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Oklahoma Cotton Harvest Aid Guide, 2020

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Harvest aids in cotton are utilized to remove foliage, inhibit regrowth and open bolls to allow for timely harvest operations so yield and quality losses due to weathering can be minimized. Defoliation and boll opening are natural processes governed by plant hormones and harvest aids are used to speed up these naturally occurring processes. The timing of harvest aid applications is primarily governed by crop maturity, but environmental conditions, the products used and rates applied also play a role. This report will cover methods for scheduling harvest aid applications, types of cotton harvest aid products available, considerations for products that can be utilized, results of previous harvest aid product evaluations and current research and finally, tables on specific products, considerations and examples of tank mix options for various crop conditions.

The timing of harvest-aid applications should be made on a field-by-field basis, as no two fields experience identical growing conditions season long. Harvest aids can hasten the natural process of defoliation and boll opening, but they do not influence boll (or fiber) maturity. Boll maturity can be determined by slicing the boll horizontally (not tip to base) to expose the developing lint and seeds. A mature boll should be firm and difficult to slice, have mature seeds (fully developed cotyledons with little liquid or "jelly" in the seeds) with a dark seed coat and the lint should string out when the two halves are separated. Occasionally, there can be a "fruiting gap" due to environmental or insect stress that results in several consecutive nodes of aborted bolls. This can occur on bottom, middle or upper nodes of the plant depending on the timing of the stress. When this occurs, it can give a skewed representation of the maturity of the field.

Recommendations regarding the timing of applications are based on crop maturity status and there are various methods used to determine this status. The most common recommendations are to time applications when:

1. The uppermost first position harvestable boll is four main-stem nodes above the uppermost first position cracked boll (four NACB; Fig. 1) or
2. 60% to 70% of the harvestable bolls on the plant are open (60% to 70% open bolls).

However, because 4 NACB doesn't necessarily equate to 60% to 70% open bolls, a combination of the two methods may be used. Boll distribution, environmental conditions, variety maturity class and management practices can impact both of these measurements and in-field variability between NACB and percent open bolls can be high, so taking into account the status of the majority of the plants in the field is recommended. Both of these measurements should be based only on the harvestable bolls on the plants, so only mature bolls should be taken into account. Harvestable bolls consist of bolls that are currently open, mature but not yet open or far enough along in the maturating process, opening by harvest is expected, assuming favorable conditions and timely application of harvest aids.

A wide array of harvest aid products are available for use in cotton. These products typically fall into one of four general categories; boll openers, defoliants, regrowth inhibitors and desiccants, although some products may serve multiple purposes. For example, boll openers (active ingredient – ethephon) speed up the natural process of boll opening, and also will provide some defoliation, especially in warm, sunny conditions. Defoliants assist in removing leaves from the plant and desiccants hasten leaf dry-down, but typically result in leaves staying attached to the plant, otherwise known as leaf stick. The selection of products should be based on what is needed to prepare the crop for harvest, the environmental conditions at application and in the short-term duration (three to five days) following application and the yield potential, which should influence the amount of financial investment that is justifiable.

Regardless of product selection or crop condition, there are a few key considerations which should be kept in mind regarding harvest aid performance and crop response:

Harvest-aid applications

- Spray coverage is key with carrier volume being critically important. A study from across the Cotton Belt in 2016 – 2017 indicated a minimum of 10 to 15 gallons per acre carrier volume is needed to achieve adequate coverage, more rapid and complete defoliation and optimal regrowth inhibition.

- Select spray nozzles and an operating pressure to produce coarse or smaller droplet sizes for optimum coverage.
- Ground speed – slower typically allows for better coverage, particularly to penetrate the crop canopy. Take ground speed adjustments into consideration when calibrating.

Crop Condition

- Terminal regrowth – typically caused by excess moisture and/or excess nitrogen in conjunction with temperatures that favor growth.
  - Can be significant if conditions favorable for vegetative growth are present and can lead to high module moisture and lint staining.
  - Typically controlled by tribufos or protoporphyrinogen oxidase (PPO) inhibitor products, but leaf removal will be key. Stuck leaves on the top of the plant can result from use of a desiccant that is undesirable, particularly if a picker is being used for harvest.
  - Plant growth regulators (PGRs) won't affect or inhibit regrowth – internodes on regrowth are very compact and leaf area is only reduced 5% to 10% while leaf thickness is increased. Once regrowth is observed, PGRs won't have an impact on internode length.
- Basal (juvenile) regrowth – can occur after plant has been defoliated, if conditions favoring growth are present. Sunlight is able to penetrate canopy and initiate growth on the lower axillary nodes of plants.
  - This also can occur in fields where verticillium wilt has resulted in premature defoliation. If verticillium wilt is present and has caused significant defoliation, watch for the initiation of regrowth at the bottom of the plant.
  - Tribufos, PPO defoliant or thidiazuron + diuron products are typically effective in removing juvenile regrowth.

Timeline for Harvest-Aid Effect

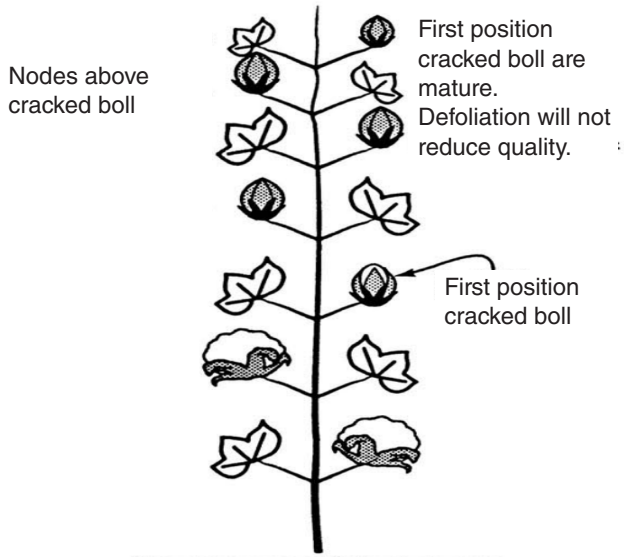
Minimal time typically needed for full effect from applied product. This can increase with adverse conditions (cool weather, drought toughened plants, etc.).

- ***Defoliants*** – (tribufos or PPOs) seven days
- ***Defoliants/regrowth control*** – (thidiazuron or thidiazuron + diuron) 14 days
- ***Boll openers*** – (ethephon) seven to 14 days.
- ***Desiccants*** – (paraquat) five to seven days

Harvest Method

Emphasis for picker-harvested cotton is on maximal leaf drop to avoid plant material being collected with harvested lint. Although pickers will not remove small immature bolls on the plant, boll opening is key as the lint should be accessible to the spindles to be effectively removed from bolls. Desiccants are occasionally used as a follow up after defoliants, but high rates should be avoided so plants are still able to bend as they move through row units.

Emphasis for stripper-harvested cotton is on desiccation. On-board field cleaners will aid in removing some plant material and burrs (fragments of the cotton boll) collected at harvest, but plant material needs to be dry to avoid wet material clogging field cleaner saws. Small, unopened bolls that were desiccated will be removed by field cleaner.



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

Figure 1. Determining nodes above crack boll. Source: Guthrie, D.; Cothren, T.; and Snipes, C. 1993. The Art and Science of Defoliation. Cotton Physiology Today Volume 4, No. 7, National Cotton Council, Cordova, TN.

Review of 2018 – 2019 Trial Results

The two previous years of harvest aid trials have offered two very different environmental conditions to evaluate product performance. In 2018, cool, wet weather predominated the harvest aid application period, resulting in enhanced regrowth fueled by October rains after applications earlier in the month, and slower defoliation response for applications made in mid- to late October. Overall, the regrowth was mostly suppressed due to cool conditions and often didn't require additional applications to remove, particularly for fields that received a desiccant application or were harvested after a killing freeze. In 2018, a field trial evaluating early October-applied products was conducted on irrigated cotton near Fort Cobb. Defoliation results from this field trial are presented in Figure 2, with the list of treatments provided in Table 1.

As October continued, conditions favorable for harvest aid efficacy deteriorated as illustrated by the results of the 2018 Tipton dryland harvest aid evaluation field trial (Figure 3). The first round of treatments at this location were applied on October 17th (Table 2). This was followed by three to four days of cool, overcast conditions, which hampered the activity of all treatments. Regardless of the products used, greater than 50% leaf removal wasn't achieved until 15 days after application (DAA).

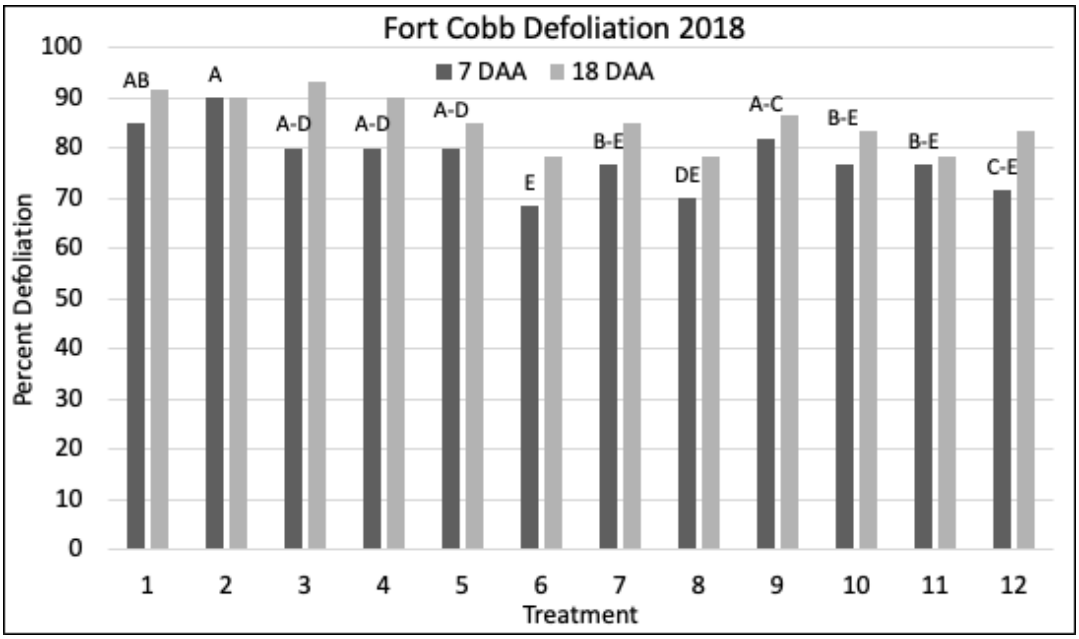


Figure 2. Defoliation ratings at seven and 18 days after the 1st application (DAA) from the Fort Cobb harvest aid evaluation field trial conducted in 2018. Columns within each DAA rating that do not share the same letter are significantly different, there was no statistical difference across treatments for defoliation at the 18 DAA rating.

Table 1. Treatment list for the Fort Cobb harvest aid evaluation field trial conducted in 2018.

Treatment No.	*1st Application 10/5/2018*	*2nd App. (if applicable) 10/17/2018*
1	1oz Saflufenacil + 32oz Ethephon	
2	1oz Saflufenacil + 8oz Tribufos + 32oz Ethephon	
3	16oz Tribufos + 32oz Ethephon	1oz Saflufenacil
4	0.6oz Carfentrazone & Fluthiacet + 32oz Ethephon	1oz Carfentrazone
5	1oz Carfentrazone + 32oz Ethephon	1oz Carfentrazone
6	0.9oz Pyraflufen + 24oz Ethephon	0.9oz Pyraflufen
7	6oz Thidiazuron & diuron + 24oz Ethephon & cycanalide	
8	16oz Tribufos + 32oz Ethephon	1oz Saflufenacil
9	16oz Tribufos + 32oz Ethephon & cycanilide	
10	16oz Tribufos + 16oz Ethephon + 16oz Ethephon & cycanilide	
11	16oz Tribufos + 32oz Ethephon + 4oz Thidazuron & diuron	
12	8oz Tribufos + 1oz Carfentrazone + 32oz Ethephon	

All rates are in fluid ounces per acre.
All treatments contained any surfactants required by label.

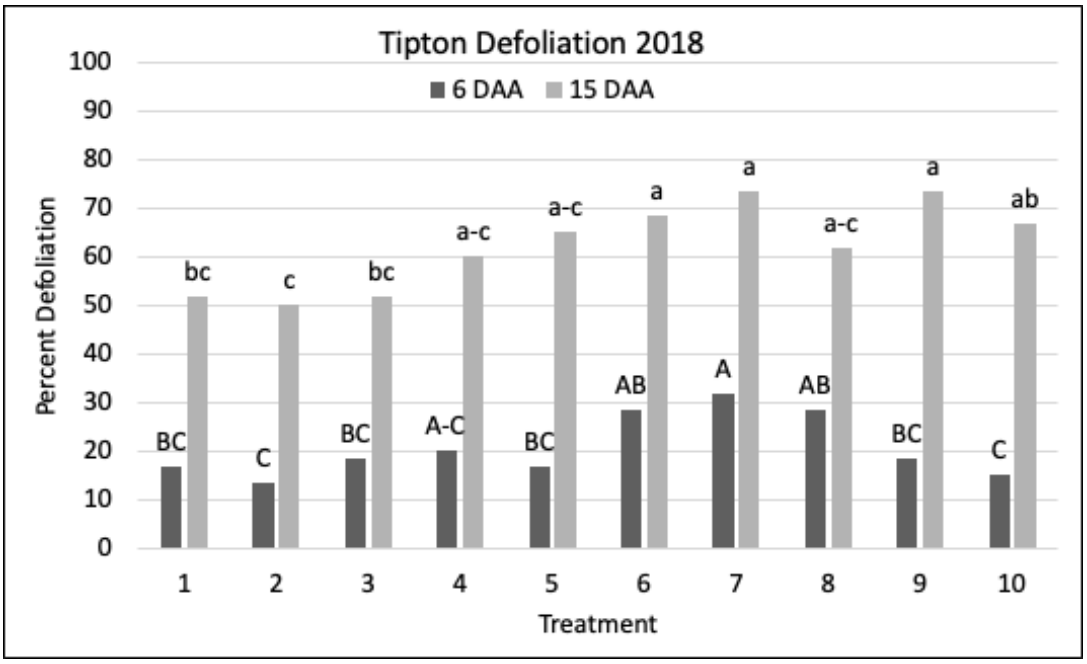


Figure 3. Defoliation ratings at six and 15 days after the 1st application (DAA) from the Tipton harvest aid evaluation field trial conducted in 2018. Columns within each DAA rating that do not share the same letter are significantly different.

Table 2. Treatment list for the Tipton harvest aid evaluation field trial conducted in 2018.

Treatment No.	*1st Application 10/17/2018*	*2nd App. (if applicable) 10/23/2018*
1	1oz Saflufenacil + 32oz Ethephon	
2	1oz Saflufenacil + 8oz Tribufos + 32oz Ethephon	
3	0.6oz Carfentrazone & Fluthiacet + 32oz Ethephon	
4	1oz Carfentrazone + 32oz Ethephon	
5	0.9oz Pyraflufen + 16oz Ethephon	0.9oz Pyraflufen + 16oz Ethephon
6	6oz Thidiazuron & diuron + 24oz Ethephon & cycanalide	
7	16oz Tribufos + 32oz Ethephon	
8	42oz Ethephon	
9	5.5oz Paraquat(2 lb.)	26.5oz Paraquat (2 lb.)
10	3.71oz Paraquat (3 lb.)	17.6oz Paraquat (3 lb.)

All rates are in fluid ounces per acre.
All treatments contained any surfactants required by label.

Compared to 2018, weather was much more favorable as harvest aid applications began in 2019. Clear and warm conditions persisted for much of late September and into early October, which is typically a period of heavy harvest aid applications in Oklahoma. However, much of the state experienced an unexpected killing freeze on the morning of October 12th for many areas of the state. After the freeze, plants that had not yet received a harvest aid application were left with frost-damaged leaves and unopened bolls, particularly on the upper third to half of the plant. Fields that had received an application prior to the freeze were in various states of defoliation and boll opening, depending on the timing of the application in relation to the freeze event. Regardless, this frost damage notably slowed the removal of leaves and boll opening with harvest aids despite the return to relatively warm and sunny conditions in the days after the freeze. This decline in activity was observed in our 2019 harvest aid evaluation field trials. Seven DAA ratings were taken the evening of October 11th, just prior to the freeze and the second round of ratings were taken at 13 DAA. Typically, near adequate defoliation (> 70 to 80% leaf drop) is observed by 14 DAA in most years across all treatments, although in 2019 only six of 19 treatments had ratings of at least 80% defoliation at the time of the second rating. In comparison to 2018, when most treatments had reached above 70% defoliation by seven DAA, in 2019 many treatments had yet to reach 50% defoliation even at 13 DAA. It is worth noting there was a one-day difference in application date between these two years (October 5th in 2018, October 4th in 2019). The year-to-year variability in weather patterns and crop response to various defoliation products was very evident in the 2018 and 2019 Fort Cobb trials.

An additional trial conducted in 2019 aimed at determining the relationship between number of nodes between the of uppermost first position cracked boll to the uppermost first position harvestable boll (NACB) and the percentage of open bolls. These were measured every four to five days starting at approximately six to seven NACB at two locations, a dryland site near Perkins and an irrigated field near Fort Cobb. Beyond geographical and management differences, the two locations also contained two different varieties, Deltapine 1820 B3XF at Perkins and PhytoGen 300 W3FE at Fort Cobb. There was a strong relationship present between these two methods of scheduling harvest aid applications at both locations, although additional years of this study will be needed to determine the year-to-year variability between these values. In 2019, 37% to 63% of bolls were open when plants were at or around the four NACB mark, with a stronger relationship between the two as plants matured further.

Tables 3 and 4 provide and general information on the function of the different active ingredients, use rates and some common names of products (Table 3), as well as some harvest aid recommendations (Table 4). As always, follow the label regarding use rates and adjuvant/surfactant guidelines. Many product labels also will include information on rates based on environmental conditions, primarily temperature and humidity.

Table 3. Active ingredients, common trade names, and application considerations.

Trade Names (Manufacturer)	*Active Ingredients*	*Considerations*
	Organophosphate Defoliant	
Folex 6 EC (Amvac)	Tribufos	Reduced activity under low temps, low humidity or stressed plants. Use higher rates under these conditions.
	PPO Inhibitor Defoliants	
ETX (Nichino)	Pyraflufen-ethyl	Addition of COC recommended.
Aim EC (FMC)	Carfentrazone-ethyl	NIS required at higher temps, COC required at lower temps. Seven-day PHI.
Display (FMC) Action (Amvac)	Carfentrazone-ethyl + Fluthiacet-methyl	
Resource (Valent)	Flumiclorac pentyl ester	Addition of COC or MSO; NIS if warm, sunny conditions.
Sharpen (BASF)	Saflufenacil	Addition of MSO + AMS or UAN required.
	Defoliants/Regrowth Inhibitor	
Freefall (Nufarm)	Thidiazuron	Higher use rates and addition of COC with temps < 65 F, or in drought conditions. Thidiazuron alone not typically recommended due to low overnight temperatures Oklahoma.
Daze (Winfield) Klean-Pik (Mana) Take Down (Loveland) Thidiazuron (Arysta)		
Ginstar EC (Bayer)	Thidiazuron + diuron	Minimum 12 hours rain-free after application for optimal performance. Higher rates required if low humidity is present.
Cutout (Nufarm) Adios (Arysta) Redi-Pik (Mana)		
	Boll Opener	
Super Boll (Nufarm)	Ethephon (6 lbs. ethephon/gal)	Seven-day PHI. Minimum six-hour rain-free period for optimal performance. Higher rates under cool and/or dry conditions, or on toughened/drought stressed foliage.
Boll'd (Winfield) Boll Buster (Loveland) Ethephon 6 (Arysta) Several other trade names		
Flash (Helena)	Ethephon (3 lbs.)	
Finish 6 Pro (Bayer)	Ethephon (6 lbs.) + cyclanilide	
First Pick (Nufarm)	Ethephon (2.28 lbs.) + urea sulfate	
	Desiccants	
Gramoxone Inteon (Syngenta) Gramoxone SL 2.0 (Syngenta)	Paraquat (2 lbs. paraquat/gal)	Addition of NIS recommended.
Firestorm (Chemtura) Parazone 3SL (Amvac) Several other trade names	Paraquat (3 lbs.)	

COC – crop oil concentrate; NIS – nonionic surfactant; MSO – methylated seed oil; AMS – ammonium sulfate; UAN – urea ammonium nitrate; PHI – pre-harvest interval.

Table 4. Harvest-Aid Decision Table (all units in per acre basis). This lists several available options but is not meant to be exclusive.

Crop Condition	*Harvest-Aid Options*[1]
Short stature (12 to 14 inches); low/limited yield potential (< 500 pounds per acre).	PPO inhibitor defoliant (rates vary) with or without the addition of a boll opener.
	PPO inhibitor defoliant (rates vary) FB[2] PPO inhibitor defoliant (rates vary).[3]
Specific tank mix selection should be based on crop requirements for harvest preparation (boll opening, leave removal, regrowth inhibition, and/or desiccation).	Paraquat formulation at 8 to 16 fl oz (2 lb.) or Paraquat at 5.3 to 10.7 fl oz (3 lb.).
	Paraquat at 4 to 12 fl oz (2 lb.) FB2 paraquat up to 32 fl oz (2 lb.) or paraquat at 2.6 to 5.3 fl oz (3 lb.) FB2 paraquat up to 21 fl oz (3 lb.).[4]
	Paraquat at 6 to 24 fl oz (2 lb.) or Paraquat at 4 to 6.7 fl oz (3 lb.) + tribufos at 8 to 16 fl oz or PPO inhibitor defoliant (rates vary).[5]
Medium stature (15 to 24 inches); 500+ pounds per acre yield potential.	Ethephon (6 lb.) at 16 to 42 fl oz or (ethephon + cyclanilide) at 16 to 42 fl oz + tribufos at 8 to 16 fl oz.
Specific tank mix selection should be based on crop requirements for harvest preparation (boll opening, leave removal, regrowth inhibition, and/or desiccation).	Ethephon (6 lb.) at 16 to 42 fl oz or (Ethephon + cyclanilide) at 16 to 42 fl oz + (thidiazuron + diuron) at 3 to 8 fl oz.
	Ethephon (6 lb.) at 16 to 42 fl oz or (ethephon + cyclanilide) at 16 to 42 fl oz + PPO inhibitor defoliant (rates vary).[3]
	PPO inhibitor defoliant (rates vary)3 + tribufos at 8 to 16 fl oz or PPO inhibitor defoliant at 0.6 to 8 fl oz[3] + (thidiazuron + diuron) at 3 to 8 fl oz.
	PPO inhibitor defoliant (rates vary)[3] FB[2] PPO inhibitor defoliant (rates vary).[3] Paraquat at 6 to 24 fl oz (2 lb.) or paraquat at 4 to 16 fl oz (3 lb.) + tribufos at 8 to 16 fl oz. Stripper-harvested only.
	Paraquat at 6 to 24 fl oz (2 lb.) or paraquat at 4 to 16 fl oz (3 lb.) + PPO inhibitor defoliant (rates vary).[3] Stripper-harvested only.
	Paraquat at 4 to 8 (2 lb.) fl oz FB[2] paraquat up to 32 fl oz total (2 lb.)[3] or paraquat at 2.6 – 5.3 fl oz (3 lb.) FB[2] Paraquat up to 21 fl oz total (3 lb.).[4] Stripper-harvested only.
	(Ethephon + urea sulfate) at 48 to 64 fl oz + (thidiazuron + diuron) at 3 to 8 fl oz.
Tall stature (> 24 inches); 1,000 + *pounds per acre* yield potential.	Ethephon (6 lb.) at 21 to 42 fl oz or (ethephon + cyclanilide) at 21 to 42 fl oz + tribufos at 8 to 16 fl oz.
Specific tank mix selection should be based on crop requirements for harvest preparation (boll opening, leave removal, regrowth inhibition and/or desiccation).	Ethephon (6 lb.) at 21 to 42 fl oz or (ethephon + cyclanilide) at 21 to 42 fl oz + (thidiazuron + diuron) 3 to 8 fl oz.
	(Ethephon + urea sulfate) at 48 to 112 fl oz + (thidiazuron + diuron) at 3 to 8 fl oz.
	Ethephon (6 lb.) at 21 to 42 fl oz or (ethephon + cyclanilide) at 21 to 42 fl oz + PPO inhibitor defoliant (rates vary).[3]
	(Ethephon + urea sulfate) at 48 to 112 fl oz + PPO inhibitor defoliant (rates vary).[3]
Other Conditions *Desiccating application for stripper harvest preparation (not to be used for picker-harvested cotton).*	Paraquat at 16 to 32 fl oz (2 lb.) or paraquat at 11 – 21 fl oz (3 lb.)
Conditioning treatment for late-maturing cotton. Apply after daily heat units drop below five, target seven days before first killing freeze date.	Paraquat at 4 to 16 fl oz (2 lb.) or paraquat at 2.6 to 10.7 fl oz (3 lb.).
	Ethephon (6 lb.) at 21 – 42 fl oz.

1 Actual rates needed will depend on weather conditions (high and low temperatures, humidity). Higher labeled rates are typically recommended under cooler and dryer conditions. Check the label for specific details on rates.
2 FB = followed by.
3 Rates will depend on product selected; check the label for appropriate rates for the selected product. No more than: 3.2 ounces per acre total of Aim EC, 2.0 ounces per acre total of Display, 2.0 ounces per acre total of Sharpen, 3.4 ounces per acre total (no more than two applications) of ETX and 14 ounces per acre (no more than two applications, max of 8 ounces per single application) of Resource may be applied during the growing season.
4 No more than 32 fluid ounces per acre of 2-pound paraquat a.i. or 21 fluid ounces per acre of 3-pound paraquat a.i. may be applied as a harvest aid in up to four applications. Subsequent applications should depend on the green leaves remaining and the rate or rates applied previously; use higher rates if excessive regrowth is present.
5 Labeled tank mix partners for paraquat include Folex, ETX and Sharpen.

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The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; family and consumer sciences; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

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