First Open Boll to Harvest

This period reflects the results of weather conditions and management steps taken throughout the season. During this stage, growers should focus primarily on water and insect management. You will also need to manage disease and make decisions about harvest aids.

Water use

At peak bloom, cotton requires about 0.3 inch of water per day. By harvest, the rate will drop considerably, to less than 0.1 inch per day (Figure 7.1).

In a "perfect environment," dryland producers would have a full profile of moisture at the third week of bloom, followed by a couple of timely rain showers. Producers with furrow irrigation have more control than dryland producers but still must make the last irrigation before bolls open.

Late applications of excessive water can lead to many problems, including boll rot, late season regrowth, an increase in late-season insect pests, added harvest aid inputs and possible grade reductions from late-season regrowth.

In West Texas, furrow irrigation should be terminated before September 1. Sprinkler or drip irrigation should be continued for 1 to 2 weeks after open boll or until 20 percent of the bolls are open. The goal is to provide adequate moisture for the last harvestable bolls to mature.

Nitrogen use

After boll opening, nitrogen uptake plummets (Figure 7.2). Although nutrient deficiencies are common during this period, it is too late to take corrective action. When boll growth peaks, so does demand for several nutrients, especially potassium.

The root system is no longer functioning at full capacity because of demands from developing bolls. Soil nitrogen needs to be in short supply by harvest. If there is too much nitrogen, regrowth problems will increase, as will harvest aid costs and potential late-season insect problems. Excessive nitrogen can also reduce lint quality.

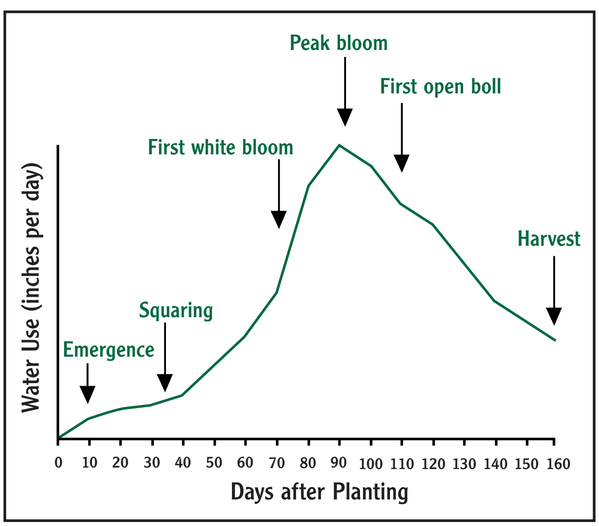

Figure 7.1. Water use for cotton up to harvest.

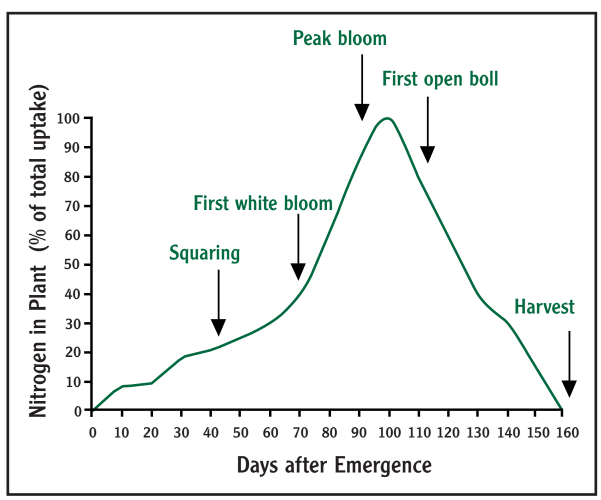

Figure 7.2. Percentage of nitrogen in the plant up to harvest.

Plant development

During this period, it is still wise to monitor nodes above white flower (NAWF) by counting the nodes above the uppermost first position white flower (Figure 7.3). The terminal node is the one with an unfurled main stem leaf larger than a quarter (more than 1 inch in diameter).

NAWF measures the potential boll loading sites remaining. At this point in the season, all carbohydrates produced by the plant are committed to boll development. Monitoring NAWF is critical at this time because pest managers need to know when the last harvestable boll has been set.

Research indicates that the last effective flowers that need to be protected appear when NAWF is equal to five. This changes somewhat in the western part of the state, where NAWF equal to four is a more reliable estimate.

Cotton physiologists define cutout to be when NAWF is equal to four or five. Before then, approximately 100 flowers will produce 1 pound of seed cotton. After cotton reaches cutout, the number of flowers needed to produce 1 pound of seed cotton increases dramatically.

In estimating when the plant has reached cutout, NAWF is a more reliable indicator than are calendar dates. Table 7.1 provides calendar dates for the last effective bloom period for some of the production regions in Texas.

The dates vary widely because of weather and location. Dates for the South, Central and Lower Rio Grande Valley are due to the effect of weather on harvest. The dates for the Rolling Plains

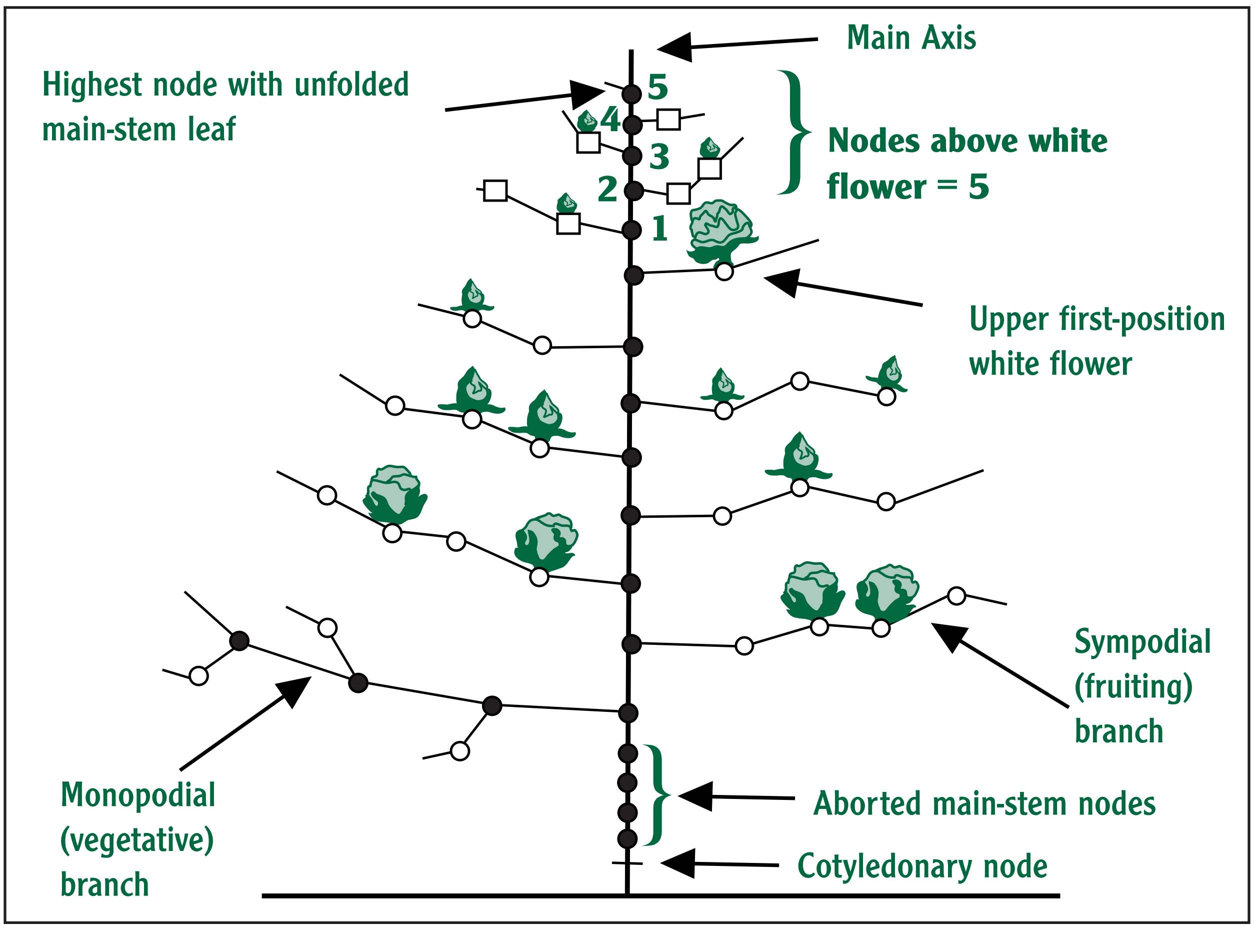

Figure 7.3. Nodes above white flower (NAWF) equal to five.

Table 7.1. Estimate of effective bloom period for some growing regions of Texas.

Lower Rio Grande Valley	June 1 to June 20
Coastal Bend	June 10 to July 5
Blacklands, Winter Garden	July 5 to July 15
Rolling Plains	August 20 to September 5
High Plains	August 15 to September 1

and High Plains are due to limited heat units. Although boll set can occur after these dates, bolls that set later generally have lower fiber quality.

Insect control

Monitoring NAWF is also a key to making late-season insect decisions. The same fruit-feeding complex that causes problems during peak bloom will also lower yields later in the season. Although thresholds change little from peak bloom, the emphasis shifts from protecting squares and bolls to protecting developing bolls.

Recent studies using the computer model COTMAN have verified treatment termination rules for fruit-feeding insects. Once bolls accumulate 350 to 450 heat units, they suffer less damage from bollworms and boll weevils (Figure 7.4).

NAWF, heat units and historical weather data can be used for more than predicting cutout. Table 7.2 is an example of using NAWF and historical weather to predict the dates when bolls are safe from insect damage in the High Plains.

In the above example, a bloom on August 1 would be safe from boll weevils on August 18 and would be a mature boll on September 19. A bloom on August 5 would mature 10 days later than a bloom on August 1.

The extra time is needed because fewer heat units accumulate later in the season. The reduced heat unit accumulation is also the reason that blooms on August 20 have a negligible impact on yield, because the chances of the bolls reaching maturity (750 DD60) are reduced in West Texas.

Blooms that accumulate 350 DD60 are safe from *Lygus* spp. feeding. Those that accumulate 450 DD60 are safe from newly hatched larvae, but larger larvae could penetrate bolls (Figure 7.4).

Insects with stronger mouthparts, such as stink bugs, can penetrate older bolls, so heat unit accumulations should reach 600 DD60 after cutout (NAWF = 5).

Table 7.2. Heat unit (HU) events based on date of cutout (NAWF=4) and actual Lubbock, TX temperatures (August 1-29). Focus on Entomology, 2001.

Heat Unit	Date When Crop Achieved Cutout (NAWF=4)					
Accumulation	August 1	August 5	August 10	August 15	August 20	August 25
+350 HU (safe from weevels)	Aug. 18	Aug. 22	Aug. 27	Sept. 2	Sept. 11	Sept. 19
+450 HU (safe from worm egg lay)	Aug. 22	Aug. 26	Sept. 3	Sept. 10	Sept. 20	Oct. 1
+750 HU (near mature boll)	Sept. 10	Sept. 18	Sept. 30	Oct. 16	N/A	N/A
+850 HU (fully mature boll)	Sept. 19	Sept. 29	Oct. 18	N/A	N/A	N/A

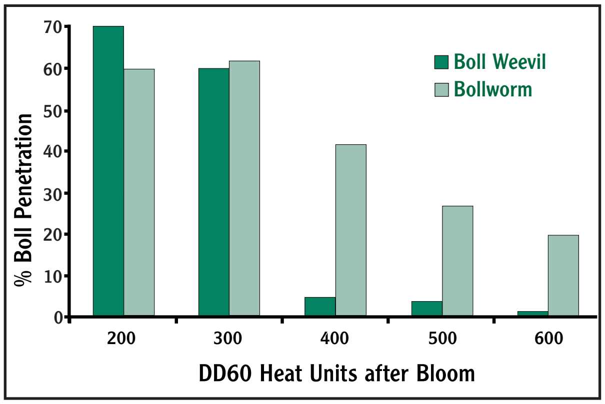

Figure 7.4. Percent penetration of bolls based on heat units after bloom. Corpus Christi, TX.

Table 7.3 depicts another example of bolls set in the top of the plant having relative lower values. Values of lint were calculated from each fruiting branch from a field averaging 893 pounds of lint per acre.

The last four fruiting branches accounted for only 6.8 percent of the final yield. Protecting this final component may not make economic sense if yields are not high (more than 700 pounds of lint per acre) or if the value of the crop is low.

In general, the majority of a cotton crop (85 to 90 percent) will come from the first 10 fruiting branches.

Problems from leaf-feeding insects can occur late in the season. Cotton can tolerate 25 to 50 percent defoliation with little loss of yield. Because the leaves are important to boll maturation, growers should extend treatment decisions for leaf feeders to 750 DD60 after cutout. However, delay treatment as long as possible before treating to allow natural enemies to reduce pest populations.

Also at this time, aphids and whiteflies can deposit honeydew. When there are open bolls, treatment thresholds for aphids drop from 50 aphids per leaf to 10 to 15 aphids per leaf. Honeydew deposits can be washed from fiber with as little as 0.25 inch of rain or sprinkler irrigation. In field trials, three applications of 0.25 inch of sprinkler irrigation resulted in the greatest reduction of honeydew deposits.

Table 7.3. Distribution of lint yield and value for cotton averaging 893 pounds of lint per acre. Weslaco, TX. 2001.

Fruiting Branch	Yield Distribution	Percent Yield Contribution	Lint Value with Price of $0.45	$0.50	$0.55
13	1.0%	Upper Third 6.80%	$3.87	$4.30	$4.73
12	1.1%		$4.2	$4.7	$5.20
11	2.0%		$7.7	$8.60	$9.46
10	2.7%		$10.45	$11.61	$12.77
9	3.7%		$14.32	$15.91	$17.50
8	7.2%	Middle Third 43.80%	$27.86	$30.96	$34.06
7	8.8%		$34.06	$37.84	$41.62
6	11.4%		$44.12	$49.02	$53.92
5	12.7%		$49.15	$54.61	$60.07
4	12.7%	Lower Third 49.40%	$49.15	$54.61	$60.07
3	13.8%		$53.41	$59.34	$65.27
2	11.1%		$42.96	$47.73	$52.50
1	11.8%		$45.67	$50.74	$55.81

Disease management

The cotton diseases described in Chapter 6 become more apparent at this stage of the season, particularly those that cause wilting problems. Among the problems that affect cotton at first boll to harvest are cotton root rot, boll rot, aflatoxin and seed rot.

As shown in Table 7.4, the timing of cotton root rot infection can affect lint quality. The earlier plants are killed, the lower the micronaire and strength.

Boll rot

Later in the season, boll rot is more of a concern, particularly in the eastern part of the state. There, late-season rains and taller cotton lead to wet and humid conditions that favor the development of boll rot pathogens.

Many species of microorganisms, primarily fungi, can cause boll rots. These microorganisms occur naturally in the soil or on plants.

Some fungi can directly penetrate the boll cuticle and enter the stomata (openings on the boll that allow the exchange of oxygen and carbon dioxide). Others can enter only if the boll is damaged, typically after feeding by insects.

To minimize boll rot problems, begin management practices that increase light penetration and increase air movement in the lower part of the canopy. Other tactics include using high-quality, disease-free seed, avoiding excess nitrogen, using plant growth regulators and controlling insects. Planting okra leaf cotton varieties also allows more sunlight into the canopy and better air circulation.

Aflatoxin

One species of fungus that causes boll rot, *Aspergillus flavus*, can cause aflatoxin contamination in cottonseed. This contamination can occur in the field before harvest.

Aflatoxin is a chronic problem in the Lower Rio Grande Valley and the Coastal Bend growing areas. It can also be a problem on the Upper Coast in years with rainy harvest seasons. Insects that damage immature bolls can allow the fungus to enter.

The lint of seed from insect-damage bolls often exhibits bright green yellow fluorescence (this lint glows green under ultraviolet light), and seeds associated with this lint have very high levels of aflatoxin.

Contamination can be even higher if mature cotton awaiting harvest is exposed to prolonged periods of rain or high humidity. In this case, there is no visible indication of contamination.

Although cottonseed commands a premium price as a dairy feed, aflatoxin levels above 20 parts per billion (ppb) cannot be used by the dairy industry. In some years, most of the cottonseed from south Texas harvested late in the season exceeds this; some seed lots will test several hundred ppb. Cottonseed sold to dairies should be tested for aflatoxin. Test gin trash also, because insect-damaged, contaminated seeds tend to concentrate there.

The only viable control option is to harvest early to avoid the rains that occur in late August and September. Insect control to minimize contamination by this fungus is not economical.

Table 7.4. Fiber qualities of lint based on time of infestation of cotton root rot. Caldwell Co., TX. 1985.

Time of Infestation	Micronaire	Length (inches)	Strength (mg/tex)	Grade
Uninfested	4.7	1.12	33	41
Late	3.2	1.08	31	41
Early	2.3	1.10	25	41

Seed rot

Seed rot is also seen late in the season. This newly recognized disorder has appeared in the Coastal Bend area of Texas as well other cotton production areas in the southeastern United States.

Seed rot is the failure of fertilized seeds in bolls to mature. Although the affected bolls look normal, the seed is poorly developed. There may or may not be rot. The locules are compact and the lint does not fluff.

To date, there is no evidence that this is an infectious disease. It apparently is not associated with particular varieties. If evidence in the future suggests that environmental stresses interfere with normal plant development, leading to this disorder, then one of the control measures is likely to be the selection of varieties that perform well under such stressful conditions.

Weather

The impact of weather on fiber qualities was discussed in Chapter 6. Remember that micronaire and strength are determined in the later stages of boll development (20 days after bloom). In the eastern part of Texas, dry conditions have the greatest effect on fiber development of later set bolls. In the western part of the state, cooler conditions have the greatest effect.

Boll opening

The boll opening process is controlled by plant hormones. The hormone primarily responsible for triggering the process of boll opening is ethylene. In a specialized layer in each suture of a boll, cells enlarge and produce enzymes that dissolve the cell walls.

Upon drying, the outer part of the boll wall shrinks more than the inner part, bending the wall outward to give the characteristic bur of the open boll.

Poor boll opening is caused by any factor that affects maturation of the boll wall, including boll age, carbohydrate stress or disease.

Yield potential is a good indicator of what kind of harvest aid program to pursue. When estimating before boll opening, include large bolls only (1 inch or more in diameter). Boll counts provide only a crude estimate of yield potential. Table 7.5 shows cotton yield estimates based on row spacing and boll numbers per linear row foot.

For example, a field that is planted on 30-inch row spacing and averaging 8.7 bolls per linear foot would have a yield estimate of one bale (500 pounds of lint) per acre.

Table 7.5. Estimating yields based on row spacing and bolls per linear foot.

Row Spacing (inches)	Bales 0.5	1.0	1.5	2.0	2.5	3.0
	Average Number of Bolls per Linear Foot of Row					
40	5.8	11.6	17.4	23.2	29.0	34.8
38	5.5	11.0	16.5	22.0	27.5	33.0
36	5.2	10.4	15.6	20.8	26.0	31.2
32	4.7	9.3	14.0	18.6	23.3	27.9
30	4.4	8.7	13.1	17.4	21.8	26.1

Timing of harvest

Timeliness of harvest is critical in cotton production. If producers initiate harvest too soon, they may sacrifice yield and micronaire. If harvest is delayed too long, producers expose the crop to excessive risk from weather conditions.

When bolls first open, the lint is white and clean because of the highly reflective nature of cellulose and the lack of any microbial degradation. Plant sugars on the fiber provide a food source for microbial degradation. The dark color of the microscopic spores gives the lint a dull or gray color.

Studies show that delaying harvest for 4 to 6 weeks does not reduce yield or quality significantly in years when there is less than 1 inch of rain after bolls open. These conditions often exist in the western part of the state. However, when rainfall exceeded 2 inches, yield and quality dropped significantly (Figure 7.5.) Studies conducted in the High Plains showed a 0.19 percent per day open boll weight loss over an 8-week period.

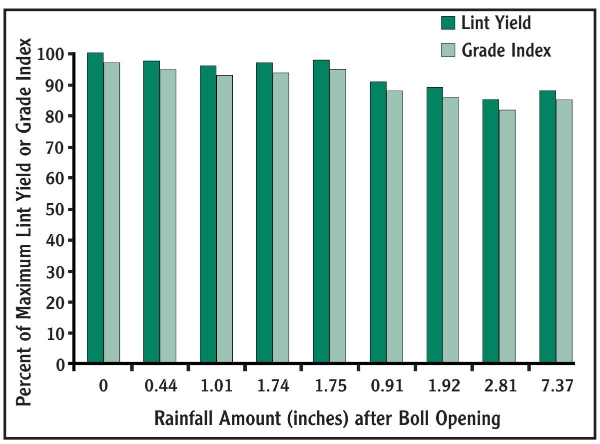

Figure 7.5. Effect of rainfall on yield and grade index. Stoneville, MS. 1983-87.

Cotton production strategies across the state have been developed to coincide with peak rainfall (Table 7.6). Weathering can be minimized by achieving early fruit retention, avoiding stress that delays crop maturity (whether it is related to insects, herbicides and/or excess nitrogen). However, timely harvest is the best way to avoid excessive lint weathering.

Harvest aids

Harvest aids are chemicals that are useful in cotton harvest. They include boll openers, defoliants and desiccants.

The use of harvest aids varies across growing regions and within regions of Texas, depending upon many crop and weather factors. Each region has its own challenges, and many people recognize that the successful use of harvest aids is as much an art as a science.

Defoliation

Defoliation (leaf abscission) is a normal process in the life of the leaf. Plants synthesize a hormone called indoleacetic acid (IAA) that maintains healthy, productive leaves. They also produce the hormone ethylene, which helps remove injured, shaded or old leaves.

Productive leaves produce enough IAA to prevent the abscission process from occurring. Abscissic acid and ethylene work in opposition of IAA to loosen and dissolve the cells on the leaf petiole where it attaches to the stem (abscission zone).

Table 7.6. Monthly rainfall for three production regions in Texas.

Region	June	July	August	September	October	November	December
Lower Rio Grande Valley	2.7	1.5	2.8	5.2	3.5	1.4	1.2
Blacklands	2.6	1.8	2.0	3.2	3.1	2.2	1.9
High Plains	2.8	2.3	2.2	2.1	1.8	0.6	0.5

Sometimes the process is interrupted, and the leaves do not drop off. Some harvest aids, if used at high rates, may kill the stem and cells in the abscission zone so that the leaf cannot fall off. A hard freeze or a disease such as cotton root rot can kill the plant quickly, before the abscission zone can form and the leaves will be "stuck."

The plant must be alive for defoliation to occur. Factors that enhance defoliation include low nitrogen levels in the plants, low moisture in the soil, plant maturity and the application of harvest aids at 60 to 70 percent open bolls.

Timing

Deciding when to apply harvest aids is a compromise between slowing or halting further development of green bolls and minimizing the weathering of open bolls. If the aids are applied too early, the plant may not defoliate properly; if applied too late, yield and lint quality may be compromised.

Most harvest aid labels suggest that the products be applied between 50 and 70 percent open bolls. Seed development also is a good indicator of boll maturity. Mature seeds have tan to brown seed coats. When the seeds are sliced open, the seed contents are firm, and the seed leaves are fully formed.

Another way to evaluate crop maturity is to check the nodes above cracked boll (NACB). Producers should search plants for the uppermost cracked boll on the first fruiting position. A cracked boll is defined as one where white lint is visible but is not sufficiently fluffed to be harvested efficiently with a spindle picker. It is more than a boll with a slight crack, where lint can be seen, and less than an open boll.

Bolls located four to five nodes above this point are generally considered mature. Defoliation at that time should not decrease yield or lint quality. Table 7.7 shows the results of a 3-year study on the effect on yield of using the NACB technique.

Table 7.7. Effect on yield by different timings of harvest aid based on nodes above cracked boll (NACB).

Percent Reduction in Yield From Defoliation	
Nodes Above Cracked Boll	Percent Weight Loss
3	1.3
4	7.9
5	14.6
6	21.3
7	28.0
8	34.7

Defoliants

Defoliants can be categorized by their mode of action. Some products have herbicidal properties and injure the leaf, causing abscission to occur: tribufos (Def®, Folex®), paraquat (Cyclone® Max), sodium chlorate and cacodylic acid (Quick Pick®).

Other products are hormonal in activity: thidiazuron (Dropp®, Ginstar®), ethephon (Prep®, Finish®, CottonQuik®) and dimethipin (Harvade®).

In most cases, preparing cotton for spindle picking requires a single application of a defoliant, a combination of defoliants or an ethephon/defoliant combination. In irrigated river bottoms, two harvest aid applications may be needed. The first application conditions the crop and the second completes defoliation.

In the southern, central and north central regions, growers typically prepare cotton for stripper harvest by applying a defoliant followed by a desiccant to dry the remaining leaves and some stem material. However, many producers have recently been harvesting without desiccants, with acceptable results.

In the Rolling Plains and High Plains, harvest aids are customized for yield, plant condition and weather. For low yields, many producers wait for a killing freeze. Some producers apply a harvest aid before then in hopes of initiating leaf drop or boll opening before the freeze sticks the leaves and prevents boll opening.

For moderate to high yields (more than 300 pounds of lint per acre), low-cost harvest aid strategies are employed. Research in the High Plains has shown no grade reductions with poor defoliation in compact, high-yielding fields. Producers can use low-cost desiccants to defoliate and desiccate plants for stripping.

Many factors are involved in obtaining acceptable results from harvest aids – warm, calm, sunny weather; low soil moisture that is sufficient to maintain plant activity without drought stress; low soil and plant nitrogen levels; few young leaves; and mature cutout plants that have at least 60 percent open bolls.

Poor results can be attributed to cool (below 60 degrees) and cloudy weather, prolonged wet periods after treatments, poor fruit set, severely drought-stressed plants and high levels of soil and plant nitrogen.