



2021 Oklahoma Cotton Harvest Aid Guide

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Harvest aids in cotton are used to remove foliage, inhibit regrowth and open bolls to allow for timely harvest operations to maximize yield and minimize quality losses due to weathering. Defoliation and boll opening are natural processes governed by plant hormones, and harvest aids are used to accelerate 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 used; results of previous harvest aid product evaluations and current research; and finally tables on specific products, considerations and rate recommendations 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 to expose the developing lint and seeds. A mature boll should be firm and difficult to slice, with mature seeds (fully developed cotyledons with little liquid or "jelly" in the seeds) with a dark seed coat and the lint stringing-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 fruit. 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 mainstem nodes above the uppermost first position cracked boll (4 NACB; Figure 1) or; 2. 60% to 75% of the harvestable bolls on the plant are open (60% to 75% open bolls). Recent research in Oklahoma has

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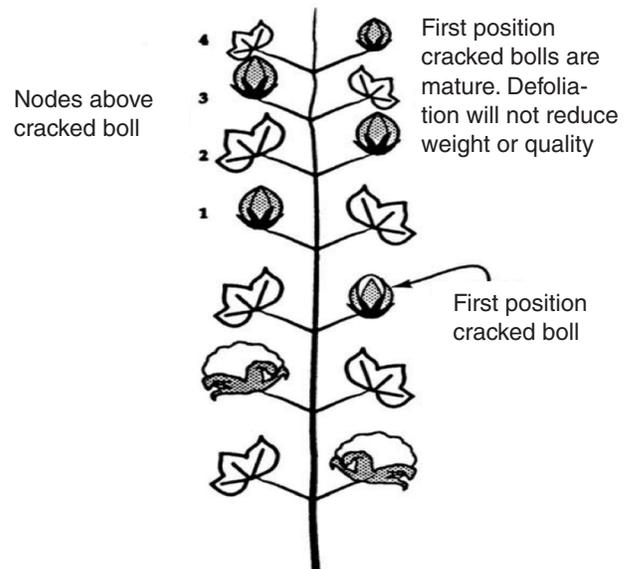


Figure 1. Determining nodes above crack boll. Source: Guthrie, D., Cothren, T., and Snipes, C. 1993. The Art and Science of Defoliation. Cotton Physiology Today Volume 4, No. 7, National Cotton Council, Cordova, TN.

illustrated there is a close relationship between NACB and percentage of open bolls, and that 60% open occurs around the 4 NACB mark (Figure 2). However, in situations where a fruiting gap may be observed due to environmental stress or insect pests resulting in fruit shed, this correlation may not exist. Further, differences in fruit distribution between varieties and maturity classes also will impact this relationship. Therefore, it is recommended to use a combination of the two methods to accurately determine crop condition. Due to in-field variability, it is recommended to evaluate multiple areas of each field and take into account the status of the majority of the plants prior to scheduling a harvest aid application. Both NACB and percent open measurements should be based only on the harvestable bolls on the plants, so only harvestable bolls should be counted. Harvestable bolls consist of bolls that are currently open, mature but not yet open or far enough along

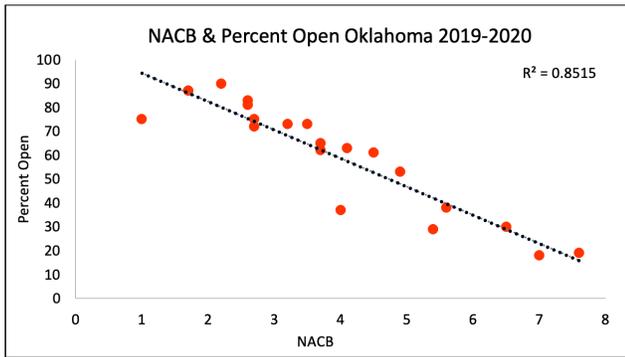


Figure 2. Relationship between the number of nodes between the uppermost first position cracked boll and the uppermost first position harvestable boll (NACB) and percentage of open harvestable bolls (Percent Open) from trials in Perkins (2019) and Fort Cobb (2019 & 2020).

in the maturation process based on the boll slicing method that are expected to open by harvest assuming favorable conditions and timely application of harvest aids.

A wide array of harvest aid products is available for use in cotton. These products typically fall into one of four general categories; boll openers, defoliant, 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 but will also provide some defoliation, especially in warm, sunny conditions. Defoliant 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 prior to the application and in the five to 14 days following the 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. Recent work from across the Cotton Belt has determined that increased carrier volume (10 to 15 GPA) results in greater coverage and more rapid and effective defoliation, boll opening and regrowth inhibition.
- Tips that produce coarse to medium-fine droplet sizes are recommended for optimum coverage.
- Ground speed – slower typically allows for better coverage and deeper penetration through the crop canopy. Take ground speed adjustments into consideration when calibrating.

Temperature

- Temperature at application and afterward will impact defoliation success and crop response. In conditions with sustained highs in the 80s or warmer, rates of most defoliant should be reduced to avoid desiccating activity resulting in leaf stick. In cooler conditions, rates should be increased to account for decreased activity.

- Most boll openers will outline rate suggestions based on temperature ranges on their label. In general, these are broken up into temperatures above 80 F, between 75 F to 80 F, and >65 F to 75 F. Refer to the label of your specific boll opener selection for details.
- Table 3 provides rate recommendations based on crop conditions. Adjust rates within the provided range based on temperatures surrounding application.

Crop Condition:

- Different defoliant products have various strengths and weaknesses. Tribufos and thidiazuron & diuron products are generally less harsh than the protoporphyrinogen oxidase (PPO) defoliant. As a result, tribufos and thidiazuron plus diuron products may be more likely to remove mature green leaves from plants and less likely to stick leaves when compared to PPOs. In contrast, PPO defoliant are typically better at removing drought-hardened leaves and aren't as sensitive to cool temperatures.
- Regrowth – there are two types of regrowth, which are described below. To inhibit both types of regrowth, include a product containing thidiazuron + diuron in the harvest aid mix. If this product isn't the primary defoliant and favorable temperatures or excess fertility and/or moisture are present, a low rate (2 to 4 ounces per acre) can inhibit regrowth.
- Terminal regrowth – typically caused by excess moisture and/or excess nitrogen in conjunction with temperatures that favor growth.
 - Can be significant if conditions are present that are favorable for vegetative growth and can lead to high module moisture and lint staining.
 - Tribufos or protoporphyrinogen oxidase (PPO) inhibitor products can remove terminal regrowth but pay attention to conditions and rates as leaf removal will be key. Stuck leaves on the top of the plant can result from use of a desiccant which 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 a plant has been defoliated, if conditions favoring growth are present. Sunlight penetrates the canopy and initiates 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 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.

Harvest Method

- Emphasis for picker-harvested cotton is on maximal leaf drop to avoid plant material being collected with harvested lint. Pickers will not remove small immature bolls on the plant that aren't opened, so boll opening and lint fluffing are critical for the lint to be accessible to the spindles and can be effectively removed from bolls. Desiccants

are occasionally used as a follow up after defoliant, 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 collected at harvest, but plant material needs to be dry to avoid wet material clogging burr extractor saws. Small unopened bolls that were desiccated will be removed by burr extractor.

Review of 2020 Trial Results

The vast majority of Oklahoma's cotton acreage experienced a cold snap that occurred in early September of 2020. This event, combined with a monthly heat unit accumulation 100 to 150 units lower than normal, made achieving optimal maturity of the crop a challenge. Despite the cooler conditions, September was generally clear and sunny, which did provide some benefits to earlier planted cotton that received a harvest aid application in the second half of the month. The 2020 harvest aid evaluation consisted of 13 harvest aid treatments as well as a non-treated control that received no harvest aid applications (Table 1).

There were two primary objectives of the 2020 harvest aid evaluation. The first was to determine the efficacy of defoliation across a range of rates from two common defoliant products in favorable weather conditions. Tribufos (treatments 2, 3 and 4) and thidiazuron (TDZ) + diuron (5 and 6) were evaluated. Both products generated acceptable levels of defoliation at low rates. The main takeaway from the first objective is low rates of either product will generate acceptable levels of defoliation if applied during favorable weather conditions (mild and sunny) to a crop that is naturally senescencing.

The second objective was evaluating conditioning treatments (treatments 7, 8 and 9). Conditioning is a strategy in which low rates of defoliant are applied at earlier growth stages in an attempt to remove leaves to allow for better coverage for the boll opener applied at traditional timings. Conditioning applications are typically used in immature or rank cotton that has excessive growth or green leaves remaining on the plant as bolls begin to open. However, because of the extent of natural senescence mentioned above, there was little to no benefit to conditioning in the 2020 evaluation. A comparison between surfactant selections in two common PPO defoliant was also included (treatments 10, 11, 12 and 13). A reduction in defoliation compared to any other treatment with a defoliant was observed when NIS (non-ionic surfactant) was utilized with carfentrazone.

Outlook for 2021

As of early September, the cotton crop across most of Oklahoma has caught up from the delayed development observed earlier in the year. This is particularly true from a fruit development standpoint, with the majority of fields blooming out of the top by the end of August. However, due to many areas receiving timely rains, and the fact that the first fruiting branch in much of our cotton is one to two nodes higher than normal, the vegetation on the plants hasn't begun naturally senescing to the extent that might typically be seen at this time of year. If the crop experiences typical September and early October conditions, defoliation will likely be just as critical as boll opening to achieve a harvest-ready crop. If a September similar to 2020 is experienced, both boll opening and defoliation will likely be incredibly challenging and product selection,

Table 1. Defoliation and boll opening ratings from 2020 harvest aid evaluation in Fort Cobb.

Conditioning Application ~30% Open Bolls	Treatment ~60% Open Bolls	Defoliation (%)		Boll Opening (%)	
		7 DAA ^{1,2}	14 DAA	7 DAA	14 DAA
	1. Non-Treated Check	58	74	63	70
	2. 16 oz Tribufos + 32 oz Ethephon	88	93	88	93
	3. 12 oz Tribufos + 32 oz Ethephon	88	94	85	94
	4. 8 oz Tribufos + 24 oz Ethephon	83	91	83	93
	5. 8 oz Thidiazuron + Diuron + 32 oz Ethephon	91	97	81	97
	6. 4 oz Thidiazuron + Diuron + 32 oz Ethephon	85	92	84	91
7. 3.2 oz Tribufos, + 3.2 oz Flumicloro pentyl ester, + 0.25% v/v NIS	7. 8 oz Tribufos + 32 oz Ethephon	88	95	84	97
8. 8 oz Tribufos	8. 8 oz Tribufos + 32 oz Ethephon	91	96	93	97
9. 0.4 oz Pyraflufen ethyl + 0.25% v/v NIS	9. 1.25 oz Pyraflufen ethyl + 0.25% v/v NIS + 32 oz Ethephon	91	95	88	96
	10. 1.6 oz Carfentrazone ethyl + 0.25% v/v NIS + 32 oz Ethephon	79	90	85	95
	11. 1.6 oz Carfentrazone ethyl + 1% v/v COC + 32 oz Ethephon	88	92	85	91
	12. 1.5 oz Pyraflufen ethyl + 0.25% v/v NIS + 32 oz Ethephon	88	95	90	94
	13. 1.5 oz Pyraflufen ethyl + 1% v/v COC + 32 oz Ethephon	90	94	86	91
	14. 42 oz Ethephon	81	89	93	94

1 Days after the 60% open application.

2 Values in bold in the highest statistical category.

Table 2. Active ingredients, common trade names, and application considerations.

<i>Trade Names (Manufacturer)</i>	<i>Active Ingredients</i>	<i>Adjuvant Recommendations</i>	<i>Rainfast</i>	<i>PHI¹</i>
Herbicidal Defoliants				
Folex® 6 EC (Amvac)	<i>Organophosphate</i> Tribufos		1 hour	7 days
ETX® (Nichino)	<i>PPO Inhibitor</i> Pyraflufen-ethyl	COC ² @ 1 – 2% v/v.	1 hour	7 days
Aim® EC (FMC)	Carfentrazone-ethyl	NIS ³ @ 0.25% v/v at temps > 80°F; COC or MSO ⁴ @ 1 – 2% v/v at temps < 80°F.	8 hours	7 days
Display® (FMC)	Carfentrazone-ethyl & Fluthiacet-methyl			
Action® (Amvac)	Flumiclorac pentyl ester	COC or MSO @ 1 – 2 pints per acre.	1 hour	7 days
Resource® (Valent)				
Sharpen® (BASF)	Saflufenacil	MSO @ 1% v/v + AMS ⁵ @ 8.5 – 17 lbs./ 100 gal or UAN ⁶ @ 1.25 – 2.5% v/v.	1 hour	5 days
Hormonal Defoliants/Regrowth Inhibitors				
Freefall® (Nufarm)	Thidiazuron	Thidiazuron alone not recommended in Oklahoma due to low temperatures.	24 hours	5 days
Daze® (Winfield)				
Klean-Pik® (Mana)				
Take Down® (Loveland)				
Thidiazuron® (Arysta)				
Ginstar® EC (Bayer)	Thidiazuron & diuron		12 hours	5 days
Cutout® (Nufarm)				
Adios® (Arysta)				
Redi-Pik® (Mana)				
Boll Openers				
Super Boll® (Nufarm)	Ethephon (6 lbs. ethephon/gal)		6 hours	7 days
Boll'd® (Winfield)				
Boll Buster® (Loveland)				
Ethephon® 6 (Arysta)				
Several trade names				
Finish® 6 Pro (Bayer)	Ethephon (6 lbs./gal) & cyclanilide		6 hours	7 days
Terminate® (Nufarm)				
CottonQuik® (Nufarm)	Ethephon (2.28 lbs./gal) & urea sulfate		6 hours	7 days
Flash® (Helena)	Ethephon (3 lbs.)		6 hours	7 days
Desiccants				
Gramoxone Inteon® (Syngenta®)	Paraquat (2 lbs./gal)			
Gramoxone SL 2.0 (Syngenta®)		NIS @ > 0.25% v/v	30 min.	3 days
Firestorm® (Chemtura®)	Paraquat (3 lbs./gal)			
Parazone® 3SL (Amvac®)				
Several other trade names				

1 PHI – pre-harvest interval
2 COC – crop oil concentrate
3 NIS – nonionic surfactant
4 MSO – methylated seed oil
5 AMS – ammonium sulfate
6 UAN – urea ammonium nitrate.

Table 3. Scenarios and rate (in fluid ounces per acre) considerations for various harvest aid products. All recommendations are based on a one-pass harvest aid program as is typical for Oklahoma.

Product	Defoliation		
	Excessive green leaf; large plants; high – moderate yield potential	Moderate natural senescence and plant stature; moderate yield potential	Advanced senescence; short stature; moderate – low yield potential
Folex® 6 EC	12 to 24 oz ¹	8 to 16 oz	6 to 12 oz
Ginstar® ²	8 to 16 oz	6 to 10 oz	4 to 8 oz
ETX®	1.4 to 1.7 oz	1.25 to 1.5 oz	0.9 to 1.25 oz
Aim® EC	1.2 to 1.6 oz	1.0 to 1.5 oz	1.0 to 1.2 oz
Display®	0.8 to 1 oz	0.6 to 0.8 oz	0.4 to 0.6 oz
Action®	6 to 8 oz	6 to 8 oz	4 to 6 oz
Sharpen®	1 to 2 oz	0.8 to 1.2 oz	0.5 to 1 oz
Ethephon® ³	Not recommended	32 to 42.7 oz	24 to 43 oz
Paraquat® (2 lbs)	Not recommended	Not recommended	4 to 6 oz ⁴
Paraquat® (3 lbs)	Not recommended	Not recommended	3 to 4 oz ⁴

Products	Boll Opening		
	Immature crop (<60% open bolls)/large stature	60 to 75% open bolls, moderate stature	>75% open bolls, short stature
Ethephon® ⁵	32 to 42.7 oz	24 to 32 oz	16 to 24 oz
Finish® 6 Pro	32 to 42.7 oz	24 to 32 oz	16 to 24 oz
CottonQuik®	56 to 64 oz	48 to 64 oz	48 to 56 oz
Flash®	56 to 86 oz	43 to 64 oz	32 to 43 oz

Products	Conditioning	Regrowth Removal⁶	Desiccation
Folex® 6 EC	4 to 8 oz	4 to 8 oz	
Ginstar® ²		2 to 6 oz	
ETX®	0.2 to 0.45 oz	1 to 1.25 oz	
Aim® EC	0.25 to 0.5 oz	1 oz	
Action®	2 to 4 oz	3 to 5 oz	
Paraquat® (2 lbs) ⁷			16 to 32 oz
Paraquat® (3 lbs)			11 to 21 oz

- 1 Use a lower range of rates for warm, clear conditions and increase rate to upper range as temperatures decrease or overcast conditions persist.
- 2 Includes Ginstar® and all generic thidiazuron + diuron products.
- 3 If ethephon is utilized alone for defoliation and boll opening. This includes all 6 pounds ethephon per gallon products.
- 4 Avoid using paraquat products as defoliant if >80% of harvestable-sized bolls are closed as boll opening will be inhibited by paraquat.
- 5 Includes all products containing 6 pounds ethephon per gallon products.
- 6 For removal of regrowth occurring after initial harvest aid application.
- 7 No more than 32 fluid ounces per acre of 2 pounds paraquat a.i. or 21 fluid ounces per acre of 3 pounds paraquat a.i. may be applied as a harvest aid. Subsequent applications should depend on the green leaves remaining and the rate or rates applied previously; use higher rates if excessive regrowth is present.

rates and application timing will be critical considerations to accomplish optimal crop conditions for harvest.

Table 2 provides information on various defoliant, regrowth inhibitors, boll openers and desiccants labeled for use in cotton. Be sure to refer to the label of any product used as a harvest aid to find specific use instructions and restrictions. Always match product selection and rates to crop condition and weather conditions. Note that for any defoliant product, as temperature increases rates should decrease. Failure to decrease rates at sustained temperatures above 80 F after application will result in greater leaf injury, resulting in stuck, desiccated foliage on plants and increased risk of fiber quality

reductions due to high leaf grade. Plants that have experienced drought stress during the growing season will typically have leaves that are “hardened off” meaning they have developed a thicker waxy outer layer. Optimal defoliation of these plants may require higher rates of defoliants.

Again, product selection and rate will vary depending on need (leaf removal, boll opening, regrowth inhibition or a combination of the three), crop condition and the forecast for five to 14 days following application. Table 3 offers some potential crop condition scenarios that govern these decisions and suggested use rates of the products listed in Table 2.

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- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective, and research-based information.
- It provides practical, problem-oriented education

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