from 110 to 170 pounds per acre following peanuts or soybeans, or from 90 to 140 pounds per acre following other crops.

Realistic yield expectations (R.Y.E.) are an estimate of the yield potential (average of the best 3 out of 5 years) of a soil series under a high level of management. In conjunction with a nitrogen factor (for cotton this factor ranges from 0.03 to 0.12 pounds of nitrogen per pound of lint yield), R.Y.E. values can be used to estimate total nitrogen needs for a specific field. For example, a Norfolk soil has an R.Y.E. value of 875 pounds of lint per acre and a nitrogen factor of 0.09; thus the calculated nitrogen rate is:

875 pounds of lint per acre x 0.09 pounds N per pound of lint = 79 pounds N per acre

The nitrogen factor varies with residual nitrogen, available water-holding capacity of the soil, and management. In general, as any of these factors increase, the efficiency of nitrogen use increases, and associated nitrogen factor for the site decreases. Thus organic and mineral-organic soils, with high residual nitrogen and available water-holding capacity, require low nitrogen factors ranging from 0.03 to 0.065, while deep sands, with low residual nitrogen and low available water-holding capacity, require nitrogen factors ranging from 0.07 to 0.12. Loamy soils require intermediate nitrogen factors ranging from 0.065 to 0.10. More information on realistic yield expectations is available via the Internet at http//www.soil.ncsu.edu/nmp/ or from your county Extension center.

Deficiency

Nitrogen deficiency symptoms first appear on the lower leaves. The leaves become a pale yellowish-green, fading with age first to hues of yellow, then variously tinted shades of red, and finally brown as they dry up and are prematurely shed. Deficient plants are stunted and generally unthrifty in appearance, and fruit-set is poor.

If a deficiency develops, nitrogen can be applied to the soil until the second or third week of bloom, or the last week of July. Beyond that point, soil applications become questionable. Foliar applications can increase yields at this stage of crop growth when plants are

deficient (see “Plant Monitoring and Foliar Fertilization”) If extended rainfall leaches nitrogen out of the rooting zone after final application but before the second week of bloom, nitrogen should be replaced. Replacement N rates generally should not exceed 30 pounds per acre.

Timing

Timing is important for cotton. Unlike crops such as corn and tobacco, cotton takes up only a small portion of the nitrogen before flower buds (squares) begin to set (Figure 7-1). About 45 days after emergence, nutrient uptake begins to increase rapidly until it reaches a prolonged peak about two weeks after first bloom, when the processes of flower production, boll filling, and boll maturation create a heavy demand for nutrients. Frequently, all the nitrogen is applied early in the season, or even at planting. While this may be the most convenient means of application, it makes little sense in North Carolinadue to unpredictable, leaching rains that can occur prior to to N peak demands. Leaching losses during this period will need to be accounted for and replaced to attain optimum yield. Heavy nitrogen applications early in the season also can lead to excessive vegetative growth, smaller, more compact root systems, and reduced early square retention.

Cotton needs only 20 to 25 pounds of nitrogen per acre to get the plant through sidedress time. If the crop is following peanuts or soybeans, no initial nitrogen may be required. If rains were predictable, the best time to sidedress would be just before first bloom. But since you can’t always count on rains at this time, it is safer to sidedress 2 to 3 weeks after first square to ensure that adequate nitrogen is available during the early-bloom period. On deep, sandy soils subject to rapid leaching, the sidedress nitrogen can be split, with half applied about 4 weeks after emergence and the remainder in 3 to 4 weeks.

Sources

Of the many nitrogen sources available for cotton fertilization, no one source has proven to be superior to others. Nitrogen solutions, ammonium nitrate, ammonium sulfate, urea, and anhydrous ammonia are most frequently used because of their high analysis. Sodium nitrate and calcium nitrate can be used, but have no proven benefit over ammonium-type fertilizers and cost more per pound of nitrogen applied. Conversion of ammonium forms to nitrate occurs very rapidly under warm, moist conditions. The choice should be based on price, convenience, and availability of equipment. Liquid nitrogen solutions are very convenient and exhibit little volatile loss when dribbled beside the row, even withoutcultivation . Anhydrous ammonia is a very economical source of nitrogen, but requires specialized handling equipment. There is a temptation with anhydrous ammonia to apply all the necessary nitrogen prior to planting. But the best results are still obtained when sidedress applications are knifed-in around the time of first square. Take care to avoid root pruning, but don’t place nitrogen out of reach of developing roots. Urea is also a suitable nitrogen source, but surface-applied sidedress applications should be lightly incorporated on light, sandy soils. High humidity can make this source sticky and difficult to handle.

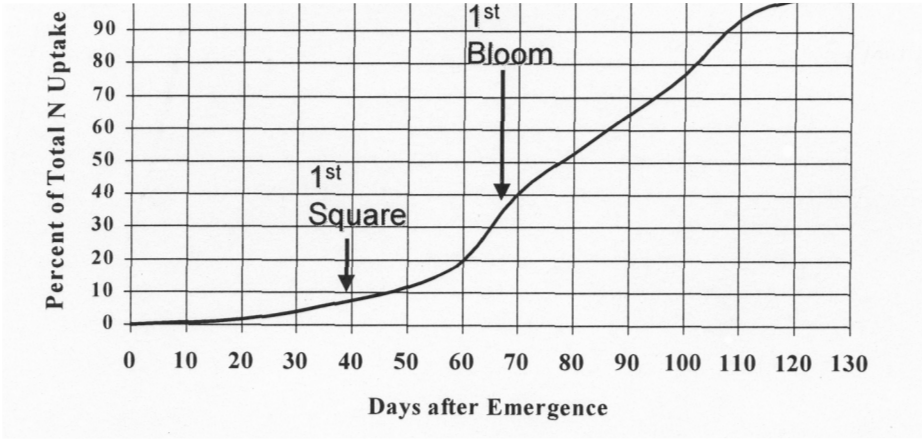

Figure 7-1. Timing of N uptake by cotton. Sidedress 2 to 3 weeks after first square should provide adequate N to sustain increased needs during the reproductive phase.

Nitrogen, Mepiquat Chloride, and Irrigation

The potential to reduce vegetative growth with the growth regulator mepiquat chloride has led some growers to increase nitrogen rates with the hope of increasing yields. On-farm tests in North Carolina consistently show that cotton yield response to nitrogen is not affected by mepiquat chloride applications. Higher than recommended nitrogen rates are not justified just because mepiquat chloride will be applied. Furthermore, where excessive rates of nitrogen are used and soil moisture is good, mepiquat chloride will not adequately control rank growth at labeled rates.

When irrigated, cotton yield potential on some soils can approach three bales. Higher nitrogen rates (90 to 120 pounds of nitrogen per acre) may be justified in these situations. When high nitrogen rates are planned for irrigated cotton, split the nitrogen applications to provide the bulk of the nitrogen as flowering begins. Plan to use mepiquat chloride to help control vegetative growth, but be aware that primary control of rank growth depends on maintaining high square retention and a heavy fruit load.

Phosphorus, Potassium, and Sulfur

Adequate supplies of phosphorus and potassium are critical for proper plant nutrition. A good soil-testing program will help alert you to potential problems before they occur.

Phosphorus deficiencies are rare and usually associated with low pH. Plants appear darker green than normal, growth rate is slow, and plants may appear stunted. Treatments to correct phosphorus deficiency seldom prove effective, so placement in the root zone before planting is essential. Plants deficient in phosphorus produce fewer and slower maturing bolls (see “Starter Fertilizers”).

The symptoms of potassium deficiency can be very pronounced and first appear on the older leaves as a yellowish-white mottling. The mottling changes to a light yellowish-green, and yellow spots appear between veins. The centers of these spots die, and numerous brown specks appear at the leaf top, around the margin, and between the veins. The tip and the margin of the leaf break down first and curl downward. As this physiological breakdown progresses, the whole leaf becomes reddish-brown, dies, and is shed prematurely. The premature shedding of leaves contributes to dwarfed and immature bolls.

In recent years, potassium deficiency symptoms have appeared in the upper part of the plant. In some cases, soil potassium levels appear to be high, but the plants are unable to obtain adequate potassium. In these cases, foliar potassium fertilization has improved yield and quality. At the present time, these symptoms have been associated with four factors:

1. the use of very high-yielding, determinate-type cultivars that set a heavy fruit load over a very short period;

2. soils that "fix" potassium in nonavailable forms;

3. an unidentified disease; and

4. mild to moderate drought stress following heavy fruit set. Symptoms are most common in parts of California and the Mid South.

Throughout most of the state, deficiency symptoms are rare and occur primarily on lower leaves of the plant, indicating improper pre-plant fertilization, in-season leaching losses, or root damage. Although potassium is retained by soils more strongly than nitrogen, it can be lost through leaching and may need replacing. Prompt replacement is important, especially early in the season. Approximately 25 to 30 pounds per acre of potash should correct most leaching losses. Where deficiencies from leaching are likely, sidedress applications of potassium have frequently solved the problem. Applications of foliar potassium (such as potassium nitrate) at mid-bloom on potassium-deficient cotton can increase yields. Routine application of foliar K is not recommended since it has been shown to reduce yields in some cases where there was already adequate K. The best way to determine whether K deficiency exists is with a plant tissue sample (see below, "Plant Monitoring and Foliar Fertilization").

A few cases of upper plant-deficiency symptoms have occurred in on-farm tests and experimental plots in North Carolina where 1) subsoil potassium levels were extremely low and short- to mid-season cultivars were planted or 2) soils contained significant amounts of 2:1 clay minerals such as vermiculite or montmorillonite (soil surveys indicate these soils have "mixed mineralogy"). Even though soil-test levels at the surface may be adequate, deficiency symptoms may still develop; plants will likely respond to foliar applications of potassium. Annual applications to build soil potassium throughout the root zone will eventually correct these problems.

A two-bale cotton crop will take up 20 to 30 pounds of sulfur. Some sulfur is supplied by the decomposition of crop residues and organic matter, and some is supplied by rainfall. In recent years, sulfur deficiencies have become more common in row crops with the decline in industrial emissions of sulfur dioxide and the increased use of higher analysis

materials and bulk blends containing less incidental sulfur. Sulfate-sulfur, the major form of sulfur taken up by plants, is mobile in most soils. Deficiencies are most likely to occur in highly leached, sandy soils with low organic matter content. Sulfur accumulates in the subsoil. If sufficient sulfur is present in the subsoil and root growth is not restricted, older plants can take up enough for normal development. Additional sulfur may still be needed for early growth. Low pH in the subsoil can decrease availability of accumulated sulfur, particularly in red clays. For more information on sulfur, see "Soil Facts: Sulfur Fertilization of North Carolina Crops" (http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-63W.pdf).

Sulfur and nitrogen reactions in the plant are interrelated, and deficiency symptoms for the two nutrients are sometimes confused. Deficiency symptoms of both nutrients appear as general leaf yellowing. However, nitrogen is mobile within the plant, and its deficiency symptoms first appear on the lower leaves. Sulfur is not mobile, and deficiency symptoms first appear on new leaves. In cotton, persistent yellowing of new leaves and reddening of the petioles are typical sulfur-deficiency symptoms. In severe cases, the whole plant may become yellow. Both nitrogen and sulfur deficiencies may be present. When attempting to correct the deficiency, it is important to diagnose the problem correctly. Plant analysis is recommended since visual symptoms are difficult to interpret. If sulfur is lacking, the addition of nitrogen will not correct the problem. Soil application of sulfur appears more effective than foliar treatments for correcting deficiencies. Early detection is critical because treatments after flowering begins have not increased yields in most cases.

As a general rule, annual applications of 10 to 20 pounds of sulfur per acre are suggested. Additional sulfur probably will not be needed if cotton follows peanuts that received gypsum (landplaster). A variety of fertilizer materials contain sulfur (see Table 7-1). Ammonium sulfate, potassium sulfate, magnesium sulfate, sulfate of potash-magnesium, or granular and pelletized gypsum can be included in dry blends as a sulfur source, or applied in a separate application. Elemental sulfur can also be used, but the sulfur must first be oxidized by soil organisms to the sulfate form. Because of this, it should be finely ground and applied early in the season to allow time for conversion to sulfate. There is increasing interest in adding 3 to 5 pounds of sulfur per acre in starter fertilizers. This practice can ensure adequate early season sulfur, but additional sulfur should be included in sidedress materials, especially on leachable, sandy soils. Sulfur-containing nitrogen solutions are now available in most areas. However, depending on the rate of nitrogen applied, the sulfur content of these solutions may not be adequate to provide sufficient sulfur for cotton without supplemental applications.

Liming to Supply Calcium and Magnesium

Lime does more than raise soil pH. It is also the primary source of calcium and magnesium for cotton. Dolomitic lime supplies both calcium and magnesium, while calcitic lime supplies only calcium. Cotton has relatively high calcium and magnesium requirements. A two-bale crop will take up 60 pounds of calcium and 23 pounds of magnesium, with 4 pounds of calcium and 7 pounds of magnesium actually removed in seed and lint. Calcitic lime may be used if soil tests show that no magnesium is needed.

Calcium deficiencies are seldom seen because acidity (low pH) and aluminum toxicity usually limit growth first. The magnesium content of soils is usually less than that of calcium because less magnesium is added, more magnesium is removed, and it is more leachable than calcium. Magnesium deficiencies are most likely to occur on highly leached, sandy soils. Heavy applications of landplaster or potassium applications can also result in magnesium deficiencies. In cotton, magnesium deficiency appears first on the lower leaves as an intense yellowing between the major veins. In severe cases, and sometimes in cool soils, a purplish-red color develops around the leaf margins and between veins, while the veins maintain their dark green color. Leaves shed prematurely. Late in the season, this color may be confused with the orange and red colors caused by normal aging of leaves. If magnesium is deficient, but it is not desirable to raise soil pH by adding dolomitic lime, then a source such as magnesium sulfate can be applied at a rate of 20 to 30 pounds of magnesium per acre.

Micronutrients

Boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) are necessary for plant growth, although the quantities needed are small. Specifically, boron, copper, zinc, and manganese should be of most concern to North Carolina cotton growers.

Boron

Boron is needed throughout the life of a cotton plant, but adequate supplies are especially crucial during flowering and boll development. Boron occurs in the soil as an uncharged molecule (boric acid) and leaches readily. Boron that is held by the soil is associated primarily with organic matter and is released as the organic matter decomposes. Dry weather can trigger a temporary deficiency as organic matter decomposition slows. Also, dry weather slows root growth and limits boron uptake. Thus, cotton grown on well-drained, sandy, low-organic-matter soils is more prone to boron deficiencies, especially in years of high rainfall or drought. Deficiencies can sometimes be induced by a soil pH greater than 6.5 or a heavy lime application in the recent past. The most pronounced boron deficiency symptoms include:

• Abnormal shedding of squares and young bolls.

• Ruptures at the base of squares or blooms or on the stem that supports the squares.

• Dark green rings on leaf petioles accompanied by discoloration of the pith under the rings.

• Death of the terminal bud and shortened internodes near the top of the plant, resulting in a dwarfed and many-branched plant.

• Mature bolls that are small, deformed, and do not fluff normally.

In many cases, the first real indication of a problem may be excessive growth. A close look at the plant will usually reveal abnormal fruit shed as the reason for this problem.

If plants are not carefully monitored, the problem may not be noticed until harvest reveals an unexpectedly poor response to nitrogen and potassium applications.

The actual uptake requirement of boron by a two-bale cotton crop is about 0.2 pound per acre. Because boron is essential to successful production but availability is difficult to assess, annual application of boron to cotton is strongly recommended. Boron can be applied to the soil or foliage. The suggested rate of soil application is 1 pound of actual boron per acre broadcast before or during seedbed preparation, or 0.2 to 0.4 pound of actual boron per acre if a borated fertilizer is banded. Manufactured fertilizers containing boron or granular borate in dry blends can be purchased. Preplant applications are most effective for soils with limited leaching potential. For foliar applications, enough boron should be supplied to account for uptake inefficiencies and to offset leaching losses. A good general recommendation is to use 0.5 pound per acre of actual boron applied at early bloom or 0.25 pound per acre at early bloom and another 0.25 pounds per acre about two weeks later.

Foliar applications allow placement of boron on the crop during peak demand. Some of the applied material will be taken into the plant and the remainder washed into the soil. Once inside the leaf, boron moves very little. This means that new, untreated tissue can be deficient in boron unless boron is supplied by the root system.

The recommended rates of boron for foliar application will provide for the immediate needs of the plant and some residual to build soil reserves. This allows supply through the root system as long as the boron remains in the root zone. On deep, sandy soils, split foliar applications ensure availability during the critical bloom and boll-filling periods. Soluble boron sources are generally compatible with mepiquat chloride and most insecticides, if enough water is used to dissolve the compound.

Copper, Manganese, and Zinc

Deficiencies of copper, manganese, and zinc are seldom seen in cotton. Determine applications of these elements based on soil-test reports. A soil-test index value less than 25 for any of these three micronutrients means that cotton may respond to an application, especially if the values are below 10 to 15. At present, the NCDA&CS Agronomic Division soil-testing laboratory prints a dollar sign ($) in the recommendation box if the soil level is low for sensitive crops, but there is no strong evidence that cotton is sensitive and will respond to additions of that element.

When in doubt, 2 pounds per acre of copper, 6 pounds per acre of zinc, or 10 pounds per acre of manganese can be applied to increase the soil levels sufficiently so that micronutrients will not limit yields. Other crops in the rotation may benefit from the application. Be sure to read the note accompanying the soil-test report, which gives valuable information about micronutrient use. A zero printed in the recommendation block for any of the micronutrients means that the soil's level is adequate.

The above suggested rates should be broadcast and soil incorporated. You also may consider banding 3 pounds per acre of either manganese or zinc near the seed (3 to 4 inches on the side and 2 to 3 inches below) with the mixed fertilizer. Foliar sprays of copper,

manganese, and zinc may be applied in emergency situations when the deficiency is discovered after the crop has been planted. Suggested foliar rates of manganese and zinc are 0.5 pound per acre; for copper, 0.25 pound per acre. Since the range between micronutrient deficiency and toxicity is quite narrow, it is important to be sure that application equipment is accurately calibrated.

Some common sources of copper, manganese, and zinc are listed in Table 7-2, and possible uses or application methods are shown in Table 7-3. In general, sulfate or chelated materials are recommended to correct sites with plants already established, or where pH values exceed 6.5. Oxides and oxy-sulfate materials are less soluble and require some time to react with the soil. These granular forms are commonly available for blending into pre-plant broadcast applications of NPK fertilizers. They are suitable for supplying micronutrients to the following crop and for building soil-test levels for later crops. Premium-grade fertilizers containing a mixture of micronutrients are available. Read the analysis tag to make sure the fertilizer will supply enough of the micronutrient in question to truly correct a soil deficiency. Also, compare prices because the cost of a premium-grade fertilizer may be more than the cost of a regular-grade fertilizer plus an application of the individual micronutrient needed.

Foliar Fertilization

Recent studies have proven that foliar-applied nutrients such as urea nitrogen, potassium, and certain micronutrients can be absorbed through the leaf. The amounts of nutrients absorbed will not meet the full daily demands for these nutrients, but can supplement the soil-supplied nutrients. Under most conditions, the soil supplies adequate levels of nutrients. Foliar fertilization is expected to increase yields only when deficiencies occur. Deficiencies may result from improper fertilization, leaching of mobile nutrients by heavy rains, drought, or insect and disease stresses that damage root systems. Some researchers have observed that foliar nitrogen application may occasionally "stick a few more bolls" early in a drought as water (and nitrogen) uptake declines. But if drought continues, these bolls will also shed. When leaves begin to wilt before noon, reactions in the leaf essentially shut down, and foliar applications become ineffective.

Deficiencies also can occur when cotton is heavily fruited, soil moisture is good, and insect control is excellent. Under these conditions, the plant directs most of its resources into making bolls rather than growing new roots and shoots, and nutrient uptake by roots can be less than required to meet peak demands. When deficiencies are detected using plant tissue or petiole analysis, foliar fertilization can improve yields. The real key is to know when deficiencies are present, and the only way to know is to monitor leaf and petiole nutrient levels also called tissue analysis. Satisfactory results are highly dependent on knowledge of the specific growth stage (that is, the week of the seedling, early vegetative, bloom, or fruiting period), since critical levels for N and K change dramatically over the reproductive period. Additionally, environmental stresses such as unusual wetness, dryness, or cloudy conditions can alter leaf chemistry and complicate interpretation of results. In these cases, it is best to suspend sampling until more benign environmental conditions return. Cotton leaf and petiole tissue analysis is available from the Agronomic

Division of the NCDA&CS at a cost of $7 per sample. Detailed sampling instructions and laboratory data interpretation guidelines are available at http://www.ncagr.gov/agronomi/pdffiles/11cotton.pdf. Contact your county Extension agent or Regional Agronomist for assistance if you would like to experiment with this management tool.

Foliar applications of nitrogen or potassium to correct late-season deficiencies are usually made using either urea (46-0-0) or potassium nitrate (13-0-44) as the source. Other materials are available and are being tested, but urea and potassium nitrate have proven to be effective in correcting deficiencies. Generally, the solution is made by mixing 10 pounds of the fertilizer material with 10 to 20 gallons of water for each acre to be treated. Both materials will cause the temperature of the water to drop as they dissolve. Use of warm water or agitation speeds dissolution. By using hot water or extended agitation, solutions as concentrated as 10 to 20 pounds of material in 5 gallons of water can be made. These are primarily used in aerial application. In some areas, premixed solutions are beginning to appear on the market. Both of these materials seem compatible with commonly used insecticides. Check the pesticide label for warnings or instructions on mixing with fertilizers because mixing order may be important. Applications during the first 5 weeks of bloom are most effective in correcting nutrient deficiencies.

Monitoring Plant Nutritional Status

Leaf or tissue analysis provides a "snapshot" in time of the nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B) that have accumulated in the uppermost mature leaves. In an actively growing cotton crop, these mature leaves are three to four nodes down from the terminal leaf and are generally 10 to 16 days old. Tissue analysis is a tool that indicates whether nutrient levels are adequate for the crop to mature with optimum yields. It evaluates nutrient shortages or excesses and helps determine appropriate corrective action. For example, nutrients that are mobile in the soil such as nitrogen (N) and sulfur (S) can easily move out of the root zone by leaching rain; this loss can be detected with tissue analysis.

When blooms first appear on cotton, the plant has accumulated only about half of its total nutrient uptake (Figure 7-1). At this stage, the root system is still active and the plant continues to accumulate nutrients and to add both vegetative and fruiting sites for several more weeks. From mid bloom through maturity, root expansion as well as nutrient uptake slows even though the crop requires 10 or more weeks to fully mature. At the later growth stages, leaf analysis is less effective in predicting nutrient needs of the crop. Because of this, cotton leaf analysis as a tool to assess nutrient requirements for the current crop is best done during the pre-bloom or early bloom period.

Monitoring fertilizer uptake through petiole analysis has proven to be a reliableindicator of available soil nutrients during the bloom period, especially for nitrate-nitrogen (nitrate). The petiole (leaf stem) has very little storage capacity for nutrients, since its primary function is to channel nutrients to and from the leaf blade. Thus, the nutrient

content in the petiole of the uppermost mature leaf is an excellent means to monitor current soil availability. It is a much more sensitive indicator of N availability than leaf analysis. As shown in Figure 7-2, nitrate concentration decreases following bloom. By comparing petiole nitrate levels each week of bloom with final yields in test plots, desired ranges for optimum yields have been established for North Carolina conditions and cultivars. Fields with "low" petiole nitrate will have a high likelihood of responding to additional nitrogen, either applied to the soil or as a foliar application.

Unfortunately, anything that affects nutrient uptake by the root system, such as drought or excess soil moisture, also strongly affects petiole nutrient levels. Thus, petiole-monitoring programs are most effective when soil moisture is good to adequate.

Starter Fertilizers

In a high-management situation, starter fertilizers can enhance early season growth, promote earlier fruiting, and increase yields. Enhanced growth frequently allows more timely and effective weed control. The extent of these effects varies with soil and climatic conditions, and effects may not be seen every year. Responses are usually greatest in cool, wet soils with low phosphorus levels but are not limited to these conditions. Over a period of several years, replicated trials with soils testing high in phosphorus have shown an average increase in cotton lint yield of 60 pounds per acre. On soils testing "very high" in phosphorus (P-index>100), there has been no advantage of including additional phosphorus in the starter band, i.e. highest yields occurred with only nitrogen in the starter. The most consistent responses have occurred when the starter is placed in a narrow band 2 inches below and 2 inches to the side of the seed. Other techniques, such as surface bands 3 to 4 inches wide applied over the row, have been successful but are much less consistent. Tests with nitrogen or nitrogen-plus-phosphorus solutions mixed with the preemergence herbicides have been the least successful. This could be expected because the fertilizer is sprayed in a much wider band, and the nutrient concentration in the row is greatly diluted. Starter fertilizer trials throughout the Southeast have shown that responses are possible in some cases with nitrogen only, with one-to-one mixes of nitrogen solutions with 10-34-0 or similar ammonium polyphosphate solutions, and with granular fertilizers such as DAP (diammonium phosphate, 18-46-0). A maximum rate of 100 to 120 pounds of starter fertilizer per acre is suggested to maximize response and minimize the chance of seedling injury. Careful setup is essential. Placement too close to the seed can mean replanting. In furrow fertilizers are not recommended for cotton!

In summary, trials throughout the Southeast support the use of starters on soils where potential yields are greater than 700 pounds per acre and where other good management practices are followed. Starters will not help much where timely weed control, insect management, and nitrogen fertilization are not practiced. But they can help a well-managed crop perform better.

Animal Wastes as a Nutrient Source for Cotton

In many of the important cotton-producing areas of North Carolina, poultry and swine manures are available for use on cropland. Manure is often a cost-effective substitute or

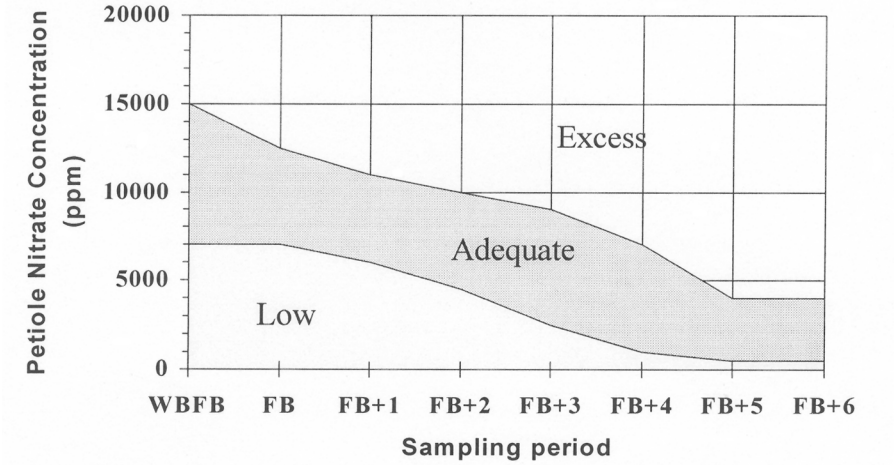

Figure 7-2. Ratings for petiole nitrate concentrations during the bloom period. *(WB = Week Before; FB = First Bloom; number after FB indicates weeks after first bloom.)*

supplement to fertilizer-supplied nutrients. Animal wastes should be analyzed prior to use to determine the kind and quantity of nutrients in the waste. The largest quantity of nutrients will be nitrogen, phosphorus, potassium, and sulfur, along with some magnesium, calcium, copper, zinc, manganese, and lime. While the rate of manure applied can be adjusted to supply the requirements of any one of these nutrients, make sure that excess available nitrogen is not supplied. Excess nitrogen is more detrimental to cotton than excesses of the other nutrients. In general, 40 to 80 percent of the total nitrogen will be available for uptake by plants in the first year of application. Recent work in Alabama indicates that essentially 100 percent of the nitrogen in poultry litter is available when incorporated just before planting. Animal wastes should be incorporated as soon as possible after application to decrease volatile losses of nitrogen and to lessen the impact of runoff on nearby water bodies. This leads to the major problem with use of animal wastes on cotton: All the manure really needs to be applied before planting. As with any nitrogen source for cotton, it is preferable to sidedress most of the applied nitrogen to avoid problems with excessive vegetative growth and delayed fruiting. One solution is to apply animal wastes at a rate to supply sufficient P pre-plant, then sidedress with a liquid fertilizer at the appropriate rate to obtain the rest of the N needed by the crop. Ongoing research will evaluate the nitrogen availability and rate of release to cotton from various animal wastes.

For more information on the use of animal wastes as nutrient sources, ask your county Cooperative Extension agent for a copy of the SoilFacts publications AG-439-4, Swine Manure as a Fertilizer Source; AG-439-5, Poultry Manure as a Fertilizer Source; and AG-439-28, Dairy Manure as a Fertilizer Source, or visit or see http://www.soil.ncsu.edu/about/publications/index.php.

Table 7-1. Sources of Sulfur in Fertilizer Materials

Materials	Nutrient Content	
	Percent Sulfur	Percent Other
Ammonium sulfate	24	21 (N)
Potassium sulfate	16	48 (K_2O)
Magnesium sulfate	14	10 (Mg)
Sulfate of potash-magnesia	22	22 (K_2O) + 11% (Mg)
Gypsum (landplaster)	17 to 20	11 (Ca)
Sulfur-containing nitrogen solutions	3 to 5	24 (N)
Elemental sulfur	88 to 100	–

Table 7-2. Micronutrient Sources, Concentrations, and Relative Cost

Micronutrient Source	Content (percent elemental)			Relative Cost per Pound
	Copper	Zinc	Manganese	
Oxide	50 or 75	70 to 80	25 to 28	Least costly
Oxy-sulfate	55			Intermediate cost
Sulfate	25	36	25 to 28	Moderate cost
Chelate	8 to 13	10 to 14	10 to 21	Most costly

Table 7-3. Suitability of Micronutrient Sources for Selected Uses

Used in	Micronutrient Source and Suitability			
	Oxides	**Oxy-sulfates**	**Sulfates**	**Complexes or Chelates[1]**
Fluid fertilizers[2]	Satisfactory in suspensions only	Satisfactory in suspensions only	Somewhat satisfactory	Satisfactory
30 % nitrogen solutions	Difficult to dissolve	Difficult to dissolve	Difficult to dissolve	Usually satisfactory
Dry blends[3]	Usually satisfactory	Usually satisfactory	Usually satisfactory	Seldom used
Manufactured fertilizer	Satisfactory	Satisfactory		Not used
Water solution sprayed for soil application	Not satisfactory			Satisfactory
Foliar sprays[4]	Not satisfactory		Usually satisfactory	Satisfactory

[1] Often the label suggests a rate that is not adequate.
[2] Usually works in clear solutions; satisfactory in suspension fertilizer.
[3] Pulverized (finely ground) product should be bonded to fertilizer granules with a small amount of nitrogen solution or diesel fuel. Granular forms work well.
[4] May cause some foliar burn. Best to use low rates and make at least two applications about two weeks apart.

8. SUGGESTIONS FOR GROWTH REGULATOR USE

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Growth regulators are used to control cotton plant height. Mepiquat chloride, the active ingredient in Mepiquat, is now available under other trade names. Mepiquat pentaborate is the active ingredient in a new growth regulator named Pentia. These growth regulators are both anti-gibberellens that control plant height and can increase earliness. Several non-mepiquat growth regulators are sold for use in cotton, but there are no data to support the use of any growth regulators that do not contain some form of mepiquat in North Carolina. Because the activity of Mepiquat chloride and Mepiquat pentaborate are similar, I will refer to them as mepiquat in this chapter.

Mepiquat can be applied as a broadcast spray or as a banded spray. Research at North Carolina State University has shown that Mepiquat also can be applied through a canvas wick applicator. The greatest advantage the wick seems to have over spray applications is that it makes it easier to apply Mepiquat to tall cotton and avoid application to shorter, stressed cotton within the same field. More detailed information about using a wick can be found on the Internet in Carolina Cotton Notes at http://www.cropsci.ncsu.edu/ccn/2000/2000.htm. Information on calibrating a wick applicator can be found at the same site.

Plant Modification

Mepiquat can help cotton growers manage the development and maturity of their crop. Research conducted in North Carolina, as well as in other areas of the cotton belt, has demonstrated that Mepiquat treatment can hasten maturity, reduce plant height, facilitate insect management, decrease boll rot, and increase yield.

These desirable features are caused by the inhibition of cell elongation in the cotton stems. Mepiquat-treated plants are normally smaller and more compact. Internodes along the stem and fruiting branches are shortened. The total number of fruiting branches also may be reduced slightly. Energy is directed toward boll production and away from vegetative growth.

Normally, our North Carolina season does not give us enough time to mature the bolls produced on the highest fruiting branches. In Mepiquat-treated cotton, those positions are not formed. In untreated cotton, those additional fruiting positions frequently are not harvested.

Season Considerations

In rain-fed cotton production, the presence or absence of timely rainfall largely determines the length of the growing season and the plant's ability to produce and mature bolls.

If we experience timely rainfall, cotton normally produces excellent yields, with or without Mepiquat. When excessive rainfall occurs, particularly when soil nitrogen is plentiful, Mepiquat treatment is usually an excellent investment.

However, what happens when drought or another stress occurs that limits square production? If the stress occurs three weeks into bloom and continues for the remainder of the bloom period, then Mepiquat-treated cotton frequently will out-yield untreated cotton because the Mepiquat-treated cotton sets a greater portion of the crop earlier. If, however, the stress occurs during or immediately following the application of 1 pint per acre of Mepiquat (a normal application amount), the situation may be quite different.

If drought continues for the remainder of the season, nothing will help. If the drought breaks after one to two weeks, the Mepiquat-treated cotton may have a difficult time resuming growth and boll loading because Mepiquat tends to reduce vegetative growth and the associated square production.

Treatment with the plant growth regulator does not guarantee the results mentioned above, particularly increased yield. Yields of Mepiquat-treated cotton may be reduced when biological and environmental conditions do not favor excessive vegetative (rank) growth. However, a single application of Mepiquat with a rate appropriate for plant size rarely decreases yield. As with any management tool, the decision to use Mepiquat should be based on a consideration of its usefulness in a specific situation. Your decision to apply Mepiquat in any given year should be made on a field-by-field (or portion-of-a-field) basis. Certain cotton fields may require treatment every year, whereas others will rarely require treatment.

Conditions Favoring Mepiquat Use

Mepiquat use is usually warranted when conditions favor rank growth and delayed maturity. Some of these conditions are:

- Cotton planted after May 15.
- Thick stands (more than 4 plants per foot of row).
- High nitrogen rates.
- Excessive rainfall within 7 days of treatment.
- Fields with a history of rank cotton growth.
- Large, indeterminate varieties.
- Fields with delayed maturity.
- Fields that will be defoliated and harvested first.

The more of these conditions that are present, the greater the likelihood of a positive response to Mepiquat treatment. Conversely, if the above conditions are not present, Mepiquat treatment may not be worthwhile.

Application Strategies

Several Mepiquat application strategies have been developed. Three—early bloom, low-rate multiple, and modified early bloom—are discussed below with guidelines for each. The low-rate multiple approach is not recommended in North Carolina due to poor early season growth. One exception might be a vigorous and late-maturing variety, such as Deltapine 555, when early weather conditions favor rapid growth.

I. Early Bloom Strategy

The most commonly used technique is the application of ½ to 1 pint of Mepiquat at early bloom (defined as 5 to 6 white blooms per 25 feet of row) on cotton that is more than 24 inches tall if conditions favor a response to Mepiquat. Cotton that is less than 20 inches tall at early bloom does not receive a treatment. The ½- to 1-pint rate is also applied if the cotton averages 28 inches tall, even if early bloom has not yet occurred.

Applications may be made after early bloom if cotton growth becomes excessive (following early bloom). Treatment rates range between ½ and 1 pint per acre. **Note:** Treatments applied later than 7 days after early bloom will have less impact on earliness and less potential to increase yield.

Mepiquat use decisions should be based on the development of the crop, environmental conditions, and time of the season. The following guidelines will assist in making situation-specific decisions for Mepiquat use. Remember that Mepiquat should not be applied to drought-stressed cotton. Wait until stress is relieved before application. Consult the label for additional precautions.

Situation 1
Plant height less than 20 inches at early bloom because of stress.
Response
Relieve stress if possible. Avoid Mepiquat application right away. Treatment may be required later, but wait and see.

Situation 2
Plant height 20 to 24 inches tall at early bloom.
Response
If bloom begins before July 10, then crop is on schedule. Wait and see. Mepiquat at 1 pint per acre may be required later, particularly if plant height exceeds 28 inches within one week of early bloom.
If bloom begins after July 10, particularly after July 20, then apply ½ pint of Mepiquat per acre to compact the boll-loading period if the crop is not under drought stress.

Situation 3
Plant height more than 24 inches at early bloom; plant growing rapidly.
Response
Apply ½ pint of Mepiquat per acre to reduce shading and improve boll set. An additional ½ to 1 pint of Mepiquat per acre (depending on previous treatment rate) may be required if plant height exceeds 28 inches one week after early bloom or 32 inches two weeks after early bloom.

Situation 4
Plant height approaching 20 to 24 inches before early bloom. Growth rapid; condition well-watered. Anticipated early bloom height more than 24 inches.
Response
If prebloom cotton is 16 inches tall, apply ¼ pint per acre. If prebloom height is 20 inches or more before first treatment, apply ½ pint per acre. An additional Mepiquat treatment may be necessary if plant height exceeds 24 inches at early bloom, 28 inches one week after early bloom or 32 inches two weeks after early bloom.

II. Low-Rate Multiple Application Strategy
Recently, an alternate strategy has been developed to reduce the risks associated with an early bloom Mepiquat treatment that precedes a drought period. This strategy employs the use of low-rate multiple applications (LRMA) of Mepiquat beginning at match-head square (50 percent of plants with one or more squares 1/8 to 1/4 inch in diameter). The first treatment of 1/8 to 1/4 pint occurs at match-head square if conditions favor a response to Mepiquat. Further treatments are made at 7- to 14-day intervals when conditions favor a response to Mepiquat.

This approach is logical and should enable you to achieve the benefits of Mepiquat, particularly if you have irrigation capabilities, while reducing the risks associated with the product (early cutout). Instead of running the risk that drought stress may occur immediately after a larger, early bloom treatment, you should be able to mete out smaller doses that enable you to fine-tune the crop's development. However, research in North Carolina has shown this strategy to be the one most likely to reduce yields, as compared to the early bloom or modified early bloom strategies.

Remember that pinhead square occurs when a cotton plant's first flower bud is just visible to the naked eye. Match-head square (squares 1/8 to 1/4 inch in diameter) occurs about 7 days later. First bloom occurs about 21 days after pinhead square and 14 days after match-head square. Early bloom (5 to 6 white blooms per 25 feet of row) occurs within 5 to 7 days of first bloom.

Table 8-1 provides a point system to help producers select rates for the LRMA approach. Because it is impossible to put all considerations into a usable chart, an experienced producer may be able to make better decisions than the chart would recommend. This point system is much better than a "shot-in-the-dark" guess that an inexperienced producer might have to make. Use the appropriate portion of the

Table 8-1. Point System for Determining Mepiquat Rates Using an LRMA Approach

FIRST SQUARE

Points

	-1	0	1	2
Moisture		fair	excellent	
Stalk height history	< 36 in.	36 to 44 in.	44 to 48 in.	> 48 in.
Date of first square		before June 15	after June 15	
Variety		short or medium	tall	

If score is greater than 3, do not apply.
If soil moisture is poor, do not apply.
Do not exceed a total of 4 ounces.

10 TO 14 DAYS AFTER FIRST SQUARE

Points

	-1	0	1	2
Moisture		fair	excellent	
Stalk height history	< 36 in.	36 to 44 in.	44 to 48 in.	> 48 in.
Square retention		>75%	<75%	
Prior Mequipat applied		> 3 oz	0 to 3 oz	
Height-to-node ratio	< 1.4	1.4 to 1.7	> 1.7	

If score is less than 3, do not apply.
If soil moisture is poor, do not apply.

EARLY BLOOM

Points

	-1	0	1	2
Moisture	fair	good	excellent	
Plant height	< 20 in.	20 to 24 in.	> 24 in.	> 48 in.
Fruit retention		> 75%	50 to 75%	< 50%
Prior Mepiquat applied	> 8 oz	5 to 8 oz	3 to 5 oz	none
Date of first bloom		before July 10	July 10 to 20	after July 20

If NAWB is less than 7, do not apply.
If score is less than 3, do not apply.
If soil moisture is poor, do not apply.

10 TO 14 DAYS AFTER EARLY BLOOM

Points

	-1	0	1	2	4
Moisture	fair	good	excellent		
NAWB	5 or less	5 to 6	6 to 7	7 to 8	above 8
Fruit retention		> 75%	< 75%		< 30%
Prior Mepiquat applied		> 12 oz	8 to 12 oz	0 to 8 oz	
Internode length*	< 1.5 in.	1.5 to 2 oz	> 2 in.		

If NAWB is less than 5.5, do not apply.
If score is less than 3, do not apply.
If soil moisture is poor, do not apply.
*The largest of the internodes below the third and fourth mainstem leaf.

table for the stage of growth. Total the points to determine Mepiquat rates. For example, using Table 8-1 at first square, if you had excellent moisture, a stalk height history of 50 inches, first square on June 20, and a short variety, you would accumulate 1, 2, 1, and 0 points. This would total 4 points. The total number of points equals the number of ounces of Mepiquat that should be applied. In our example, the producer would apply 4 ounces.

III. Modified Early Bloom Strategy

Many producers have a difficult time treating their entire acreage in a timely manner using the early bloom strategy due to large acreage, lack of equipment, or wet weather. This often results in applications made too late to successfully control plant size and influence earliness. These producers may wish to use the modified early bloom approach on at least a portion of their acreage. This approach involves possible treatments 10 to 14 days before early bloom (10 to 14 days after first square), at early bloom, and 10 to 14 days after early bloom. The last application is seldom necessary if this approach is used successfully. Table 8-2 presents guidelines for its use.

Note in the charts that the internode length that triggers Mepiquat application is 2.5 inches on the first two potential applications. On irrigated cotton or cotton on extremely productive soils, one may want to be less conservative and use 2 or 2.25 inches as the trigger.

Table 8-2. Determining Mepiquat Rates Using a Modified Early Bloom Approach

10 TO 14 DAYS AFTER FIRST SQUARE			
	Plant Height		
	< 17 in.	17 to 20 in.	> 20 in.
Height-to-node ratio >1.85	4 oz	6 oz	8 oz
Internode >2.5 in.*	4 oz	6 oz	8 oz

If soil moisture is poor, do not apply.
*The largest of the internodes below the third and fourth mainstem leaf.

EARLY BLOOM — *if Mepiquat has already been applied*				
	Plant Height			
	<24 in.	24 to 27 in.	27 to 30 in.	>30 in.
Plant height >24 in.	0 oz	6 oz	9 oz	12 oz
Internode >2.5 in.*	6 oz	6 oz	9 oz	12 oz

If soil moisture is poor, do not apply.
If NAWB is <7, do not apply.
*The largest of the internodes below the third and fourth mainstem leaf.

Table 8-2. continued

EARLY BLOOM — if Mepiquat has NOT been applied				
	Plant Height			
	<24 in.	24 to 27 in.	27 to 30 in.	>30 in.
Plant height >24 in.	0 oz	8 oz	12 oz	16 oz
Internode >2.5 in.*	8 oz	8 oz	12 oz	16 oz

Do not apply if soil moisture is poor.
Do not apply if NAWB <7.
*The largest of the internodes below the third and fourth mainstem leaf.

10 TO 14 DAYS AFTER EARLY BLOOM		
Mepiquat applied at early bloom		
	>8 oz	0 to 8 oz
Internode <2.5 in.*	0 oz	0 oz
Internode 2.5 to 3.5 in.	8 oz	12 oz
Internode >3.5 in.	12 oz	16 oz

If soil moisture is poor, do not apply.
If NAWB is <5.5, do not apply.
*The largest of the internodes below the third and fourth mainstem leaf.

9. DISEASE MANAGEMENT IN COTTON

Steve Koenning
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Cotton diseases are caused by organisms such as fungi, nematodes, and bacteria that grow on and within plant tissues. They often result in stunting of the plants, poor color, reduced vigor and yields, and sometimes death. Seeds and seedlings attacked by these pathogens often die, while older plants often survive but perform poorly. Diseases also can result from an inhospitable environment, such as a field with too much or too little water or fertilizer, or from air pollutants, temperatures unfavorable for plant growth, or chemical injury, such as herbicide carryover. Diseases caused by organisms are contagious (will spread from plant to plant) and usually affect only one plant species, whereas diseases caused by environmental factors produce symptoms on all plants in the affected area but will not spread from plant to plant.

Plants are more prone to attack by pathogens when stressed by an inhospitable environment, insects, or other causes. As a result, contagious diseases are often associated with insect infestations and poor growing conditions. For example, wet, cold soils often lead to fungal rotting of seeds and seedlings; insect injury to bolls increases the chance of fungal boll rots.

This chapter discusses cotton diseases that affect seeds, seedlings, and mature plant roots. Emphasis is placed on fungi and nematodes, the two most important pathogen groups on cotton. Injury to plants caused by fertilizer, herbicides, or environmental problems is covered in other chapters of this publication.

Seed and Seedling Diseases

Seedling diseases cause an estimated average annual yield loss of 5 percent and are usually the major disease problems in cotton production in North Carolina. Several soil-borne fungi are responsible; however, cultural and environmental factors that delay seed germination and seedling growth make the problem more severe.

Environmental Factors and Seedling Disease Control

Seedling disease occurs more frequently under cool, wet conditions. Environmental factors are very important in influencing the development of seedling diseases (Table 9-1). Other factors, such as planting depth, poor seedbed conditions, compacted soil, nematode or insect infestations, and misapplication of soil-applied herbicides such as dinitroanalines, may increase the problem. Seedling diseases tend to be more severe in reduced tillage situations and when beds are absent. Planting on beds elevates the seed, allowing

for more rapid emergence, especially after heavy rains. Plants are more prone to attack by pathogens when stressed by insects or other causes. As a result, contagious diseases are often associated with insect infestations and poor growing conditions. Damage from thrips in particular can delay seedling development and enhance damping-off diseases caused by various fungi.

Table 9-1. Point System for Determining the Need for In-Furrow Fungicides

Factor	When Does It Matter	Points
Soil temperature	<65^{0}F	75
5-day forecast	Colder and wetter	50
Seed quality	Cold germination <59^0	75
Field history	Severe disease	100
Tillage	Minimum tillage	50
Row preparation	Beds absent	75
Seeding rate	Less than 3 to 4 per ft of row	100
Poorly drained soil	-	50
TOTAL		

If total exceeds 200, consider using an in-furrow fungicide.

**This point system is only a guide as to the probability of cotton seed benefitting from an application of an in-furrow fungicide.*

Fungi Causing Seedling Diseases

Several species of fungi can cause seedling disease, but the primary agents are *Pythium* spp., *Rhizoctonia solani*, *Phoma exigua* (*Ascochyta*), and *Fusarium* spp. These disease-causing organisms can attack the seed before or at germination. Plant-parasitic nematodes will generally enhance the ability of these fungi to cause disease. The fungi also can attack the young seedling before or after emergence. Symptoms include seed decay, decay of the seedling before emergence, partial or complete girdling of the emerged seedling stems, and seedling root rot. Seed and seedling disease is characterized by a soft, watery rot. Damaged seedlings that emerge are pale, stunted, slower growing, and sometimes die within a few days. Examination of infected seedlings may reveal dark lesions on the stem and root. Often the taproot is destroyed, and only shallow-growing lateral roots remain to support the plant. The "sore shin" phase of seedling disease is characterized by reddish-brown, sunken lesions at or below ground level. These lesions enlarge, girdle the stem, and cause it to shrivel. Seedling diseases do not usually kill the entire seedling population, but rather result in uneven, slow-growing stands with skips in the rows. In some years, replanting is necessary. Poor stand establishment causes problems with the management of other pests and may reduce yields.

The most common fungi associated with seedling diseases in North Carolina are *Pythium* spp. and *Rhizoctonia solani*. Often both fungi can be found on the same seedling. The same fungus may cause seed decay, seedling root rot, or both. However, *Pythium* spp. and *Fusarium* spp. usually attack the seed and below-ground parts of young seedlings, while

R. solani usually causes sore shin. *R. solani* and *P. exigua* may attack seedlings from the time they emerge until they are about 6 inches tall. After this stage, the stem becomes woody, and subsequent infection rarely occurs unless the stem is injured.

Pythium spp. Several species of fungi in the genus *Pythium* can cause seedling disease in cotton as well as several other crops. *Pythium* spp. are generally classified as water molds, producing spores that move actively in soil water. In general, *Pythium* is commonly the culprit if the soil has remained saturated for several days or is poorly drained. Mefenoxam (Ridomil Gold) or etridiazole (ETMT, Terrazol) is necessary to control *Pythium* spp. seedling disease.

Rhizoctonia solani. This fungus typically causes sore shin and is more common on sandy, well-drained soils. Plants injured by sand blasting are particularly susceptible to this pathogen. Fungicides containing PCNB (Terrachlor), iprodione (Rovral), azoxystrobin (Quadris), or pyraclostrobin (Headline) are generally effective against *Rhizoctonia solani*.

Phoma exigua (*Ascochyta gossypii*). This fungus can cause postemergence damping-off. This disease is characterized by premature dying of cotyledons, which turn brown and shrivel; and it has been observed when night temperatures fall into the 50s and are accompanied by foggy or misty conditions (see also *Plant Pathology Cotton Information Note No. 2*). Fungicide effectiveness against *P. exigua* has not been evaluated.

Fusarium spp. Various species of the fungal genus *Fusarium* are typically found on diseased cotton seedlings. Seed-applied fungicides are generally effective in managing it.

Seedling Disease Management

A control program for seed and seedling diseases is based on preventive rather than remedial treatments. The program uses fungicides along with cultural practices to make conditions more favorable for the young cotton and less favorable for the disease-causing organisms. Poor-quality seed with low germination potential should be avoided. For additional information see http://www.ces.ncsu.edu/depts/pp/notes/Cotton/cdin1/cdin1.htm.

Seed Treatment. All cotton seed offered for sale in North Carolina are treated with fungicides. Systemic fungicides provide temporary protection from certain types of preemergence and postemergence damping-off. Several relatively new products are now available for cotton nematode control. These include Avicta's complete pack system from Syngenta, which also has the insecticide Cruiser for thrips control and additional fungicide treatments on the seed, and Aeris with Poncho/Votivo, which has an an option to add Gaucho Grande for thrips

control and additional fungicides if desired by the producer. Avicta complete pack has abamectin (a nematicide used for treatment of heartworm in dogs), and Aeris has thiodicarb (Larvin), which acts as a nematicide.

In most years, seed treatment fungicides are sufficient for controlling seedling disease, unless the quality of the seed is low or weather conditions are unfavorable for germination.

Table 9-3. Probability of Nematode Damage to Cotton

	Numbers of Nematodes per Pint of Soil (fall count)		
Nematode	**Slight**	**Moderate**	**High**
Root-knot nematode	0-749	750-1,499	1,500+
Stubby-root nematode	0-299	300-499	500+
Sting nematode	0*	0*	10+
Lance nematodes:			
common	0-999	1,000+	
Columbia	0-99	100-499	500+
Reniform nematode	0-999	1,000-1,999	2,000+

Reduced Tillage. The recent trend to reduced or no-till cotton has resulted in an increase in the frequency and severity of seedling diseases. The lack of a raised bed, inadequate seed bed preparation, and additional crop residue associated with reduced tillage all contribute to delays in emergence and stand establishment. The use of an in-furrow fungicide should be considered in reduced tillage situations.

Rotation. Rotating cotton with other crops helps prevent buildup of some cotton diseases. Continuous cropping to one host crop usually causes an increase in disease. *Rhizoctonia solani*, for example, can grow on dead plant remains and later infect nearby seeds, roots, or stems of susceptible hosts.

Other. Proper fertilization and liming promote early growth, which gets the seedling to a resistant stage sooner. Early cutting and shredding of stalks aid in the control of seedling disease by reducing the amount of inoculum that carries over from year to year. Also, it is important to prepare a good seed bed to control seedling disease. Raised beds give some control of seedling disease, especially in early planted cotton. Avoid planting when soil temperatures are below 65°F. Below this temperature, germination is slow, and the seed and seedlings are more vulnerable to infection.

Boll Rot

Boll rot is generally a problem when excessive insect damage or excessively wet conditions exist. Boll rot typically starts with small brown lesions that expand until the entire boll becomes blackened and dry. Chapter 11, "Managing Insects on Cotton," and Chapter 2, "The Cotton Plant," explain how to reduce insect damage and lower humidity in the canopy (by preventing rank growth) to reduce boll-rot problems.

Leaf Spots. Cotton leaves often get small, brown, circular lesions that enlarge to approximately ½ inch. Old lesions sometimes develop gray centers, which may fall out. Leaf-spot diseases are typically of minor importance, and specific controls are not recommended. These lesions often are not a disease at all but rather phytotoxicity symptoms caused by a variety of crop protection chemicals. Leaf spots may be minimized by using the proper amounts of fertilizer and adequate drainage and by minimizing rank vine

growth, which can promote excessively high humidity in the crop canopy.

Cotton Stem Canker. Numerous fields in the northeastern portion of the state and in Virginia were affected by cotton stem canker in 1999. This was caused by the fungus *Phoma exigua* (often referred to as *Ascochyta*). This fungus typically causes a leaf spot in North Carolina during wet years. Unseasonably cool weather in June was largely responsible for the outbreak of this disease. All varieties of cotton were apparently susceptible. Rotation and cultural practices did not have an impact on the severity of the disease. No fungicides are currently labeled for foliar application on cotton in the southeastern United States. Hot, dry weather prevented further development of the disease, although stands in many fields were reduced and cotton maturity was delayed in some instances. For additional information, see http://www.ces.ncsu.edu/depts/pp/notes/Cotton/cdin2/cdin2.htm.

Nematodes

Nematodes are microscopic worms that feed on or in plant roots, robbing them of nutrients and causing injury. Nematodes occur in damaging levels in approximately 5 percent of the cotton fields of the state (Table 9-3). But problems are more common and severe in the southeastern counties, where as many as 50 percent of the fields may be infested with damaging levels of nematodes. This high level of infestation is probably due to intensive cotton production (short or no rotation) and the lack of resistant varieties. Table 9-3 lists the plant-parasitic nematodes that damage cotton and the current economic thresholds. More information on nematodes on cotton is available on the Web at http://www.cotton.org/cf/nematodes/region.cfm.

Nematode problems are most common in coarse-textured soils, although the reniform nematode is often a problem on heavier land. Damage caused by nematodes limits water and nutrient uptake and makes the root system more susceptible to other diseases. Symptoms can include increased seedling disease (root-knot and reniform nematodes), stunting, lower yield, poor stands, loss of green color, root galling (root-knot), stunted roots (sting and Columbia lance nematodes), and various nutrient deficiency symptoms. In some cases, there can be yield reduction without visible symptoms above ground. Forexample, reniform nematodes may cause 5 to 15 percent suppression in cotton lint yield in apparently healthy cotton fields. Yield losses caused by nematodes often result from abortion or dropping of bolls because of nematode-induced nutrient or water stress.

It is thought that the northeastern portion of the state has no significant nematode problems due to extensive rotations of cotton with peanuts. However, soil samples with damaging levels of root-knot nematodes after cotton have increased significantly in all areas of North Carolina in recent years. Growers should monitor nematodes through soil sampling when cotton is grown without rotation or in rotation with other crops susceptible to the southern root-knot nematode, such as most vegetable crops, some soybean varieties, tobacco, corn, or cucumbers. The southern portion of the state has historicallyexperienced nematode damage, and other areas can expect similar problems if cotton production continues to intensify.

Information from North Carolina State University surveys and from the NCDA&CS Nematode Advisory Service provides a fairly accurate assessment of nematode infestations across the state. During 1990, approximately 35 percent and 47 percent of fields surveyed in Cumberland and Scotland counties, respectively, were infested with reniform nematodes. This nematode also has been detected in Harnett, Hoke, Richmond, Johnston, Robeson, and Sampson counties in past surveys. Columbia lance nematodes have been detected in fifteen counties, including Bladen, Brunswick, Columbus, Craven, Cumberland, Duplin, Hoke, Jones, Lenoir, New Hanover, Onslow, Pender, Richmond, Robeson, and Scotland. The highest infestations were in Scotland (83 percent), Robeson (43 percent), and Cumberland (35 percent). As expected, root-knot nematodes were found in all counties and in most of the fields. experienced nematode damage, and other areas can expect similar problems if cotton production continues to intensify.

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Sampling for Nematodes

The kinds and numbers of nematodes in fields can be determined through a soil sample. Soil samples collected in the fall (September through November), when nematode numbers are highest, provide the best information, although samples can be collected anytime. The general procedure for collecting a soil sample for a nematode assay is outlined in the pamphlet *A Nematode Diagnostic and Advisory Service for North Carolina*, available from your county Extension agent. Briefly, it suggests that a soil sample represent no more than four to five acres that have been farmed uniformly, and that at least 20 probes of soil be obtained from the top 6 to 8 inches of soil using a soil probe approximately 1 inch in diameter. Thoroughly mix the collected soil in a bucket, place a 1-pint sample in a plastic bag, and take it to your county Extension agent. Include $3 for processing. Samples will be forwarded to the NCDA&CS Nematode Advisory Service, where nematodes are separated from the soil and counted. Numbers reported to you and your county Extension agent represent the number of nematodes per pint (500 cc) of soil. Make sure to carefully fill out the form that accompanies your sample.

Crop rotation is used to aid the Nematode Advisory Service in interpreting the importance of nematodes found. For example, there are four common species of root-knot nematodes found in North Carolina, but only one species (southern root-knot, *Meloidogyne incognita*) is a parasite on cotton.

Nematode Control Strategies

Cultural Practices and Varieties. Cotton nematode control is accomplished through crop rotation, resistance, and nematicides. Some varieties have shown extreme susceptibility to Columbia lance nematode and should be avoided in heavily infested fields. Long-season cotton varieties generally perform better than short-season ones when Columbia lance nematode is present. For example, Stoneville 4892BR, Stoneville 5599BR, and Fibermax FM989BR appear to be relatively tolerant to this nematode.

Nematode control is best accomplished by preventing the buildup of harmful numbers of these parasites through rotation to crops that do not support their reproduction (Table 9-4). Subsoiling can help reduce losses due to Columbia lance and other nematodes in areas where a hardpan is common. Destroying cotton roots after harvest will help reduce nematode survival in general since cotton is basically a perennial plant and some reproduction may occur after cotton harvest if soil temperatures remain warm. Some weeds also serve as hosts for nematodes and should be controlled in cotton and rotational crops.

Cover crops like rye or wheat may aid in suppression of reniform and Columbia lance nematodes. Rye and wheat, however, are fair hosts for root-knot, Columbia lance, sting, and stubby-root nematodes. Cover crops should be planted as late in the fall as possible and either killed or tilled under in the spring before soil temperatures increase above 55°F to prevent nematode reproduction.

Table 9-4. Resistance of Cotton Varieties to Root-Knot Nematodes[1]

Resistance Level	*Variety*
Very Susceptible	Febermas 989BR
Susceptible	Deltipine 451BRR Deltapine 569ORR
Moderately resistant	Deltapine 451BRR Stoneville ST5599BR

[1] Resistance ratings are based on information supplied by companies and limited field testing.

Table 9-5 Suitability of Various Crops for Reducing Cotton Nematode

	Rotational Crop	
Nematode	**Good Choice**	**Bad Choice**
Southern root-knot	Sorghum Grasses Grain Alfalfa Peanuts Soybeans (resistant)	Cotton Corn Soybeans (susceptible)
Lesion	Grain Corn Peanuts	Cotton Soybeans
Sting	Watermelons Clover Alfalfa Grain Tobacco	Cotton Corn Soybeans Peanuts
Columbia lance	Grasses Peanuts Tobacco Small Grain Milo	Sorghum Soybeans Cotton Cantaloupes Corn
Reniform	Grasses Corn Peanuts Small Grain Sorghum Mustard Turnips Peppers Soybeans (resistant	Soybeans (susceptible) Cotton Cantaloupes Sweetpotatoes Tobacco Cucumbers

[1] *Except for white clover*
[2] *Reniform-resistant varieties include Anand, Asgrow A4702RR, Centennial, Coler 6847, Delsoy 5710, Delta Grow 4710, Deltapine 726, Delatpine 7375RR, Fowler, Hartz 7190, Maxcy, Syngenta NK S53-07, Deltapine 5644,*

Table 9-6. Nematicides for Control of Cotton Nematodes

Nematicide	Amount/acre	Precautions/Remarks
Aeris		Seed treatment
AVICTA Complete Pack	—	Seed treatment.
Aldicarb (Temik) 15G	5 to 7 lb	Apply in-furrow.
Aldicarb (Temik) 15G	10-14 lb	Incorporate in a 6-inch band.
1,3-dichloropropene (Telone II) + Aldicarb (Temik) 15G	1.5 to 6 gal + 3.50 lb	Inject Telone 1 to 2 weeks before planting 8 to 12 inches deep. Apply Temik in-furrow at planting.
Aldicarb (Temik) 15G + Vydate C-LV[1]	5 to 7 lb + 8.5 to 17 fl oz	Apply Temik in-furrow at planting. Broadcast Vydate at 2nd to 5th trueleaf stage.
Metam-sodium (Vapam) + Aldicarb (Temik) 15G	3 to 12 gal + 3.5 lb	Inject Vapam 2 to 3 weeks before planting 8 to 12 inches deep. Apply Temik in-furrow at planting.

[1] *Vydate for root-knot and reniform nematode only.*

10. WEED MANAGEMENT IN COTTON

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WNR Professor Emeritus

Effective weed management is one of many critical components of successful cotton production. Cotton requires better weed control than either corn or soybeans. Because cotton does not compete well with weeds, especially early in the season, a given number of weeds will reduce cotton yield more than corn or soybean yield. Weeds also may interfere more with harvesting of cotton, and they can reduce lint quality because of trash or possibly stain.

Crop Rotation

Crop rotation aids in the management of nematodes and diseases. Additionally, it can be a significant component of a weed management program. Crop rotation allows the use of different herbicides on the same field in different years. By rotating cotton with other crops and selecting a herbicide program for the rotational crop that effectively controls the weeds that are difficult to control in cotton, one can reduce or prevent the buildup of problem weeds and help keep the overall weed population at lower levels. **Crop rotation and properly planned herbicide rotation are also critical components of a herbicide resistance management strategy.** See the section on *Herbicide Resistance Management.*

When selecting a herbicide program for crops that will precede cotton, consider rotational restrictions for the various products. This information can be found on herbicide labels. Many of the commonly used herbicides for corn, peanuts, sorghum, soybeans, and tobacco do not carry over to cotton. However, labels for products listed below contain significant rotational restrictions for cotton. Similarly, cotton herbicides, such as diuron, fluometuron, prometryn, prometryn + trifloxysulfuron, pyrithiobac, and trifloxysulfuron have rotational restrictions for other crops. See Table 10-1 for brand names.

Active ingredient	Products containing active ingredient
chlorsulfuron	Finesse
diclosulam[1]	Strongarm[1]
imazaquin	Scepter
imazapic	Cadre, Impose, Nufarm Imazapic
imazethapyr	Authority Assist, Extreme, Matador, Optill, Pursuit, Tackle, Thunder, Thunder Master
sulfentrazone	Authority Assist, Authority First, Authority Maxx, Authority MTZ, Authority XL, Sonic, Spartan, Spartan Charge
[1] Rotational restrictions apply only to Camden, Currituck, Pasquotank, and Perquimans counties.	

Planning a Herbicide Program

Before selecting one or more herbicides, you should know what weeds are present or expected to appear, the soil characteristics (such as texture and organic matter content), the capabilities and limitations of the various herbicides, and how best to apply them.

Weed Mapping

The first step in a weed management program is to identify the problem. This is best accomplished by weed mapping. Survey the fields each fall and record on a field map or another suitable place the species present and the general population levels. Species present in the fall will likely be the predominant problems during the following year. You can better plan a herbicide program if you know ahead of time what species to expect. Additionally, by referring to weed maps over a period of two or three years, you can detect shifts in the weed populations and make adjustments in the herbicide program to deal with changes that occur.

In-Season Monitoring

During the first eight weeks after planting, check fields at least weekly to determine the need for postemergence herbicides. After eight weeks, check fields periodically to evaluate the success of the weed management program and to determine the need for preharvest control measures. If weeds are controlled for the first eight to ten weeks, any later emerging weeds will seldom become problems.

Proper weed identification is necessary because different weed species respond differently to various herbicides. Contact your local Extension center for aid in weed identification.

Application rates for soil-applied herbicides depend on soil texture and organic matter content. Failure to adjust application rates for these soil characteristics may result in poor weed control or crop injury.

Before using any herbicide, learn the capabilities and limitations of the various products labeled for cotton, how best to apply them, what weeds they will and will not control, and any special considerations, such as rotational restrictions.

Burndown in No-Till or Strip-Till Cotton

Cover crops (or heavy stands of winter weeds) should be killed at least two to three weeks before planting. This will avoid soil moisture depletion by the cover crop or weeds, allow the soil to warm quicker, reduce cutworm problems, and allow time to apply additional burndown herbicide, if needed, to kill streaks that may have been missed during the original application. Heavy residue from a cover crop will help suppress weeds, but growers should consider their equipment capabilities for planting into residue in deciding when to terminate a cover crop. One can kill a strip over the row early and allow the cover crop in the row middles to continue to grow. Recommended burndown herbicides and application rates for small grain cover crops are outlined in Table 10-2.

If no-tilling or strip-tilling into natural cover (i.e., winter weeds), the need for an early burndown treatment will depend on the weed species present and the size of the weeds. An early burndown is normally advantageous, especially if ryegrass, cutleaf eveningprimrose, wild mustard, wild radish, curly dock, or glyphosate-resistant horseweed is present. For recommendations on the burndown of natural cover, see Table 10-3.

Growers are strongly encouraged to incorporate 2,4-D or dicamba into their no-till or strip-till management programs. Several species, including cutleaf eveningprimrose, common eveningprimrose, curly dock, field pansy, vetch, and larger wild radish, are not adequately controlled by glyphosate alone. Additionally, glyphosate-resistant horseweed is now very common in eastern North Carolina. See the discussion on glyphosate-resistant horseweed in the section *Herbicide Resistance Management*. There are waiting intervals between application of 2,4-D or dicamba and cotton planting; see details in Table 10-2. The ideal time to apply 2,4-D or dicamba is early March. Suggested rates of 2,4-D vary by species. For cutleaf eveningprimrose, 6 to 8 fluid ounces of a typical 3.8 pound per gallon 2,4-D formulation are adequate. Use one pint for other weeds, and two pints for resistant horseweed. A residual herbicide, such as flumioxazin, is also recommended in the mixture for control of glyphosate-resistant horseweed and glyphosate-resistant Palmer amaranth. Management programs for these weeds are discussed in the section *Herbicide Resistance Management*. In addition to the burndown herbicide applied two to three weeks or more before planting, one normally needs to apply glyphosate or paraquat at planting to kill any weeds emerging after the earlier burndown application.

A two-step burndown program may be a consideration in fields with a history of heavy winter weed infestations and where one will be planting into the previous crop's stubble. Thifensulfuron plus rimsulfuron premix (see Table 10-1) plus glyphosate can be applied in late fall or early winter. Thifensulfuron plus rimsulfuron added to glyphosate will improve control of henbit and wild radish as compared to glyphosate alone. If horseweed or cutleaf eveningprimrose is emerged, also include 2,4-D or dicamba. Thifensulfuron plus rimsulfuron will provide residual control of later-emerging winter weeds, including horseweed. This late fall or early winter application will then be followed by a second burndown containing flumioxazin 3 to 4 weeks ahead of planting. Flumioxazin, in this case, is recommended to aid in control of Palmer amaranth. If the thifensulfuron plus rimsulfuron controls weeds as expected, 2,4-D or dicamba may not be needed in this second burndown application.

Weed Management in Roundup Ready Flex Cotton

Comparing Glyphosate Brands

A number of brand names and formulations of glyphosate are available. Most currently available products are formulated as isopropylamine salts or potassium salts, although a few products are formulated as dimethylamine salts or as mixtures of ammonium salt and potassium salt. Products vary in their concentration of active ingredient. Labels for some brands direct the user to add nonionic surfactant. Other brands are "loaded formulations", meaning additional surfactant is not necessary in most cases. Read the label of the brand you use to determine the need for surfactant.

The best way to compare various glyphosate products and application rates is on the basis of acid equivalence (a.e.). See Table 10-8 for assistance in determining the rate of formulated product that gives the desired rate in pounds a.e.

Timing of Application

Brands of glyphosate with specific labeling for Roundup Ready Flex cotton may be applied overtop or directed any time from cotton emergence until seven days prior to harvest. The maximum rate for any single application between crop emergence and the 60 percent open boll stage is 1.125 pounds a.e. (see Table 10-8 for assistance in determining rates of formulated product). A total of 4.5 pounds a.e. can be applied during this time frame. Hence, depending upon application rate, four to six applications can be made overtop or directed. An additional 1.55 pounds a.e. can be applied from the 60 percent open boll stage until seven days prior to harvest. Although labeling allows numerous applications of glyphosate, growers should not overly rely on glyphosate. See the section on *Herbicide Resistance Management*.

Need for Soil-Applied Herbicides

Weed resistance to glyphosate is a serious problem (see section on *Herbicide Resistance Management*). A key component of a resistance management strategy is to utilize

multiple herbicide modes of action. Use of preplant and/or preemergence residual herbicides in Roundup Ready Flex cotton is strongly encouraged. These herbicides will not only aid in resistance management but also make timing of the first glyphosate application much less critical.

Should replanting be necessary where preemergence herbicides have been used, it is best to run the planter back in the original drill without any soil preparation if soil conditions permit. In this case, do not apply any additional residual herbicides. If weeds have emerged, glyphosate or paraquat can be applied for burndown. Paraquat will also control emerged cotton from the first planting.

If reworking the seedbed is necessary, use shallow tillage such as light disking. Do not apply additional preplant-incorporated herbicide. If the original preemergence herbicide was broadcast, do not apply any more. If the preemergence herbicide was originally banded, a second preemergence banded application at the minimum rate for the soil type would be in order.

Do not rebed without first disking. Rebedding without disking can lead to severe crop injury.

Tank Mixes with Glyphosate Applied Overtop

Pyrithiobac (Pyrimax or Staple LX) can be mixed with glyphosate and applied overtop of Roundup Ready Flex cotton from the cotyledonary stage until 60 days prior to harvest. Pyrithiobac rates in a glyphosate tank mix range from 1.3 to 3.8 fluid ounces.

A mixture of glyphosate plus pyrithiobac will improve control of hemp sesbania, morningglory (except tall morningglory), spreading dayflower, and glyphosate-resistant Palmer amaranth (assuming it is not also ALS-resistant) as compared with glyphosate alone. Pyrithiobac also may give residual control of susceptible weeds, such as pigweed species, spurred anoda, and velvetleaf. Palmer amaranth resistant to pyrithiobac and other ALS inhibitors is very common in North Carolina.

Compared with glyphosate alone, a mixture of glyphosate plus pyrithiobac may injure cotton. Applied overtop, pyrithiobac often causes temporary yellowing of the cotton bud. Research has demonstrated that cotton recovers quickly, and there is seldom an adverse effect on yield or maturity. On occasion, however, pyrithiobac applied overtop can cause moderate to severe injury. The potential for significant injury from pyrithiobac appears to be greater when the herbicide is applied during or shortly before a period of cool temperatures. In addition to cool temperatures, other stresses such as wet weather, seedling disease, or thrips damage may worsen injury. Slower recovery from pyrithiobac injury has particularly been noted on cotton infested with thrips. Sufficient research to verify the impact of this level of injury on yield and maturity has not been conducted. Visually, the cotton appears to recover when favorable weather returns.

Trifloxysulfuron (Envoke) can be mixed with certain brands of glyphosate and applied overtop of Roundup Ready Flex cotton from the 5-leaf to 12-leaf stage. The mixture may cause some yellowing in the cotton terminal and shortening of internodes. Less response is typically observed on larger cotton. Compared to the glyphosate products alone, the mixture will give greater control of nutsedge, morningglory, and smartweed.

S-metolachlor (Brawl, Dual Magnum, Medal) can be applied overtop of cotton that is at least 3 inches tall until 100 days prior to harvest. Crop injury from a mixture of glyphosate plus S-metolachlor overtop is typically minor, with only necrotic speckling noted on leaves exposed to the spray. This injury is temporary; no speckling on later-emerging leaves, no stunting, and no adverse effect on yield or maturity have been noted. The exception has been when additional adjuvants or insecticides are included in the mixture. In some cases, severe injury has been observed when adjuvants or insecticides were included in the mixture. Injury will also be greater if S-metolachlor is applied when dew is on the cotton or when the weather is extremely hot and humid.

Mixing S-metolachlor with glyphosate will have little to no effect on control of emerged weeds by glyphosate. However, if timely rainfall for activation is received, S-metolachlor in the mixture can provide residual control of most annual grasses (only suppression of Texas panicum), pigweed species (including Palmer amaranth), and doveweed, and suppression of yellow nutsedge and spreading dayflower. S-metolachlor mixed with glyphosate may also broaden the window of application for directed herbicides on pigweed species, including Palmer amaranth.

Both metolachlor and S-metolachlor are available. Growers should be aware that metolachlor is less effective than S-metolachlor. Metolachlor is a mixture of four stereoisomers. Two of the isomers (referred to as S-metolachlor) are herbicidally active, whereas the other two isomers (referred to as R-metolachlor) have little herbicidal activity. Check the ingredient statement on the label before buying. Products whose labels designate S-metolachlor contain primarily the active isomers. Labels for products containing metolachlor specify the same rate of formulated product per acre as those containing S-metolachlor, hence growers are getting less of the active form of the herbicide when using metolachlor products. One would have to increase the rate of a metolachlor product by 50 percent to get the same activity as a product containing S-metolachlor.

Labels advise growers to not mix S-metolachlor or metolachlor products with pyrithiobac.

A prepackaged mixture of the potassium salt of glyphosate plus S-metolachlor (Sequence) is available. Applied at 2.5 pints per acre, this premix is equivalent to 0.7 pound a.e. of glyphosate plus 1 pint of S-metolachlor.

Acetochlor (Warrant) can be used in a manner similar to S-metolachlor. Acetochlor plus glyphosate can be applied after cotton is completely emerged but before first bloom. Weed control and crop tolerance is similar to that with S-metolachlor. Acetochlor does

not control emerged weeds. Best results will be obtained, especially on Palmer amaranth, if acetochlor plus glyphosate is applied to 1- to 2-leaf cotton before Palmer amaranth emerges. A second application can be made. Do not tank mix acetochlor with pyrithiobac.

Pendimethalin (only the brand Prowl H2O) can be mixed with glyphosate and applied overtop to Roundup Ready Flex cotton in the 4- to 8-leaf stage. Do not include insecticides or other herbicides in this mixture. Do not use EC formulations of pendimethalin. Similar to acetochlor or S-metolachlor, Prowl H2O is not effective on emerged weeds. Crop tolerance is typically good, with only minor leaf distortion noted as leaves in the bud at the time of application grow out. Pendimethalin requires more rainfall for activation than does either acetochlor or S-metolachlor. Pendimethalin is effective on most annual grasses (see preemergence response in Table 10-4) but is less effective than acetochlor or S-metolachlor on pigweed species, including Palmer amaranth.

Clethodim, fluazifop, quizaqlofop, and sethoxydim (See Table 10-1 for brands) can be mixed with glyphosate applied to Roundup Ready Flex cotton to control volunteer Roundup Ready corn.

Tank Mixes with Glyphosate Directed

In many cases, growers may wish to tank-mix another herbicide with glyphosate postemergence-directed to improve control of certain species or to provide some residual control. Tank mixes are also recommended as part of a resistance management program (see section on *Herbicide Resistance Management*). Potential tank-mix partners with glyphosate applied postemergence-directed include acetochlor, carfentrazone, diuron, flumioxazin, prometryn, prometryn plus trifloxysulfuron, pyrithiobac, S-metolachlor, and trifloxysulfuron.

Carfentrazone (Aim) is very effective on morningglory, and carfentrazone mixed with glyphosate will improve control of larger morningglory compared to glyphosate alone. Cotton should be at least 16 inches tall, and the spray must be directed precisely to the woody portion of the stem. Spray contact with green stem tissue will cause injury. This combination does not provide residual control.

Diuron or prometryn mixed with glyphosate will improve control of larger morningglory compared to glyphosate alone. Products containing diuron applied at 1.5 pints or products containing prometryn applied at 2 pints will provide some residual control of small-seeded broadleaf weeds, such as pigweed, if an activating rainfall is received. Diuron is generally more effective on pigweed, including Palmer amaranth, than prometryn. Cotton should be at least 12 inches tall before directing diuron or prometryn at these rates. Occasionally, mixing diuron or prometryn with glyphosate will reduce grass control by glyphosate or at least delay death of the grasses. This is most likely to occur under dry growing conditions when grasses are large. Do not reduce the glyphosate rate when tank-mixing. See Table 10-1 for brands containing diuron or prometryn.

Prometryn plus trifloxysulfuron (Suprend) mixed with glyphosate will improve control of larger morningglory and nutsedge. It also will provide residual control of susceptible broadleaf weeds. Cotton should be at least 6 inches tall when directing prometryn plus trifloxysulfuron.

Flumioxazin (Outflank, Panther, Valor SX) mixed with glyphosate will improve control of doveweed, Florida pusley, and larger morningglory, compared to glyphosate alone. Cotton needs to be 16 inches tall, and the spray should be allowed to contact only the bottom 1 to 2 inches of the cotton stem. Flumioxazin will provide residual control of susceptible broadleaf weeds, such as pigweed, lambsquarters, and eclipta.

Pyrithiobac (Pyrimax or Staple LX) mixed with glyphosate will improve control of hemp sesbania, morningglory (except tall morningglory), spreading dayflower, and glyphosate-resistant Palmer amaranth compared to glyphosate alone. Pyrithiobac can also provide residual control of susceptible species such as prickly sida, pigweed species, spurge, velvetleaf, and spurred anoda. Palmer amaranth resistant to pyrithiobac and other ALS inhibitors is very common in North Carolina.

Trifloxysulfuron (Envoke) mixed with glyphosate will improve control of nutsedge and larger morningglory compared to glyphosate alone. Cotton should be at least 6 inches tall. Trifloxysulfuron has residual activity on susceptible broadleaf weeds, including Palmer amaranth. Palmer amaranth resistant to trifloxysulfuron and other ALS inhibitors is common in North Carolina.

S-metolachlor (Brawl, Dual Magnum, Medal) mixed with glyphosate will not improve postemergence weed control compared to glyphosate alone. However, if S-metolachlor is activated by rainfall, it will provide residual control of annual grasses (Texas panicum/ Texas millet is only suppressed), pigweed species, and doveweed and suppression of yellow nutsedge and spreading dayflower. This combination can be directed to cotton that is at least 3 inches tall through layby.

Acetochlor (Warrant) can be mixed with glyphosate and directed to cotton up to first bloom. Warrant will not control emerged weeds, but if activated with timely rain, it will provide residual control of annual grasses and small-seeded broadleaf weeds, including Palmer amaranth.

Glyphosate vs. Other Directed Herbicides

On Roundup Ready Flex cotton, you have the option of directing either glyphosate or a traditional herbicide combination. Better broadleaf weed control is sometimes obtained when traditional directed herbicides are used. Additionally, there is often a benefit from the residual activity of traditional directed herbicides. However, if grasses are a predominant problem and they are larger than 1 to 1.5 inches, glyphosate may be the more effective option. Other herbicides may be mixed with directed glyphosate to

enhance broadleaf control if needed; see discussion under *Tank Mixes with Glyphosate Directed*. This will also help in resistance management. Alternatives to glyphosate for directed application are presented in Table 10-2 under the section on *Postemergence-Directed Herbicides – Any Variety*.

Difficult-to-Control Weeds in Roundup Ready Systems

Dayflower and Doveweed. Glyphosate will not control spreading dayflower or doveweed. Spreading dayflower can be controlled with pyrithiobac applied postemergence or with directed herbicide combinations containing MSMA (see Table 10-6). Pyrithiobac or postemergence- directed herbicides should be applied when spreading dayflower shoots are 3 inches long or less. MSMA at rates suitable for over-the-top application will not control it.

Less information is available on doveweed. S-metolachlor appears to control doveweed well if the herbicide is applied and activated before doveweed germination. Paraquat applied with a hooded sprayer is very effective on doveweed. And, directed applications of flumioxazin plus MSMA, flumioxazin plus glyphosate, and diuron plus glyphosate appear to be effective. Diuron plus MSMA does not adequately control doveweed.

Florida pusley. This weed, which is usually confined to very sandy fields, is very difficult to control with glyphosate. Glyphosate at 0.75 pound a.e. per acre will control it only if applied when the weed is very small (two leaves or less) and growing conditions are good; multiple applications are often necessary. One should consider using a preplant incorporated or preemergence herbicide in fields where this weed is expected (see Table 10-5).

Morningglory. One application of glyphosate may not adequately control morningglory. It will, however, halt growth of small morningglory so that the weed can be taken out with cultivation, a second application of glyphosate, or a later application of a conventional directed herbicide. For morningglory (except the species tall morningglory) 3 inches or larger, a tank mix of glyphosate plus pyrithiobac is more effective than glyphosate alone. Diuron, fluometuron, or pyrithiobac applied preemergence also will aid in control of morningglory. Trifloxysulfuron, discussed under *Postemergence-Overtop Herbicides – Any Variety*, is very effective on morningglory.

For layby application, conventional chemistries, such as MSMA plus diuron, diuron plus linuron, flumioxazin, lactofen, prometryn, and prometryn plus trifloxysulfuron will often be more effective on morningglory than glyphosate. However, if one chooses to use glyphosate, the addition of carfentrazone, diuron, diuron plus linuron, flumioxazin, prometryn, prometryn plus trifloxysulfuron, or trifloxysulfuron would be beneficial.

Hemp sesbania. Hemp sesbania is very difficult to control with glyphosate if the weed is beyond the first true leaf stage. Where heavy infestations of hemp sesbania are expected, a preemergence application of fluometuron should be considered. Follow with glyphosate plus pyrithiobac postemergence and then a postemergence-directed application of a

conventional herbicide combination. Combinations containing lactofen, trifloxysulfuron, or prometryn plus trifloxysulfuron would be good options for the directed application.

Volunteer Roundup Ready corn. Clethodim, fluazifop, quizalofop, or sethoxydim may be applied alone or mixed with glyphosate and applied overtop to control volunteer Roundup Ready corn in Roundup Ready cotton. See labels for these products concerning maximum corn size and use of adjuvants when applying alone or mixed with glyphosate.

Volunteer Roundup Ready soybean. Fluometuron applied preemergence may provide adequate control. Pyrithiobac alone typically does not adequately control volunteer soybean. However, pyrithiobac applied to three- to four-trifoliate soybean followed by a directed application of diuron plus MSMA, prometryn plus MSMA, or prometryn plus trifloxysulfuron plus MSMA may provide adequate control. The most effective option to control volunteer soybean is trifloxysulfuron applied overtop to soybean with less than six trifoliate leaves. Trifloxysulfuron may not control soybean that is taller than about 12 inches.

Nutsedge. Two applications of glyphosate at 0.75 pound a.e. per acre normally control yellow and purple nutsedge. Good results also have been obtained with glyphosate at 0.75 pound a.e. applied overtop, followed by a directed application of MSMA at 2.5 pints per acre or trifloxysulfuron at 0.15 ounce per acre. In severely infested fields, best results will be obtained with glyphosate plus trifloxysulfuron overtop or two overtop applications of glyphosate followed by a directed application of glyphosate, MSMA, trifloxysulfuron, or prometryn plus trifloxysulfuron. A second directed application of glyphosate or MSMA can be made if needed. Tank mixing MSMA with glyphosate applied overtop is not recommended.

Avoid Spray Drift

Non-Roundup Ready crops, especially tobacco, corn, and many vegetable crops, are highly susceptible to glyphosate. Spray drift should not be much of a problem when directing glyphosate. However, extreme caution is urged when applying glyphosate overtop near non-Roundup Ready crops. Avoid nozzle and pressure combinations that create fine droplets, and avoid spraying in windy conditions. Most glyphosate labels allow addition of a drift control agent.

Weed Management in LibertyLink Cotton

Varieties with the LibertyLink trait only have excellent tolerance of glufosinate (Liberty) but are not tolerant of glyphosate. The glufosinate label currently allows three applications of 29 fluid ounces, for a seasonal total of 87 ounces. Alternatively, one can apply 30 to 43 fluid ounces once followed by one more application of 29 fluid ounces, for a seasonal total of 72 ounces. The label allows application from cotton emergence until the early bloom stage.

Because of weed resistance to glyphosate, and because herbicides with new modes of action are not being developed, glufosinate will play a significant role in cotton weed management for the foreseeable future. It is imperative that growers follow sound

resistance management strategies to avoid or delay selection for resistance to glufosinate (see later section on *Herbicide Resistance Management*). In addition to integrating other herbicides into the management program, growers are strongly encouraged to limit glufosinate use to two applications per year.

Timing of Application

Application of glufosinate should be based on weed size rather than crop size. The optimum weed size for treatment with glufosinate varies, depending on the weed species and growing conditions; see label for details. In general, broadleaf weeds should be no more than 4 inches tall. Pigweed species, including Palmer amaranth, and annual grasses should be no more than 3 inches tall. Under dry conditions, pigweed species and annual grasses should be 1 to 2 inches when treated. Optimum timing for the first application generally occurs about two weeks after cotton planting, with optimum timing of the second application about two weeks after the first application.

Time of day of glufosinate application can greatly affect Palmer amaranth control. The impact on control of other common weeds is unknown. **Glufosinate should not be applied sooner than two hours after sunrise nor later than one hour prior to sunset**.

Application Equipment

Glufosinate behaves much like a contact herbicide, so good spray coverage is necessary. The label recommends flat-fan nozzles, at least 40 pounds pressure per square inch (psi), and a minimum of 10 gallons per acre spray volume. Ideally, the spray volume is at least 15 gallons per acre. Drift-reducing nozzles, such as air-induction nozzles that are commonly used to apply glyphosate, may not be appropriate for glufosinate application. Drift-reducing nozzles produce large droplets that may not give adequate spray coverage for a contact herbicide.

Need for Soil-Applied Herbicides

Preplant and/or preemergence residual herbicides are strongly encouraged in LibertyLink cotton. These herbicides help control annual grasses, pigweed species, and Florida pusley, the common weeds that can be difficult to control with glufosinate. These herbicides will allow greater flexibility in timing of the first glufosinate application. And, most importantly, they will help prevent selection for glufosinate-resistant weeds. See Tables 10-2, 10-4, and 10-5 for information on soil-applied residual herbicides.

Tank Mixes With Glufosinate Applied Overtop

Pyrithiobac (Pyrimax or Staple LX) can be mixed with glufosinate applied overtop. The typical rate of pyrithiobac would be 1.3 to 2.7 fluid ounces per acre to improve control of larger pigweed species. Pyrithiobac, if activated by rainfall, also will provide residual control or suppression of susceptible species, such as pigweed species. Pyrithiobac does

not control biotypes of Palmer amaranth and other species resistant to ALS inhibitors (see Table 10-9 for a list of ALS inhibitors).

S-metolachlor (Brawl, Dual Magnum, Medal) can be tank-mixed with glufosinate applied overtop to cotton 3 inches or larger until 100 days prior to harvest. S-metolachlor will not improve control of emerged weeds. If activation is timely, however, it will provide residual control of annual grasses and pigweed species.

Pyrithiobac or S-metolachlor mixed with glufosinate will usually cause some crop injury; see comments concerning pyrithiobac and S-metolachlor use in the section on *Weed Management in Roundup Ready Cotton*. This injury will typically not be sufficient to cause much concern in LibertyLink cotton. Do not tank-mix both S-metolachlor and pyrithiobac with glufosinate.

Do not mix glufosinate and postemergence grass control herbicides such as clethodim, fluazifop, quizalofop, or sethoxydim. Reduced grass control will occur. If the grass-control herbicides are applied first, delay glufosinate application at least three days. If glufosinate is applied first, delay grass-control herbicide application seven days.

Directed Herbicides in LibertyLink Cotton

Glufosinate can be directed to LibertyLink cotton up to the early bloom stage. Glufosinate can be directed alone or mixed with carfentrazone, diuron, prometryn, or pyrithiobac. Most glufosinate-based management systems will include two overtop applications of glufosinate. Even though the glufosinate label allows up to three applications per season, growers are encouraged to avoid more than two applications per season in order to reduce selection pressure. Any conventional directed herbicide labeled for cotton can be applied to LibertyLink cotton. See the section on *Postemergence-Directed Herbicides—Any Variety*.

Difficult-to-Control Weeds in Glufosinate-Based Systems

Florida pusley. This weed is typically a problem only on very sandy fields. Glufosinate has very little activity on Florida pusley. Use of a soil-applied herbicide is strongly encouraged on fields where this weed is expected (see Table 10-5).

Pigweed species. Pigweed species, including Palmer amaranth, can be controlled by glufosinate. However, timing of application to pigweed species is usually critical, especially under dry conditions. A preplant and/or preemergence herbicide is recommended for fields with a history of pigweed. Use of a preemergence herbicide will make the timing of the first application of glufosinate much less critical. Pyrithiobac (Pyrimax or Staple LX) can be mixed with glufosinate to improve control of emerged pigweed. However, Palmer amaranth resistance to pyrithiobac is common.

Goosegrass and other annual grasses. In general, glufosinate is more effective on broadleaf weeds than grasses. Timing of application to grasses, and especially goosegrass,

is critical. Two applications of glufosinate are normally needed to control or suppress goosegrass. A soil-applied herbicide (see Tables 10-2 and 10-4) can help tremendously in controlling goosegrass and other annual grasses. S-metolachlor mixed with glufosinate will not improve control of emerged grasses, but it can provide residual control. This can be important in control of goosegrass as this grass tends to emerge a little later than most other annual grasses.

Glufosinate should not be tank-mixed with postemergence grass-control herbicides. These tank mixes are very antagonistic (reduced grass control). If additional grass control is needed, any of the grass-control herbicides (clethodim, fluazifop, quizalofop, sethoxydim) can be applied three days before glufosinate or seven days after glufosinate.

Nutsedge. Glufosinate will significantly burn nutsedge, but the weed typically grows back. Adequate control of nutsedge can usually be obtained with glufosinate followed by trifloxysulfuron applied overtop or glufosinate followed by one or two directed applications of MSMA. See comments on use of trifloxysulfuron under *Postemergence-Overtop Herbicides—Any Variety*. Do not mix trifloxysulfuron with glufosinate.

Dayflower and Doveweed. Glufosinate will not control spreading dayflower. This weed can be controlled with pyrithiobac (Pyrimax or Staple LX) applied postemergence at 2.6 to 3.8 fluid ounces per acre or directed herbicide combinations containing MSMA (see Table 10-6). Postemergence herbicides should be applied when spreading dayflower shoots are 3 inches long or less.

Glufosinate has some activity on doveweed. However, the weed often recovers and grows back. Paraquat, applied under a hood, is very effective on doveweed. Preliminary results indicate that S-metolachlor is very effective if applied before doveweed germination. Flumioxazin plus MSMA directed is also effective.

Weed Management in GlyTol LibertyLink Cotton

Varieties are now available that contain both the GlyTol and the LibertyLink traits. Cotton with these traits is very tolerant of both glyphosate and glufosinate. Any brand of glyphosate herbicide registered for use on cotton may be used over the top of cotton containing GlyTol technology, unless expressly prohibited on the herbicide label. Application rates, timing of application, and maximum use rates per season are the same as for Roundup Ready Flex cotton.

Weed management systems in GlyTol LibertyLink cotton would be basically the same as those discussed above for Roundup Ready Flex cotton and LibertyLink cotton. This includes use of preplant and/or preemergence herbicides, use of residual herbicides applied postemergence with glyphosate or glufosinate, use of layby herbicides, and timely application to small weeds.

GlyTol LibertyLink cotton gives growers the option of using both glyphosate and glufosinate, either sequentially or in a tank mix. Tank mixes of these herbicides can be

antagonistic (reduced control), especially when the rate of one or both herbicides is reduced. Generally speaking, glyphosate does not impact the activity of glufosinate, but glufosinate can antagonize glyphosate. Whether or not tank mixes should be considered or avoided depends upon the species being targeted. The primary species of concern are grasses and pigweed species, including Palmer amaranth. A tank mix is not recommended for perennial grasses (bermudagrass or johnsongrass); use glyphosate alone. If annual grasses are the primarily the target, glyphosate alone is preferred. However, if one needs to use glufosinate for the broadleaf weeds and grasses larger than 2 inches are present, a tank mix of glyphosate plus glufosinate may be in order. In this case, a full rate of glyphosate is needed. Control of the annual grasses by the tank mix will usually be similar to that with glyphosate alone and better than that with glufosinate alone.

The suitability of a tank mix of glyphosate plus glufosinate on Palmer amaranth or other pigweed species depends upon whether these species are susceptible or resistant to glyphosate. Control of glyphosate-susceptible Palmer amaranth by a tank mixture will be less than control by glyphosate alone but equal to or better than control by glufosinate alone. Control of glyphosate-resistant Palmer amaranth by the tank mixture will be as good as or better than control by glufosinate alone. Control of glyphosate-resistant common ragweed should be similar with glufosinate alone and glufosinate plus glyphosate.

From a practical standpoint, there are only two situations where one might consider sequential applications of glyphosate and glufosinate. The first situation would be where there is a heavy infestation of annual grasses plus glyphosate-resistant Palmer amaranth, glyphosate-resistant common ragweed, or heavy morningglory. In this case, it would be better to apply glufosinate first simply because weed size is less critical with glyphosate than with glufosinate. If glyphosate is applied first, the glyphosate-resistant weeds will be too large for control by glufosinate at the second application. If the grass control is not adequate, a second application of glyphosate or glyphosate plus glufosinate can be made after new growth is observed on the grasses. Separate these applications by at least seven days. A second situation where sequential applications might be considered would be where one currently has no glyphosate resistance and wishes to alternate modes of action to help prevent resistance. In this situation, it would be better to apply glufosinate first for reasons stated above.

Weed Management in Phytogen WideStrike Cotton

LibertyLink cotton was transformed to include the bacterial *bar* gene which codes for an enzyme that very effectively deactivates glufosinate (Liberty herbicide). LibertyLink cotton tolerance of glufosinate is excellent. In Phytogen's WideStrike cotton, the bacterial *pat* gene was inserted for use as a selectable marker during transformation events for lepidopteron pest resistance. The *pat* gene also codes for the enzyme that deactivates glufosinate. However, tolerance of varieties with the WideStrike trait to glufosinate is not complete. Varieties with the WideStrike and Roundup Ready traits have excellent tolerance of glyphosate.

According to the EPA, glufosinate herbicide can be applied to WideStrike cotton. However, **the grower is liable for any crop injury resulting from the application**. Neither Bayer CropScience nor Dow AgroSciences/Phytogen recommend or warrant the use of glufosinate on WideStrike cotton.

Some injury can be expected when glufosinate is applied to WideStrike cotton. The injury is basically leaf burn, and can range from very minor to rather significant. The injury is contact in nature, and the crop generally recovers. Most research in North Carolina has not shown significant yield reduction of WideStrike cotton when glufosinate is used as described below. However, exceptions have occurred with PHY 499 WRF.

If glufosinate is used in WideStrike cotton, only two applications at 29 fluid ounces each are suggested. Make the first application to 1- to 3-leaf cotton and the second to 5- to 8-leaf cotton. Rates in excess of 29 fluid ounces are discouraged unless absolutely needed for weed control; higher rates cause more foliar burn. Ammonium sulfate can increase weed control by glufosinate. However, ammonium sulfate can increase WideStrike cotton response to glufosinate and its use is generally discouraged. Additionally, application after the eight-leaf stage of WideStrike cotton should be avoided. Application near first bloom or later may cause unacceptable crop injury and yield reduction. S-metolachlor, acetochlor (Warrant), or insecticides added to glufosinate usually increase WideStrike cotton injury, and there is some evidence that these mixtures may reduce yield.

Postemergence-Overtop Herbicides—Any Variety

Pyrithiobac (Pyrimax, Staple LX) can be applied overtop of cotton from the cotyledonary stage until 60 days before harvest. Two applications per year are allowed as long as the total applied per season does not exceed 5.1 fluid ounces (see comments in Table 10-2).

If applied in a timely manner, pyrithiobac controls many broadleaf weeds (Table 10-7). Note that pyrithiobac applied postemergence does not adequately control lambsquarters, ragweed, sicklepod, spurge, tall morningglory, or tropic croton. Timing of application is critical. Most susceptible broadleaf weeds should not be taller than 3 to 4 inches. Prickly sida must be 1 inch or less for acceptable control. Palmer amaranth should be 2 inches or less. Carefully read the label for specific recommendations on weed size. Palmer amaranth resistant to pyrithiobac is common across eastern North Carolina.

Tank mixes of pyrithiobac with clethodim, fluazifop, quizalofop, or sethoxydim are not recommended because antagonism (reduced grass control) is often observed. Pyrithiobac labels allow a tank mix with quizalofop for control of johnsongrass, but the label discourages tank-mixing with other grass-control herbicides or application to other grass species.

When making sequential applications of pyrithiobac and a postemergence grass-control herbicide, apply the pyrithiobac at least 3 days before or 1 day after application of the

grass-control herbicide. Longer intervals between applications of the two herbicides are preferred.

Trifloxysulfuron (Envoke) can be applied overtop cotton with a minimum of five leaves up to 60 days prior to harvest (see comments in Table 10-2). In cotton larger than about 10 inches, directed or semi-directed application may improve spray coverage on weeds below the crop canopy. Trifloxysulfuron controls or suppresses nutsedge plus a number of broadleaf weeds (see Tables 10-6 and 10-7). For best control, weeds should be 2 to 4 inches tall. Note that trifloxysulfuron does not control jimsonweed, prickly sida, spreading dayflower, or spurred anoda, and it is not adequately effective on tropic croton. Control of Palmer amaranth is often inadequate.

Pyrithiobac and trifloxysulfuron have the same mode of action. Hence, Palmer amaranth resistant to pyrithiobac will not be controlled by trifloxysulfuron. Palmer amaranth resistant to both pyrithiobac and trifloxysulfuron is common in North Carolina.

Cotton will sometimes be injured by trifloxysulfuron applied overtop. Injury is expressed as yellowing in the growing point and shortened internodes. Some degree of crop response can almost always be expected. In most cases, the injury is relatively minor and the crop recovers. On occasion, however, moderate to severe injury has been observed. Smaller cotton appears to be injured more than larger cotton. Other factors contributing to crop injury are unknown. However, growers are encouraged to not apply trifloxysulfuron to cotton with fewer than five leaves (7 to 8 leaves are preferred) and to not apply the herbicide to cotton under stress from wet or dry weather or thrips. Also, carefully follow label directions for adjuvant usage, and do not tank-mix trifloxysulfuron with other herbicides when applying overtop cotton. Tank-mix trifloxysulfuron only with those insecticides specifically mentioned on the trifloxysulfuron label.

Tank mixes of trifloxysulfuron with clethodim, fluazifop, quizalofop, or sethoxydim should also be avoided. Separate applications of trifloxysulfuron and the grass-control herbicides by at least 3 days if the grass-control herbicide is applied first or 5 days if trifloxysulfuron is applied first.

Grass-control herbicides. Clethodim, fluazifop, quizalofop, and sethoxydim can be applied overtop cotton from emergence through mid-season (see brands in Table 10-1 and comments in Table 10-2). These products control annual and perennial grasses but are ineffective on nutsedge and broadleaf weeds (see Table 10-6). All of these products are safe on cotton and are effective when applied to small grasses under good growing conditions. However, clethodim and sethoxydim tend to be more effective over a range of annual grass species and environmental conditions. Clethodim, fluazifop, and quizalofop tend to be more effective on perennial grasses than sethoxydim. When using any of these herbicides, follow label directions for application rates, application methods, use of adjuvants, and optimum grass size for treatment. Tank-mixing broadleaf herbicides such as pyrithiobac or trifloxysulfuron with these postemergence grass-control herbicides is not recommended.

Postemergence-Directed Herbicides—Any Variety

A number of herbicide combinations are available for directed application to any variety of cotton (see Table 10-2). These postemergence-directed herbicide combinations are primarily for annual broadleaf weeds and nutsedge. See Tables 10-6 and 10-7 for weed response. MSMA In the combinations will also control annual grasses 1.5 to 2 inches tall or less. Except for MSMA and lactofen plus MSMA, these directed options also provide some residual control of small-seeded broadleaf weeds. S-metolachlor can be mixed with some of the herbicide combinations. See the herbicide labels for minimum cotton size to treat, maximum weed size, application directions and precautions, and rotational restrictions.

Perennial Broadleaf Weeds

Perennial broadleaf weeds, such as horsenettle, trumpetcreeper, common milkweed, and hemp dogbane can be problems in no-till situations. Soil-applied herbicides will not control perennial broadleaf weeds, and, with the exception of horsenettle, conventional postemergence-directed herbicides are ineffective. Acceptable control of horsenettle has been obtained with postemergence-directed herbicide combinations containing MSMA. Two applications of MSMA or a combination containing MSMA will usually be needed. Other species can be suppressed or controlled in non-glyphosate-tolerant cotton by glyphosate applied with a hooded sprayer. Harvest-time applications of glyphosate are also an option to suppress perennial weeds for the following year (see *Preharvest Herbicide Application*).

Perennial broadleaf weeds can be suppressed or controlled with multiple applications of glyphosate applied to glyphosate-tolerant cotton. Later applications are generally more effective on perennials, and two applications are more effective than one. Adequate spray coverage should be obtained on low-growing perennials such as trumpetcreeper and horsenettle with standard directed sprayers. Taller species such as milkweed and hemp dogbane may require overtop application.

Curly dock is best controlled by a preplant application of thifensulfuron plus tribenuron (see Tables 10-1 and 10-3.).

Perennial broadleaf weeds can be suppressed or controlled in corn or Roundup Ready soybeans grown in rotation with cotton. In corn, an early postemergence application of dicamba alone or mixed with a nicosulfuron-containing herbicide followed by a layby application of dicamba is most effective. Alternatively, glyphosate or a tank mix of 2,4-D plus dicamba can be applied to infested spots after corn harvest. In Roundup Ready soybeans or Roundup Ready corn, two postemergence applications of glyphosate will suppress perennial broadleaf weeds.

Preharvest Herbicide Application

Preharvest herbicide applications are of questionable value in most cases. Desiccating mature weeds likely will not increase harvesting efficiency nor reduce harvesting

losses. The major exception would be fields heavily infested with vining weeds such as morningglory and cowpea. Problems with extraneous green matter in harvested cotton are probably overstated. Lint staining from weeds has not been a significant problem in spindle-picked cotton in North Carolina. Desiccating weeds will more likely increase rather than decrease trash in cotton because gins can remove green plant parts more easily than finely ground, desiccated plant parts. However, if present in large quantities, extraneous green matter can increase the potential for overheating, rot, and stain if the cotton is packed into a module and the module is not properly monitored.

There are no established guidelines for determining when the level of weed infestation justifies a preharvest herbicide application. The information below is based on general observations in North Carolina and other cotton-producing states.

Annual Weeds

Carfentrazone (Aim) is registered for use as a defoliant. Good desiccation of morningglory and cocklebur has been observed with carfentrazone if spray coverage is good. Results on pigweed species have been inconsistent but generally not acceptable. Carfentrazone will not desiccate grasses or sicklepod. See the carfentrazone label concerning use of crop oil concentrate.

Glyphosate can be applied to glyphosate-tolerant varieties seven or more days ahead of harvest regardless of the percentage of open bolls.

Another option is paraquat applied after cotton defoliation. In this program, the cotton is defoliated as normal. After at least 75 to 80 percent of the bolls are open, the remaining bolls expected to be harvested are mature, and most of the cotton leaves have dropped, apply paraquat at 1.9 pints of a 2 lb/gal formulation or 1.3 pints of a 3 lb/gal formulation (see chapter 12, "Cotton Defoliation," for discussion on determining boll maturity). Broadcast the paraquat in a minimum of 20 gallons of water per acre and add 1 pint of nonionic surfactant per 100 gallons of water. Wait 5 days before picking, and then pick as soon as possible. If spray coverage is good, paraquat will desiccate most annual weeds.

Perennial Weeds

Glyphosate can be applied in the fall to control or suppress perennial weeds for the following year. For johnsongrass control, glyphosate at a rate of 0.75 to 1.5 pounds a.e. per acre may be tank-mixed with the defoliant. Apply when at least 60 percent of the bolls are open. Alternatively, glyphosate may be applied after defoliation. Application after defoliation may be preferred in rank cotton to improve spray coverage. Additionally, a separate application of glyphosate allows treatment of only the infested areas of a field, thus reducing herbicide cost.

For other perennial weeds, such as bermudagrass, nutsedge, trumpetcreeper, horsenettle, common milkweed, and hemp dogbane, glyphosate-defoliant tank mixes are not

recommended. If you need to control these weeds, defoliate the cotton as usual. Apply the glyphosate after most of the cotton leaves have dropped. Suggested application rates are 2.25 pounds a.e. per acre for nutsedge, trumpetcreeper, common milkweed, and bermudagrass, and 3 pounds a.e. for horsenettle and hemp dogbane. To reduce costs, spot-spray only infested areas.

For tall-growing weeds, such as johnsongrass, common milkweed, and hemp dogbane, the glyphosate should be applied after most of the cotton leaves have dropped but before harvest. The glyphosate can be applied to low-growing weeds, such as bermudagrass, nutsedge, horsenettle, and trumpetcreeper, after most of the cotton leaves have dropped and either before or after harvest. Glyphosate should be applied at least 7 to 10 days before the first killing frost.

Herbicide Resistance Management

Herbicide resistance in weeds is not a new problem. With discovery of weed resistance to glyphosate, however, the threat posed by herbicide resistance was elevated to a much higher level. Horseweed resistant to glyphosate is very common across eastern North Carolina. Common ragweed resistant to glyphosate exists in several northeastern counties. Ryegrass resistant to glyphosate occurs in at least two counties in the southern Piedmont. And, of major significance, glyphosate-resistant Palmer amaranth is now widespread across the state. The vast majority of Palmer amaranth populations contain at least some resistant individuals. Most Palmer amaranth populations are also resistant to ALS inhibitors.

In previous years, growers with herbicide-resistant weeds were fortunate to have new herbicides (specifically, new modes of action) come to the marketplace before the problem became overwhelming. That will not be the case in the foreseeable future; new modes of action are simply not on the horizon. It is therefore imperative that growers take herbicide resistance management very seriously in an attempt to maintain the usefulness of the products currently available.

What Causes Resistance

Herbicide resistance is the inherited ability of a biotype of a weed to survive and reproduce following exposure to a dose of herbicide normally lethal on that species. Herbicides do not cause resistance. Rather, herbicides select for resistance that may naturally occur in the weed population. Greater reliance on a particular herbicide, or group of herbicides with the same mode of action, puts greater selection pressure on any resistant individuals that may be in the population. A shift to conservation tillage and a corresponding decrease in cultivation have led to greater reliance on herbicides and greater potential problems with resistance.

Resistance Management Strategies

There are two prerequisites for resistance. First, one or more individuals possessing genes conferring resistance must be present in the population. Second, selection pressure

resulting from extensive use of a herbicide to which these rare individuals are resistant must be exerted on the population. Growers have no way to know if a few plants carrying resistance are present on their farm. Hence, the only way to prevent a buildup of resistant plants is to utilize management systems that reduce selection pressure on any resistant individuals that may be present.

Ninety-five percent of the cotton in North Carolina was planted to glyphosate-resistant varieties in 2013. Not all of that cotton was treated with glyphosate since 60 percent of the acreage was in WideStrike or GlyTol LibertyLink varieties. A high percentage of the soybean acreage also was planted to Roundup Ready varieties, and about 75 percent of the corn acreage was planted to Roundup Ready hybrids. Glyphosate is obviously being applied on many acres, and it is often being applied multiple times. In many cases, growers have relied almost exclusively on glyphosate for weed control. Extensive reliance on a single mode of action (the mechanism by which the herbicide kills susceptible plants) over that much acreage puts tremendous selection pressure on any resistant weeds that may be in the population. Use of PPO-inhibiting herbicides, such as flumioxazin and fomesafen (see Table 10-9 for list of PPO inhibitors), has increased dramatically in cotton and other crops with the greater occurrence of glyphosate-resistant biotypes. There is concern that use of these herbicides repeatedly will result in selection for PPO-resistant biotypes. Similarly, reliance on glufosinate in glufosinate-tolerant cotton as the primary mode of action will select for resistance to glufosinate. It is absolutely essential that herbicide programs be diverse in mode action in order to reduce selection pressure for resistant weeds.

The key component of a resistance management strategy is to integrate herbicides having different modes of action into the cropping system. Table 10-9 is included as an aid to help growers select herbicides with various modes of action. The table lists the brand names and active ingredients of herbicides used in agronomic crops in North Carolina. In addition, there is a numeric code for each mode of action. An effective resistance management strategy in cotton will incorporate herbicides having at least three (preferably more) different modes of action. Additionally, growers are encouraged to minimize their reliance on ALS-inhibiting herbicides as these chemistries are highly vulnerable to resistance.

Cotton growers can incorporate the recommended diversity in modes of action into a glyphosate-based or a glufosinate-based management program by using soil-applied residual herbicides, tank-mixing another herbicide with glyphosate or glufosinate applied postemergence, and using alternatives to glyphosate or glufosinate or at least a tank mix with glyphosate or glufosinate at layby. Use of full rates of glyphosate or glufosinate, even in tank mixes, is encouraged. Crop rotation can aid in resistance management if herbicide modes of action for the rotational crop are wisely selected. Where practical, cultivation would also be a very effective component of a resistance management strategy.

Glyphosate-Resistant Horseweed

Glyphosate-resistant horseweed (also called marestail) is now very common across eastern North Carolina. Further spread is expected as seed of horseweed are easily spread

by wind and equipment. Growers planting no-till or strip-till cotton east of U.S. 1 should assume that horseweed present in fields is resistant to glyphosate.

Horseweed emerges primarily in the fall. It will be in a rosette stage and large enough for easy identification by early winter. Pictures of small horseweed and identifying characteristics can be found at www.ppws.vt.edu/weedindex.htm.

It is critical that glyphosate-resistant horseweed be controlled before planting cotton; options to control this weed after emergence of Roundup Ready varieties are very limited. Glyphosate-resistant horseweed can be controlled by tank mixes of glyphosate plus 0.95 pound a.e. of 2,4-D (2 pints of typical 3.8 lb a.e./gal formulation) or glyphosate plus 0.5 pint of dicamba. Mixtures with dicamba may perform more consistently than 2,4-D mixtures. Application in early to mid-March is recommended. The tank mix with 2,4-D should be applied at least 30 days ahead of planting (see comments in Table 10-2). Cotton planting must be delayed at least 21 days after the accumulation of 1 inch of rainfall following dicamba application. This often means a four- to six-week delay between dicamba application and planting. Although injury to cotton is possible from either 2,4-D or dicamba applied in a cold, dry spring, research to date in North Carolina has shown no problems when the above guidelines were followed.

Horseweed normally germinates in the fall, but additional plants may emerge in late spring. These spring-germinating plants will not be controlled by previously applied 2,4-D or dicamba. Flumioxazin has poor postemergence activity on horseweed; hence adding flumioxazin to glyphosate will not improve control of emerged plants. However, flumioxazin has good preemergence activity on horseweed. Flumioxazin included in a tank mix of glyphosate plus 2,4-D or glyphosate plus dicamba will reduce problems with late-emerging horseweed. Fluometuron applied preemergence is the best option to control late-emerging horseweed in the crop. Paraquat should be included with the fluometuron to kill emerged weeds at time of planting.

Another option to control glyphosate-resistant horseweed is a mixture of glyphosate plus saflufenacil (Sharpen). Saflufenacil is very effective on emerged horseweed and it gives residual control of later-emerging horseweed. Dicamba or 2,4-D can also be added to the mixture. There is a long waiting interval between saflufenacil application and planting. The saflufenacil label specifies a waiting interval of 42 days plus accumulation of one inch of rainfall.

Although less effective and less consistent in performance than the programs above, a mixture of paraquat plus diuron may adequately control horseweed if the mixture is applied when daytime temperatures exceed 70 degrees F. Paraquat plus diuron (see Table 10-2 for rates) plus crop oil concentrate should be applied 15 to 45 days ahead of planting. Warm temperatures are critical for success with this treatment.

Glufosinate (Liberty) at 29 ounces per acre will also control horseweed if applied when daytime temperatures exceed 75 degrees F. Glufosinate is an option to control

spring-emerging horseweed at planting time or in situations where growers have failed to follow one of the programs previously outlined. Glufosinate can be applied any time prior to cotton planting or during planting. It is critical that glufosinate be applied under warm conditions. If one is planning to use a glufosinate-based system for Palmer amaranth control, an alternative to glufosinate for at-planting burndown is suggested. This will reduce selection pressure on the Palmer amaranth population.

Glufosinate is the only option to control glyphosate-resistant horseweed in emerged cotton. Glufosinate can be applied overtop LibertyLink, GlyTol LibertyLink, or WideStrike varieties, or applied with a hooded sprayer in Roundup Ready varieties. Smaller horseweed is more easily killed.

Glyphosate-Resistant Palmer Amaranth

Palmer amaranth is a very aggressively growing pigweed species now widespread across North Carolina. This weed grows very rapidly and often becomes 6 to 8 feet tall by cotton harvest. It is highly competitive with cotton, it is very prolific, and it has long been considered one of our worst weeds in cotton.

Glyphosate-resistant Palmer amaranth is the most serious production problem growers currently face. Growers must undertake an aggressive program to control existing resistant populations and a proactive program to reduce further selection for resistant biotypes.

Palmer amaranth is a dioecious plant, meaning there are separate male and female plants. Hence, it is an obligate outcrosser; pollen must move from male to female plants for seed production to occur. Research in Georgia has demonstrated that resistant pollen can move at least 1,000 feet and fertilize susceptible females. At least some of the offspring are resistant. Rapid spread can be expected through pollen movement and seed movement on equipment or in gin trash. That implies that excellent control of existing glyphosate-resistant populations is necessary to slow the spread of this biotype.

In formulating a resistance management program for Palmer amaranth and glyphosate or glufosinate, growers must keep foremost in their minds the need to prevent further selection for ALS resistance. Weed biotypes resistant to ALS inhibitors, including a biotype of Palmer amaranth, exist in North Carolina. Unfortunately, Palmer amaranth resistant to both glyphosate and ALS inhibitors is now common. This multiple resistance is particularly bad because there are no effective postemergence over-the-top options left in Roundup Ready cotton. Additionally, there is increasing concern over potential resistance to PPO inhibitors (see Table 10-9 for list of these herbicides). Although resistance to PPO inhibitors has not been encountered in the Southeast, growers are putting tremendous selection pressure on this group of herbicides.

Table 10-1. Brand Names and Formulations for Active Ingredients Mentioned in Chapter 10

Active ingredients(s)	Brand name(s)	Concentration	Formulation
2,4-D	Numerous brands	3.8 lb a.e./gal	S or EC
acetochlor	Warrant	3 a.i. lb/gal	AS
carfentrazone	Aim	2 lb a.i. /gal	EC
clethodim	Arrow, Clethodim, Intensity, Shadow	2 lb a.i./gal	EC
	Intensity One, Select Max, Tap Out	0.97 lb a.i./gal	EC
dicamba	Clarity, Clash, Detonate, Diablo, Dicamba DMA salt, Dicamba HD, Strut, Vision	4 lb a.e./gal	S
diuron	Diuron 80DF, Karmex DF, Parrot DF	80%	DF
	Direx 4L, Diuron 4L, Parrot 4L, Sekor 4L	4 lb a.i./gal	F
diuron + linuron	Layby Pro	20.3 + 20.0%	DF
fluazifop-P-butyl	Fusilade DX	2 lb a.i./gal	EC
flumiclorac	Resource	0.86 lb a.i./gal	EC
flumioxazin	Outflank, Panther, Valor SX	51%	WDG
fluometuron	Cotoran	4 lb a.i./gal	F
fomesafen	Battle Star, Dawn, Reflex, Ringside, Top Gun	2 lb a.i./gal	S
glufosinate	Liberty 280 SL	2.34 lb a.i./gal	S
glyphosate	See Table 10-7	various	S
glyphosate + S-metolachlor	Sequence	2.5 lb a.e./gal + 3 lb a.i./gal	EC
lactofen	Cobra	2 lb a.i./gal	EC
MSMA	MSMA-6 Plus	6 lb a.i./gal	S
paraquat	Gramoxone SL	2 lb a.i./gal	S
	Bonfire, Firestorm, Parazone, Quik-Quat	3 lb a.i./gal	S
pendimethalin	Prowl H2O	3.8 lb a.i. /gal	AS
	Acumen, Helena Pendimethalin, Prowl 3.3 EC, Stealth	3.3 lb a.i./gal	EC
prometryn	Caparol, Cotton-Pro, Prometryne	4 lb a.i./gal	F
prometryn + trifloxysulfuron	Suprend	79.3% prometryn + 0.7% trifloxysulfuron	DF
pyraflufen	ET	0.208 lb a.i./gal	EC
pyrithiobac	Pyrimax, Staple LX	3.2 lb a.i./gal	S
quizalofop P-ethyl	Assure II, Targa	0.88 lb a.i./gal	EC
S-metolachlor	Brawl, Medal, Dual Magnum	7.62 lb a.i./gal	EC
saflufenacil	Sharpen	2.85 lb a.i./gal	AS
sethoxydim	Poast	1.5 lb a.i./gal	EC
	Nufarm Sethoxydim SPC, Poast Plus	1.0 lb a.i./gal	EC
thifensulfuron + rimsulfuron	Leadoff	16.7 + 16.7%	WDG

Table 10-1. Brand Names and Formulations for Active Ingredients Mentioned in Chapter 10

Active ingredients(s)	Brand name(s)	Concentration	Formulation
thifensulfuron + tribenuron (continued)	FirstShot	25 + 25%	WDG
	Harmony Extra	33.33 + 16.67%	WDG
	Treaty Extra	50 + 25%	WDG
trifloxysulfuron	Envoke	75%	WDG
trifluralin	Treflan 4L, Trifluralin 4 E.C., Trifluralin 4 EC, Trifluralin HF, Triflurex HFP	4 lb a.i./gal	EC

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names.

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
EARLY PREPLANT BURNDOWN: Emerged annual weeds in no-till, strip-till, or stale seedbed systems	glyphosate	0.56 to 1.13 lb a.e.	Apply any time prior to planting to control emerged weeds. See Table 10-8 for equivalent rates of various glyphosate products. See Table 10-3 for weed response. Note there are some weeds that glyphosate alone will not control. Rates for small grain cover crops: Wheat < 12 inches: 0.56 lb a.e. Wheat > 12 inches: 0.75 lb a.e. Rye < 18 inches: 0.56 lb a.e. Rye > 18 inches: 0.75 lb a.e. See comments below for glyphosate-resistant horseweed.
	glyphosate + 2,4-D (3.8 lb a.e./ gal)	0.56 to 1.13 lb a.e. + 0.5 to 1 pt.	See comments for glyphosate alone. Many, but not all, brands of 2,4-D are labeled for application at least 30 days ahead of cotton planting. No problems with cotton tolerance have been observed in NC research when any formulation of 2,4-D was applied 30 or more days ahead of cotton planting. See Table 10-3 for weed response. Six to 8 fl oz of 2,4-D are adequate for cutleaf eveningprimrose; use 1 pint for other weeds. See later section on glyphosate-resistant horseweed.
	glyphosate + carfentrazone (2 EC)	0.56 to 1.13 lb a.e. + 0.5 to 1 fl oz	See comments for glyphosate alone. Carfentrazone (Aim) added to glyphosate will increase speed of control but long-term control is generally not improved. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed.
	glyphosate + dicamba (4 L)	0.56 to 1.13 lb a.e. + 8 fl oz	See comments for glyphosate alone. Following application of dicamba and a minimum of 1-inch rainfall, a waiting period of at least 21 days is required before planting. It is important that this restriction be followed to avoid cotton injury. This combination suppresses Carolina geranium and curly dock but is somewhat less effective on primrose than glyphosate + 2,4-D. This tank mixture will control glyphosate-resistant horseweed.
	glyphosate + pyraflufen (0.208 EC)	0.56 to 1.13 lb a.e. + 0.5 to 2 fl oz.	See comments for glyphosate alone. Pyraflufen (ET) added to glyphosate will increase speed of control but long-term control is generally not improved. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed.
	glyphosate + [thifensulfuron + rimsulfuron]	0.56 to 1.13 lb a.e. + 1.5 oz	Thifensulfuron + rimsulfuron is a premix product. Apply from late fall to 30 days prior to planting. Controls emerged winter annual weeds plus provides residual control of later emerging winter weeds. See label for adjuvant recom-mendations. Dicamba or 2,4-D can be included, especially for emerged horseweed, cutleaf eveningprimrose, Carolina geranium, or larger wild radish. Best use of thifensulfuron + rimsulfuron is a late fall or winter application followed by another burndown containing flumioxazin 3 to 4 weeks ahead of planting.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
EARLY PREPLANT BURNDOWN: Emerged annual weeds in no-till, strip-till, or stale seedbed systems (continued)	glyphosate + [thifensulfuron + tribenuron] (50 WDG, 1:1 ratio) (50 WDG, 2:1 ratio) (75 WDG, 2:1 ratio)	0.56 to 1.13 lb a.e. + 0.8 oz 0.75 oz 0.5 oz	Thifensulfuron + tribenuron is a premix product. See comments for glyphosate alone. Add surfactant according to the thifensulfuron + tribenuron label. Thifensulfuron + tribenuron should be applied at least 14 days prior to planting. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed.
	glyphosate + flumiclorac (0.86 EC)	0.56 to 1.13 lb a.e. + 2 to 4 fl oz	See comments for glyphosate alone. Flumiclorac (Resource) added to glyphosate will increase speed of control and may improve control of some species. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed.
	Glyphosate + flumioxazin (51 WDG)	0.56 to 1.13 lb a.e. + 1 to 2 oz	See comments for glyphosate alone. Applied at 1 oz/acre, flumioxazin will give 2 to 4 weeks residual control of lambsquarters, pigweed, prickly sida, spurge, and Florida pusley. At 2 oz/acre, flumioxazin will give 6 to 8 weeks residual control of these species. Application to cover crop or dense stand of winter weeds may reduce residual control. Tillage after application will reduce or eliminate residual control. Regardless of glyphosate product used, flumioxazin labels recommend a nonionic surfactant. A minimum of 14 days must pass and a 1-inch rainfall must occur between flumioxazin application and cotton planting when flumioxazin is applied at 1 oz/acre; 21 days must pass when applied at 1.5 to 2 oz/acre. If strip-tillage will follow flumioxazin application, the waiting interval can be reduced to 14 days for the 2 oz. rate. A minimum of 30 days must pass, and 1 inch of rainfall must occur, between flumioxazin application and planting of conventionally tilled cotton. Carefully follow label directions for cleaning out sprayer after each day's use.
	paraquat (2 lb/gal brands) paraquat (3 lb/gal brands)	2.6 to 4 pt 1.7 to 2.7 pt	Apply any time prior to planting to control emerged weeds. See Table 10-3 for weed response. Add surfactant or crop oil according to label directions. Rates for rye cover crop are 2 pints of 2 lb/gal product or 1.33 pt of 3 lb/gal product. Rates for wheat are 2.5 pt of 2 lb/gal product or 1.67 pt of 3 lb/gal product. Best control of small grain cover crops will be achieved if paraquat applied at the boot stage or later.
	paraquat (2 lb/gal brands) paraquat (3 lb/gal brands) + diuron (4F)	2.6 to 4 pt 1.7 to 2.7 pt + 1 to 2 pt	See comments for paraquat alone. Crop oil is the preferred adjuvant. One pint of diuron is sufficient to enhance activity of paraquat. Higher rates may be used for greater residual control. See diuron label for application rates based on soil texture. Apply 15 to 45 days ahead of planting. If fluometuron or diuron is applied preemergence, reduce rates to account for residual activity of preplant diuron. If 1.5 pt or more diuron is applied preplant, do not apply fluometuron or diuron preemergence.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
EARLY PREPLANT BURNDOWN: Emerged annual weeds in no-till, strip-till, or stale seedbed systems (continued)	glufosinate (2.34 L)	29 to 43 fl oz	Glufosinate (Liberty) can be applied any time prior to cotton emergence. Control is greatly affected by temperature; apply on a sunny day with temperature above 75 degrees. The primary use for glufosinate in burndown would be for glyphosate-resistant horseweed. See below section on "Glyphosate-Resistant Horseweed" and comments in text of this chapter.
EARLY PREPLANT BURNDOWN: Glyphosate-resistant horseweed	glyphosate + 2,4-D (3.8 lb a.e./gal) + flumioxazin (51 WDG)	0.56 to 1.13 lb a.e. + 2 pt. + 1 to 2 oz	Assume all horseweed in eastern NC is glyphosate-resistant. Glyphosate plus 2,4-D plus flumioxazin or glyphosate plus dicamba plus flumioxazin are the preferred treatments. See previous comments concerning waiting intervals between application of 2,4-D, dicamba, and flumioxazin and planting. Apply on a warm day using at least 15 GPA. The saflufenacil (Sharpen) label specifies a 42-day waiting interval between application and cotton planting, plus accumulation of 1 inch of rainfall. Dicamba or 2,4-D may be added to this mixture. Paraquat plus diuron must be applied 15 to 45 days ahead of cotton planting. Adjust diuron rate according to soil type, as described on product label. Best results will be obtained if sprayed when daytime temperatures exceed 70 degrees. Add 1 gal of crop oil concentrate per 100 gal spray solution. Dicamba or 2,4-D may be added to this mixture for better control of emerged horseweed, as long as appropriate waiting intervals between application and planting are maintained. A minimum of 15 GPA and fine spray droplets are suggested. This treatment is often less effective on horseweed than 2,4-D or dicamba plus flumioxazin plus glyphosate. Glufosinate is recommended for fields where growers have failed to control glyphosate-resistant horseweed and cotton will be planted in less than 15 days. Best results will be obtained if sprayed when daytime temperatures exceed 75 degrees. Glufosinate is not effective in cool weather. A minimum of 15 GPA and fine spray droplets are suggested.
	glyphosate + dicamba (4 L) + flumioxazin (51 WDG)	0.56 to 1.13 lb a.e. + 8 fl oz + 1 to 2 oz	
	glyphosate + saflufenacil (2.85 F)	0.56 to 1.13 lb a.e. + 1 fl oz	
	paraquat (2 lb/gal brands) (3 lb/gal brands) + diuron (4 F)	4 pt 2.7 pt + 1 to 2 pt	
	glufosinate (2.34 L)	29 to 43 fl oz	

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
AT PLANTING BURN-DOWN: Burndown of cover crops and weeds at planting	glyphosate	0.56 to 1.13 lb a.e.	If an early burndown treatment was applied, apply glyphosate or paraquat in combination with desired residual herbicides at planting. If an early burndown treatment was not used, apply glyphosate or paraquat7 to 21 days ahead of planting. If weeds are emerged at planting, make a second application in combination with desired residual herbicides. Glyphosate and paraquat rates depend upon weed species and size; see labels for details. Add surfactant or crop oil to paraquat according to label directions. Need for adjuvants with glyphosate depends upon brand used; see specific labels for details. For glufosinate (Liberty), see comments under early preplant burndown. Glufosinate will not adequately control cover crops. Glyphosate rates for small grain cover crops: Wheat < 12 inches: 0.56 lb a.e. Wheat > 12 inches: 0.75 lb a.e. Rye < 18 inches: 0.56 lb a.e. Rye > 18 inches: 0.75 lb a.e. Paraquat rates for small grain cover crops: Wheat: 2.6 pt of 2 lb/gal product or 1.7 pt of 3 lb/gal product Rye: 2.0 pt of 2 lb/gal product or 1.33 pt of 3 lb/gal product
	paraquat (2 lb/gal brands) (3 lb/gal brands)	2.6 to 4 pt 1.7 to 2.7 pt	
	glufosinate (2.34 L)	29 to 43 fl oz	
PREPLANT INCORPORATED, ANY VARIETY: annual grasses and small-seeded broadleaf weeds	pendimethalin (3.3 EC) pendimethalin (3.8 L)	1.2 to 3.6 pt 2 to 4 pt	Incorporate in top 2 in. of final seedbed according to label directions. Deep incorporation, especially on sandy soils, may cause stunting and delayed crop development. Incorporation of trifluralin and pendimethalin can be delayed 24 hours and 7 days, respectively. Immediate incorporation suggested. See Tables 10-4 and 10-5 for weeds controlled. See labels for specific rates on various soils. Not effective on organic soils.
	trifluralin (4 EC)	1 to 2 pt	
	trifluralin (4 EC) + fluometuron (4 F)	1 to 2 pt + 1 to 2 qt	See labels for specific rates on various soils. Follow trifluralin label for incorporation directions. Fluometuron usually more effective on broadleaf weeds as a preemergence application if adequate rainfall for activation is received. See above comments for trifluralin preplant incorporated.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
PREEMERGENCE, ANY VARIETY: annual broadleaf weeds	fluometuron (4 F)	1 to 2 qt	See label for specific rates on various soils. Not effective on organic soils. Apply before crop emergence. May be mixed with liquid nitrogen. May be mixed with acetochlor, fomesafen, pendimethalin, or pyrithiobac.
	diuron (4 F) diuron (80 DF)	1 to 2 pt 0.63 to 1.25 lb .	See labels for specific rates on various soils. Not effective on organic soils. Apply before crop emergence. May be mixed with acetochlor, fomesafen, pendimethalin, or pyrithiobac. See rotational restrictions on labels.
	fomesafen (2 L)	1 pt	Labels restrict application only to coarse-textured soils. There is a greater chance of injury on medium- or fine-textured soils. Suggested primarily for control of Palmer amaranth. May be mixed with acetochlor, diuron, fluometuron, pendimethalin, or pyrithiobac. Fomesafen applied to very dry soil followed by rainfall or irrigation shortly after planting can cause cotton injury. Injury may also be observed if the first rainfall after application splashes soil onto emerging cotton seedlings. Reducing fomesafen rates to 10 to 12 oz when mixed with acetochlor, diuron, or fluometuron may reduce injury with little reduction in Palmer amaranth control.
	pyrithiobac (3.2 L)	1.7 to 2.1 fl oz	Do not apply to soils with less than 0.5% organic matter. May be mixed with diuron, fluometuron, fomesafen, or pendimethalin. Palmer amaranth biotypes resistant to pyrithiobac are common in North Carolina.
PREEMERGENCE, ANY VARIETY: annual grasses, pigweed, and lambsquarters	pendimethalin (3.3 EC) pendimethalin (3.8 L)	2.4 to 3.6 pt 2.1 to 4 pt	Pendimethalin is more effective when incorporated. If applied preemergence, a tank mix with another herbicide is suggested. See labels for specific rates on various soils. Not effective on organic soils.
PREEMERGENCE, ANY VARIETY: annual grasses and pigweed	acetochlor (3 ME)	3 pt	Acetochlor (Warrant) is usually applied in combination with another preemergence herbicide such as diuron, fluometuron, or fomesafen. Acetochlor is effective on mineral-organic soils; see label for rates.
POSTEMERGENCE OVERTOP, ANY VARIETY: annual grasses	clethodim (2 EC) clethodim (0.97 EC)	6 to 8 fl oz 9 to 16 fl oz	See labels for maximum weed size to treat, suggested rates for specific species, and adjuvant recommendations. See Table 10-1 for brands and Table 10-6 for weeds controlled.
	fluazifop (2 EC)	8 to 12 fl oz	
	quizalofop (0.88 EC)	7 to 8 fl oz	
	sethoxydim (1.5 EC) sethoxydim (2 EC)	16 fl oz 24 fl oz	
POSTEMERGENCE OVERTOP, ANY VARIETY: rhizome johnsongrass	clethodim (2 EC) clethodim (0.97 EC)	8 to 16 fl oz 12 to 32 fl oz	Apply to actively growing johnsongrass 24 in. tall or less. Repeat if needed when regrowth or new plants are 6 to 12 in. tall. See labels for rates for the second application and for adjuvant recommendations.
	fluazifop (2 EC)	10 to 12 fl oz	
	quizalofop (0.88 EC)	10 fl oz	
	sethoxydim (1.5 EC) sethoxydim (1 EC)	24 fl oz 36 fl oz	

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE OVERTOP, ANY VARIETY: bermudagrass	clethodim (2 EC) clethodim (0.97 EC)	8 to 16 fl oz 12 to 32 fl oz	Apply to actively growing bermudagrass before runners exceed 6 in. A second application may be made if needed when regrowth is 6 in. or less. See labels for rates for the second application and for adjuvant recommendations. Spray coverage, especially with second application, may be improved by directing spray under cotton. See Table 10-5 for weed response.
	fluazifop (2 EC)	12 fl oz	
	quizalofop (0.88 EC) Poast Plus (1 EC)	10 fl oz	
	sethoxydim (1.5 EC) sethoxydim (1 EC)	24 fl oz 36 fl oz	
POSTEMERGENCE OVERTOP, ANY VARIETY: annual broadleaf weeds	trifloxysulfuron (75 WDG)	0.1 oz	Apply after cotton has a minimum of five true leaves (seven preferred) until 60 days prior to harvest. May be applied twice, but do not exceed 0.0188 pound active ingredient trifloxysulfuron per acre per year from combined use of all products containing trifloxysulfuron. Add nonionic surfactant at 1 qt per 100 gal; do not use other types of adjuvants. Do not mix with postemergence grass control herbicides. See label for precautions on mixing with insecticides and for weeds controlled and weed size to treat. May be applied overtop at 0.15 oz per acre if needed for larger weeds. Will not control ALS-resistant Palmer amaranth.
	pyrithiobac (3.2 SL)	2.6 to 3.8 fl oz	Apply from cotyledonary stage of cotton until 60 days before harvest. Can apply twice per season, but do not exceed 5.1 fl oz per season. Avoid application during or near a period of cool weather or to thrips-infested cotton. Add nonionic surfactant at 1 qt per 100 gal spray solution. See label for weeds controlled and recommended weed size to treat. Do not mix with malathion-containing insecticides. Do not mix with acetochlor or S-metolachlor. Will not control ALS-resistant Palmer amaranth.
	pyrithiobac (3.2 L) + trifloxysulfuron (75 WDG)	1.3 to 1.9 fl oz + 0.1 oz	See comments for pyrithiobac and trifloxysulfuron applied alone. Cotton should be in at least the fifth leaf stage, preferably larger, for this application. Compared to trifloxysulfuron alone, mixture is more effective on eclipta, jimsonweed, and spurred anoda. Compared to pyrithiobac alone, mixture is more effective on ragweed, lambsquarters, tall morningglory, sicklepod, and nutsedge.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE OVERTOP, **GLUFOSINATE-TOLERANT VARIETIES:** annual grasses and broadleaf weeds	glufosinate (2.34 L)	29 to 43 fl oz	Apply anytime up to the early bloom stage of cotton. On larger cotton, semi-directed application may give better spray coverage on weeds under the crop canopy. Multiple applications are allowed, but do not exceed a total of 87 fl oz if 29 fl oz are applied per application or 72 fl oz if the first application is greater than 29 fl oz. Apply in a minimum of 15 GPA using flat fan nozzles at 30 to 60 PSI. Increase spray volume if weed or crop canopy is dense. See label for weeds controlled, recommended weed size for treatment, application directions and rates, and precautions. Application rate and timing of application are critical. In general, broadleaf weeds should be 4 in. or less. Pigweed species and annual grasses should be 3 in. or less. Surfactant or crop oil is not needed; ammonium sulfate may improve control.
	glufosinate (2.34 L) + S-metolachlor (7.62 EC)	29 to 43 fl oz + 1 to 1.33 pt	See comments for glufosinate alone. Apply overtop to cotton at least 3 in. tall. Do not add any adjuvants. Do not tank mix pyrithiobac with S-metolachlor. Some foliar burn from S-metolachlor may occur; tank mixing with insecticides may increase crop response. S-metolachlor provides residual control of annual grasses and pigweed species.
	glufosinate (2.34 L) + pyrithiobac (3.2 L)	29 to 43 fl oz + 1.3 to 2.7 fl oz	See comments for glufosinate alone. Compared to glufosinate alone, tank mix will improve control of larger pigweed, including Palmer amaranth (unless it is ALS resistant), and will provide residual control of pigweed, lambsquarters, prickly sida, jimsonweed, smartweed, spurred anoda, and velvetleaf. Use 2.7 oz of pyrithiobac to suppress or control spreading dayflower. Apply overtop from cotyledonary stage to early bloom stage. Adjuvants are not necessary. Tank mixing with insecticides may increase crop injury.
POST-EMERGENCE OVERTOP, **GLYPHOSATE-TOLERANT VARIETIES:** annual and perennial grasses, annual broadleaf weeds, and nutsedge; suppression of perennial broadleaf weeds	glyphosate	21 to 32 fl oz	See Table 10-8 for rate conversions among formulations. Glyphosate may be applied overtop or directed any time from cotton emergence to 7 days prior to harvest. See labels for maximum use rates per season. Clethodim, fluazifop, quizalofop, or sethoxydim may be mixed with glyphosate to control volunteer Roundup Ready corn. See the discussion on Herbicide Resistance Management in the text of this chapter.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POST-EMERGENCE OVERTOP, **GLYPHOSATE-TOLERANT VARIETIES:** annual and perennial grasses, annual broadleaf weeds, and nutsedge; suppression of perennial broadleaf weeds (continued)	glyphosate + S-metolachlor (7.62 EC)	0.75 to 1.13 lb a.e. + 1 to 1.33 pt	See comments for glyphosate alone. Tank mix may be applied overtop from 3 in. tall until 100 days before harvest. Do not mix S-metolachlor and pyrithiobac. Some foliar burn may occur. Chances of foliar burn are lessened when one avoids application to cotton with dew or during extreme temperatures. Insecticides in the mixture often increase burn. Sequence is a premix containing glyphosate and S-metolachlor. See the discussion on Herbicide Resistance Management in the text of this chapter.
	glyphosate + acetochlor (3 ME)	+ 3 pt	See comments for glyphosate alone. Warrant is the only brand of acetochlor registered for this use. Tank mix may be applied overtop cotton that is completely emerged until the first bloom stage. Some foliar burn may occur. Chances of foliar burn are lessened when one avoids application to cotton with dew or during extreme temperatures. Insecticides in the mixture often increase burn. See the discussion on Herbicide Resistance Management in the text of this chapter.
	glyphosate + trifloxysulfuron (75 WDG)	0.75 to 1.13 lb a.e. + 0.1 oz	See comments for glyphosate and trifloxysulfuron applied alone. Tank mix can be applied overtop cotton from 5-leaf stage until 60 days prior to harvest. For better crop safety, however, cotton should have at least 7 to 8 leaves at time of application. See the discussion on Herbicide Resistance Management in the text of this chapter.
	glyphosate + pyrithiobac (3.2 L)	0.75 to 1.13 lb a.e. + 1.3 to 3.8 fl oz	See comments for glyphosate and pyrithiobac applied alone. Tank mix may be applied overtop from the cotyledonary stage until 60 days prior to harvest. See the discussion on Herbicide Resistance Management in the text of this chapter.
POSTEMERGENCE-DIRECTED, ANY VARIETY: Annual broadleaf weeds, small annual grasses, and nutsedge	MSMA (6 lb/gal)	2.67 pt	Do not apply after first bloom. Do not apply these rates overtop. Two applications usually needed for acceptable nutsedge control.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, ANY VARIETY: Annual broadleaf weeds, small annual grasses, and nutsedge (continued)	prometryn (4 F) + MSMA (6 lb/gal)	1.3 to 2.4 pt + 2.67 pt	Direct 1.3 pt prometryn after cotton is at least 6 in. tall; increase rate to 2.4 pt after cotton is at least 12 in. tall. At the higher rate, prometryn may give limited residual control of susceptible broadleaf weeds, such as pigweed. Add nonionic surfactant at 2 qt per 100 gal. Do not apply MSMA after first bloom. See rotational restrictions on prometryn label. Carfentrazone (Aim) 2 EC at 1 fl oz or lactofen (Cobra) at 6 to 8 fl oz may be added to this combination to improve control of large morningglory. Cotton should be at least 16 in. tall when applying carfentrazone. Do not allow carfentrazone to contact green stem tissue. S-metolachlor at 1 to 1.3 pt can be included for additional residual control of annual grasses, pigweed species, and doveweed.
	lactofen (2 EC) + MSMA (6 lb/gal)	12.5 fl oz + 2.67 pt	Direct lactofen (Cobra) to cotton at least 6 to 8 in. tall, preferably larger. Add 1 qt nonionic surfactant per 100 gal spray solution for cotton less than 12 in.; add 0.5 to 1 pt per acre crop oil concentrate on cotton larger than 12 in. Do not apply MSMA after first bloom. This combination does not provide residual control.
	lactofen (2 EC) + diuron (4 F) + MSMA (6 lb/gal)	12.5 fl oz + 0.8 to 1.2 pt + 2.67 pt	Direct to cotton at least 12 in. tall. Add 1 to 2 pt per acre of crop oil concentrate. Do not apply MSMA after first bloom. See rotational restrictions on diuron label.
	fluometuron (4 F) + MSMA (6 lb/gal)	1 to 2 qt + 2.67 pt	Direct fluometuron (Cotoran) to cotton at least 3 in. tall. Do not apply MSMA after first bloom. Add nonionic surfactant at 1 qt per 100 gal. See rotational restrictions on fluometuron label. S-metolachlor at 1 to 1.3 pt may be added for additional residual control of annual grasses, pigweed species, and doveweed.
	diuron (4 F) + MSMA (6 lb/gal)	1.6 to 2.4 pt + 2.67 pt	Direct to cotton at least 12 in. tall. See label and adjust rate according to soil types. Add nonionic surfactant at 1 to 2 qt per 100 gal spray solution. Label prohibits use on sand or loamy sand soils, or any soil with less than 1% organic matter, although research in NC has not shown this to be a problem. See rotational restrictions on diuron label. Do not apply MSMA after first bloom. Carfentrazone (Aim) at 1 fl oz or lactofen (Cobra) at 6 to 8 fl oz may be added to this combination to improve control of larger morningglory. Cotton should be at least 16 in. tall when applying carfentrazone. Do not allow carfentrazone to contact green stem tissue.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, ANY VARIETY: Annual broadleaf weeds, small annual grasses, and nutsedge (continued)	[diuron + linuron] (4 F) + MSMA (6 lb/gal)	2 pt + 2.67 pt	Diuron + linuron is a premix. Direct to cotton at least 15 in. tall. Add crop oil concentrate at 1 gal per 100 gal spray solution. Label prohibits use on sand or loamy sand soils or on any soil with less than 1% organic matter. Do not apply MSMA after first bloom.
	flumioxazin (51 WDG) + MSMA (6 lb/gal)	2 oz + 2.67 pt	Direct to cotton at least 16 in. tall. Direct spray to lower 2 in. of cotton stem. Do not allow spray to contact green stem tissue. Add nonionic surfactant at 1 qt per 100 gal spray solution. Do NOT use crop oil concentrate, methylated seed oil, organo-silicone adjuvants, or any adjuvant product containing any of these. Do not apply MSMA after first bloom. No rotational restrictions of concern.
POSTEMERGENCE-DIRECTED, **GLYPHOSATE-TOLERANT VARIETIES:** Annual grass and broadleaf weeds, nutsedge, and suppression of perennial weeds	glyphosate	0.75 to 1.13 lb a.e.	Can be directed at any growth stage. Precise directing to avoid contact with the crop is not necessary. Precision, however, is required when directing tank mixes. Use of other herbicides, in addition to glyphosate, is recommended to aid in resistance management. See the discussion on Herbicide Resistance Management in the text of this chapter. See Table 10-8 for conversions among glyphosate formulations.
	glyphosate + carfentrazone (2 EC)	0.75 to 1.13 lb a.e. + 1 to 1.5 fl oz	Direct to cotton at least 16 in. tall; do not allow carfentrazone to contact green stem tissue. Add crop oil concentrate according to carfentrazone label. Compared to glyphosate alone, this combination improves control of larger morningglory. This tank mix does not give residual control.
	glyphosate + prometryn (4 F)	0.75 to 1.13 lb a.e. + 1 to 2 pt	Direct to cotton at least 6 to 8 in. tall. Use 1 to 1.3 pt prometryn on cotton 6 to 12 in. tall; rate can be increased to 2.4 pt on cotton at least 12 in. tall. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will improve control of larger morningglory and may provide residual control of small-seeded broadleaf weeds, such as pigweed. This tank mix may give less control of larger grasses or grasses under drought stress compared with glyphosate alone.
	glyphosate + diuron (4 F)	0.75 to 1.13 lb a.e. + 1 to 1.5 pt	Direct to cotton at least 8 in. tall. Use 1 pt diuron on cotton 8 to 12 in. tall; rate can be increased to 1.5 pt on cotton at least 12 in. tall. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will improve control of larger morningglory and may provide residual control of small-seeded broadleaf weeds, such as pigweed. This tank mix may give less control of larger grasses or grasses under drought stress compared with glyphosate alone.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, **GLYPHOSATE-TOLERANT VARIETIES:** Annual grass and broadleaf weeds, nutsedge, and suppression of perennial weeds (continued)	glyphosate + S-metolachlor (7.62 EC)	0.75 to 1.13 lb a.e. + 1 to 1.33 pt	See Table 10-7 for glyphosate formulations and rate conversions. Direct to cotton 3 in. tall through layby. Add surfactant according to the label of the brand of glyphosate used. See above comments for glyphosate alone. Compared to glyphosate alone, this combination will not improve control of emerged weeds, but it can give residual control of grasses and pigweed species. Sequence is a premix of glyphosate and S-metolachlor. It can be directed at 2.5 pints per acre.
	glyphosate + acetochlor (3.0 ME)	0.75 to 1.13 + 3 pt	Warrant is the only brand of acetochlor registered for this use. Can be directed to cotton up to first bloom stage. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will not improve control of emerged weeds, but it can give residual control of grasses and pigweed species.
	glyphosate + trifloxysulfuron (75 WDG)	0.75 to 1.13 lb a.e. + 0.1 to 0.2 oz	Direct to cotton at least 6 in. tall, preferably taller. Add surfactant according to the trifloxysulfuron label. Compared to glyphosate alone, this combination will improve control of larger morningglory and nutsedge.
	glyphosate + [prometryn + trifloxysulfuron] (80 WDG)	0.75 to 1.13 lb a.e. + 1 lb	Prometryn + trifloxysulfuron is a premix. Direct to cotton at least 6 to 8 in. tall. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will improve control of larger morningglory and nutsedge and provide residual control of small-seeded broadleaf weeds, such as pigweed. This tank mix may give less control of larger grasses or grasses under drought stress compared with glyphosate alone.
	glyphosate + flumioxazin (51 WDG)	0.75 to 1.13 lb a.e. + 1 to 2 oz	Direct to lower 2 in. or less of stem on cotton at least 16 in. tall. Do not allow spray to contact green stem tissue. Add nonionic surfactant at 1 qt per 100 gal spray solution. Do NOT use crop oil concentrate, methylated seed oil, organo-silicone adjuvants, or any adjuvant product containing any of these. Compared to glyphosate alone, this combination will improve control of larger morningglory and provide residual control of a number of broadleaf weeds.
POSTEMERGENCE WITH HOODED SPRAYER, ANY VARIETY: Annual grass and broadleaf weeds, perennial grass and broadleaf weeds, and nutsedge	glyphosate	0.75 to 1.13 lb a.e.	Rate depends on weed species and size: see label of brand used for specific rates. Hoods should be kept as close to the ground as possible so spray solution does not contact crop. Application to base of non-glyphosate-tolerant cotton will cause injury. Speed should not exceed 5 mph. Use 5 to 10 GPA and maximum pressure of 25 PSI. Do not use liquid nitrogen as the carrier. Other herbicides as discussed in the section on directed applications may be mixed with glyphosate to improve burndown on morningglory and other problem weeds and to provide residual control.

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names. *continued*

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE WITH HOODED SPRAYER, ANY VARIETY: Annual grass and broadleaf weeds, suppression of nutsedge	paraquat (2 lb/gal brands) (3 lb/gal brands0	1.2 to 2.4 pt 0.8 to 1.6 pt	Hoods should be kept as close to the ground as possible. Do NOT allow the spray solution to contact cotton plants. Apply in a minimum of 10 GPA (higher GPA preferred) at maximum pressure of 25 PSI. Do not exceed 5 mph. It is suggested cotton be at least 6 in. tall. Add nonionic surfactant according to label. Diuron or prometryn may be mixed with paraquat. Tank mixes are usually more effective than paraquat alone.
	glufosinate (2.34 L)	29 to 43 fl oz	On non-glufosinate tolerant varieties, keep hoods close to the ground and avoid contact with the cotton. Apply in at least 15 GPA. No adjuvant necessary. Can add diuron, fluometuron, pendimethalin, prometryn, pyrithiobac, or S-metolachlor for residual control.
HARVEST AID: Annual grasses and broadleaf weeds	paraquat (2 lb/gal brands) (3 lb/gal brands)	1 to 2 pt 0.67 to 1.33 pt	Defoliate cotton as normal. After at least 75% to 80% of the bolls are open, the remaining bolls expected to be harvested are mature, and most of the cotton leaves have dropped, apply paraquat in a minimum of 20 gal per acre and add 1 pt nonionic surfactant per 100 gal. Wait 5 days before picking, then pick as soon as possible.

Table 10-3. Weed Response to Burndown Herbicides for Conservation-Tillage Cotton[1]

Weed	2,4-D[2]	Glyphosate	Glyphosate + dicamba[3]	Glyphosate + 2,4-D[2]	Glyphosate + thifensulfuron + tribenuron[4]	Glyphosate + saflufenacil[5]	Glyphosate + thifensulfuron + rimsulfuron[6]	Glyphosate + flumioxazin[7]	Paraquat	Paraquat + diuron[8]
Annual bluegrass	N	E	E	E	E	E	E	E	GE	E
Little barley	N	E	E	E	E	E	E	E	G	E
Buttercups	G	E	E	E	E	E	E	E	E	E
Carolina geranium	PF	PF	G	F	GE	---	G	G	GE	E
Chickweed	P	E	E	E	E	E	E	E	E	E
Cudweed	NP	E	E	E	E	E	E	E	FG	G
Curly dock	F	F	GE	FG	E	---	F	F	NP	P
Cutleaf eveningprimrose	E	PF	G	E	F	---	PF	FG	F[9]	G[9]
Field pansy	P	F	F	F	F	---	--	F	G	GE
Henbit	PF	G	E	E	E	---	E	E	E	E
Horseweed (marestail)	GE[10]	GE[11]	E	E[10]	GE[11]	E	GE[11]	E[11]	PF	G
Prickly lettuce	G	E	E	E	E	E	E	E	P	PF
Ryegrass	N	G	G	G	G	G	GE	G	F	FG
Smartweed	F	FG	E	G	E	---	G	—	F	G
Speedwell	PF	E	E	E	E	E	E	E	E	E
Swinecress	F	FG	FG	G	GE	---	--	—	P	G
Vetch	E	F	E	E	G	---	--	FG	PF	F
Virginia pepperweed	GE	G	GE	E	G	---	G	GE	G	G
Wheat or rye cover crop [12]	N	E	E	E	E	E	E	E	G[14]	GE[14]
Wild mustard, wild radish	FG[13]	FG	G	E	GE	---	FG	G	FG	G

Note: E = excellent, 90% or better control; G = good, 80 to 90% control; F = fair, 50 to 80% control; P = poor, 25 to 50% control; N = no control, less than 25% control

[1] See Table 10-1 for brand names and Table 10-2 for application rates.

[2] Apply 2,4-D at least 30 days ahead of planting.

[3] Following application of dicamba and a minimum of 1 in. of rainfall, a minimum 21-day waiting period is required before planting.

[4] Apply thifensulfuron + tribenuron at least 14 days ahead of planting.

[5] A minimum of 42 days must pass and 1 inch of rainfall must occur between application of saflufenacil and cotton planting.

[6] Apply thifensulfuron + rimsulfuron at least 30 to 60 days, depending upon rate, ahead of planting.

[7] A minimum of 14 days must pass and 1 inch of rainfall must occur between application of flumioxazin at 1 oz and planting. Delay planting 21 days after application of 1.5 to 2 oz of flumioxazin. See exceptions for strip-tillage in Table 10.2.

[8] Diuron should be applied 15 to 45 days ahead of planting.
[9] This level of control requires that the primrose be blooming when treated.
[10] This level of control requires 2 pt of 2,4-D.
[11] Control will be poor on glyphosate-resistant horseweed.
[12] Glyphosate rate is 0.56 lb a.e. for wheat less than 12 in. or rye less than 18 in., or 0.75 lb a.e. for wheat greater than 12 in. or rye greater than 18 in.
[13] Wild radish and wild mustard control by 2,4-D is good if application is made before plants begin flowering. Use 1 pt per acre of 2,4-D to control these species.
[14] Wheat or rye must have visible seed heads for this level of control.

Table 10-4. Grass and Nutsedge Response to Soil-Applied Herbicides[1]

Weed	Pendimethalin or trifluralin PPI	Fluometuron PRE	Diuron PRE	Pendimethalin PRE	Fomesafen PRE	Pyrithiobac PRE	Acetochlor PRE
Bermudagrass	N	N	N	N	N	N	N
Broadleaf signalgrass	G	P	P	F	FG	P	G
Crabgrass	E	FG	FG	G	FG	P	E
Crowfootgrass	E	FG	FG	G	—	P	--
Fall panicum	G	F	P	F	—	PF	E
Foxtails	E	FG	—	G	—	P	E
Goosegrass	E	F	F	G	—	PF	E
Johnsongrass							
Seedling	E	P	P	G	—	FG	PF
Rhizome	P	N	N	N	—	N	N
Texas panicum	G	P	P	F	F	N	PF
Nutsedge							
Purple	N	N	N	N	—	F	N
Yellow	N	N	N	N	GE	F	PF

Note: PPI = preplant-incorporated; PRE = preemergence

E = excellent, 90% or better control
G = good, 80 to 90% control
F = fair, 50 to 80% control
P = poor, 25 to 50% control
N = no control, less than 25% control

[1] See Table 10-1 for brand names.

Table 10-5. Annual Broadleaf Weed Response to Soil-Applied Herbicides[1]

Weed	Pendimethalin or trifluralin PPI	Fluometuron PRE	Diuron PRE	Pendimethalin PRE	Fomesafen PRE	Pyrithiobac PRE	Acetochlor PRE
Citronmelon	N	FG	F	N	—	FG	N
Cocklebur	N	FG	F	N	G	NP	N
Common purslane	E	E	E	G	G	G	G
Common ragweed	N	E	G	N	G	NP	P
Cowpea	N	P	P	N	—	FG	N
Crotalaria	N	G	G	N	—	—	--
Eclipta	P	G	G	P	GE	—	FG
Florida beggarweed	P	GE	G	N	P	G	F
Florida pusley	E	FG	PF	FG	P	F	GE
Hemp sesbania	N	P	P	N	P	P	N
Jimsonweed	N	G	G	N	—	FG	N
Lambsquarters	GE	E	E	G	E	G	F
Morningglory species							
Tall	P	G	F	P	PF	P	N
Others	P	G	F	P	PF	F	N
Pigweed species							
Redroot or smooth	GE	E	E	FG	E	E	GE
Palmer amaranth	G	G	G	PF	E	G[2]	G
Prickly sida	N	G	F	N	—	G	P
Sicklepod	N	G	F	N	P	PF	N
Smartweed	N	G	G	N	—	G	N
Spurge	N	PF	F	N	—	G	F
Spurred anoda	N	F	F	N	—	E	N
Tropic croton	N	FG	FG	N	FG	FG	N
Velvetleaf	N	F	PF	N	—	E	N
Volunteer peanuts	N	PF	P	N	P	P	N

Note: PPI = preplant-incorporated; PRE = preemergence

E = excellent, 90% or better control
G = good, 80 to 90% control
F = fair, 50 to 80% control
P = poor, 25 to 50% control
N = no control, less than 25% control

[1] See Table 10-1 for brand names.
[2] No control of ALS-resistant Palmer amaranth.

Table 10-6. Annual and Perennial Grass, Nutsedge, and Dayflower Response to Postemergence Herbicides[1]

Weed	Quizalofop	Fluazifop	Sethoxydim	Clethodim	Trifloxysulfuron	Pyrithiobac
Bermudagrass	G[2]	G[2]	F[2]	G[2]	N	N
Broadleaf signalgrass	G	GE	E	E	N	N
Crabgrass	G	G	GE	GE	P	N
Crowfootgrass	G	F	FG	G	N	N
Fall panicum	GE	GE	E	E	NP	N
Foxtails	E	E	E	E	NP	N
Goosegrass	G	GE	GE	GE	NP	NP
Johnsongrass						
Seedling	E	E	E	E	F	P
Rhizome	E	GE	G	GE	P	NP
Texas panicum	G	G	E	E	NP	N
Nutsedge						
Yellow	N	N	N	N	G	PF
Purple	N	N	N	N	FG	PF
Dove weed[3]	N	N	N	N	—	N
Spreading dayflower[4]	N	N	N	N	N	FG

[1] See Table 10-1 for brand names.

[2] Two applications may be needed for adequate control.

continued

Table 10-6. Annual and Perennial Grass, Nutsedge, and Dayflower Response to Postemergence Herbicides[1] (continued)

Weed	Prometryn + MSMA[3]	Lactofen + MSMA[3]	Fluometuron + MSMA[3]	Diuron + MSMA[3]	Diuron + linuron + MSMA[3]	MSMA[3]	Prometryn + trifloxysulfuron + MSMA[3]	Flumioxazin + MSMA[3]	Glyphosate[4]
Bermudagrass	N	N	N	N	N	N	N	N	F[5]
Broadleaf signalgrass	FG	F	F	F	FG	F	FG	F	E
Crabgrass	FG	F	F	F	FG	F	FG	FG	E
Crowfootgrass	FG	F	F	F	FG	F	FG	FG	E
Fall panicum	FG	F	F	F	FG	F	FG	FG	E
Foxtails	FG	F	F	F	FG	F	FG	F	E
Goosegrass	FG	F	F	F	FG	F	FG	F	E
Johnsongrass									
Seedling	FG	F	F	F	FG	F	FG	F	E
Rhizome	P	P	P	P	P	P	P	P	E
Texas panicum	F	P	P	P	F	P	F	PF	EE
Nutsedge									
Yellow	FG[6]	FG[6]	FG[6]	G	G	FG[6]	E	G	F[5]
Purple	F[6]	F[6]	F[6]	F[6]	F[6]	F[6]	EV	FG[6]	FG[5]
Dove weed[3]	N	N	N	—	—	N	—	—	P
Spreading dayflower[4]	G	G	G	G	G	G	G	G	P

[1] See Table 10-1 for brand names.

[3] Applied postemergence-directed only.

[4] Applied overtop or directed to glyphosate-tolerant cotton only.

[5] Good control with two applications of glyphosate.

[6] Good control can be obtained with two applications of MSMA.

continued

Table 10-6. Annual and Perennial Grass, Nutsedge, and Dayflower Response to Postemergence Herbicides[1] (continued)

Weed	Glyphosate + carfentrazone[7]	Glyphosate + prometryn[7]	Glyphosate + diuron[7]	Glyphosate + trifloxysulfuron[7]	Glyphosate + pyrithiobac[4]	Glyphosate + prometryn + trifloxysulfuron[7]	Glyphosate + flumioxazin[7]	Glufosinate[8]	Glufosinate + pyrithiobac[8]
Bermudagrass	F[5]	F[5]	F[5]	F[5]	F[5]	F[5]	F[5]	N	N
Broadleaf signalgrass	E	GE	GE	E	E	GE	E	G	G
Crabgrass	E	GE	GE	E	E	GE	E	FG	FG
Crowfootgrass	E	GE	GE	E	E	GE	E	G	G
Fall panicum	E	GE	GE	E	E	GE	E	G	G
Foxtails	E	GE	GE	E	E	GE	E	G	G
Goosegrass	E	GE	GE	E	E	GE	E	P	P
Johnsongrass									
Seedling	E	GE	GE	E	E	GE	E	G	G
Rhizome	GE	G	G	E	GE	G	GE	F[9]	F[9]
Texas panicum	E	GE	GE	E	E	GE	E	G	G
Nutsedge									
Yellow	F[75]	F[5]	F[5]	E	FG[5]	E	F[5]	F	F
Purple	FG[5]	FG[5]	FG[5]	E	FG[5]	GE	FG[5]	F	F
Doveweed	P	P	—	—	P	—	E	P	P
Spreading dayflower	P	P	P	P	FG	P	P	PF	FG

[1] See Table 10-1 for brand names.

[4] Applied overtop or directed to glyphosate-tolerant cotton only.

[5]Good control with two applications of glyphosate.

[7] Applied postemergence-directed to glyphosate-tolerant cotton only.

[8]Applied overtop or directed to glufosinate-tolerant cotton only.

[9]Good johnsongrass control can be obtained with two applications of glufosinate.

Table 10-7. Annual Broadleaf Weed Response to Postemergence Herbicides[1]

Weed	Trifloxysulfuron	Pyrithiobac	Prometryn + MSMA[2]	Lactofen + MSMA[2]	Fluometuron + MSMA[2]	Diuron + MSMA[2]	Diuron + linuron + MSMA[2]	MSMA[3]	Prometryn + trifloxysulfuron + MSMA[2]	Flumioxazin + MSMA[2]
Citronmelon	GE	GE	FG	G	G	G	G	F	—	—
Cocklebur	GE	G	E	E	E	E	E	E	E	E
Common purslane	—	F	FG	G	FG	G	G	PF	—	G
Common ragweed	G	P	E	E	GE	E	E	F	E	GE
Cowpea	G	G	G	FG	G	G	G	FG	G	G
Crotalaria	—	G	G	G	G	G	G	G	E	—
Eclipta	PF	G	G	E	G	E	E	—	E	E
Florida beggarweed	GE	G	E	E	E	E	E	E	E	E
Florida pusley	NP	NP	F	F	F	F	F	P	F	FG
Hemp sesbania	—	GE	PF	F	PF	PF	—	N	—	—
Jimsonweed	N	E	G	GE	GE	G	G	F	G	E
Lambsquarters	G	N	G	F	G	G	G	PF	GE	G
Morningglory species										
Tall	G	P	GE	E	G	GE	GE	F	E	E
Others	G	G	GE	E	G	GE	GE	F	E	E
Pigweed species										
Redroot or smooth	FG	GE	G	G	G	GE	GE	PF	GE	GE
Palmer amaranth	PF[4]	F[4]	FG	G	FG	G	G	P	G	G
Prickly sida	N	F	GE	GE	FG	GE	GE	P	GE	GE
Sicklepod	E	PF	GE	PF	G	GE	GE	F	E	GE
Smartweed	G	G	F	F	G	F	F	P	—	G
Spurge	—	FG	G	G	PF	G	G	N	—	G
Spurred anoda	P	G	F	F	FG	F	F	P	—	G
Tropic croton	PF	NP	G	E	G	G	G	F	GE	E
Velvetleaf	G	G	G	G	F	G	G	P	—	G
Volunteer peanuts	PF	P	FG	PF	FG	G	G	PF	G	FG

Note: E = excellent, 90% or better control; G = good, 80 to 90% control; F = fair, 50 to 80% control; P = poor, 25 to 50% control; N = no control, less than 25% control

[1]See Table 10-1 for brand names.

[2]Applied post-directed only.

[3]Ratings assume directed rates of MSMA.

[4]No control of ALS-resistant Palmer amaranth.

continued

Table 10-7. Annual Broadleaf Weed Response to Postemergence Herbicides[1] (continued)

Weed	Glyphosate[5]	Glyphosate[6] + carfentrazone	Glyphosate[6] + prometryn	Glyphosate[6] + diuron	Glyphosate[6] + trifloxysulfuron	Glyphosate[5] + pyrithiobac	Glyphosate[6] + prometryn + trifloxysulfuron	Glyphosate[6] + flumioxazin	Glufosinate[7]	Paraquat[8] + diuron
Citronmelon	GE	GE	GE	GE	E	E	E	E	G	E
Cocklebur	E	E	E	E	E	E	E	E	E	E
Common purslane	FG	FG	GE	GE	—	—	GE	GE	F	E
Common ragweed	E[9]	E[9]	E[9]	E[9]	E[9]	E[9]	E[9]	E[9]	E	G
Cowpea	GE	GE	GE	GE	GE	GE	E	E	G	E
Crotalaria	G	G	G	G	—	G	G	—	—	—
Eclipta	E	E	E	E	E	E	E	E	G	G
Florida beggarweed	E	E	E	E	E	E	E	E	G	E
Florida pusley	PF	G	G	G	PF	PF	G	GE	PF	FG
Hemp sesbania	PF	GE	—	—	—	GE	—	—	—	FG
Jimsonweed	E	E	E	E	E	E	E	E	E	E
Lambsquarters	G	GE	GE	GE	GE	GE	E	GE	E	G
Morningglory species										
Tall	FG	E	GE	GE	E	GE	E	E	E	E
Others	FG	E	GE	GE	E	GE	E	E	E	E
Pigweed species										
Redroot or smooth	E	E	E	E	E	E	E	E	G	E
Palmer amaranth	E[10]	E[11]	E[10]	E[10]	E[11]	E[11]	E[11]	E[10]	FG	GE
Prickly sida	FG	FG	G	G	FG	G	G	GE	GE	G
Sicklepod	E	E	E	E	E	E	E	E	E	E
Smartweed	G	GE	G	G	E	E	E	G	GE	GE
Spurge	G	GE	GE	GE	G	G	E	G	FG	—
Spurred anoda	E	E	E	E	E	E	E	E	P	G
Tropic croton	E	E	E	E	E	E	E	E	G	G
Velvetleaf	E	E	E	E	E	E	E	E	—	—
Volunteer peanut	F	FG	FG	G	FG	F	FG	FG	GE	FG

Note: E = excellent, 90% or better control; G = good, 80 to 90% control; F = fair, 50 to 80% control; P = poor, 25 to 50% control; N = no control, less than 25% control

[1] See Table 10-1 for brand names.
[5]Applied overtop or directed to glyphosate-tolerant cotton only.
[6]Applied postemergence-directed to glyphosate-tolerant cotton only.
[7]Applied overtop or directed to glufosinate-tolerant cotton only.
[8]Paraquat must be applied only under a hood to avoid contact with cotton.
[9]Glyphosate-resistant common ragweed occurs is some areas of North Carolina.
[10]Poor on glyphosate-resistant Palmer amaranth.
[11]Poor to fair on glyphosate-resistant Palmer amaranth.

Table 10-8. Comparison of Glyphosate Formulations and Acid Equivalence

Formulation	Glyphosate acid equivalent (a.e.)	Brand names[1]	Comparative rates on basis of acid equivalent (a.e.)
isopropylamine salt 4.0 lb/gal	3.0 lb/gal	Gly-4 Plus, Glyphogan Plus, GlyStar Gold, Mad Dog Plus, Makaze	0.563 lb a.e. = 24 fl oz 0.750 lb a.e. = 32 fl oz 1.125 lb a.e. = 48 fl oz
isopropylamine salt 5.0 lb/gal	3.75 lb/gal	Extra Credit 5	0.563 lb a.e. = 19.2 fl oz 0.750 lb a.e. = 25.6 fl oz 1.125 lb a.e. = 38.4 fl oz
potassium salt 5.0 lb/gal	4.17 lb/gal	Touchdown Total Traxion	0.563 lb a.e. = 17.3 fl oz 0.750 lb a.e. = 23 fl oz 1.125 lb a.e. = 34.5 fl oz
potassium salt 5.5 lb/gal	4.5 lb/gal	Roundup PowerMax Roundup WeatherMax	0.563 lb a.e. = 15.9 fl oz 0.750 lb a.e. = 21.3 fl oz 1.125 lb a.e. = 32 fl oz
potassium salt 6.0 lb/gal	5.0 lb/gal	Touchdown HiTech	0.563 lb a.e. = 14.3 fl oz 0.750 lb a.e. = 19.2 fl oz 1.125 lb a.e.= 28.8 fl oz
dimethylamine salt 5.4 lb/gal	4.0 lb/gal	Duramax Durango DMA	0.563 lb a.e. = 18 fl oz 0.750 lb a.e. = 24 fl oz 1.125 lb a.e. = 36 fl oz
ammonium salt 1.8 lb/gal + potassium salt 1.65 lb/gal	3.0 lb/gal	NuFarm Credit Extra	0.563 lb a.e. = 24 fl oz 0.750 lb a.e. = 32 fl oz 1.125 lb a.e. = 48 fl oz

[1] These brands are registered for overtop application to glyphosate-tolerant cotton after the four-leaf stage. Several other brands, not registered for this use, can be used in burndown application.

Table 10-9. Herbicide Ingredients and Modes of Action

Brand Name(s)	Active Ingredient(s)	Mode(s) of Action[1]
AAtrex	atrazine	5
Accent, Accent Q	nicosulfuron	2
Acumen	pendimethalin	3
Aim	carfentrazone	14
Armezon	topramezone	27
Arrow	clethodim	1
Atrazine	atrazine	5
Assure II	quizalofop	1
Authority Assist	sulfentrazone + imazethapyr	14 + 2
Authority First	sulfentrazone + cloransulam	14 + 2
Authority MTZ	sulfentrazone + metribuzin	14 + 5
Authority XL, Authority Maxx	sulfentrazone + chlorimuron	14 + 2
Axial XL	pinoxaden	1
Axiom	flufenacet + metribuzin	15 + 5
Balance Flexx	isoxaflutole	27
Banvel	dicamba	4
Basagran	bentazon	6
Basis	rimsulfuron + thifensulfuron	2 + 2
Battle Star	fomesafen	14
Beyond	imazamox	2
Bicep II Magnum	s-metolachlor + atrazine	15 + 2
Bonfire	paraquat	22
Boundary	s-metolachlor + metribuzin	15 + 5
Brawl, Brawl II	s-metolachlor	15
Brawl II ATZ	s-metolachlor + atrazine	15 + 5
Breakfree	s-metolachlor	15
Breakfree ATZ	s-metolachlor + atrazine	15 + 5
Broclean	bromoxynil	6
Buctril	bromoxynil	6
Bullet	alachlor + atrazine	15 + 5
Butyrac	2,4-DB	4
Cadence	acetochlor	15
Cadence ATZ	acetochlor + atrazine	15+ 5
Cadre	imazapic	2
Callisto	mesotrione	27
Canopy	metribuzin + chlorimuron	5 + 2
Canopy EX	chlorimuron + tribenuron	2 + 2
Caparol	prometryn	5
Capreno	tembotrione + thiencarbazone	27 + 2
Cinch	s-metolachlor	15
Cinch ATZ	s-metolachlor + atrazine	15 + 5
Clarity	dicamba	4
Clash	dicamba	4
Classic	chlorimuron	2
Clethodim	clethodim	1
Cloak	metribuzin + chlorimuron	5 + 2

continued

Table 10-9. Herbicide Ingredients and Modes of Action

Brand Name(s)	Active Ingredient(s)	Mode(s) of Action[1]
Cloak EX	chlorimuron + tribenuron	2 + 2
Cobra	lactofen	14
Collide	oxyfluorfen	14
Command	clomazone	13
Corvus	thiencarbazone-methyl + isoxaflutole	2 + 27
Cotoran	fluometuron	7
Cotton-Pro	prometryn	5
Curbit	ethalfluralin	3
Curio	chlorimuron	2
Dawn	fomesafen	14
Degree	acetochlor	15
Degree Xtra	acetochlor + atrazine	15 + 5
Detonate	dicamba	4
Devrinol	napropamide	15
Diablo	dicamba	4
Dicamba HD, Dicamba DMA Salt	dicamba	4
Direx	diuron	7
Distinct	dicamba	4
Diuron	diuron	7
Dual Magnum, Dual II Magnum	metolachlor or s-metolachlor	15
Edition Broadspec	thifensulfuron + tribenuron	2 + 2
Edition Tankmix	thifensulfuron + tribenuron	2 + 2
Envive	flumioxazin + chlorimuron + thifensulfuron	14 + 2 + 2
Envoke	trifloxysulfuron	2
Eptam	EPTC	8
ET	pyraflufen ethyl	14
Evik	ametryne	5
Expert	glyphosate + s-metolachlor + atrazine	9 + 15 + 5
Express	tribenuron	2
Extreme	glyphosate + imazethapyr	9 + 2
Finesse	chlorsulfuron + metsulfuron	2 + 2
Finesse Grass & Broadleaf	chlorsulfuron + flucarbazone	14 + 2
Firestorm	paraquat	22
Firstrate	cloransulam	2
Firstshot	thifensulfuron + tribenuron	2 + 2
Flexstar	fomesafen	14
Flexstar GT	fomesafen + glyphosate	14 + 9
FulTime	acetochlor + atrazine	15 + 5
Fusilade DX	fluazifop	1
Fusion	fluazifop + fenoxaprop	1 + 1
Galigan	oxyfluorfen	14
Gangster	flumioxazin + cloransulam	14 + 2
Glory	metribuzin	5
Glyphosate (numerous brands)	glyphosate	9
Goal, Goal Tender	oxyfluorfen	14

continued

Table 10-9. Herbicide Ingredients and Modes of Action

Brand Name(s)	Active Ingredient(s)	Mode(s) of Action[1]
Gramoxone Inteon, Gramoxone SL	paraquat	22
Guardsman Max	dimethenamid + atrazine	15 + 5
Halex GT	s-metolachlor + glyphosate + mesotrione	15 + 9 + 27
Harmony Extra	thifensulfuron + tribenuron	2 + 2
Harmony SG	thifensulfuron	2
Harness	acetochlor	15
Harness Xtra	acetochlor + atrazine	15 + 5
Hoelon	diclofop	1
Huskie	pyrasulfotole + bromoxynil	27 + 6
Impact	topramezone	27
Impose	imazapic	2
Instigate	mesotrione + rimsulfuron	27 + 2
Intensity, Intensity One	clethodim	1
Intrro	alachlor	15
Karmex	diuron	7
Keystone	acetochlor + atrazine	15 + 5
Lariat	alachlor + atrazine	15 + 5
Laudis	tembotrione	27
Layby Pro	diuron + linuron	7 + 7
Leadoff	rimsulfuron + thifensulfuron	2 + 2
Lexar, Lumax	mesotrione + s-metolachlor + atrazine	27 + 15 + 5
Liberty 280	glufosinate	10
Lightning	imazethapyr + imazapyr	2 + 2
Linex	linuron	7
Lorox	linuron	7
Marksman	dicamba + atrazine	4 + 5
Matador	imazethapyr + metolachlor + metribuzin	2 + 15 + 5
Matrix	rimsulfuron	2
Medal, Medal II	s-metolachlor	15
Medal II AT	s-metolachlor + atrazine	15 + 5
Me-Too-Lachlor, Me-Too-Lachlor II	metolachlor	15
Metribuzin	metribuzin	5
Metri DF	metribuzin	5
Micro-Tech	alachlor	15
MSMA-6 Plus	MSMA	17
Nufarm Imazapic	imazapic	2
Optill	imazethapyr + saflufenacil	2 + 14
Option	foramsulfuron	2
Osprey	mesosulfuron	2
Outflank	flumioxazin	14
Outlook	dimethenamid	15
Overtime	acetochlor	15
Overtime ATZ	acetochlor + atrazine	15 + 5
Oxystar	oxyfluorfen	14

continued

Table 10-9. Herbicide Ingredients and Modes of Action

Brand Name(s)	Active Ingredient(s)	Mode(s) of Action[1]
Panther	flumioxazin	14
Parallel, Parallel PCS	metolachlor	15
Parallel Plus	metolachlor + atrazine	15 + 5
Parazone	paraquat	22
Parrot	diuron	7
Peak	prosulfuron	2
Poast, Poast Plus	sethoxydim	1
Powerflex	pyroxsulam	2
Prefix	s-metolachlor + fomesafen	15 + 14
Princep	simazine	5
Prometryne	prometryn	5
Prowl, Prowl H2O	pendimethalin	3
Pruvin	rimsulfuron	2
Pursuit	imazethapyr	2
Pyrimax	pyrithiobac	2
Python	flumetsulam	2
Quik-Quat	paraquat	22
Rapport Broadspec	thifensulfuron + tribenuron	2 + 2
Rapport Tank Mix	thifensulfuron + tribenuron	2 + 2
Raptor	imazamox	2
Realm Q	rimsulfuron + mesotrione	2 + 27
Reflex	fomesafen	14
Require Q	rimsulfuron + dicamba	2 + 4
Resolve	rimsulfuron	2
Resolve Q	rimsulfuron + thifensulfuron	2 + 2
Resource	flumiclorac-pentyl	14
Rifle	dicamba	4
Ringside	fomesafen	14
Roundup brands	glyphosate	9
Rhythm	fomesafen	14
Sandea	halosulfuron	2
Scepter	imazaquin	2
Sekor	diuron	7
Select, Select Max	clethodim	1
Sequence	glyphosate + s-metolachlor	9 + 15
Shadow	clethodim	1
Sharpen	saflufenacil	14
Simazine	simazine	5
Sim-Trol	simazine	5
Slider	dimethenamid	15
Slider ATZ	dimethenamid + atrazine	15 + 5
Solida	rimsulfuron	2
Sonalan	ethalfluralin	3
Sonic	Sulfentrazone + cloransulam	14 + 2
Sortie	dimethenamid	15
Sortie ATZ	dimethenamid + atrazine	15 + 5

continued

Table 10-9. Herbicide Ingredients and Modes of Action

Brand Name(s)	Active Ingredient(s)	Mode(s) of Action[1]
Spartan	sulfentrazone	14
Spartan Charge	sulfentrazone + carfentrazone	14 + 14
Stalwart	metolachlor	15
Stalwart Xtra	metolachlor + atrazine	15 + 5
Staple	pyrithiobac	2
Status	dicamba + diflufenzopyr	4 + 19
Steadfast, Steadfast Q	nicosulfuron + rimsulfuron	2 + 2
Stealth	pendimethalin	3
Sterling Blue	dicamba	4
Storm	acifluorfen + bentazon	14 + 6
Stout	nicosulfuron + thifensulfuron	2 + 2
Strategy	ethalfluralin + clomazone	3 + 13
Strongarm	diclosulam	2
Strut	dicamba	4
Suprend	prometryn + trifloxysulfuron	5 + 2
Surpass	acetochlor	15
Synchrony XP	chlorimuron + thifensulfuron	2 + 2
Tackle	glyphosate + imazethapyr	9 + 2
Tapout	clethodim	1
Targa	quizalofop	1
Thunder	imazethapyr	2
Thunder Master	glyphosate + imazethapyr	9 + 2
Top Gun	fomesafen	14
TopNotch	acetochlor	15
Treaty	thifensulfuron	2
Treaty Extra	thifensulfuron + tribenuron	2 + 2
Treflan	trifluralin	3
Tricor	metribuzin	5
Trifluralin	trifluralin	3
Triflurex	trifluralin	3
Ultra Blazer	acifluorfen	14
Unity	thifensulfuron	2
Valor SX	flumioxazin	14
Valor XLT	flumioxazin + chlorimuron	14 + 2
Verdict	dimethenamid + saflufenacil	15 + 14
Victory	tribenuron	2
Vision	dicamba	4
Volunteer	clethodim	1
Warrant	acetochlor	15
Weedmaster	2,4-D + dicamba	4 + 4
2,4-D (numerous brands)	2,4-D	4
2,4-DB (numerous brands)	2,4-DB	4

[1] The numerical system to describe modes of action is taken from the Weed Science Society of America. Modes of action are as follows:

continued

1	ACCase inhibition
2	ALS inhibition
3	Microtubule assembly inhibition
4	Synthetic auxin
5	Photosystem II, different binding behavior than groups 6 and 7
6	Photosystem II, different binding behavior than groups 5 and 7
7	Photosystem II, different binding behavior than groups 5 and 6
8	Inhibition of lipid synthesis – not ACCase inhibition
9	EPSP synthase inhibition
10	Glutamine synthetase inhibition
12	Inhibition of carotenoid biosynthesis at PDS
13	Inhibition of carotenoid biosynthesis, unknown target
14	PPO inhibition
15	Inhibition of very long-chain fatty acids
17	Unknown mode of action
19	Auxin transport inhibition
22	Photosystem I electron diversion
27	Inhibition of HPPD

Table 10-10. Management Programs for Palmer Amaranth in Cotton[1]

Tillage	Preplant incorporated or early preplant burndown	Preemergence	First POST 14 days after planting	Second POST 14 days after 1st POST	Layby 16-20 days after 2nd POST
Conventional	fomesafen split[2] + pendimethalin or trifluralin Incorporate no deeper than 1 to 1.5 inches within 7 days of planting	fomesafen split[2] + one of the following: acetochlor diuron diuron + acetochlor	*RRF, WRF, or GL cotton:* glyphosate + residual[3] *LL, GL, or WRF cotton:* glufosinate + residual[3]	*RRF, WRF, or GL cotton:* glyphosate alone or with residual[4] *LL, GL, or WRF cotton:* glufosinate alone or with residual[4]	diuron + MSMA
	pendimethalin or trifluralin Incorporate no deeper than 2 inches	One of the following: acetochlor + fomesafen, diuron + fomesafen, diuron + fomesafen + acetochlor			
No-till or Strip-till	Glyphosate + flumioxazin + 2,4-D	paraquat + one of the following: acetochlor + fomesafen, diuron + fomesafen, diuron + fomesafen + acetochlor, pendimethalin + fomesafen	*RRF, WRF, or GL cotton:* glyphosate + residual[3] *LL, GL, or WRF cotton:* glufosinate + residual[3]	*RRF, WRF, or GL cotton:* glyphosate alone or with residual[4] *LL, GL, or WRF cotton:* glufosinate alone or with residual[4]	diuron + MSMA

[1] RRF = Roundup Ready Flex; WRF = WideStrike with Roundup Ready Flex; GL = GlyTol LibertyLink; LL = LibertyLink. See Table 10-1 for brand names; see Table 10-2 for application rates and comments.
[2] Fomesafen split program is 12 fl oz preplant incorporated followed by 8 fl oz preemergence. Fomesafen must be incorporated no deeper than 1 to 1.5 inches; deeper incorporation will result in poor control.
[3] Residual options for first POST: If no Palmer amaranth emerged, use acetochlor or S-metolachlor. If Palmer amaranth is emerged and less than 1 inch tall, use pyrithiobac. Pyrithiobac will not be effective if the Palmer amaranth is ALS-resistant.
[4] Residual options for second POST will vary depending upon what was used in first POST. S-metolachlor may be applied overtop only once per year. Warrant may be applied overtop twice, but the total annual use from all applications cannot exceed 8 pints. Only one overtop application of pyrithiobac is suggested. Pyrithiobac will not control ALS-resistant Palmer amaranth.

11. MANAGING INSECTS ON COTTON

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Cotton insect pests can cause significant yield losses from the time of plant emergence through boll maturity. Additionally, pests such as bollworms and stink bugs lower lint quality indirectly by causing maturity delays. However, producers can keep insect damage to a minimum following these six practices:

- Recognize the major pest and beneficial insects.
- Follow recommended scouting procedures.
- Follow recommended thresholds.
- Apply insecticides quickly after a threshold has been reached.
- Follow insecticide-use recommendations designed to stall resistance.
- Use cultural and biological controls when possible.

Insect control costs in North Carolina are lower than in most other regions of the cotton belt, providing our producers with an economic advantage over their counterparts elsewhere. However, sometimes thrips, plant bug, cotton aphid, stink bug and/or spider mite feeding can result in significant yield losses.

The Boll Weevil Eradication Program, begun in 1978 on approximately 15,000 acres in northeastern North Carolina, resulted in the eradication of the boll weevil from the southeastern United States, the Mid South, and most of the Far West. However, boll weevils may still be unintentionally transported back into weevil-free areas. These "hichhikers" are most often the result of either passive transport of weevils aboard vehicles or cotton equipment, such as cotton pickers, module builders, and module haulers. The Southeastern Boll Weevil Foundation supervises our large-scale, pheromone trap-based Boll Weevil Containment monitoring program; however, this program is implemented by the North Carolina Department of Agriculture and Consumer Services.

Because no weevils have been found in the Southeast for the past nine years, the pheromone trapping density and associated containment costs have been reduced during this period. North Carolina cotton producers will likely be assessed a fee of approximately $0.90 per acre, or less, in 2014.

2013 Cotton Insect Summary

Thrips levels were generally high in most areas of the state, in part due to the quick drying down of lush thrips host surrounding cotton fields. A very high percentage of North

Carolina cotton producers now use both a seed treatment and a follow-up foliar spray for thrips. Approximately 90 percent of our cotton acreage was treated with a follow-up foliar insecticide for thrips in 2013.

Aphids were generally a very minor problem on most farms, with approximately 1.5 percent of our cotton acreage treated in 2013. Growers and consultants have become more confident of the effectiveness of beneficial insects, primarily pasisitoids called "mummies" in the pupal form and in the fungus *Neozygites fresenii,* in reducing cotton aphids to sub-economic levels in most cases. Because cotton aphid resistance to the chloronicotinoid class of insecticides (Admire Pro, Centric, Belay and Assail) was confirmed in 2013, producers should be aware that this chemical class may not provide effective aphid control. Carbine and Transform are each in different chemical classes, and resistance has not yet developed to these classes of chemistry. In most years and situations, the above biocontrol measures are a producer's best bet for managing cotton aphids.

Plant bugs have become a more common pest in recent years, particularly in our far eastern counties. In 2013, approximately 20 percent and 45 percent of the pre-bloom and post-bloom acreage, respectively, were treated by our consultants' clients.

Stink bug damage to bolls was moderate to heavy by recent standards across most of the state in 2013, causing a mean of approximately 6.5 percent boll damage compared to approximately half that damage averaged over the past six years.

The major late-season bollworm moth levels and boll damage from bollworms were the lowest on record in 2013, at least in part resulting from the very prolonged wet soil conditions contributing to pupal stage mortality. Many light traps had moth counts of zero for consecutive days during the "major moth flight," essentially an unprecedented occurrence.

Migratory beet and "cotton/corn" race of fall armyworms did not reach North Carolina's cotton acreage in significant numbers this past growing season. Additionally, both WideStrike and Bollgard II varieties show a high degree of resistance to both armyworm species (however, see note in fall armyworm section), as well as to cabbage loopers and European corn borers. WideStrike and Bollgard II varieties are not resistant to early season damage to seedlings from cutworm, however.

Bt varieties (those that have been genetically altered to express the caterpillar toxin of) were planted on over 99 percent of the state's cotton acreage in 2013.

Early-Season Insect Management

Thrips are probably North Carolina's and Virginia's most economically damaging insect complex. Because thrips have the potential to cause significant yield losses and maturity delays, this pest group must be controlled every year.

Thrips damage cotton seedlings by puncturing and rasping the outer cells of young leaves and buds. Then they consume plant juices. Damage frequently results in ragged-looking

plants with crinkled or "possum-eared" leaves. This damage stunts growth, can result in fruiting at higher positions, causing maturity delays and reduced yields. Damage from thrips can be significant when plants fail to grow because of cool conditions, exposing these slow-growing plants to thrips at a susceptible stage. Dry weather may inhibit the uptake of at-planting insecticides, also making the seedlings more susceptible to damage. Dry spring weather additionally results in the premature drying of alternate thrips hosts (for example, various hosts like wheat and weeds) during dry periods. This in turn may force large numbers of flying adult thrips to abandon these plants in search of younger, greener hosts, such as cotton seedlings.

Almost all cotton producers in North Carolina used a seed treatment (Cruiser, Gaucho Grande, Avicta Complete, Aeris, Aeris/Poncho/VOTiVO, and Acceleron I and N) for thrips in 2013. These products typically provide some degree of protection from thrips, ranging from 10 to 21 days. The thrips control provided by the above seed treatments is similar. Even when a soil-applied systemic insecticide is used, thrips often occur in damaging numbers. As mentioned above, dry weather may retard the uptake and performance of the product used. Also, extended cool weather may delay plant growth, keeping the plants susceptible longer and exceeding the time frame of the product's effectiveness. In this case, the persistence of a product's activity can be very important. When a systemic insecticide fails to control thrips, a foliar spray is often warranted. However, in some cases, a spray may give rise to other problems. Aphid and mite populations may increase, for example. In most cases, the use of an at-planting insecticide, often followed by a foliar spray, is successful and is recommended over a foliar-spray-only approach because it is far more persistent and sometimes produces higher yields.

Primary thrips control options:

1. Gaucho Grande—Gaucho Grande (insecticide only) usually provides thrips control for approximately 10 to 21 days. Conditions of exceptionally high thrips levels, poor insecticide uptake or cool weather conditions can limit thrips control. A foliar treatment for thrips is usually needed with Gaucho Grande-treated seed and is ideally targeted to the first true leaf cotton stage, or approximately three weeks after planting, whichever comes first, especially on early-planted cotton. Gaucho Grande is very safe to humans and wildlife (with the possible exception of some beneficial insects, including honeybees). Gaucho Grande without a follow-up spray may also suffice in cotton planted after May 15 to 20 or later, where long residual activity is sometimes unnecessary.

2. Cruiser Seed Treatment—Cruiser seed treatment (insecticide only) is in the same insecticide class as Gaucho Grande and shows thrips activity similar to Gaucho's. A foliar insecticide is often recommended to compensate for this product's short residual activity, just as with Gaucho.

3. Acceleron I—Insect seed treatment (insecticide only) contains the same active ingredient, imidacloprid, as Gaucho Grande and its performance should be similar to that product.

4. Avicta Complete, Aeris and Acceleron N—Avicta Complete (Cruiser, plus the nematicide abemectin, plus the three-way fungicide Dynasty), Aeris (Gaucho Grande, the nematicide thiodicarb, plus fungicides added either by the manufacturer or dealer) and Acceleron N (the standard formulation contains the same nematicide and insecticide as Avicta plus dual strobilurin chemistries) offer thrips control similar to Cruiser and Gaucho Grande. Thus, in many cases producers may need to plan for an insecticide application at the first true leaf stage or within approximately three weeks after planting with either product.

5. **Aeris/Poncho/VOTiVO**—This combination treatment has the additional biological nematicide *Bacillus fermis* and the insecticide clothianidin in addition to Aeris. This seed treatment has not received enough evaluation in the upper Southeast to determine if it provides extended thrips control beyond that of other seed treatments.

6. Seed treatment/imidacloprid combination—Research conducted during the past three years here suggests that using a combination of treated seed along with imidacloprid liquid directed into the open furrow onto the seed before closing may provide North Carolina cotton producers a "one-and-done" (no follow-up foliar spray for thrips) option for thrips control. However, we strongly recommend scouting for thrips following the control option for live thrips in the event that a foliar application may be needed.

Prior to bloom, plant bugs, or *Lygus*, damage cotton by feeding in tender terminals and, more commonly, directly on small squares with their needlelike mouthparts, causing the squares to abort. When blooming begins, plant bugs continue to feed on squares. Feeding on larger squares may cause "dirty blooms" (white blooms with darkened pollen anthers and sometimes with small on the flower petals). Additionally, plant bug feeding on small bolls up to approximately 11 days old may cause stink-bug-like external boll spotting and internal boll damage, such as callous growth (warts), deformed or rotted fruit, or small boll abortion. This boll damage is often identical to that caused by stink bugs. In recent years, this damage appears to have become more common than damage to pre-bloom cotton. Plant bugs are capable of causing all of the damage symptoms shown in Table 11-1.

Early-season monitoring for plant bug activity, especially retention counts of small squares (approximately 1/8 to 3/16 inches long, including bracts), is recommended. If square retention counts remain high (80 percent or more), further sampling for plant bugs is probably unnecessary at that time. If retention rates of small, upper, and other first- or second-position squares drop below the 80 percent level, further sampling for live plant bugs may be needed. One method of sampling for missing square positions is to find one randomly selected terminal square (or its missing position) and one first- or second-position square (or its missing position) two or three nodes from the top of the plant are inspected per plant from 25 randomly selected plants within a field (50 squares total). Sweep net sampling for plant bug adults and large nymphs typically involves the taking of 25 sweeps at 8 to 10 locations per cotton field (each not less than 50 feet from the field edge) and is recommended before bloom. Be mindful of field edges along ditch

banks, adjacent host plants such as weedy flowering fields, or where Irish potatoes or a substantial acreage of corn is present, especially our far eastern counties. The above areas are a likely source of migrating adult plant bugs but should not be over-sampled (nor overlooked).

Once blooming has been underway for a week or more, square retention is a less reliable indicator of possible plant bug feeding. At this point, the plant may show natural square loss due to mostly weather-related reasons and energy directed to bolls. Late-season damage by plant bugs may be assessed by monitoring cotton plants for "dirty blooms," for small bolls with signs of internal bug damage, and for the plant bugs themselves via drop cloths. Examining open white flowers for the occurrence of one of more brown pollen anthers (dirty blooms) as an indication of recent plant bug feeding on large squares is not used to determine if a spray is needed, but as an indication of whether additional sampling is warranted. If the level of dirty blooms is in the range of 0 to 6 percent, further more tedious sampling for plants bugs should not be needed for 5 to 7 days. If the level of dirty blooms exceeds approximately 6 percent, additional sampling is advised. A black drop cloth (ground cloth) is the preferred method of direct sampling for plant bugs once blooming is underway. Black ground cloths are easily constructed by spraying the cloth part of the sampling device with black spray paint. The drop cloth threshold, developed and recommended by Mid-south entomologists, is 1.6 to 2.6 adult plus immature plant bugs per 5 row feet (or the level contained in a 5-foot drop cloth sampled from each of 2.5 row foot length on either side of the cloth) or a rounded-off level of two to three plant bugs per drop cloth sample. If nymphs, particularly late instars, are also easily seen (with the exception of the tiny first instars, which often experience high mortality), indicating that reproduction has occurred, the population is regarded as potentially more damaging to squares and young bolls.

Table 11-1. Plant Bug and Stink Bug Damage to Cotton Plants

Plant stage	Plant part	Bug type	Damage symptoms
Prebloom	Terminals	Plant bug	With heavy feeding, terminals may be deformed or killed, resulting in a loss of apical dominance (crazy cotton).
	Small squares		Squares yellowing, turning brown, then black, and finally aborting, leaving a scar at the fruiting site.
Blooming	Various squares		Small squares, same as above; larger squares with internal damage to pollen anthers (shows up as "dirty blooms").
	White blooms		Darkened pollen anthers (dirty blooms from plant bug feeding on large squares); petal deformations.
	Bolls	Plant bug, Stink bug	Aborted small bolls, external spotting, internal pin prick-like feeding "stings," wart-like growths, and stained lint; may cause boll rots, hard lock.

Although essentially all of the cotton now planted in NC (over 99.9 percent) is two-gene *Bt* gene cotton, ***to date*** *no tobacco budworms have survived on a Bt cotton plant in the field from a naturally occurring tobacco budworm population*. Although bollworms survive at low levels in WideStrike and Bollgard II cotton, as of this December 2013 writing, we do not have evidence that bollworm resistance to this technology has occurred. Bollworms appear to increasingly tolerate pyrethroids, however, based on trends of higher bollworm moth survival in adult vial testing in recent years.

Mid-Season Insect Management

Although technically beginning at first bloom in late June to early July, the start of the major mid-July to early-August bollworm (corn earworm) moth flight usually signals the onset of potential bollworm and stink bug damage. The bollworm-tobacco budworm complex, typically composed of mostly bollworms, is the primary target for foliar insecticides in conventional cotton. Fall and beet armyworm can cause fruit damage to cotton, in most cases resulting from moving over from dried down weed hosts (see additional note on FAW). Stink bugs are now the dominant late-season pest in *Bt* cotton varieties. Because of the potential for severe boll damage from one or more of the above pests, and because cotton damaged at this time of year usually compensates little for boll damage, insect damage to bolls must be minimized during all or part of late July through mid-to-late August in North Carolina.

The first two generations of bollworms occur primarily on field corn. Third-generation (sometimes referred to as the second field, or F2, generation) moths usually emerge in large numbers from mid-July to early August when corn is drying, and they fly to the more attractive, blooming cotton.

Systematic, regular weekly scouting of conventional (non-*Bt*) cotton for the bollworm and its relative, the tobacco budworm, should begin in early to mid-July in North Carolina. Weekly scouting is adequate until egg laying or light-trap catches increase, although light traps are ineffective in monitoring budworm moths. (Check with your county Extension agent for possible light-trap counts for the major bollworm moth flights; additionally, the counts from approximately 20 light traps are available online during the moth flight at http://ipm.ncsu.edu/cotton/insectcorner/.)

At the beginning of the major bollworm moth flight, fields should be scouted weekly (and a proportion of these fields twice weekly), with the emphasis on finding eggs and small worms, until insecticide treatments begin. After the onset of the moth flight and initial application(s), a 4- to 7-day scouting schedule usually will suffice for conventional cotton, depending on the insecticide rate used, the egg pressure, and the susceptibility of the cotton plants. Employing an egg threshold remains the most profitable way to manage this generation of bollworms in conventional cotton. Once the egg threshold has been met and treatment(s) made (see “Thresholds” section), the primary focus of scouting shifts toward finding small bollworms feeding on squares and bolls, including those under pink flowers and bloom tags (dried flowers). Eggs also should be monitored, however, particularly down in the plant canopy or in yellow, pink, and dried flowers and on stems.

At times, tobacco budworm populations persist into the major bollworm moth flight period. Because tobacco budworm adults are not readily attracted to black-light traps and because they sometimes begin laying eggs on cotton before the bollworm egg threshold is met, occasional fields may reach a 3 percent larval threshold on conventional cotton before bollworm treatment begins. Deploying tobacco budworm pheromone traps, especially clusters of 5 to 10 traps on a farm, and correctly identifying adult tobacco budworm moths within fields can help you recognize this situation. However, pheromone traps are not always a reliable indicator of moth levels and attract only males, so one should interpret pheromone counts cautiously. If 20 to 25 percent or more budworms are suspected or confirmed as part of the bollworm/budworm flight, pyrethroids may be ineffective, and the use of Steward, Tracer, Denim, Prevathon, or Belt may be more appropriate for the initial application.

After the upper bolls that will be harvested have become difficult to cut with a pocketknife, the field is normally safe from further bollworm attack. Fields are also normally safe from further bollworm establishment when blooms and/or non-terminal squares are less than one per 1 to 2 row feet or more. Bollworm scouting can normally be stopped at that time—usually in mid to late August to early September, depending on the intensity of the moth flight and the maturity of cotton plants. Spot scouting for FAW in conventional or Bollgard fields should continue through approximately September 1, especially in fields of late-maturing cotton or in green areas, if this species is present. Because FAW are migratory pests, in some years this species does not reach North Carolina cotton fields in appreciable numbers, particularly in the more northern counties.

Due to our low late-season spray environment in North Carolina, the green stink bug (Chinavia *hilare*) and the brown stink bug (*Euschistus servus*) have become more abundant and damaging since the adoption of *Bt* varieties. The most yield-reducing damage to bolls takes place during weeks three to five or six of blooming.

Stink bugs damage cotton by puncturing the carpal walls of bolls with their "beaks" and by feeding primarily on the soft, developing seeds. Heavy feeding on rare occasions destroys small bolls, causing them to abort. When stink bugs feed on slightly larger to medium-sized bolls (up to about 3.5 weeks old), they may introduce boll-rot pathogens, resulting in partially or entirely destroyed locks, hard-lock, and a lower grade of harvested cotton. This damage is further expressed in opening cotton under wet conditions.

Externally, boll damage is characterized by small, round, shallow, purplish depressions, usually in the 1/32- to 1/16-inch range. These spots tend to be larger than the tiny black gossypol gland spots. Internally, bug-damaged bolls will often have a yellowish to tan to brown stain in the seed areas, often, but not always, under the external feeding spots. Other damage symptoms include small wart-like growths and/or dark "pin prick" spots on the inside of the boll wall. We recommend counting both stained lint and warts as damage, but not external boll spotting or internal "pin pricks." Internal boll damage may be present without obvious external evidence. Also, the external boll spotting caused by stink bugs and plant bugs may be difficult to separate from other kinds of spotting on the boll surface, for

example, that caused by bloom tags that adhere to the top or side of the boll.

Stink bug damage is more prevalent in fields where bollworm treatments have been minimal (that is, none or one). Because stink bug and plant bug damage to bolls is often indistinguishable, damaged bolls may be the result of feeding by either bug group. At present, stink bug damage to bolls is more much more widespread than plant bug damage in most areas of the state in most years.

The distribution of stink bugs and plant bugs in a cotton field may be uneven, with bug numbers and damage higher at field edges and in rank areas, but also dispersed in a clumpy manner throughout the cotton field. Do not oversample unrepresentative areas; however, they should be noted.

A sample of 25 quarter-sized bolls (more in larger cotton fields—approximately 1 boll/acre) should be inspected at each scouting session, beginning at early boll development, but with an emphasis on weeks three through five or six of the bloom period.

To determine if a boll has been damaged by stink bugs, the quarter-sized bolls should either be crushed by hand or cut open to examine the locks and inner boll wall surface. Except for "pin pricks," count all internal boll damage, including stained or spotted lint and callous growth or inner boll wall warts. Current research suggests that a threshold of 50 percent, then 30 percent internal damage may be more appropriate during the first two weeks of blooming, as well as using higher thresholds later in the boll production period, when the ratio of larger, "safe" bolls to smaller, susceptible bolls increases (Table 11-2).

Cotton growers and scouts in the Southeast can use a Web-based phone app stink bug decision aid to assess and manage stink bug damage based on thresholds for different cotton growth stages. This scouting decision aid was developed for use in the Southeast to encourage (1) enhanced adoption of stink bug scouting in cotton, (2) better field identification of stink bug-induced boll damage symptoms, and (3) use of recommended scouting procedures. This stink bug app describes the decision aid and how to use it. The aid relies on the latest dynamic threshold for stink bugs in cotton based on week of bloom. The use of a simple decision aid can help producers and scouts:

- select the correct boll sizes for stink bug damage assessments,
- recognize stink bug damage,
- follow straightforward scouting steps, and
- utilize the "dynamic" threshold to avoid yield losses and minimize unnecessary insecticide use.

The stink bug app should improve stink bug management because the dynamic threshold is based on the cotton growth stages when the crop is most susceptible to stink bug damage. It relies on lower thresholds during weeks of maximum susceptibility (weeks three through five of the bloom period) and higher thresholds during stages of lower vulnerability (weeks one to two and six to nine of the bloom period).

Description and Use
The front (Figure 1) side of the 3-inch by 6-inch decision aid on the app provides recommended scouting procedures:

1. Select a random sample of the correct size bolls.
2. Assess an adequate number of bolls.
3. Sort the bolls into two piles, those with and those without obvious external damage lesions.
4. Crack bolls between the thumb and forefinger or cut them open with a knife and inspect **all** internal boll wall surfaces for internal warts (**not just areas visible from the initial crushing or from the initial knife cut**), and examine all locks for stained lint. (**Helpful hint**: crack and inspect bolls with obvious external lesions first to determine if the internal damage threshold is met, as bolls with external lesions are more likely to be damaged internally; assessing these bolls first can save time.)
5. If the threshold is not met, check the remaining bolls for internal damage.
6. Treat only if the threshold has been met for that week.

The measuring holes provide an efficient way to select correctly sized bolls. Cotton scouts should target bolls with an outside diameter between 0.9 to 1.1 inches. **Bolls of this size correlate best with recent stink bug damage.**

The front side also lists the recommended dynamic threshold by week of bloom. The asterisks for weeks 4 and 5 of the bloom period permit nuances in scouting frequency recommendations by the various southeastern states.

The reverse side of the aid found on the app provides images (in addition to the images of stink bug damage found on the app itself) to help properly identify stink bug damage: internal warts, and stained lint; and external damage lesions (Figure 2). As explained in recommendation 3, above, external damage symptoms may be used to sort the pulled bolls into two groups.

Table 11-2. Stink bug internal boll damage thresholds

Week of Bloom	Threshold (%)
1*	50 (treatment seldom justified)
2	30
3	10
4	10
5	10
6	20
7	30
8	50

*Threshold seldom met during first week of bloom

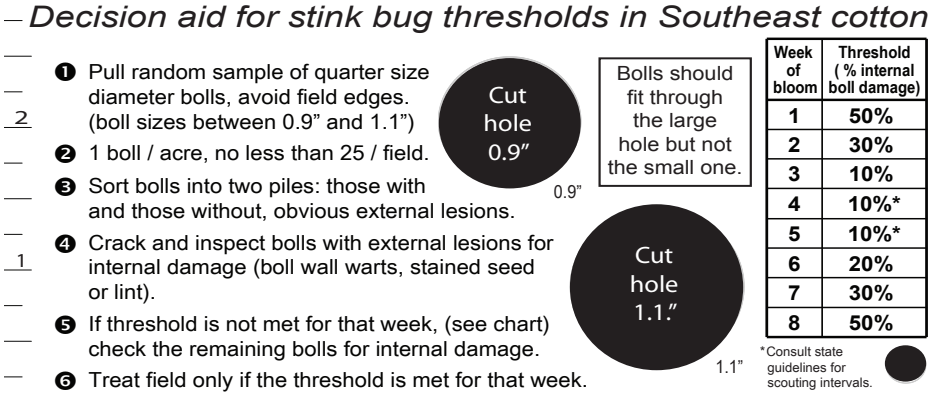

Figure 1. Front side of field decision aid showing scouting procedures, boll size selection range, and internal boll damage thresholds by week of bloom.

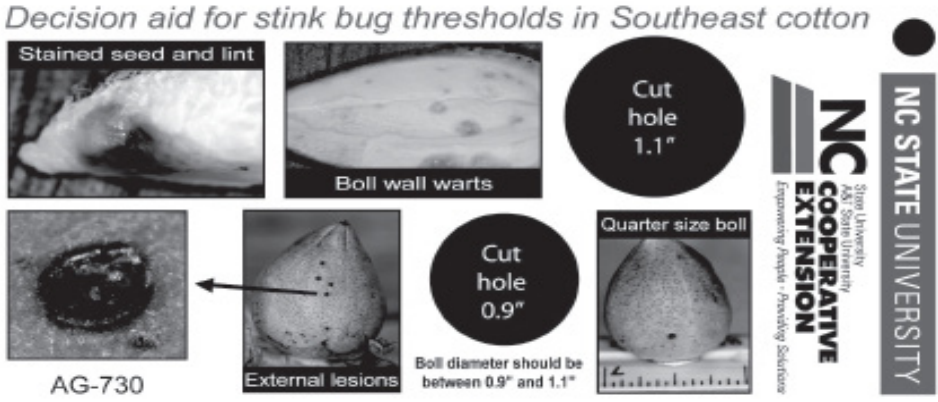

Figure 2. Reverse side of aid showing external and internal stink bug damage symptoms.

If two or more consecutive scouting checks reveal stink bug damage at approximately two-thirds of the threshold level, treatment may be justified.

Once the damaged-boll threshold has been met, it may be helpful to determine if the brown stink bug (*Ecschistus servus*) or green stink bug (usually *hilare)* is the predominate species group, as brown stink bugs are more difficult than green stink bugs to control with pyrethroids.

To determine which stink bug species is more prevalent, make general observations while scouting (in the case of high population levels), sample with a beat cloth (six 6-row-foot samples or more until adequate stink bug numbers are observed), or use a sweep net (sample until adequate numbers of stink bugs are observed). Since these observations or samples are conducted solely to determine if the stink bugs are brown or green, they may be done quickly and include visual observations. For beat cloth sampling, a 3-by-3 or 3- by-2.5-foot beat cloth is unfurled between two adjacent rows, and the cotton plants in the two adjoining rows are beaten, or shaken over the cloth, causing the large nymphs and adults to fall onto the cloth so they can be counted. Count any adult stink bugs seen flying if the color can be distinguished. In sweep net sampling, individual sweeps should be made with firm, pendulum-like motions (handle up, net down), swinging down with both hands through the upper middle canopy while walking down the row. If the sweeping motion is correct and vigorous enough, some bolls and leaves usually will be knocked into the net. In either of the above approaches of assessing live stink bugs, count adults and large nymphs. This quicker sampling may be stopped once an adequate sample (approximately 10 stink bugs) has been counted.

As the proportion of large "stink bug safe" bolls increases relative to the smaller susceptible bolls during the end of July and throughout August and early September, the threshold may be raised, as indicated in Table 1 and in Figure 1. Once-a-week scouting for stink bugs on *Bt* (or minimally treated) cotton is recommended under most situations.

Transgenic Cotton

The two-gene lines represented by Bollgard II and WideStrike varieties control only caterpillars, not other pest insects, such as thrips, cotton aphids, plant bugs, and stink bugs. Also, different caterpillar pests are not controlled to the same degree. For example, field tests have shown that tobacco budworms attempting to feed on *Bt* cotton lines in the field are all killed (at least for the time being). However, bollworms can damage squares and bolls, though generally at a low rate. The two-gene *Bt* technology typically provides good control of both armyworm species (however, see information in the later section on fall armyworms. In BG II cotton, unless bollworm pressure is very high and chemical disruption has occurred (such as an overspray with Bidrin or Orthene just prior to or during the moth flight), sprays for bollworms may not be needed in WideStrike and Bollgard II varieties, although some WideStrike cotton fields had be treated two or three times for bollworms in 2010.

Because beneficial insects are not adversely affected by Bollgard cotton, their abundance and impact have increased in situations where disruptive insecticide applications are

either less frequent or not made. Higher beneficial insect numbers present with fewer sprays for caterpillars have led to somewhat more effective suppression of third-generation bollworms and other caterpillars in *Bt* cotton lines.

Cotton

The planting of Bollgard cotton varieties is no longer permitted in the U.S. Essentially all cotton planted, with the exception of limited conventional cotton, will be composed of at least two-gene *Bt* technology (for now, Bollgard II and WideStrike with the possible introduction of limited amounts of WideStrike 3 in 2014). Because these new lines have been shown to be highly resistant to bollworm establishment, a refuge is not required for two-gene varieties.

The effectiveness of *Bt* genes against North Carolina's major caterpillar pests is influenced by a number of factors, including the pest in question, the level of Bt gene expression in the fruiting forms, the level of supplemental, beneficial insect "help," and the phenology or maturity of the cotton crop. Under irrigation, and/or if a beneficial-insect-reducing spray is applied just before or early in the bollworm moth flight (for example, a spray for stink bugs), moderate to occasionally heavy bollworm establishment may occur with associated significant yield reductions.

In addition to greater bollworm effectiveness than Bollgard cotton, the stacked, two-gene-*Bt* products (presently Bollgard II and WideStrike) also provide good to excellent control of beet and fall armyworms (see information under the fall armyworm section) and cabbage and soybean loopers, but not early cutworms.

TwinLink Varieties

Additional two-gene Bt TwinLink and three Bt-gene WideStrike varieties may have a limited introduction in 2014. This technology will be similar in bollworm and other caterpillar effectiveness to WideStrike and Bollgard II varieties.

Scouting Transgenic Cotton

A few cotton scouting suggestions are indicated below:

1. Use of a very high egg threshold for the major bollworm generation: Because bollworms must hatch from eggs and consume enough of the *Bt* toxin to be killed, neither the egg stage nor the small, soon-to-die, first instar bollworms are now used as the basis for the treatment threshold in *Bt* cotton (see "Thresholds").

2. Use of "multiple pest thresholds" is encouraged: If sub-threshold levels of different pests add up to or exceed a one-pest threshold, treatment is advised (for example, 40 percent of the bollworm threshold and 75 percent of the stink bug threshold equal 115 percent, or more than 100 percent of the treatment threshold). Selection of the appropriate insecticide should target products that are active again both insect groups.

3. Focus on second instar bollworms: The point at which *Bt* cotton lines may require a supplemental insecticide for caterpillar control will be the point at which bollworm establishment occurs at a potentially high enough level to cause economic loss. Thus, it will be essential to recognize the difference between both the first and second bollworm stages, and to respond only to bollworms that are second stage larvae or larger (1/8-inch and longer).

4. A high proportion of the bollworms that become established often do so under red flowers and bloom tags. This is a very common "trigger" for treatment: In monitoring blooms and bloom tags, however, remember to raise the 3 percent bollworm treatment threshold according to the ratio of total bolls to bloom-tagged bolls. For example, if bloom tags represent 10 percent of the sampled boll population in the field, if a bollworm is present under each of these bloom tags, and if no bollworms are found on the remaining (non-bloom-tagged) sampled bolls, then sampling only bloom tags (100 percent bloom tags) would result in overestimating the bollworm population in the field ten-fold. In this case, the treatment threshold for this sample containing only small bolls with bloom tags should be raised from 3 percent to 30 percent. On the other hand, the threshold for bollworms on *Bt* cottons is low—it takes very few worms under bloom tags in late July to mid-August to justify treatment.

5. Scouting for other insects: Stink bugs and plant bugs have, in the absence of insecticides directed toward bollworms, become more numerous and require more intensive scouting than they would in conventional, more frequently treated, cotton. Weekly scouting is recommended for BG II and WideStrike cotton varieties, with a subsample of fields assessed twice weekly to detect cases of rapid establishment.

6. Beneficial insects: Beneficial insects will likely be more abundant in untreated or less-treated *Bt* cotton, and their identification and population levels should be at least informally monitored.

7. Summary: WideStrike and BGII and upcoming two and three *Bt* gene varieties will require 1) no scouting for second-generation tobacco budworms, 2) an emphasis on the appearance of second instar boll-worms, 3) and major emphasis on stink bugs and plant bugs as the trigger for foliar insecticide treatment. Scouting for ECB damage is no longer required.

Management of Miscellaneous Insects

Aphids

Cotton aphids are an occasional headache for cotton producers. Chloronicotinoid insecticides (Centric, Admire Pro, and Assail) usually are effective. Additionally, because this insecticide class is used in both cotton seed treatments (Avicta Complete, Cruiser, Gaucho Grande, Aeris, and Acceleration) and for other cotton insects (i.e., plant bugs), aphid resistance to this somewhat-new class of insecticides is a concern, with a confirmed resistant population detected in Gates County in 2012 and additional resistant colonies suspected. The insecticides Carbine and Transform, which provide aphid control similar

to the chloronicotinoids, is listed as having a different modes of action (MOA class 9C and 4C) and thus may provide an alternative to the chloronicotinoid class of insecticides (MOA class 4A).

Fortunately, high levels of aphid mummifying parasites and the fungus *Neozygites fresenii* that in most cases hold or reduce aphids to subeconomic numbers are common in our region, often becoming established in the second or third week of July. The combination of predators, parasites, and fungi usually justifies our general recommendation not to treat cotton aphids, except under dry, stressed conditions, very high aphid levels, and little or no evidence of mummies or the fungus. In opening cotton, aphid-caused sooty mold or sticky cotton (from the heavy presence of honeydew) may become a problem, though not typically in the Southeast. After the defoliant has been applied, however, cotton aphids are typically only present at very low levels.

On the Aphid Rating Scale, a level of 4 or higher in cotton just before opening, plus honeydew presence, along with low levels of mummies or the fungus, may be a good indicator of the need to treat (see Aphid Rating Scale, Table 11-3). Treatments for cotton aphids have been low for the past 10 years.

Table 11-3. Aphid Rating Scale

0	No aphids.
1	Occasional plants with low numbers of aphids.
2	Plants with low numbers common; heavily infested plants rare; honeydew visible occasionally.
3	Most plants with some aphids; occasional plants heavily infested; honeydew easily visible in most areas of the field.
4	Heavily infested plants common; aphids clumped on upper leaves; honeydew common; cotton under stress.
5	Many heavily infested plants; infestations are on most plants in large areas of the field; cotton under stress.

Spider Mites

Spider mite damage, rare in North Carolina in most years but sometimes more common on cotton in the northeastern peanut-production counties or in our far eastern counties, can occur almost any time during the season and is usually more prevalent during dry conditions and on sandy soils. Mite damage appears as a slight yellow stippling of the leaves, which later changes to a reddish or bronze color. Mite damage also can be recognized by the presence of fine webbing on the underside of the affected leaves. This webbing, if present on lower leaves, often traps blown sand grains in seedling cotton. In severe infestations, the damage can cause widespread leaf yellowing, followed by bronzing and defoliation, often beginning with lower leaf drop.

Visual spot checks for mites can be made while scouting for other pests. Initial mite infestations often occur at field borders adjacent to drying corn, weeds, or mowed ditch

banks or roadways, although with the widespread adoption of strip-till and no till cotton, spider mites can sometimes build up throughout cotton fields. Even with obvious yellowing and defoliation, the presence of an active mite population in the field should be confirmed before treating. A hand lens of 10x magnification or greater is indispensable when scouting for these tiny arthropods and their eggs and in identifying the fungal parasite. In treating for mites, one to two expensive applications with excellent coverage are sometimes required and often provide only fair control. A fungus that preys on mites is often present, particularly under rainy or humid conditions, and may greatly reduce mite numbers while the damage symptoms are still present. Do not spray if rain is likely.

Fall Armyworms and Beet Armyworms

The presence of fall armyworms and their damage are recorded as part of bollworm scouting. Additional samples are usually unnecessary. Damage from fall and beet armyworms is typically low or absent in Bollgard II and in WideStrike cotton lines, with the rare exception of 1) beet armyworms moving into adjacent cotton from pigweed infestations, or 2) fall armyworm moving over into cotton some weed hosts. However, fall armyworm larvae resistant to one of the two genes in WideStrike cotton (Cry1F) were found on field corn in eastern North Carolina in 2013. How widespread this resistance is in North Carolina going forward and to what extent this resistance may affect cotton is unknown at this time. However, fall armyworms are usually only a sporadic pest of cotton, even back in the conventional cotton days. Because FAW migrate into North Carolina from farther south, their numbers vary greatly from year to year and normally reach higher levels in the southern and far eastern counties.

Beet armyworms are rarely cotton pests in North Carolina in two-gene Bt cotton, although a few are noted on cotton almost every year, thought usually at low levels.

Loopers

Cabbage and soybean loopers rarely damage cotton in North Carolina because they prefer foliage, are prone to virus attack (less so with the soybean looper), occur sporadically, and seldom become established on two-gene cotton varieties. In conventional cotton, observing foliage during routine late season scouting for other pests in most cases suffices for looper monitoring.

If significant leaf feeding is seen, the average percentage of defoliation across the entire field should be recorded. As a general rule, if defoliation exceeds 30 percent in cotton with a significant portion (25 percent or more) of the bolls still immature and filling out, treatment may be needed. Soybean loopers are not controlled with pyrethroids. Fortunately, Bollgard II and WideStrike cotton lines provide excellent resistance to loopers.

Beneficial Insects

About a dozen beneficial insects are commonly found in North Carolina cotton: ambush bugs, big-eyed bugs, minute pirate bugs, green lacewings, two species of ladybird beetles, and several types of spiders. They are of two types: (1) predators that prey upon an insect pest or (2) parasites that live within the host insect. These insects, particularly

the predators, reduce the number of eggs and larvae of bollworms and other caterpillars, as well as cotton aphids. Because these allies lessen the impact of pest insects, common sense dictates that producers use them as a management tool. Their presence often means that growers can delay—and, on occasion, eliminate—some insecticide applications, particularly aphid treatments.

Many complex factors are involved in determining just how many of each beneficial insect species are needed to influence a given level of pests. Therefore, it is usually not practical to assess the value of these insects except in a very general way. That is, if relatively high numbers of beneficial insects are consuming a large proportion of aphids or bollworm eggs and larvae, the treatment threshold will be reached later than would otherwise be the case, reducing the number of insecticide applications needed. Or in the case of fungal pathogens attacking spider mites or cotton aphids, the finding of even small amounts of the pathogen may signal the beginning of an epizootic that often reduces pest levels significantly over a widespread area. By the same token, beneficial insects appear to have only a limited impact on stink bugs and plant bugs in most situations.

Presently, the careful observation of sound economic thresholds offers the producer the best odds of balancing beneficial insect numbers against damaging insects. Cotton aphid infestations are usually best managed by avoiding insecticides and allowing beneficial insects and fungi to limit populations.

Cultural Control of Cotton Insects

Fortunately, most of our agronomic and weed management recommendations geared toward providing the cotton crop a fast start, rapid development, and early maturity also aid in the management of late-season insects, particularly bollworms and stink bugs. Practices that encourage early maturity, such as avoidance of June planting, render the cotton plant less attractive to moths and bugs and less attractive and susceptible to boll damage. In our fall boll-damage surveys, late rank plants often sustain 2 to 4 times the damage of those that mature early. These are a few recommended cultural practices:

1. Matching varieties to soil type—Some mid- and late-season varieties can grow excessively large, rank plants, precipitating late season insect problems; reserve these varieties for earlier planting and/or sandy soils.

2. Avoidance of late planting—While employing the earliest possible planting date is not critical (and may result in higher thrips damage), avoidance of late planting (after the fourth week in May) can have a dramatic effect on minimizing late-season insects. This is the single most important cultural factor in reducing late-season insect damage.

3. At-planting application of Temik—While available, the use of Temik at recommended insecticide rates in conventional cotton often promotes accelerated growth, earlier maturity, and increased yields, thereby controlling thrips and helping late-season insect management, although the new seed treatments at the present rates, coupled with a

thrips spray at about the first true leaf stage, offer similar growth rates and yields in most cases. The use of seed treatments generally increases the odds of having to treat for cotton aphids and spider mites.

4. Adherence to recommended nitrogen levels—High levels of nitrogen, particularly when coupled with late planting and high rainfall levels, can trigger rank cotton growth and high bollworm populations on conventional cotton and higher stink bug and plant bug levels on *Bt* cottons.

5. Use of PGRs (plant growth regulators)—The use of mepiquat chloride and other similar products on fields with either a history of rank growth or a propensity for fast plant growth hastens maturity and may facilitate late season insect control.

Thresholds

A threshold is the level of plant damage or the number of insects at which treatment is recommended—that is, the level at which treatment will pay for itself. Threshold numbers are usually expressed in terms of the percentage or number of insects or instances of damage observed per sample (such as a given number of bolls, sweep net samples, or drop cloth samples). Often based on years of research, these thresholds form the basis for sound treatment decisions. Thresholds, however, are only general guidelines applicable to the entire state. A knowledgeable consultant or advisor may be able to modify a threshold, depending on the region of the state, its history of insect problems, and the amount of risk that the consultant and the farmer are willing to take. Also, these thresholds are refined periodically on the basis of new research.

Current thresholds for the important cotton pests are:

Thrips

• On cotton from the cotyledon to the 5 true leaf stage: An average of 2 immature thrips per plant. Alternatively, an average of 1 immature thrips per plant for each 1 true leaf.
• Timing of thrips applications, especially following seed treatments, is often best targeted at the first true leaf stage.

Plant Bugs

Pre-bloom thresholds to be used when square retention rate drops below 80 percent. From initiation of squaring until the first or second week of blooming:
• Eight plant bugs per 100 sweeps.
• The sweep net threshold may be raised to 10 if fruiting begins on nodes 4 through 6 or lowered to 6 to 7 if fruiting begins on node 8 or higher. Thresholds also may be lowered somewhat in stressed cotton.

Post-bloom thresholds

• 0 to 6 percent dirty blooms – no additional scouting for plant bugs is indicated for five to seven days. Count any brown anthers as damaged. This "threshold" should be used along with other assessments, if indicated. Higher dirty bloom levels indicate need for

additional assessments (with a ground cloth).
• 10 to 50 percent initial internal damage to quarter-sized bolls based on week of bloom, as part of stink bug sampling. (See Figures 1 and 2.)
• Two to three adults and medium to large nymphs/5 row feet with a black beat cloth (ground cloth). (Sweep net thresholds for plant bugs in post-bloom cotton typically underestimate the levels of immature plant bugs.)

Cabbage and Soybean Loopers
• 30 to 35 percent defoliation and presence of more than 25 percent immature bolls.

Spider Mites
• General leaf discoloration (chlorosis, bronzing, or both), plus live mites over most of the field and defoliation from mites in 25 percent or more of the field. (If rain is imminent, delay treatment and reevaluate 3 to 4 days after the rain. If a miticide is used, two applications are sometimes necessary.)

Stink Bugs
Damaged Bolls (dynamic threshold)
• 10 to 50 percent stink bug internal damage to quarter-sized bolls (see Table 11-1). The higher thresholds are used during the initial two weeks of blooming or later in the season to reflect advancing boll maturity (see Table 11-2 and Figure 1). The lower 10 percent threshold is advised during weeks 3 to 5 of blooming. Yield losses resulting from stink bug damage are less likely during the initial two weeks and final weeks of blooming.

Beat Cloth (shake cloth; black) and Sweep Net (15-inch diameter)
• *These devices should be used only to confirm the presence of green vs. brown stink bugs and are thus technically no longer employed to determine if threshold levels are present.*

Conventional Cotton—Bollworms and Tobacco Budworms
Prebloom (with Bollgard, WideStrike cotton, early season June damage from bollworm and tobacco budworms is essentially nonexistent). On our few remaining acres of conventional cotton limit a possible treatment to one well-timed application of a non-pyrethroid, such as Prevathon, Coragen, Belt, Blackhawk, Steward or Denim. Treatment before bloom seldom pays, however).
• 15 bollworms per 100 terminals.
or
• 8 bollworms per 100 squares.
Postbloom: Egg Threshold (after the onset of the major bollworm moth flight)
• 10 or more eggs per 100 terminals.
or
• 2 to 3 eggs per 100 fruiting forms.
Larval Threshold (usually after the egg threshold has been employed; but also used after blooming begins and before major bollworm flight, particularly if tobacco budworms are present).
• 3 live worms per 100 fruit (squares, blooms, or bolls).

Transgenic Bt *Cotton (used against the major bollworm generations) Larval threshold only*

• 3 second-stage (⅛ inch or larger) bollworms per 100 squares or bolls. Pay particular attention to bollworms in or under yellow, pink, and dried blooms, but sample only in proportion to their occurrence.
or
• 2 second-stage bollworms (as above) on 2 consecutive scouting trips.
or
• 1 second-stage bollworm (as above) on 3 consecutive scouting trips.

Fall Armyworms (conventional cotton)

Same as the post-bloom larval threshold for bollworm but may be revised upward late in the season (after September 1). The fall armyworm is primarily a late-season cotton pest. Pay particular attention to the small, grayish, fuzzy egg masses deposited on the undersides of leaves and to "window-paning" in the bracts of lower bolls and blooms for the presence of larvae. Correct identification is critical; many bollworm insecticides are ineffective against fall armyworms.

European Corn Borers (conventional cotton)

Use of the old bollworm egg threshold (10 percent eggs in terminals or 2 to 3 percent down in the canopy, or on blooms) will often control much of the late ECB generation on conventional cotton. *Bt* cotton lines are seldom damaged. Follow the more detailed guidelines in the Cotton Insect Scouting Guide (ENT-cot-6).

Beet Armyworms (conventional cotton)

• 10 percent live beet armyworms in squares, blooms, or small bolls in blooming cotton.
or
• 10 beet armyworms per foot of row later in the season (when squares and blooms will not produce harvestable bolls).
or
• 15 percent of blooms with one or more live larvae.

Cotton Aphids

• Using the Aphid Rating Scale, treat at a rating of 4 in opening cotton (15 percent open bolls or greater) or at a rating of 5 in pre-opening cotton if plants are under stress or stunted and if aphid mummies and fungi are at low levels. Treatment is discouraged under most circumstances because of its deleterious effect on beneficial predators and parasites that attack aphid populations. In opening cotton, treat only if plants are heavily infested and honeydew is detected in significant portions of the field.

The Aphid Rating Scale may help define situations where treatment may be indicated.

Recommendations

A complete listing of recommended insecticides for use in controlling cotton insects may be found in the *2014 North Carolina Agricultural Chemicals Manual.*

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 material(s) 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 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.

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. An NACB of 4 is usually safe for defoliation. If you have low plant populations (less than two plants per foot of row), an NACB count of 3 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 15-25 are likely to never mature. Producers should walk each field and 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:

1. They 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.

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 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. This 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 3 to 5 days afterward can retard the activity of defoliants and cause less than desirable defoliation. If possible, defoliants should not be applied during cool snaps. Better defoliation will occur if you can wait for a warm spell that is predicted to last for at least 3 to 4 days.

Defoliation is not always justified. Cotton that is completely cutout with "tough" leaves may not need defoliation if harvested with care. In this situation, it is important not to pick too early or late in the day to avoid excess moisture. If you are considering picking without defoliation, pick a trailer full and see how well it cleans up at the gin. If the gin can clean the lint so that it will grade a 41 or better, then defoliation may not be needed.

Herbicidal vs. 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 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, and Klean-Pik) 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 it 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 a material 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. 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. 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 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 50WP and FreeFall 50WP. Dropp and FreeFall defoliate mature leaves essentially as well as the phosphate-type defoliants. However, Dropp and FreeFall provide excellent removal of juvenile growth and are strong inhibitors of terminal regrowth. A minimum of 0.05 lb ai per acre is needed for 10-14 days of regrowth inhibition. Higher rates will result in longer periods of regrowth inhibition. Dropp and FreeFall 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 Dropp or FreeFall 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 or Prep is tank-mixed with Dropp or FreeFall.

Dropp and FreeFall 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 Dropp or FreeFall with organophosphates (phosphate insecticides, Def), the use of 0.5 percent nonionic surfactant is recommended by the manufacturers to improve tank cleanout.

A minimum of 0.05 pounds a.i. per acre of Dropp or FreeFall will provide regrowth control for a short period (10 to 14 days). Higher rates are needed for longer periods of control.

Thidiazuron is produced in dry and liquid formulations. Liquid formulations are Dropp SC, Freefall SC, and Thidiazuron 4 SC. Dry formulations are Freefall, Klean-Pik, and Thidiazuron 50 WSB. 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)	Dropp SC, Freefall SC, and Thidiazuron 4 SC (oz product/acre)	Freefall, Klean-Pik, and Thidiazuron 50 WSB (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 morninglories.

Finish. Finish contains the boll opener ethephon, plus a material 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. This is also a new Dropp formulation that includes Dropp (thidiazuron) and the herbicidal defoliant Diuron, plus another active ingredient that acts as an enhancing agent. Defoliation is faster than with Dropp alone. 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 mixure of Dropp and Harvade. Research with Leafless is limited in North Carolina. The recommended rate of 10 to 12 ounces per acre provides 0.125-0.15 pounds of Dropp per acre and 6.4-7.7 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 0.5-1 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 suggest the addition of 1-2 pints of COC be added, or a non-ionic 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. 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 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. Demonstration work conducted in Georgia suggests that a crop of about 20 green bolls per 10 feet is needed to justify the expense of Prep as a boll opener at the lower-labeled rates. Out of these 20 bolls, about 6 bolls would be expected to open naturally and another 6 or 7 would be opened within 7 to 14 days by Prep. The remaining 8 bolls will probably not open until later. Therefore, a crop with 25 to 50 green bolls per 10 feet is a more likely candidate for Prep treatments.

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 boll cracking and opening. Paraquat is generally used when weather conditions are cool and bolls are fully mature. Paraquat at lower rates (3-6 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.

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 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 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 Dropp or FreeFall does appear to be reduced on drought-stressed cotton. Therefore, higher rates of Dropp or FreeFall may be needed on drought-stressed cotton. Mixtures of Def and Dropp or FreeFall 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 Dropp or FreeFall 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 has adequate moisture and excess nitrogen. Controlling potential regrowth with Dropp is more effective than reapplying defoliants after regrowth has occurred. Reapplication of defoliants is permitted, but that 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 or permanent markers will keep uniform swath widths and result in more uniform defoliation. Typical swath widths for popular agricultural aircraft are listed in Table 12-2.

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- 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 10 to 20 gallons per acre.

Frost Defoliation

Some producers like to wait and let frost defoliate cotton. This 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

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.

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

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. - 0.1. lb ai) (defoliation or regrowth control)

3. Def (0.5 - 1 pt) + Dropp or FreeFall (0.05 - 0.1 lb ai) (defoliation or regrowth)

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

5. Dropp or FreeFall (0.05 - 0.1 lb) + Prep (1.33 pt) (defoliation or regrowth/ boll opening)

6. Def (0.1 - 1.3 pt) + Prep (1.33 pt) (defoliation or boll opening)

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

8. Finish (1.3 pt.) (defoliation and boll opening; add Dropp or FreeFall (0.05 - 0.1lb 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 - 0.15 lb ai) (defoliation or regrowth)

10. Aim, Blizzard, ET or Resource (recommended rates) (0.5 - 0.75 pt) + Prep (1.33 pt) (defoliation or boll opening)

11. CottonQuik/FirstPick (2 qt) + Dropp or FreeFall (0.05 - 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 (0.75-1.0 pt) (defoliation)

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

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

4. Dropp or FreeFall 50 (0.05 - 0.1 lb ai) + Def (0.25 - 0.50 pt) +Prep (1.33 pt) (defoliation or regrowth control/boll opening)

5. Def (0.75 - 1.25 pt) + Prep (1.33 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 - 0.1 lb ai) (defoliation or regrowth)

8. . Aim, Blizzard, ET or Resource (recommended rates) (0.5 - 0.75 pt) + Prep (1.33 pt) (defoliation or boll opening) - Finish or FirstPick can be substituted for Prep

9. Finish (1.3 pt) (defoliation and boll opening; add Dropp or FreeFall (0.05 - 0.1lb ai) or Def (0.5 pt) if rank growth or regrowth is present)

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

11. Ginstar (3-5 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 (1.5 - 2 pt) (defoliation)

2. Dropp or FreeFall 50 WP (0.125 - 0.2 lb) + Def (1 - 2 pt) (defoliation or regrowth)

3. Dropp or FreeFall 50 WP (0.125 - 0.2 lb) + Prep (5.33 oz) (defoliation enhancement)

4. Dropp or FreeFall 50 WP (0.1 - 0.125 lb) + Def (0.25 - 0.50 pt) + Prep (1.33 pt) (defoliation or regrowth/boll opening)

5. Def (1.5 - 2 pt) + Prep (1.33 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 - 4 lb active ingredient) (defoliation or weed desiccation) (less effective)

9. Aim, Blizzard, ET, or Resource (recommended rates) + Dropp or FreeFall (0.125 - 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

11. Aim, Blizzard, ET, or Resource (recommended rates) + Def (1 - 1.25 pt) (defoliation)

12. Finish (1.3 - 1.5 pt) (defoliation and boll opening; add Dropp or FreeFall (0.05 -0.1 lb) or Def (0.5 pt) if rank growth or regrowth is present)

14. CottonQuik (2 qt) + Dropp or FreeFall (0.05 - 0.1 lb) or Def (0.5 pt) (defolia-tion and boll opening)

15. Finish (1.3 - 1.5 pt) or CottonQuik (2 qt) + Harvade (0.5 pt) + crop oil (1 pt)(defolia-tion, boll opening, and weed desiccation)

16. Ginstar (7 - 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 (2 - 3 pt) (defoliation)

2. Dropp or FreeFall 50 WP (0.1 - 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 - 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) (1 - 1.5 pt) + Dropp or FreeFall (0.125 - 0.2 lb) (defoliation or regrowth)

8. Aim, Blizzard, ET, or Resource (recommended rates) (1 - 1.5 pt) + Prep (1.33 - 2 pt) (defoliation/boll opening at higherPrep rates)

9. Aim, Blizzard, ET, or Resource (recommended rates) (1 - 1.5 pt) + Harvade (0.5 pt) + crop oil (1 pt) (defoliation)

10. Aim, Blizzard, ET, or Resource (recommended rates) (1 - 1.5 pt) + Def (1 - 1.5 pt) (defoliation)

11. Finish (1.5 qt) (defoliation and boll opening; add Dropp or FreeFall (0.05 - 0.1lb) or Def (1-1..5 pt) if rank growth or regrowth is present)

12. CottonQuik (2 qt) + Dropp or FreeFall (0.05 - 0.1 lb) or Def (1-1.5 pt) (defoliation and boll opening)

13. Finish (1.3 - 2 pt) or CottonQuik (2 qt) + Harvade (0.5 pt) + crop oil (1 pt)(defoliation, boll opening, and weed desiccation)

14. Ginstar (8 - 10 oz) (defoliation or regrowth control); add boll opener if needed.

Table 12-4. Harvest Aid Performance

		Expected activity			
Material	**Estimated minimum temperature**	**Mature leaves**	**Juvenile growth**	**Regrowth prevention**	**Boll opening**
Def/Folex	60ºF	Excellent	Fair	Poor	None
Thidiazuron	65ºF	Excellent	Excellent	Excellent	None
Harvade	55ºF	Excellent	Fair	Poor	None
Ginstar	60ºF	Excellent	Excellent	Excellent	None
Aim	55ºF	Excellent	Excellent	Poor	None
ET	55ºF	Excellent	Excellent	Poor	None
Resource	55ºF	Excellent	Excellent	Poor	None
Blizzard	55ºF	Excellent	Excellent	Poor	None
Prep/SuperBoll, others	60ºF	Fair	Poor	Poor	Excellent
Finish	60ºF	Excellent	Poor	Fair	Excellent
CottonQuik/FirstPick	60ºF	Excellent	Poor	Poor-Fair	Excellent
Glyphosate	55ºF	Fair	Fair	Excellent	None
Sodium Chlorate	55ºF	Fair	Fair	Poor	None
Paraquat	55ºF	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 4 to 7 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 7 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 3 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 to 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 to 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 coil 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 7 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)	phosphorotrithioate	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.
Dropp 50 WP or FreeFall 50 WP (0.2 - 0.4 lb)	thidazuron	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 5 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.

Table 12-7. Defoliants (continued)

Trade Name (products/a)	Common Name	Application Instructions
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.
Dropp 50 WP or FreeFall 50 WP (0.2 - 0.4 lb)	thidazuron	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 5 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.
Ginstar 1.5 EC(6.5 - 10 oz)	thidazuron + diuron	Do not exceed 10 o/z/acre unless under extremely cool conditions. Ginstar is similar to Dropp Ultra but contains an enhancing agent, and thereforre an adjuvant should be used.

continued

Table 12-7. Defoliants (continued)

Trade Name (products/a)	Common Name	Application Instructions
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 oilconcentrate(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. Pre-Harvest Interval (PHI) is 7 days.

13. COTTON PRODUCTION WITH CONSERVATION TILLAGE

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Cotton and Soil Conservation

Conventionally tilled cotton on sloping, erodible land has a well-deserved reputation for contributing to soil erosion. Cotton grows slowly during early summer and provides little crop protection from raindrop impact and soil erosion. Cultivation enhances the potential for soil erosion. Cotton also provides relatively little residue to return to the soil or to leave on the surface to protect it from erosion during the winter.

Conservation compliance was introduced in the 1985 Farm Bill and reinforced in the 1990 and 1996 Farm Bills. Fundamental to these bills were efforts to reduce soil loss associated with cultivation of annual crops on highly erodible land (HEL, which is defined according to a formula that considers normal rainfall patterns, the gradient and length of slopes, and the inherent erodibility of the specific soil). To be eligible for program benefits, including "market transition payments" and conservation cost share, growers were required to have and follow an approved conservation farm plan if highly erodible land was involved. The 2002 Farm Bill maintains this focus on conservation. Provisions related to conservation tillage include cost-share opportunities for long-term no-till through the Environmental Quality Incentives Program (EQIP) and perhaps other opportunities through a new Conservation Security Program. Consult with local program offices for details. Producers need to consider that long-term no-till currently requires a 5-year time commitment and that the cropping system must provide 80 percent ground cover. This may require careful cover crop management to insure optimum stands and sufficient residue.

Conservation tillage is often the agreed-upon and most effective approach to protect against soil erosion and to meet conservation compliance requirements on highly erodible land. No-tillage planting into a residue cover offers the additional benefits of conserving moisture on drought-prone soils and protecting young cotton seedlings from sandblasting. Also, a no-tillage system can save time during the planting season, allowing growers to plant cotton and other crops closer to the optimum planting date.

Research results, as well as the experience of growers in North Carolina and other states, show that cotton can grow successfully under conservation tillage systems. However, in these methods of cotton production, which are sometimes collectively referred to as "no-till cotton," success requires planning and a high level of management. Growers are encouraged to start with a small acreage of "no-till cotton," seeking to resolve the practical challenges of this system within their own operations. Many sources of information exist, including the successful growers in many counties where thousands of acres of conservation-tilled cotton are now being grown.

Cover Crop Selection and Management

To meet conservation-tillage requirements in North Carolina, surface residues must provide at least 30 percent ground cover after planting. A cover crop will be required in most situations. Residues from a good previous corn crop may provide sufficient cover; residues from soybeans, peanuts, tobacco, or cotton will not be adequate**. If relying on residues from a previous crop** to provide sufficient cover, do not perform any tillage operations between harvest of the previous crop and planting of the cotton.

Potential cover crops include small grains (most commonly wheat or rye) and winter legumes (vetch or crimson clover). Nitrogen production is the primary advantage of a legume cover crop. Vetch or crimson clover typically will provide nitrogen to cotton equivalent to 50 to 70 or more pounds of fertilizer N per acre. However, this nitrogen production can be a liability in that it is difficult to accurately predict the amount and timing of the nitrogen availability to the following cotton crop. Thus, it may be difficult to decide how much, if any, additional fertilizer nitrogen to apply. Excess nitrogen can lead to substantial problems, both in production of cotton and in protection of the environment (see the discussion of nitrogen fertilization in Chapter 7, "Fertilization").

Small-grain cover crops are generally preferred for no-till cotton. The seed is more economical, and small grains are easier to establish and easier to kill than legumes. Small grains can be successfully established later in the fall than can legumes, allowing more time to get cotton and other crops harvested before seeding the cover crop. Small grains typically provide more protection from soil erosion during the fall and winter months than do legumes. With increasing concern about nitrogen and protection of water quality, small-grain cover crops can help by "scavenging" leftover nitrogen from the crop season to reduce its movement to groundwater. Additionally, small-grain mulch is more persistent than that of legumes and provides better weed suppression.

Rye produces more mulch than wheat, and the mulch provides better weed suppression. The major disadvantage of rye is that it will become too tall unless mowed, grazed, or killed well ahead of planting. If the rye is allowed to become excessively tall, it can interfere with planting and the application of postemergence-directed herbicide sprays. For that reason, wheat is generally preferred.

Soil samples should be taken in early fall to allow time for analysis before seeding the cover crop. Suggested lime and phosphorus (unless the required $P_2 0_5$ can be applied in a starter band application) should be broadcast and worked into the soil during seedbed preparation for the cover crop. Where a strict no-till system is used, lime, phosphorus and

potassium are not incorporated into the soil. Since these amendments move very slowly into the soil, they can become concentrated in the surface soil and deficient lower in the root zone. It is imperative that adequate levels of these amendments be applied to the soil and incorporated throughout the root zone before initiating a strict no-till system. Once adequate fertility and pH are achieved throughout the root zone, decrease the soil sampling depth from 8 to 4 inches on no-till fields.

Except for sandy, less productive soils, nitrogen fertilization of the cover crop is generally unnecessary and may promote excessive vegetative growth of the cover crop. In general, it also would make the small-grain cover less effective in removing soil nitrogen for the benefit of water quality protection. Fall tillage to prepare a cover crop seedbed also will help to avoid problems with horseweed and cutleaf evening primrose and will provide some suppression of perennial weeds.

Planting Methods

During the last decade or so we have seen increasing acreages of North Carolina cotton being grown with some form of conservation tillage. Although often referred to simply as "no-till cotton," several approaches are being used successfully. Some of these are:

1. **In-row subsoiling** at depths of 10 to 16 inches. This is really a form of strip tillage in that considerable soil preparation in the row zone is provided by the coulter, ripper, and other components of the unit that closes the ripper slit in the soil. Planters may be attached to the ripper unit for one-pass planting, or the strip tillage can be done in a separate pass some time before planting. Due to the tractor power required for a six- or eight-row ripper unit, it may be necessary to do the planting in a separate pass.

2. Strip tillage in the row zone **without subsoiling**. This may be done with an arrangement of coulters or spider gangs to till a row zone of about 8 to 12 inches in width. This works especially well when beds have been made the preceding fall or in early spring.

Strip-till equipment currently on the market generally includes combinations of coulters, rolling baskets, spider gangs, rubber firming wheels, and/or other devices. These serve to do some soil conditioning in the row zone and to close the slits left by the subsoilers or other types of shanks that offer deep tillage and are included with these strip-till machines. However, these row-zone tillage devices also may allow shallow soil mixing, especially when rolling baskets or spider gangs are included and are properly adjusted to accomplish that function.

3. No-till planting using a row planter only. This commonly includes a fluted, bubble, or ripple coulter mounted ahead of the planter. The width of the tillage is narrow, typically from 3/8 inch to 1½ inches, and is determined by the lateral pushing and fracturing of the soil by the coulter flutes (waves) or by the "bubbles" on that coulter type.

Bedding and Ripper/Bedding

In general, a cotton crop is susceptible to extended periods of both wet and cool soils. Bedding provides some protection from both, especially early in the growing season. For this reason, planting cotton on raised beds is a strong preference of many

conventional-tillage cotton growers. If growers decide to change to conservation tillage and wish also to plant on some degree of a bed, then special efforts are needed. Achieving **conservation-tilled cotton with bedding** requires either fall bedding or re-using the remnant bed from the previous crop. Further, **when conservation compliance is required**, or where growers simply wish to gain benefits from conservation tillage, establishment of a cover crop on these beds is generally necessary in order the meet the residue cover required for acceptance as conservation tillage (a minimum of 30 percent of the soil surface under residue cover after planting of the summer crop).

This could be done by fall bedding or ripper/bedding, with a small-grain cover crop being planted at the same time or shortly after the fall bedding. This practice is successful where cotton follows tobacco, peanuts, or corn because these crops allow ample time after harvest for some root decomposition, fall tillage, and cover crop establishment. However, following cotton, fall bedding works best if the cotton stalks are uprooted by rigorous disking or by some form of stalk pulling.

In a continuous cotton operation, fall bedding (especially ripper/bedding) is often very difficult when the harvest is completed in late November or even in December. In general, we do not recommend using an in-row subsoiling device, especially a conventional ripper/bedder, running directly into the old (non-tilled) cotton row positions in the fall or early winter. This usually presents frequent problems with roots wrapping and clogging on the rippers. Running rippers in mid-row positions would work better, but it is difficult to maintain the alignment to do this well.

Where cotton follows cotton, and where subsoiling is desired because of sandy soils and pan layers, useful alternatives are the **"Paratill"** of the Tye Company and Bigham Brothers Inc. and a similar tool known as the TerraMax of Worksaver Inc. These tools feature a deep loosening point that is carried in the soil on an angled shank ("leg"). A leading coulter cuts the residue in the path of the shank. These tools generally run without problems of root clogging, mainly because the shank enters the soil from the side of the old row. Again, careful driving to maintain tillage and row alignment is important. The effectiveness of such equipment in shattering pan layers is without question. The shatter zone is somewhat larger than that of conventional rippers. However, this equipment may require greater pulling power per shank than conventional in-row subsoilers, and there is significant expense involved in replacing the worn points on the legs of the Paratill units.

Establishment of a good cover crop in a continuous cotton system requires an emphasis on achieving timeliness. Wet weather and other time conflicts make it a challenge to establish the cover crop properly and sufficiently early to achieve the desired residue and cover benefits. Where new beds are made in the fall, some shaping or leveling of the bed is desirable before seeding the cover crop.

Because of these difficulties and the costs of achieving both bedding and good cover-crop establishment, growers are often forced to give up beds in conservation-tilled cotton. This is especially true where cotton follows cotton. Nevertheless, in typical growing seasons (when drought stress is more serious than wetness), the moisture-conserving benefits of good residue cover under conservation tillage more often than not offset the lack of benefit from bedding.

Where the following cotton crop will be flat-planted, consider using a no-till drill to plant into standing cotton stalks while the cotton is being picked. This will save time and help to get the cover crop seeded earlier. Stalks can then be mown afterward. These drills perform quite well if seeding depth is adjusted to compensate for ground-level differences of the beds and valleys. One exception is the case of drills having an exposed drive chain, where cotton stalks can cause the chain to run off. A home-made chain shield could be added to prevent this. This approach to seeding cover crops works best on flat-planted cotton residue, or where existing beds are being used for cotton the following year. On the other hand, simply broadcasting small grain seed on fresh bedded or bed-shaped land may give adequate cover-crop establishment. Where cotton is to follow peanuts, growers often have had good cover-crop success by distributing wheat or rye seed just ahead of peanut digging, assuming that the peanut "hay" is not being removed for animal feed.

Where cotton is flat-planted, rows can be offset by about 2 to 6 inches from one year to the next, thus possibly avoiding some no-till planting difficulties caused by previous crop stalks located in the exact new row position. Without beds, planting of the cover crop in the fall is easier and quicker. For flat-planted cotton, in-row subsoiling done a few inches beside the old row, either in the fall or spring, is also less problematic.

With several years of conservation tillage, there is some indication that soil porosity and drainage behavior may improve. Except in soils with naturally high water tables, this could even reduce the need for bedding to protect from the risks of soil wetness. These aspects of soil management with long-term conservation tillage are now receiving the attention of farmers and researchers.

Fall Ripping and Carryover Effects of Subsoiling

To spread the work load and make efficient use of available tractor power, growers ask whether fall ripping is as effective as ripping at planting time. We recently completed a three-year study of "carryover" ripper effectiveness, including one site in a strong pan-layer prone soil (Conetoe loamy sand). **Fall ripper/bedding was fully as effective for cotton yield as was ripping in the spring.** We followed the fall ripper/bedding by a wheat cover crop, strip-killed the cover crop over the intended row zone, and then no-till-planted cotton without ripping. In that study we also attempted to use the ripped zone for a full second and third year of straight no-till planting over the previous ripped row. **We lost about half of the ripper benefit in the first carryover year and about 80 percent of the benefit in the second carryover year.** These studies were done in a cotton/corn rotation.

Strip Tillage vs. No-Tillage

Strip tillage simply means some form of tillage in the row zone, generally 8 to 16 inches wide. This may be only 1 to a few inches deep or, in the case of in-row subsoiling, typically 10 to 16 inches deep. This is being done with rubber wheels, aggressive coulters, rolling tines, shallow shanks, or shovels (any of these must provide appropriate closure and soil-conditioning devices). Also, it may involve deeper chisel or ripper shanks (with appropriate soil closure devices).

After some 20 replicated studies of cotton comparing conventional tillage, fluted coulters (1-inch flutes), shallow strip tillage, and in-row subsoiling, we have found that in at least three-quarters of the studies there were somewhat lower lint yields from use of the fluted coulter alone. The reasons for these lower yields from simple coulter-no-till appear to vary according to soil properties and residue conditions. In most cases there are somewhat more stand skips where no row-zone tillage is done (such as by a ripper, coulters, or rolling tines). This is especially likely where residue is tough or heavy (rather mature rye or wheat) and the soil is soft. Under these conditions, "hair pinning" often results in inadequate closure of the seed furrow and poor seed-soil contact.

Prior killing of a narrow strip in the row-zone (**strip-killing**) has shown some benefit for cotton-stand establishment in cases of fairly heavy rye or wheat residue at planting time. In other cases, soil properties influence the cotton response to some row-zone tillage. In the more sandy, pan-layer-prone soils, subsoiling generally provided the superior yield. In eroded, poor-tilth, crust-prone, coastal plain fields, shallow strip tillage was superior. In wet seasons or wet-natured soils, conventional tillage may be favored. In any case, where satisfactory cotton stand and good weed control are achieved, one of these forms of conservation-tilled cotton has generally given similar yields to conventional tillage.

Concepts of Strip Tillage vs. Methods of Deep Tillage

At present there are several brands of effective commercial strip tillage equipment on the market. When operating correctly, a strip-till operation should:

1. Leave the row zone in a near-ready planting condition.
2. Provide deep tillage (subsoiling) to an appropriate soil depth, if desired.
3. **Not leave** large clods, sod clumps, or major surface holes or mounds that the planter would handle poorly, especially if the soil will be allowed to dry and harden before planting.
4. **Not leave** subsurface cavities in which there will be little rooting and which, during wet periods (when the soil may reach saturation and the cavities could act like a tile drain), could possibly cause root death.

Growers should keep in mind the differences between an effective strip-tillage operation, as described above, **versus** the actions and the potential advantages and disadvantages of deep-tillage tools, the most familiar of which is the subsoiler in its various configurations. On all commercial strip tillage equipment available today, the in-row subsoiler provides a major part of the row-zone soil preparation, combined with important actions of the accompanying devices, namely coulters, rolling baskets, and wheels. Therefore, depending on the depth of subsoiler operation, strip till rigs also usually perform deep tillage. Such in-row subsoiling often helps deepen the crop rooting pattern, especially if pan layers exist in the soil. You may wish to consult the publication *Subsurface Compaction and Subsoiling in NC—An Overview* (AG-353, North Carolina Cooperative Extension Service) for concepts of pan layers and deep tillage. Deep-tillage effects, however, can be minimal or even detrimental, depending on various aspects of soil properties, operational depth and travel speed, soil hardness or stickiness in the zone of the deep tillage, and the shape and size of the "point" of the deep tillage tool used.

Because of current grower interest, we have examined under on-farm conditions the effects of a typical subsoiler **in contrast with** those produced by the "no-till point" currently marketed by the DMI company. We have found that the large DMI point commonly leaves cavities in the soil at the depth of operation of the point. No such cavities were found in the zone of operation of the traditional in-row subsoiler. These DMI-point cavities were still very apparent near the end of the growing season in September after the tillage had been done in late March. The cavity typically is from 2 to 4 inches wide and about 1.5 inches high. Generally, no roots have grown directly through the cavity, although roots commonly pass around the sides. We do not yet have evidence that this is detrimental to crop performance, although logically one would prefer to loosen a volume of soil in the prime zone of root growth, thus providing ideal soil physical conditions for crop root development. Attaining this objective would not include leaving a cavity zone unsuitable for root growth.

Some growers are interested in operating tools such as the DMI with winged points in a diagonal direction to the intended cotton rows, which certainly would reduce the area of such cavities directly under rows. Although this may be a useful compromise, it is likely to leave segments of row that would not benefit from this soil loosening, especially in specific fields where pan layers and soil hardness are actually limiting factors for root development.

Agronomic Considerations

Research in North Carolina has shown that yields of no-till, and especially of strip-tilled cotton, are comparable to those of conventionally planted cotton if adequate stands and weed control are achieved. Yields of no-till cotton have sometimes exceeded those of conventionally planted cotton in dry years. The exception has been in wet-natured soils, where no-till cotton sometimes has not performed well.

The soil temperature under a good cover-crop residue generally will be 2° F to 4° F cooler than under bare soil. In addition, the soil may be moister. These cooler, moister conditions are more conducive to slower germination and seedling disease development. Plant conventional cotton first, allowing time for the soil to warm in no-till fields (see the discussion of soil temperatures in Chapter 4, "Planting Decisions"). Also, because of the cooler and moister conditions under a heavy cover crop residue, the chances of obtaining a response to an in-furrow fungicide are greater than under conventional tillage situations (see the discussion on in-furrow fungicides in Chapter 9, "Disease Management in Cotton"). Also, especially in years when cool weather restricts DD-60s during the seedling development period, no-till and strip-till cotton are likely to show an economic response to starter fertilizer (see Chapter 7, "Fertilization").

Research in North Carolina has shown that stands in no-till cotton average about 10 percent fewer plants than stands in conventionally planted cotton. This should not be a concern unless you are using a low seeding rate (see the discussion of seeding rate in Chapter 4, "Planting Decisions").

When planting no-till cotton, adjust the planting depth carefully. Remember to plant ½ to 1 inch deep. Given the variability and hardness of no-till fields and the shallow depth of

double-disk openers, it may be difficult to stride the line between adequately covering the seed and planting too deeply. Avoid planting when the soil is too wet for the seed furrow to be properly and consistently closed.

Insect Management

In reduced or no-till cotton production, as in conventional tillage, likely damage from thrips will require the use of an at-planting, in-furrow insecticide. Because of the potentially cooler soils and resulting slower seedling growth, young plants may be subject to thrips populations over a somewhat longer period of time, putting a greater demand on the persistence of the at-planting insecticide. Alternatively, preliminary research suggests that thrips populations may be lower in reduced- and no-till cotton. Monitoring or sampling for thrips in reduced-tillage cotton culture is the same as with conventional cotton production (see Chapter 11, "Managing Insects on Cotton").

Preliminary research has shown the impact of insects such as cotton aphids, plant bugs, and late-season caterpillars in reduced-tillage cotton to be similar to that found in conventional cotton. In a limited number of experiments with strip-till cotton planted into wheat or rye cover crops, some stand-reducing cutworm damage has been observed. Stand reductions in commercial cotton have been locally severe following the previously mentioned cover crops and behind corn, soybeans, and cotton in which winter annual weeds have served as a host for spring cutworms. Cutworms appear to be lower in cotton planted into hairy vetch or clover, but these covers are not commonly used in North Carolina. Because cutworms can persist at least 2 weeks following the application of a burndown herbicide, a waiting period of approximately 2½ to 3 weeks is advised to reduce the possibility of damaging cutworm populations. If cotton fields have a history of cutworm damage, a broadcast or banded insecticide before or after planting may be appropriate. For example, the insecticide might be tank-mixed with a preemergence herbicide, or the insecticide alone might be sprayed into and up on the collar of the furrow in a T-band. Alternatively, if scouting reveals a stand reduction of 15 percent or more and an active population of cutworms (mostly "hiding" under soil clumps near cotton seedlings), then a banded or post-directed insecticide treatment is recommended. Cutworm-labeled pyrethoids or Lorsban 4E should provide adequate control.

Disease Management

Because conservation tillage often includes more variable seedbed conditions—including seed-soil contact, depth of coverage, zones of soil wetness, and cooler soil temperatures—it is important to use high-quality seed. Refer to Chapter 4, "Planting Decisions," Chapter 6, "Cotton Seed Quality and Planting Decisions," and Chapter 9, "Disease Management in Cotton," for further information on these management concerns.

Weed Management

Most of the same weed-control techniques of conventional cotton culture are applicable to cotton produced with conservation tillage, with the exception of broadcast preplant-incorporated herbicides and most forms of cultivation. Chapter 10, "Weed Management in Cotton," gives key information on these topics.

14. AVOIDING 2,4-D INJURY TO COTTON

Alan C. York, WNR Professor Emeritus

Cotton injury from 2,4-D continues to be a common and unnecessary problem in North Carolina. The problem can result from sprayer contamination, spray drift, and vapor drift.

Sprayer Contamination

Cotton injury can occur from minute residues of 2,4-D (or 2,4-DB) in a sprayer. It is best that any sprayer previously used to apply 2,4-D not be used in cotton. If such a sprayer must be used, it should be washed thoroughly before spraying cotton. Special attention should be given to sprayers used to apply glyphosate or emulsifiable concentrates because these products seem to be particularly effective at pulling 2,4-D residues out of a sprayer.

The following procedure is suggested for washing out sprayers that have been used to apply 2,4-D. Keep in mind that this procedure may not totally remove 2,4-D residues, especially from the hoses. Dispose of rinsates in an approved manner.

1. Remove nozzles, nozzle strainers, and in-line strainers. Using a soft brush, wash the nozzles and strainers with soapy water. Be sure to remove any visible deposits. On sprayers with a “hard” or metal boom, remove any end caps beyond the last nozzle and check for deposits.

2. Before replacing nozzles and strainers, fill sprayer tank with water and add commercial spray tank cleaner at rates recommended by the manufacturer. Agitate for 15 minutes and then flush about one-fourth of the water-tank cleaner mixture through the lines. Replace nozzles and strainers and flush remainder of water-tank cleaner mixture through the nozzles.

3. Spray diesel fuel or kerosene on the inside surfaces of the tank. Make sure to spray inside the top of the tank and any irregular surfaces inside the tank. Start the sprayer to fill the lines, and let the diesel fuel sit in the lines for a few hours. Then spray out the diesel fuel. Note: This step is suggested only if the sprayer has previously been used to apply an ester formulation of 2,4-D.

4. Fill the tank with water and add household ammonia at the rate of 1 quart per 25 gallons of water. Agitate for 15 minutes, spray a few gallons of the mixture through the nozzles, and let the remainder sit in the tank and lines for several hours, preferably overnight or longer. Then spray out the remainder of the ammonia-water mixture.

5. Fill the tank with water and commercial tank cleaner. Agitate for several minutes and spray it out.

6. Fill the tank with fresh water, and spray it all through the nozzles.

Be careful not to introduce 2,4-D from other sources, such as measuring devices for cotton pesticides that have previously been used to measure 2,4-D.

It is relatively easy to wash 2,4-D out of tanks and other hard surfaces. On the other hand, it is nearly impossible to get all of the 2,4-D out of hoses. Older hoses that may have cracks in the walls are particularly troublesome. Any time the sprayer is stopped for a few minutes, minute amounts of 2,4-D can be released from inside the hoses. One will typically see 2,4-D symptoms on cotton for the first hundred or so feet after the sprayer starts and then no more symptoms. This problem can be avoided by turning the sprayer on at the field edge and letting it flush the boom for about 30 seconds before entering the cotton.

Spray Drift

Spray drift means movement of spray droplets by wind. As opposed to vapor drift (described below), spray drift can occur with any formulation of 2,4-D (or any other product). Spraying during windy conditions and using nozzles and pressures that result in the creation of fine spray droplets increase the risk of spray drift.

Except in extreme cases, such as spraying in very windy conditions and using nozzles and pressures that create very fine droplets, spray drift normally is observed only over short distances. A buffer of 200 feet between the area being sprayed and the susceptible crop usually is adequate to prevent injury from spray droplet drift unless it is very windy. If there is no wind or if the wind is blowing away from the cotton field, a shorter buffer is acceptable. All herbicide labels now contain information on drift management.

Vapor Drift

Many cases of 2,4-D injury to cotton result from vapor drift of an ester-containing formulation of 2,4-D. Vapor drift results when the herbicide volatilizes and the vapors move to a susceptible crop such as cotton. Hot temperatures, moist soils, and thermal inversions all increase the potential for vapor drift. Injury from vapor drift can occur at rather long distances from the sprayed area.

Vapor drift can be avoided simply by refraining from the use of ester-containing formulations of 2,4-D. Ester formulations of 2,4-D should not be used within a mile of any cotton field during the months that cotton is in the field. Most commercially available ester formulations are considered “low volatile.” These formulations are still volatile, and their use can lead to cotton injury. Weedone 638 and any other formulations containing a mixture of 2,4-D ester and 2,4-D acid also should be avoided in cotton-producing areas. Amine formulations of 2,4-D have negligible volatility.

Ester and ester-acid formulations of 2,4-D are popular because they mix well with liquid nitrogen. Amine formulations also can be mixed with liquid nitrogen if the 2,4-D is premixed with water before adding it to the liquid nitrogen.

Add the water/2,4-D amine mixture to the tank slowly while the agitator is running. Maintain constant agitation until the nitrogen/herbicide mixture has been sprayed out.

15. SPRAYER CALIBRATION

Alan C. York, WNR Professor Emeritus

The performance of any pesticide depends upon many things, not the least of which is proper application at the correct rate. Failure to apply the correct rate uniformly can lead to poor pest control, crop injury, or unnecessary expense.

Every sprayer should be thoroughly calibrated before the first use of the season, and the calibration should be checked periodically during the season. Additionally, the sprayer should be recalibrated every time nozzles, pressure, or travel speed is changed.

Before Calibration

Remove nozzles and strainers, including in-line strainers. Using a soft brush, wash nozzles and strainers in soapy water. Be sure to remove all deposits. Do not clean nozzles with any hard object (such as a knife or wire) because this will destroy the nozzle.

Thoroughly wash out sprayer and flush lines using a strong detergent or commercial tank cleaner. Check hoses and connections for leaks or signs of aging or damage. Replace defective hoses. Check components such as the pressure gauge, pressure relief/regulating valve, control valves, and agitator. Replace defective parts.

Select proper size and type of nozzle for the particular pesticide application planned. Consult nozzle manufacturers' catalogs or pesticide labels for guidance. Replace nozzles at least once a year. If the sprayer is used on a large acreage, nozzles may need replacing more frequently. Remember that brass nozzles wear more quickly than stainless steel or ceramic nozzles.

Make sure every nozzle on the sprayer is the same type and size (an exception may be hooded sprayers; see discussion below). Then check for proper spray pattern. Replace nozzles that do not produce the proper pattern. Next, check for uniformity of nozzle output. This needs to be done even if new nozzles are installed.

To check for uniformity of output, partially fill sprayer with clean water. Adjust pressure to the level desired during the spraying operation. Catch and measure output from each nozzle separately for a given length of time. Replace any nozzle having an output of 10 percent more or less than the average of all nozzles.

Calibration Procedure

The procedure outlined below is called the 1/128th-of-an-acre method. It is based on the fact that there are 128 fluid ounces in a gallon. Ounces of spray solution applied to 1/128th of an acre are, therefore, equivalent to gallons per acre.

Six basic steps are needed to calibrate a sprayer using the 1/128th-of-an-acre method. They are listed below with specific examples:

Step 1. Determine average nozzle spacing (in inches).

For broadcast application, average nozzle spacing is the distance between nozzles.

For banded application, average nozzle spacing is the row width divided by the number of nozzles per band.

Step 2. Using the following formula, determine a specified distance to drive, based on your average nozzle spacing.

$$\text{Distance to drive} = \frac{4{,}084}{\text{average nozzle spacing}}$$

Step 3. Record the length of time required to travel the distance determined in step 2. It is important that this be done under actual use conditions. Measure off this distance in a field with surface conditions similar to fields to be sprayed. Engage any equipment to be used during the actual spraying operation (such as a disk or planter), choose the gear and throttle setting you plan to use during actual spraying, and determine the time required to drive the designated distance. You can improve your accuracy by doing this several times and taking the average.

Step 4. Partially fill the tank with the desired liquid carrier, but do not add pesticide. Adjust the pressure to the level that will be used during the actual spraying operation. Catch the output from each nozzle separately for the same length of time as determined in step 3. Measure the output in ounces. Determine the average output of all nozzles. The average number of ounces collected per nozzle is equivalent to sprayer output in gallons per acre.

Flow rate through a nozzle will be affected by the viscosity of the spray solution. When liquid fertilizer is used as the carrier, it is best to use the same liquid fertilizer during the calibration procedure.

Step 5. Determine how many acres a specified volume of spray solution (such as a tank full) will cover using the following formula:

$$\frac{\text{Gallons of spray solution}}{\text{Gallons per acre}} = \text{Acres covered}$$

Step 6. Determine how much pesticide to add to the tank. If broadcasting, multiply the acres covered by the broadcast rate of the pesticide as specified on the label.

$$\text{Amount to add to tank} = (\text{acres covered})\,(\text{pesticide broadcast rate per acre})$$

If banding, multiply the acres covered by the broadcast rate of the pesticide as specified on the label and by the band width, and divide by the row spacing.

$$\text{Amount to add} = \frac{(\text{acres covered})(\text{broadcast rate/acre})(\text{band width})}{(\text{row spacing})}$$

Examples

Broadcast Application: Preplant, Preemergence, or Postemergence Overtop

Assume you plan to broadcast 1.0 pint per acre of Reflex. Your sprayer has nozzles mounted 19 inches apart along the boom, and the tank holds 240 gallons. (Note: Row spacing is not a factor when calibrating for a broadcast application.)

Step 1. Determine average nozzle spacing. For broadcast application, this is the average distance between nozzles. In this example, average nozzle spacing is 19 inches.

Step 2. Determine distance to drive.

$$\text{Distance} = \frac{4{,}084}{\text{average nozzle spacing}} = \frac{4{,}084}{19} = 215 \text{ ft}$$

Step 3. Determine length of time required to drive 215 feet. For this example, assume it takes 25 seconds.

Step 4. Determine average output per nozzle in 25 seconds. For this example, assume the average output per nozzle is 12 ounces in 25 seconds. This means your sprayer is applying 12 gallons per acre.

Step 5. Determine acres covered per tank.

$$\frac{\text{Gallons of spray solution}}{\text{Gallons per acre}} = \text{acres covered}$$

$$\frac{240 \text{ gal}}{12 \text{ gal/acre}} = 20 \text{ acres covered}$$

Step 6. Determine how much Reflex to add to the tank.

Amount to add = (acres covered) (broadcast rate per acre)

Amount to add = (20 acres) (1.0 pt/acre) = 20 pt

Banded Application Using One Nozzle Per Row: Preemergence or Postemergence Overtop

Assume you plan to apply a 16-inch band of Cotoran using a single nozzle mounted behind each planter. Your cotton is planted on 40-inch rows, and your sprayer tank holds 270 gallons. You determine that the appropriate rate of Cotoran for your soil, on a broadcast basis, is 3 pt per acre.

Step 1. Determine average nozzle spacing.

$$\text{Average nozzle spacing} = \frac{\text{row width}}{\text{nozzles per band}} = \frac{40}{1} = 40 \text{ in}$$

Step 2. Determine distance to drive.

$$\text{Distance} = \frac{4{,}084}{\text{average nozzle spacing}} = \frac{4{,}084}{40} = 102 \text{ ft}$$

Step 3. Determine length of time required to drive 102 feet. For this example, assume it takes 15 seconds.

Step 4. Determine average output per nozzle in 15 seconds. For this example, assume the average output per nozzle is 9 ounces in 15 seconds. This means your sprayer is applying 9 gallons per acre.

Step 5. Determine acres covered per tank.

$$\frac{\text{Gallons of spray solution}}{\text{Gallons per acre}} = \text{acres covered}$$

$$\frac{270 \text{ gal}}{9 \text{ gal/acre}} = 30 \text{ acres covered}$$

Step 6. Determine how much Cotoran to add to the tank.

$$\text{Amount to add} = \frac{(\text{acres covered})(\text{broadcast rate per acre})(\text{band width})}{(\text{row width})}$$

$$\text{Amount to add} = \frac{(30 \text{ acres})(3 \text{ pt/acre})(16 \text{ in})}{(40 \text{ in})} = 36 \text{ pt}$$

Banded Application Using Two Nozzles Per Row: Postemergence-directed

Assume you plan to direct Caparol in a 16-inch band under the cotton. Your cotton is planted on 36-inch rows, you have two nozzles per row on your directed sprayer, and your sprayer tank holds 250 gallons. You determine that the desired broadcast rate for Caparol 1 quart per acre.

Step 1. Determine average nozzle spacing.

$$\text{Average nozzle spacing} = \frac{\text{row width}}{\text{nozzles per band}} = \frac{36}{2} = 18 \text{ in}$$

Step 2. Determine distance to drive.

$$\text{Distance} = \frac{4{,}084}{\text{average nozzle spacing}} = \frac{4{,}084}{18} = 227 \text{ ft}$$

Step 3. Determine length of time required to drive 227 feet. For this example, assume it takes 34 seconds.

Step 4. Determine average output per nozzle in 34 seconds. For this example, assume the average output per nozzle is 7 ounces in 34 seconds. This means your sprayer is applying 7 gallons per acre.

Step 5. Determine acres covered per tank.

$$\text{Acres} = \frac{\text{gallons of spray solution}}{\text{gallons per acre}} = \frac{250 \text{ gal}}{7 \text{ gal/acre}} = 35.7 \text{ acres covered}$$

Step 6. Determine how much Caparol to add to the tank.

$$\text{Amount to add} = \frac{(\text{acres covered})(\text{broadcast rate per acre})(\text{band width})}{(\text{row width})}$$

$$\text{Amount to add} = \frac{(35.7 \text{ acres})(1 \text{ qt/acre})(16 \text{ in})}{(36 \text{ in})} = 15.9 \text{ qt}$$

Hooded sprayers

Hooded sprayers can be a challenge to calibrate, depending upon the particular design and how one intends to use them. Hooded sprayers are relatively simple to calibrate if one is using them to apply herbicides only to the row middles or only directed under the cotton row. In that case, one would follow the procedures previously outlined for calibrating a banded application.

The original Redball hoods (Model 410 Conservation Spray Hoods) typically had three nozzles under the hood and one nozzle on either side of the hood directing spray into the row. The later "layby" or "dolphin nose" hoods (Redball model 420 Lay-By Spray Hoods) have one nozzle under the hood and one mounted into either side of the hood and directed under the row. Many operators block the nozzles mounted into the sides of the "layby" hoods and mount an adjustable post-directed nozzle on each rear corner of the hood. The newest version of spray hoods is the Willmar Model 915. It has three nozzles mounted under the row, and a kit can be purchased to mount a nozzle on the back of either side of the hood to direct under the row. If using adjustable post-directed nozzles spraying under the cotton row, make sure the patterns produced by the two nozzles overlap sufficiently under the row to provide uniform coverage across the band.

Any of the above types of hoods can be plumbed so that the nozzle or nozzles under the hood are on a separate system from the nozzles directing into the row. This allows one to apply different chemicals in the row middle from what is directed into the row. In that case, one would need to calibrate for each system independently. One would follow the previously described procedures for calibrating banded applications in the row middles and repeat the process for the directed spray.

When using the "layby" type hoods to apply the same chemical under the hood and directed into the cotton row, it is critical that one selects a lower output nozzle for direct-

ing under the row compared with the nozzle spraying under the hood. If all nozzles are the same size, and one tries to calibrate based on average nozzle output, there will be a much higher than intended herbicide rate in the directed band and a lower than intended rate in the row middles. This may result in cotton injury or inadequate control in the row middles. For example, if one is covering 28 inches with the single nozzle under the hood and directing a 14-inch band under the row using two nozzles, the effective coverage per nozzle under the hood is 28 inches and the effective coverage per nozzle in the row is 7 inches. If the same size nozzle is used both under the hood and directed into the row, the application rate in the cotton row will be four times greater than the rate in the row middle.

As an example of how to calibrate a hooded sprayer, assume your rig has three nozzles spraying under the hoods and two nozzles directing into the row and you have 36-inch rows. Your sprayer is plumbed to apply separate herbicides under the hoods and directed under the row. Assume the area being effectively covered under the hoods is 27 inches and you are making a 12-inch band under the row. The tank supplying under the hood is 400 gallons, and the tank supplying under the row is 220 gallons. You intend to apply 2.0 pints Direx plus 3.0 pt Gramoxone under hood, and 1.25 pounds of Suprend plus 2.5 pt of MSMA under the row. You will need to calibrate under the hood and under the row separately.

Under the hood:

Step 1. Determine average nozzle spacing.

$$\text{Average nozzle spacing} = \frac{\text{row width}}{\text{nozzles per row}} = \frac{36}{3} = 12 \text{ in}$$

Step 2. Determine distance to drive.

$$\text{Distance} = \frac{4{,}084}{\text{average nozzle spacing}} = \frac{4{,}084}{12} = 340 \text{ ft}$$

Step 3. Determine length of time required to drive 340 feet. For this example, assume it takes 46 seconds.

Step 4. Determine average output per nozzle in 46 seconds. For this example, assume the average output per nozzle is 17 ounces in 46 seconds. This means your sprayer is applying 17 gallons per acre.

Directed under the row:

Step 1. Determine average nozzle spacing.

$$\text{Average nozzle spacing} = \frac{\text{row width}}{\text{nozzles per row}} = \frac{36}{2} = 18 \text{ in}$$

Step 2. Determine distance to drive.

$$\text{Distance} = \frac{4{,}084}{\text{average nozzle spacing}} = \frac{4{,}084}{18} = 227 \text{ ft}$$

Step 3. Determine length of time required to drive 227 feet. Obviously, one will be spraying under the hoods and under the row at the same time. When calibrating under the hood, you previously determined it took 46 seconds to drive 340 ft. By calculation, you determine it should take 30.7 seconds to drive 227 feet.

$$\frac{227 \text{ ft}}{340 \text{ ft}} \times 46 \text{ seconds} = 30.7 \text{ seconds, or 31 seconds rounded off}$$

Step 4. Determine average output per nozzle in 31 seconds. For this example, assume the average output per nozzle is 11 ounces in 31 seconds. This means your sprayer is applying 11 gallons per acre.

Step 5. Determine acres covered per tank.

Under the hood:

$$\text{Acres} = \frac{\text{gallons of spray solution}}{\text{gallons per acre}} = \frac{400 \text{ gal}}{17 \text{ gal/acre}} = 23.5 \text{ acres covered}$$

Directed under the row:

$$\text{Acres} = \frac{\text{gallons of spray solution}}{\text{gallons per acre}} = \frac{220 \text{ gal}}{11 \text{ gal/acre}} = 20 \text{ acres covered}$$

For convenience, it would be better to refill both tanks at the same time. Hence, you want both tanks to cover 20 acres. To make this work out, you would totally fill (220 gallons) the tank for the directed spray but put only 340 gallons in the tank for spraying under the hoods.

$$\frac{20 \text{ acres}}{23.5 \text{ acres}} \times 400 \text{ gallons} = 340 \text{ gallons}$$

Step 6. Determine how much herbicide to add to the tank.

$$\text{Amount of Suprend to add to directed tank} = \frac{(\text{acres covered})(\text{broadcast rate per acre})(\text{band width})}{\text{row width}}$$

$$\text{Amount of Suprend to add to directed tank} = \frac{(20)(1.25 \text{ lb})(12)}{36} = 8.33 \text{ lb}$$

$$\text{Amount of MSMA to add to directed tank} = \frac{(\text{acres covered})(\text{broadcast rate per acre})(\text{band width})}{\text{row width}}$$

$$\text{Amount of MSMA to add to directed tank} = \frac{(20)(2.5 \text{ pt})(12)}{36} = 16.67 \text{ pt}$$

$$\text{Amount of Direx to add to hood tank} = \frac{(\text{acres covered})(\text{broadcast rate per acre})(\text{band width})}{\text{row width}}$$

$$\text{Amount of Direx to add to hood tank} = \frac{(20 \text{ acres})(2.0 \text{ pt/acre})(27 \text{ inches})}{36 \text{ inches}} = 30 \text{ pt}$$

$$\text{Amount of Gramoxone to add to hood tank} = \frac{(\text{acres covered})(\text{broadcast rate per acre})(\text{band width})}{\text{row width}}$$

$$\text{Amount of Gramoxone to add to hood tank} = \frac{(20 \text{ acres})(3.0 \text{ pt/acre})(27 \text{ inches})}{36 \text{ inches}} = 45 \text{ pt}$$

16. PROTECTING WATER QUALITY AND REDUCING PESTICIDE EXPOSURE

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Protection of our environment is receiving much national attention, and a great deal of this concern is related to agriculture. In future years, environmental issues will be an integral part of Extension educational programs and agricultural policy. North Carolina agriculture and cotton production will not be immune to these concerns. Everyone involved in the agricultural industry, including producers, agribusiness, and educational organizations, must be concerned with the protection of our natural resources. One of the most important of these resources is our water supply. Protecting both surface water and groundwater from nutrients and pesticide residues should be a goal for every farmer in North Carolina.

Reducing pesticide exposure to humans and wildlife is also important in today's modern farming operations. The following are some measures that cotton producers and professional applicators can take to minimize the threat to water quality and reduce pesticide exposure to humans and wildlife.

Minimize Pesticide and Fertilizer Use Where Possible

Pesticide use should be only one part of an overall pest management program. This is true for insects, diseases, and weeds. Factors such as crop rotation, proper site selection, the use of thresholds where available, promoting a healthy and vigorous crop with good cultural practices, and proper fertilization are very basic principles that protect the environment. These principles also reduce pesticide and fertilizer inputs; therefore, they make good economic sense. Refer to the chapters on insect, disease, and weed management; growth regulators; and defoliation for proper management of these issues.

Fertilizer use also impacts both pest problems and water quality. A careful soil-testing program followed by application of only those nutrients recommended is part of a sound cotton fertilization program. Refer to Chapter 7, "Fertilization," for guidelines to a sound program.

Select a Pesticide Carefully

While cultural practices are important parts of a sound pest management program, pesticides must still be used. Care must be taken to match the pesticide with the pest.

This involves proper identification of the pest and then selection of a pesticide, rate, and application method that is most effective for control. The selection process should also include consideration of potential effects on water and safety to humans and wildlife.

Apply Pesticides Carefully

Extreme care must be taken to make sure the pesticide is applied only to the crop. This is especially important in cotton because aerial application is common for many insecticides. Field borders consist of ditches, hedge rows, and woods that are vital habitat for wildlife. Imprecise application can be detrimental to these areas, and contaminated water in ditches may move into larger bodies of water such as ponds, lakes, and rivers.

Prevent Soil Movement

As soil particles become dislodged, they carry pesticides and nutrients that may eventually find their way into a water source. Therefore, sound soil conservation practices, including the use of cover crops and waterways and avoiding unnecessary disking and cultivations, must be practiced to minimize contamination of our water resources. Consult your local Natural Resources Conservation Service and Cooperative Extension Service agent for proper conservation practices. Additionally, see Chapter 13, "Cotton Production with Conservation Tillage."

Potential for Pesticide Contamination of Surface Water and Groundwater

Pesticides commonly used on cotton differ in their potential to contaminate surface water or groundwater. Predicting which pesticides may reach groundwater and on which soils this is most likely to occur is very difficult (because of such factors as differences in soil, chemical, and physical characteristics and in water table depth). As a general rule, rolling soils in the piedmont have more potential for surface water contamination, whereas the highly leachable soils of the coastal plain may be more susceptible to groundwater contamination. However, surface water contamination can occur on slightly sloping soils found in the coastal plain. The Natural Resources Conservation Service can help you determine the leaching and runoff potential of your specific fields. We also can use some general guidelines to help determine which pesticides may present the highest risk for contaminating the environment. These guidelines are based on knowledge of the chemical characteristics of different pesticides and are summarized in Table 16-1. This list includes most of the commonly used cotton pesticides.

Two guidelines for pesticide use are *surface loss potential* and *leaching potential*. Surface loss potential indicates the tendency of the pesticide to move with sediment in runoff. A rating of "large" means the pesticide has a high tendency to move with sediment, while a rating of "small" means the pesticide has a low tendency to move with sediment. Leaching potential indicates the tendency of a pesticide to move in solution with water and leach below the root zone. The ratings of "large," "medium," and "small" also describe the potential for leaching. A rating of "large" means the pesticide has a high potential for leaching. "Small" means the pesticide should not leach with

percolating water. These are general guidelines and should be interpreted as such. They must be interpreted in relation to local soil characteristics.

Pesticide Toxicity

An "LD_{50}" is used to measure pesticide toxicity to humans and other mammals and represents the amount of a substance that will cause death in 50 percent of a target population. The lower the number, the more acutely (short-term) toxic the substance is. An LD_{50} can only be used to measure short-term toxicity and is not a measure of chronic (long-term) toxicity, such as the ability to cause cancer. Care should be taken to minimize exposure of humans and wildlife to all pesticides. However, extreme caution should be taken with pesticides that have low LD_{50}s, such as Temik, Di-Syston, Nemacur, methyl parathion, Thimet, and paraquat.

Most pesticide exposure occurs in one of three ways: (1) exposure to skin (dermal), (2) ingestion (oral), or (3) inhalation (breathing vapors). Wear protective clothing when handling pesticides. Rubber gloves, boots, and goggles or a face shield should always be worn when mixing pesticides. Use a respirator when handling pesticides that have a strong odor and are easily detected by smell. This is especially true with fumigants such as Telone II. The potential for pesticide exposure is always greater when handling concentrated pesticides (not mixed with water) as opposed to a diluted solution (mixed with water in a sprayer). Also, pesticides should never be added to a spray tank by lifting a pesticide container above a person's head to pour the substance into the tank.

Consult your county Extension Service agent for additional information on how to reduce pesticide exposure from mixing and applying pesticides. If pesticide poisoning is suspected, contact the Carolina Poison Center at 1-800-848-6946. This is a 24-hour consultant service for the diagnosis and treatment of human illness resulting from toxic substances.

Table 16-1. Water Contamination Potential and Mammalian Toxicity of Commonly Used Cotton Pesticides

Common Name	Trade Name(s) [1]	Surface Loss Potential [2]	Leaching Potential[2]	Oral	LD_{50} [3]	Dermal
acephate	Orthene	Small	Small	1,030*		10,250*
aldicarb	Temik	Small	Large	2.25		>2,000
bifenthrin	Capture	_____	_____	375		>2,000
bromoxynil	Buctril	Medium	Small	779		>3,660
captan	Captan	_____	_____	9,000		_____
chlorpyrifos	Lorsban	Large	Small	96-270		2,000
clethodim	Select	_____	_____	2,920		>5,000
clomazone	Command	Medium	Large	1,406		>2,000
cyanazine	Bladex	Medium	Medium	334		>2,000
cyfluthrin	Baythroid	_____	_____	900*		>5,000*
cyhalothrin	Karate	_____	_____	64		1,820
cypermethrin	Ammo, Cymbush	Large	Small	250		>2,000
dichloropropene	Telone II	Medium	Medium	224		333
dicofol	Kelthane	Large	Small	820-960		2,100
dicrotophos	Bidrin	Small	Medium	17-22		224
dimethipin	Harvade	Small	Large	1,180		8,000
dimethoate	Cygon, DeFend	Small	Medium	291*		>2,000*
disulfoton	Di-Syston	Medium	Small	2-12*		3.6-15.9*
diuron	Karmex	Large	Medium	5,000*		>5,000*
fenamiphos	Nemacur	Medium	Medium	6*		80*
fluometuron	Cotoran, Meturon	Medium	Medium	1,840		>3,038
fluazifop	Fusilade DX	Large	Medium	2,721		>2,000

continued

Table 16-1, continued

Common Name	Trade Name(s)[1]	Surface Loss Potential[2]	Leaching Potential[2]	Oral	LD_{50}[3]	Dermal
glyphosate	Roundup Ultra	Large	Small	5,400		>5,000
linuron	Lorox, others	Large	Medium	1,196		Non-toxic
mepiquat chloride	Pix, Mepichlor, Mepix	Large	Small	464		>2,000
metalaxyl	Ridomil PC, Ridomil Gold	Small	Medium	669*		>3,100*
methidathion	Supracide	Medium	Small	20*		>5,000*
s-metolachlor	Dual Magnum	Medium	Medium	2,500		>5,000
methomyl	Lannate	Small	Medium	17		5,880
methyl parathion	Penncap-M	Medium	Very Small	20		491
MSMA	Several products	Large	Small	700		2,500
norflurazon	Zorial	Medium	Medium	>8,000		>20,000
oxydemeton-methyl	Metasystox-R	Small	Large	30-75*		150*
oxyfluorfen	Goal XL	Large	Small	>5,000*		>10,000*
paraquat	Boa, Gramoxone Max	Large	Small	138		480
PCNB	Terraclor	Large	Small	1,700*		<4,000*
pendimethalin	Prowl	Large	Small	3,956		2,200
permethrin	Ambush, Pounce	Large	Small	430-4,000*		>2,000*
phorate	Thimet, several others	Large	Medium	2-4*		99*
phosphamidon	Swat, Dimecron	Small	Large	17-30		267
profenofos	Curacron	Large	Small	662		192
prometryn	Caparol, Cotton-Pro	Medium	Small	3,920		>2,000
propargite	Comite	Large	Small	2,200		_____

continued

Table 16-1, continued

Common Name	Trade Name(s) [1]	Surface Loss Potential [2]	Leaching Potential [2]	Oral	LD_{50} [3]	Dermal
pyrithrobac sodium	Staple	_____	_____	4,000		>2,000
quizalofop	Assure II	_____	_____	5,700		>5,000
sethoxydim	Poast, Poast Plus	Small	Small	2,676		Non-toxic
sulprofos	Bolstar	Medium	Small	150*		820*
thidiazuron	Dropp	Medium	Medium	4,000		>1,000
thiodicarb	Larvin 3.2 Flowable	Medium	Small	145		>2,000
thiram	Thiram	Medium	Medium	780		_____
tralomethrin	Scout X-tra	_____	_____	1,070		>2,000
tribufos	Def, Folex	Large	Small	200*		4,000
trifluralin	Treflan, several others	Large	Small	>10,000*		>2,000*

[1] Most common trade names; others may be available.
[2] Surface loss and leaching potential as rated by the Natural Resources Conservation Service.
[3] LD_{50}: The dose (amount) of a substance that will be lethal to 50 percent of the organisms in a specific test situation. It is expressed as weight of the chemical (mg) per unit of body weight (kg). The lower the number, the more toxic. Oral refers to toxicity through ingestion, while dermal refers to toxicity by skin contact. Values are from the *Farm Chemicals Handbook '95* and the *Herbicide Handbook,* 6th Edition.
* LD_{50} is for the technical material. The technical material may be more or less toxic than the formulated product.

17. COTTON CLASSIFICATION

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Samples are taken from each North Carolina bale of cotton at the gin and sent to the United States Department of Agriculture-Agriculture Marketing Service (USDA-AMS) Cotton Classing office in Florence, South Carolina. These samples give cotton buyers information about the quality of the cotton the growers have produced. Producers should understand the classing system, as many aspects of cotton quality can be influenced by management decisions. Most of the information below is taken from the USDA publication *Cotton Classification Results*, which is available through the USDA-AMS, Cotton Division, 3275 Appling Road, Memphis, Tennessee 38133.

The high volume instrument (HVI) classification system consists of the classer's judgment on color grade, leaf grade, and extraneous matter (if any), plus instrument measurements for fiber length, micronaire, strength, color, trash, and length uniformity.

Most classification data are provided to the industry by telecommunications, computer tapes, diskettes, and computer punchcards. In order to provide classification data for individual bales, the incoming bale identification tag must meet certain requirements, which are discussed below. For ease of explanation, the Universal Classification Data Format is used as an example for explaining the various quality measurements.

USDA-AMS Cotton Division
Universal Classification Data Format

On the next page is a list of the quality parameters measured at the classing office and the corresponding column where you will find each quality parameter listed. This applies to all methods of data dissemination offered by the Cotton Division. Columns 36, 46, 55, 58, and 62 are left blank intentionally.

Gin Code Number (Columns 1-5)

The gin code number is composed of five digits. The first two digits denote the classing office, and the last three digits identify the gin. The local classing office assigns this code number and can provide codes for any gin.

Table 17-1. USDA-AMS Cotton Division	
Universal Classification Data Format	
FIELD NAME	***COLUMN***
Gin Code Number	1-5
Gin Bale Number	6-12
Date Classed	13-18
Module, Trailer, or Single Bale	19
Module/Trailer Number	20-24
Bales in Module/Trailer	25-26
Producer Account	27-29
Color Grade	30-31
Fiber Length (32nd)	32-33
Mike (Micronaire)	34-35
Strength	37-40
Leaf Grade	41
Extraneous Matter	42-43
Remarks	44-45
HVI Color Code	47-48
Color Quadrant	49
HVI Rd	50-51
HVI + b	52-54
HVI Trash Percent Surface	56-57
Fiber Length (100th)	59-61
Length Uniformity Percent	63-64
Upland or Pima	65
Record Type	66
CCC Loan Premiums and Discounts	67-71

Gin Bale Number (Columns 6-12)

The seven-digit bale numbers are assigned by the gin. A bar-coded bale identification tag, preprinted with the gin code number and gin bale number, is placed between the two halves of the sample for identification purposes. The classing office scans the bar codes to enter the bale identification into its computer before classing the sample.

Date Classed (Columns 13-18)

This is the date the bale was classed in the classing office.

Module, Trailer, or Single Bale (Column 19)

This one-digit code indicates whether the sample was outturned as a single bale or came from a bale that was module/trailer averaged.

Single bale = 0, Module = 1, Trailer = 2

Module/Trailer Number (Columns 20-24)

A five-digit number identifies the module/trailer number assigned at the gin.

Bales in Module/Trailer (Columns 25-26)

A two-digit number identifies the number of bales in the module/trailer that were averaged to determine the value of all the bales in the module/trailer.

Producer Account (Columns 27-29)

The producer account number space is reserved for USDA use.

Color Grade (Columns 30-31)

The color grade that appears on the classification record is determined by the classer, based on the official color grade standards. Color refers to the gradations of whiteness and yellowness in the cotton. Codes that identify extraneous matter and special condition cotton are shown in the "Extraneous Matter" and "Remarks" sections. Producers can influence color by having good defoliation and by getting the crop harvested before wet weather damages fiber color. The codes that identify American Upland color grades are as follows:

Special Condition Codes for Upland Cotton

96 - Mixture of Upland and Pima
97 - Fire Damaged
98 - Water Damaged

Table 17-2. Color Grades of Upland Cotton

	White	Light Spotted	Spotted	Tinged	Yellow Stained
Good Middling	11*	12	13	—	—
Strict Middling	21*	22	23*	24	25
Middling	31*	32	33*	34*	35
Strict Low Middling	41*	42	43*	44*	—
Low Middling	51*	52	53*	54*	—
Strict Good Ordinary	61*	62	63*	—	—
Good Ordinary	71*	—	—	—	—
Below Ordinary	81	82	83	84	85

** Physical standards. All others are descriptive.*

Fiber Length - 32nds (Columns 32-33); **l00ths** (Columns 59-61)
The HVI system measures length in hundredths of an inch. Length (staple) is reported on the classification record in both 32nds and 100ths of an inch. Low staple length has become more of a problem in the Southeast. Growers should avoid varieties with low staple length. Cotton with low staple length and high micronaire is very hard to sell. Growers should totally avoid varieties with both low staple length and high micronaire.

Micronaire (Columns 34-35)
An airflow instrument is used in the HVI system to measure fiber fineness. The measurements, commonly referred to as micronaire or "mike" readings, are the same as those that have been provided for many years in cotton classification. Micronaire and maturity are highly correlated within a variety. High mike is often a problem in North Carolina in drought-stressed years, especially where defoliation is delayed past optimum timing. Growers should try to avoid planting high micronaire varieties in fields that often have significant drought stress.

Strength (Columns 37-40, Decimal in Column 39)
Fiber strength is influenced most by variety selection. In general, full-season varieties have higher strength than short-season varieties. The fiber strength measurement is made by clamping and breaking a bundle of fibers, with a 1/8-inch spacing between the clamp jaws. Results are reported in terms of "grams per tex" to the nearest 10th. A tex unit is equal to the weight in grams of 1,000 meters of fiber. Therefore, the strength reported is the force in grams required to break a bundle of fibers one tex unit in size. The following table shows some general descriptions of HVI 1/8-inch gauge-strength measurements in grams per tex.

Table 17-3. Fiber Strength Table	
Descriptive Designation	**HVI 1/8" Gauge Strength (grams per tex)**
Weak	23 and below
Intermediate	24–25
Average	26–28
Strong	29–30
Very Strong	31 and above

HVI Rd (Columns 50-51)

HVI +b (Columns 52-54)

The HVI color measurements cover grayness and yellowness. *Grayness* (HVI Color Rd) indicates how light or dark the sample is, and *Yellowness* (HVI Color +b) indicates how much yellow color is in the sample. The Nickerson-Hunter cotton colorimeter color diagram on page 11 of *Cotton Classification Results* is based on current official standards for American Upland cotton and shows how these measurements are coded and how they relate to the color of the grade standards. Each color grade is subdivided into quadrants to denote color differences within a color grade for more precise measurements. This information is reported as a two-digit Color Grade Code and a single digit grade quadrant. The resulting three-digit number is derived by locating the intersection of the Rd and +b readings on the diagram.

The Nickerson-Hunter cotton colorimeter color diagram on page 12 of *Cotton Classification Results* is based on the official standards for American Pima cotton. Color grades shown in the chart are the one-digit color grades of American Pima. Two digits are shown on the classification record, the first digit being zero (0). Grade quadrants are not used for American Pima.

HVI Trash Percent Surface (Columns 56-57)

The two-digit trash code reported on the classification record is the percentage of the sample surface covered by trash particles as determined by a video scanner. For example, a reading of 04 indicates that trash particles cover 0.4 percent of the sample surface. Trash particles include extraneous matter such as grass, bark, etc. However, the classer will continue to identify samples containing extraneous matter. Table 17-4 illustrates the relationship of leaf grade to the percentage of the surface area measured by the HVI trashmeter for the 1993 crop.

Length Uniformity Percent (Columns 63-64)

Length uniformity is a two-digit number that is a measure of the degree of uniformity of fibers in a sample. The descriptive terms in Table 17-5 may be helpful in understanding the measurement results.

Table 17-5. Length Uniformity Percent	
Descriptive Designation	**HVI Length Uniformity**
Very Low	Below 77
Low	77–79
Average	80
High	83–85
Very High	Above 85

Upland or Pima (Column 65)

The one-digit code indicates whether the sample is Upland or American Pima.

1 = Upland
2 = Pima

Record Type (Column 66)

The one-digit code gives the type of record, according to the following:
0 = Original, 1 = Review, 2 = Rework, 3 = Duplicate, 4 = Correction

CCC Loan Premiums and Discounts (Columns 67-71)

The five-digit code gives the CCC loan premium and discount points for Upland cotton.

Upland—Column 67 (+) if Premium, (-) if Discount
Columns 67-71 will be left blank if the quality is not eligible for loan.

18. COTTON TERMINOLOGY

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adulticide—A chemical, usually an insecticide, that is targeted toward the adult stage.

aphicide—An insecticide that is active against aphids.

beat cloth—A square (typically 3 feet by 3 feet, or 2.5 x 2.5 feet) or rectangular piece of usually light-colored cloth or synthetic sheeting (i.e., Tyvek material) with dowels at opposite ends; used to assess insect populations by catching them when plants are beaten or shaken over the device, which is normally unrolled and placed on the ground between rows. More recently, drop cloths made of black material are being sold due to the dark background offering more contrast in recognizing immature plant bugs (nymphs). Also called a shake cloth or ground cloth.

beet armyworm—(*Spodoptera exigua*) An armyworm species whose damage to cotton is characterized by leaf skeletonizing by early instars feeding in groups, often associated with webbing and frass. Later instar larvae may feed on squares and bolls and are difficult to control with insecticides; eggs are deposited in masses; adults are migratory and do not overwinter in the Carolinas.

beneficial arthropods—A general group of insects and their cousins (predatory mites and spiders) that either consume (predator) or live within (parasite) the host insect.

bloom tag—The dried brown cotton bloom that sticks to the tip (or, at times, off to one side) of the young boll; more frequent in dry weather; sometimes provides a refuge under which young bollworms or tobacco budworms develop protected from beneficial insects and insecticides. Inexperienced scouts sometimes tend to oversample young bolls having a bloom tag. The sampling of bloom-tagged bolls should be carried out in proportion to their percentage of the total boll population.

blooming out the top—A cotton growth state characterized by the presence of first-position blooms almost entirely in the upper canopy of the cotton plant. This occurrence may indicate premature cutout of the crop. Often called bumblebee cotton when this condition occurs abnormally early on short, stressed cotton.

blooms—Large, showy, off-white flowers that arise from buds (squares) and typically last only one day, becoming pinkish on the second and brown on subsequent days; they usually fall from the new, developing boll on days three to five. Cotton blooms are at times attractive sites for bollworm egg deposition, western flower and other thrips, and fall armyworms. Blooms in the tops of cotton plants (blooming out the top or bumblebee cotton) often indicate very dry weather or that the crop is cutting out.

boll weevil—(*Anthonomous grandis*) A small brownish to grayish weevil that survives the winter as an adult and invades cotton in the spring to infest one-third grown or larger cotton squares, causing fruit abortion via feeding punctures or egg punctures; completes life cycle within fallen squares in 2 ½ to 3 weeks. A major pest of cotton in North Carolina before the beginning of the Boll Weevil Eradication Program in 1978, which has successfully eliminated this pest. May undergo three to four generations per year in the Carolinas.

Bollgard II cotton—A cotton variety that has two "stacked" (or "pyramided") genes that each encode for the expression of separate endotoxins (Bacillus thuringiensis; Cry1Ac and Cry2Ab proteins) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms, compared to Bollgard.

bollworm—(*Helicoverpa zea*) The larval or caterpillar stage of the corn earworm moth. Typically North Carolina's most significant cotton pest, primarily infesting fruit (squares, blooms, and bolls). Undergoes three to four generations annually in the Carolinas, with the first two generations developing primarily in field corn (initial generation primarily on whorl stage corn and the second generation primarily on early ear stage corn) and the third on cotton, soybeans, peanuts, and other crops. Also called soybean podworm and tomato fruitworm, depending upon host.

bract—The three modified leaves at the base of the cotton fruit. Bracts typically surround developing squares, affording some protection to bollworms and other pests from beneficial insects and insecticides; must be opened to reveal developing square when monitoring fruit for damage.

brown stink bug— (*Euschistus servus*) A brownish, medium-sized member of the stink bug family (Pentatomidae) that usually undergoes a generation on hosts, such as wheat, corn and other grass species, before moving into cotton, often during boll formation. Feeding by adults and large nymphs with needle-like stylets,on bolls of all sizes, causes small, rounded, dark spots on the exterior carpel wall; feeding can transmit hardlock organism, resulting in unharvestable bolls and low-quality lint. Brown stink bugs are more difficult to control with pyrethroids than green stink bugs. This species' life cycle (egg to adult) typically takes 40 days.

calyx—Outer protective covering of the flower bud (square); the leaf-like green segment also called sepals.

canopy—The foliage of a cotton crop; said to be closed when plant growth of adjacent rows closes over and shades row middles; direct sunlight penetration between rows constitutes an opened canopy.

carbamates—A class of chemicals, usually insecticides, that inhibits cholinesterase, resulting in unregulated nerve-ending activation and paralysis in insects (e.g., Temik, Sevin, Larvin).

carpal wall—The thick outer walls of the boll. If insects (e.g., bollworms, green stink bugs) penetrate the carpal walls, they may cause damage to locks (see definition) or may cause boll rot, translating into lost yield and/or lower lint quality.

caterpillar—The immature damaging stage of a butterfly or moth. Larva is the general term for immature stages of moths (caterpillars), flies (maggots), beetles (grubs), and others.

chloronicotinoid—A widely used class of insecticides that blocks nerve transmission in insects (i.e., imidacloprid and thiamethoxam). This chemical class is widely used to control thrips, cotton aphid, and plant bug, although a number of cases of resistance have been reported.

cotton aphid—(*Aphis gossypii*) The aphid species most commonly associated with outbreaks on cotton in the Southeast; has many generations per year and is often resistant to various classes of insecticides; typically subject to heavy mortality via predation and parasitism; also called the melon aphid.

cotyledon—In dicotyledonous plant species, the initial growth stage characterized by the presence of "seed leaves." These leaves were initially contained in the seed and provide food for seed germination.

cumulative threshold—The point at which consecutive scouting assessments of subthreshold levels of the same species justify treatment.

cutout—Final stage of cotton plant growth before boll opening; characterized by the predominance of more mature fruit, general absence of squares and blooms, and cessation of new terminal growth. According to more recent terminology, cotton is approaching cutout at five nodes above white bloom and is generally considered to be cutout at three nodes above white bloom. Cotton blooming out the top is considered cutout.

defoliant—A harvest-aid material applied to the cotton plant to accelerate leaf drop in preparation for harvest (see defoliation).

defoliation—The loss of leaves from the cotton plant; may be damaging and happen prematurely (i.e., soybean loopers consuming cotton plant leaves before cutout or leaf loss caused by a potassium deficiency) or naturally (the predictable loss of leaves of all deciduous plants).

egg—A single cell or ovum from an ovary; the first stage of an insect or mite; may be deposited singly (e.g., bollworm) or in a mass (e.g., European corn borer).

European corn borer—(*Ostrinia nubilalis*) A pest of cotton in the Southeast where corn is planted, this boring caterpillar passes its initial two generations on corn, potatoes, wheat, and various weed species in North Carolina; the third and a partial fourth generation can be damaging to cotton, primarily because the pest bores into medium to large bolls and to a lesser extent into stems; female moths deposit small, fish scale-like egg masses deep within the plant canopy and on the underside of cotton leaves. Egg masses are difficult to find. In two-gene *Bt* cotton European corn borer damage is essentially nonexistent.

fall armyworm—(*Spodoptera frugiperda*) A migratory species that does not overwinter in the Carolinas; larvae hatch from egg masses often deposited in the upper third of the cotton plant, often on the underside of leaves but also in the terminal area; small larvae typically etch the bracts of medium and large bolls before penetrating the carpel walls, often at the base of the boll. Fall armyworm larvae are also often associated with blooms. Medium to large established larvae are difficult to kill with insecticides.

foliar feeding—On cotton: (1) leaf consumption, usually by caterpillars; (2) the feeding of nutrients, such as nitrogen-containing fertilizer, to the cotton plant via a liquid applied to the foliage.

frass—A term applied to insect feces, the shape of which is sometimes used in family- or species-level identification; also called fecal pellets, droppings, or turds.

fruit—Refers to cotton squares (or flower buds), blooms, and bolls; reproductive parts of the plant. Cotton fruit is susceptible to a wide range of insect pests.

fruiting branch—Lateral branch of a cotton plant, typically arising from the fourth through eighth node and higher on the plant; has fruiting position at each node; sympodium or reproductive branch.

fruiting position—Any main stem, vegetative branch, or fruiting branch location on which fruit is either present or aborted.

fungicide—A material used to control or kill fungi.

green stink bug—(*Chinavia hilare*) A large green member of the stink bug family (Pentatomidae) that usually undergoes a generation on wild hosts, such as elderberry and wild cherry, before moving into cotton, often during boll formation. Feeding by adults and large nymphs with needle-like stylets, often on bolls of all sizes, causes small, rounded, dark spots on the exterior carpel wall; feeding can transmit hardlock organisms, resulting in unharvestable bolls and low-quality lint. This species' life cycle (egg to adult) typically takes 30 to 40 days.

herbicide—A material used to kill weeds. In cotton the material usually is characterized by (1) timing: "PPI" (prior to planting and incorporated), "pre" (prior to plant emergence from soil), and "post" (after plant emergence); or by (2) application type: "broadcast" (applied evenly over an area), "banded" (applied over a portion of the total area), or "directed" (targeted at a specific area), usually toward the base of the cotton plant.

insect growth regulator—A compound, either natural or synthetic, that influences insect growth and development (e.g., Dimilin affects boll weevil grub integument formation during shed, resulting in deformed pupae and adults or premature death). Often referred to by its acronym, IGR.

insecticide—A material that kills insects.

instar—Stage of nymph (e.g., stink bug) or larva (e.g., bollworm) between molts.

internode—The portion of the main stem between nodes; in cotton it is often used as an indicator of growth, i.e., a greater internode length indicates faster growth and the possible need of a growth regulator capable of slowing growth, such as Pix.

label—A legally binding document affixed to every pesticide container outlining the product's constituents, amount of active ingredients, primary uses, precautions, and Worker Protection Standard (WPS) information.

larva—The immature stage of an insect with four distinct metamorphic stages (e.g., cabbage looper: egg, larva [caterpillar], pupa, and adult).

larvicide—A compound that kills the larval stage of insects.

lay-by—A final, typically post-directed herbicide application designed to eliminate or suppress weeds through harvest time.

Liberty Link cotton—A cotton variety that has been genetically altered to tolerate the herbicide Ignite (glufosinate).

licensed consultant—An individual licensed by the North Carolina Department of Agriculture and Consumer Services, who is trained to interpret information and make recommendations.

light trap—A device consisting of at least an ultraviolet light (which is attractive to a number of night-flying insects) and a collection container. Used to monitor the timing and relative abundance of selected insect species (e.g., bollworm, green stink bug, and tobacco horworm moths).

lock—The major, individual, internal section of a cotton boll in which seed and lint development take place; four or sometimes five locks per boll are typical.

match-head square—Early stage of growth when the flower bud (excluding the outer bracts) reaches approximately the size of a large kitchen match head.

migratory—A term applied to an insect species that undergoes long-range movement, sometimes hundreds of miles (e.g., fall armyworms do not overwinter in the Carolinas but rely instead on annual, long-range, northward movement by consecutive generations "hopscotching" from the southern United States). It can also refer to shorter, more localized flights or transport (e.g., the migration of thrips from alternative hosts to cotton).

mites—A group of small, active, non-insect arthropods, some of which are predators of other mites and small insects (e.g., thrips); most species are plant feeding. The two-spotted spider mite (*Tetranychus urticae*) is the predominant mite on cotton in the Southeast, typically more of a problem under hot, dry conditions, and damages cotton plants by rasping mostly lower leaf cells; populations are often reduced by naturally occurring fungi, particularly under humid conditions.

miticide—A material that kills mites.

multipest threshold—The point at which the combined effects of subthreshold levels of two or more pests justify treatment.

naturalites—A class of fermentation products called spinosads derived from an ascomycetous fungus, which is active against Lepidoptera and selected members of other insect families and some mite species.

node—A point, usually along the main stem, at which lateral vegetative and fruiting branches arise.

nodes above cracked boll—Term applied to the number of mainstem nodes from the highest first position cracked boll to the plant terminal (often used as a method of assisting with measurements of cotton readiness for defoliation).

nodes above white bloom—Term applied to the number of mainstem nodes from the last developed first-position white bloom to the plant terminal; used as a measure of plant growth (e.g., to assist in growth regulator assessments or as an index of degree of "cut-out"). All plants will not have a first-position white bloom at a given time.

organophosphates—A class of organic, phosphorus-containing insecticides that inhibit cholinesterase, causing excess nerve activation, paralysis, and eventual death; some insecticides in this class with a high phosphorus content (e.g., methyl parathion) may delay cotton crop maturity if applied at an early stage; abbreviated OP.

overtop herbicide application—A herbicide application which is made over the top of the cotton canopy. These herbicides do not negatively impact, or only minimally effect, the growth of the cotton plant (e.g., glyphosate on Roundup Ready cotton, the ALS inhibitor Staple, and others).

ovicide—A material that kills the egg stage of an organism.

parasite—An organism that lives wholly off and often feeds within another organism (called a host); with most insect species, insect parasites usually kill their hosts and are referred to as parasitoids.

pheromone trap—A trap that uses either a natural or, more typically, a synthetic insect sex attractant pheromone; these traps are usually species specific.

pinhead square—In practice, this misnomer most often applies to match-head squares. Pinhead squares are just visible to the naked eye.

plant bugs—Small, active, dark brown bugs with piercing-sucking mouthparts. Their immatures are bright green. The mouthparts make tiny needle-like holes in small squares, causing darkening and abortion. At high population levels, terminal feeding may result in unusual upper growth (crazy cotton) and loss of apical dominance; late in the season, high levels of plant bugs can also damage larger squares, blooms, and small bolls. In the Southeast, the primarly pest species is the tarnished plant bug, *Lygus lineolaris*.

plant growth regulator—A substance applied to cotton plants that affects growth or aging (e.g., Pix and Prep); abbreviated PGR.

plant map—A precise, prescribed manner of recording, or mapping, cotton plant growth that shows the location and stage of fruit by its position on each node of all vegetative and fruiting branches. Plant maps are often used to determine nodes above white bloom, nodes above cracked boll, and fruit retention and to compartmentalize and compare fruit retention on selected horizontal or vertical zones of the cotton plant. Modified mapping systems are available that focus on particular vertical zones of cotton, such as first position only.

point sampling—A scouting method that relies on randomly selecting a prescribed number of sites or points within a cotton field for intensive scouting of a predetermined number of plants or feet of row (best suited to uniform fields).

postemergence-directed—Herbicide placement after seedling emergence directed to the base of cotton plants; better control if cotton has grown significantly taller than weeds (e.g., Bladex).

postemergence over the top—Herbicides applied directly over the canopy of both cotton and weeds; sometimes represents a salvage treatment following inadequate PPI or pre-

emergence weed control; some compounds may cause maturity delays and yield reductions (e.g., Cotoran).

predator—An organism that kills and consumes another (its prey); a number of small predator insects can provide significant natural control of several pests.

preemergence—A term most often referring to broadleaf herbicides applied at or after planting but before seedling emergence; "pre" herbicides (e.g., Zorial).

preplant incorporated—Refers mostly to grass and small-seeded broadleaf herbicides (but also some other weed species such as nutsedge) applied and incorporated before planting; PPI herbicides (e.g., Treflan).

pupa—The compact, often protected, resting stage of an insect preceding the adult stage (bollworms overwinter in the pupal stage under the soil surface).

pyramided genes—See stacked genes.

pyrethroids—A class of insecticides characterized by very low mammalian toxicity and high insect control at low usage rates.

random sampling—A scouting method that relies on continuous inspections throughout most of a cotton field; better suited for regions with variable soils within fields.

rank—A term signifying tall, vegetative cotton growth; often a result of late planting, excessive nitrogen fertilizer, fertile soils, or excessive moisture. Rank growth often renders cotton plants more attractive and susceptible to late-season insects, more susceptible to boll rot, and more difficult to defoliate.

refugia—In cotton insect management, an area used to maintain the production of susceptible insect populations. A refugia is a crop or host area that is left untreated with an insecticide or type of technology so that adults that are resistant to the chemical, chemical class, or technology in question will have a high probability of mating with the higher number of refugia-produced, susceptible adults, thus producing susceptible offspring. For example, to preserve the effectiveness of Bt single-gene cotton, a specified acreage of non-Bt cotton at one time had to be set aside to produce enough Bt-susceptible adult bollworms and tobacco budworms to mate with a high enough proportion of the Bt-produced resistant individuals to maintain a population of budworms and bollworms susceptible to Bt cotton.

resistance—The inherited development of insect, weed or disease biotypes that are tolerant to an insecticide, fungicide, or herbicide, respectively, which formerly provided control of the particular pest species. For example, biotypes of Palmer amaranth have developed that survive high rates of glyphosate.

restricted entry interval—The mandatory period of time a person must wait between application of a chemical and entry to the treated area.

Roundup Ready—Trademark term applied to varieties that have been genetically altered to be tolerant to the herbicide glyphosate.

sample—The portion of a population collected in a prescribed manner upon which a judgment is made about the entire population.

scout—An individual trained to collect information about cotton insect and plant populations; scouts are not responsible for interpreting data or providing recommendations.

scouting—The procedures followed by a scout.

skeletonizing—A type of insect damage characterized by insect feeding on leaf areas between veins; it can result in a lacy appearance to the leaf.

soybean looper—(*Pseudoplusia includens*) A light-green, defoliating caterpillar; migratory adults overwinter in the southern United States or Caribbean basin and typically arrive in the Carolinas in late summer or fall.

square—The flower bud of a cotton plant with a central corolla containing the pollen anthers and sepals and surrounded by three (or sometimes four) bracts; squares are often a preferred site of insect feeding, e.g., plant bugs, boll weevils, bollworms.

square retention—The proportion of squares, usually expressed as a percentage, retained by the cotton plant (often employed early in the growth of a cotton plant as an index of plant development).

stacked—Using two or more genes in a cotton variety for expression of similar characteristics (Bollgard II will use two Bt genes to express different endotoxins for caterpillar control) or dissimilar characteristics (Bollgard gene plus Roundup Ready gene for herbicide tolerance to Roundup herbicide).

stacked genes (or pyramided genes)—Two or more genes inserted into the plant's DNA that express similar (though enhanced) activity (e.g., two genes that encode for separate *Bacillus thuringiensis* endotoxin expression in the same variety (such as in Bollgard II, Widestrike, and TwinLink varieties) or two genes that express different activities in the same variety, such as caterpillar resistance plus Roundup Ready glyphosate tolerance).

starter fertilizer—Fertilizer placed close to the seed, usually at planting; also called "pop-up" fertilizer.

sweep net—A sturdy net composed of a 15-inch (standard size) rigid wire support and a heavy-duty cloth bag used to "sweep" across the upper canopy of cotton plants to assess insect populations.

systemic—A pesticide that is taken up through the roots or leaf tissues into the cells of the cotton plant (as opposed to remaining on the surface), often in concentrations high enough to cause a biological change (e.g., a systemic might be an at-planting soil insecticide taken up by cotton seedling roots and transported through the plant's vascular system to suppress or kill leaf-feeding thrips, or it might be Roundup herbicide absorbed into the vascular system of weeds and translocated to the root zone in high enough concentrations to kill the weed).

terminal—The dominant, upper mainstem part of a cotton plant containing three to four expanding leaves and developing squares; if they are all retained, the number of squares typically is identical to the number of leaves; also called "apex."

threshold—The point at which an action is taken; often applied to insects. (Most thresholds are action thresholds; an action is taken when a level or number of eggs or caterpillars is reached. It can also be an economic threshold, which takes the commodity value and treatment cost into consideration.)

thrips—Tiny, active insects of the order Thysanoptera, which move in high numbers primarily into seedling cotton, often because their alternative hosts are drying up.

TwinLink—A cotton variety that has two "stacked" (or "pyramided") genes that each encode for the expression of separate endotoxins (*Bacillus thuringiensis*; Cry1Ab and Cry2Ae proteins) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms, compared to the former Bollgard varieties.

tobacco budworm—(*Heliothis virescens*) A caterpillar pest of primarily squares and bolls; a close relative of the corn earworm. It undergoes three to four generations annually and often is the predominant species of the bollworm/budworm complex in June in the Carolinas. Mid South populations of tobacco budworms have developed resistance to all major classes of insecticides.

transgenic cotton—Cotton that has been genetically altered by recombinant DNA techniques to express tolerance to either herbicides (e.g., Roundup Ready and LibertyLink) or insect pests (e.g., Bollgard II against tobacco budworms).

vegetative branch—Lateral branch on a cotton plant that does not have a fruit at each node; fruiting branches, however, can develop from vegetative branches. Vegetative branches have a terminal and often develop fruiting branches, especially under low plant populations.

vegetative growth—General term for undesirable cotton plant growth, typified by lack of fruit; often tall and rank.

wart— A small, typically round, area of callous growth on the inside of the boll wall associated with stink bug or plant bug feeding. Warts are usually counted as damage in scouting assessments.

weed map—A simple diagram, typically developed in the fall, of a field or field portion showing the location of predominant, economically important weeds; used in planning weed management programs.

whitefly—A small, white-winged insect with piercing-sucking mouthparts; damages cotton both directly via its sap-feeding and indirectly via voiding honeydew, resulting in "sticky cotton," a ginning and milling problem.

WideStrike cotton—A cotton variety that has two "stacked" (or "pyramided") genes that each encode for the expression of separate endotoxins (Bacillus thuringiensis; Cry1Ac and Cry2Ab) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms when compared to Bollgard.

WideStrike 3 cotton—A cotton variety that has three "stacked" (or "pyramided") genes that each encode for the expression of two endotoxins and a single exotoxin (*Bacillus thuringiensis*; Cry1Ac and Cry2Ab and Vip3A) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms when compared to Bollgard.

windowpaning—See skeletonizing.