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Defoliating Cotton under Adverse Conditions: Drought-stress, Cool Temperatures, and Rank Growth

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Introduction

Modern chemical harvest aids are applied to induce leaf abscission, hasten mature-boll dehiscence, and inhibit regrowth (Gwathmey and Hayes 1997; Snipes and Cathey 1992). Their use can result in increased machine harvest efficiency and fewer lodged plants while reducing boll rot, the trash in seed cotton, and the time from defoliation to harvest (Benedict 1984). The challenge of using harvest aids is the inconsistent way cotton responds to them, making defoliation one of the most unpredictable management practices (Benedict 1984; Gwathmey and Hayes 1997). The effectiveness of a harvest aid depends upon crop maturity, uniformity of plant growth, weather conditions, spray coverage, absorption, and translocation (Benedict 1984; Gwathmey and Hayes 1997).

Defoliation allows producers to harvest earlier than if the crop matured naturally, but it can reduce yield and alter fiber quality if the application of the harvest aid is premature (Snipes and Baskin 1994). Producers attempt to optimize the timing of harvest-aid applications by maximizing the number of young bolls that are mature and harvestable without sacrificing the yield and quality of older bolls (Larson et al. 2002; Snipes and Baskin 1994). They use several techniques to determine crop maturity, including percent open bolls (60 percent), nodes above cracked boll (3 NACB), and visual inspection of cut bolls (hard to cut, brown seed coats, and "stringy" lint). *Cotton Harvest Aid Selection and Application Timing*, Virginia Cooperative Extension publication 424-201, and *2005 Virginia Cotton Production Guide*, Virginia Cooperative Extension publication 424-300, have more information on timing defoliation with crop maturity. The number of days required to develop bolls to maturity depends upon growing conditions and weather. Hot and dry conditions will generally hasten maturity, while cool and wet conditions delay cotton maturity. Other factors that can impact maturity are fertility, plant-growth regulators, insect control, irrigation termination, and stand density. Cotton maturity is difficult to determine without using one of the above techniques to monitor the crop. Producers should employ proper techniques to determine cotton maturity before initiating harvest-aid applications.

Harvest-aid efficacy is influenced by environmental conditions before, at the time of, and following application (Benedict 1984; Gwathmey and Hayes 1997). The producer can more effectively and economically prepare cotton for harvest by selecting the appropriate harvest aid(s) based on environmental and crop conditions (Gwathmey and Hayes 1997; Logan and Gwathmey 2002).

Commercially Available Harvest Aids

There are several commercially available chemical harvest aids with defoliation attributes (Table 1). Folex or Def contains tribufos, an inexpensive organophosphorus compound that is one of the few earlier developed defoliants still used extensively today (Cathey 1986). Finish (ethephon plus cyclanilide) and CottonQuik (ethephon plus AMADS) are harvest aids that effectively open mature bolls and defoliate leaves. Cyclanilide and AMADS are synergists that are included in formulations to enhance the activity of ethephon. Finish and CottonQuik are two harvest aids marketed for boll opening and defoliation, but not regrowth control. Aim (carfentrazone) and ET (pyraflufen) are two newer contact-type defoliants that are steadily gaining acceptance and recognition as harvest aids. Both of these new contact-type chemicals have a protoporphyrinogen oxidase (PPO) inhibiting mode of action, and have been labeled recently for use as harvest aids in cotton. While the speed of carfentrazone and pyraflufen activity is similar to that of paraquat, cotton's response to these two PPO-inhibiting harvest aids is slightly slower and less harsh, resulting in better defoliation with less leaf sticking than with paraquat. For more information on

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harvest-aid products and functions, refer to *Cotton Harvest Aid Selection and Application Timing*, Virginia Cooperative Extension publication 424-201.

The selection of components for a harvest-aid application is highly dependent upon the desired effects. An individual harvest-aid chemical generally performs one operation in preparing the cotton for harvest, necessitating combinations of chemicals to achieve the multiple operations desired for harvestability. Prep (and other ethephon products) and Dropp (and other thidiazuron products) are the standard harvest aids for boll opening and regrowth inhibition, respectively (Table 1). The selection of a harvest aid for defoliation is influenced by many plant physiological and environmental factors, including day/night temperatures, soil moisture, and whether or not the cotton is rank in growth.

Day and night temperatures at the time of and shortly after application have been documented to be the most influential factors in the performance of defoliants (Logan and Gwathmey 2002). In Tennessee, Folex/Def plus Prep performed better in cool conditions, while Dropp plus Prep performed better in warm conditions (Gwathmey and Hayes 1997). Finish performed equivalently to Folex/Def plus Prep in warm conditions, but Finish performed with lower defoliation efficacy in cooler conditions (Hayes et al. 1996).

Soil moisture conditions also influence the performance of defoliants, especially those with hormonal-like activity. Inadequate moisture increased leaf cuticle thickness by 33 percent, thus reducing the penetration of ^{14}C-labeled Harvade (dimethipin) (Oosterhuis et al. 1991). Reduced penetration results in decreased defoliant efficacy on cotton that receives less than adequate rainfall or irrigation. Cloud cover and relative humidity also influence defoliant activity with high sunlight intensity and low relative humidity more conducive for effective defoliation (Logan and Gwathmey 2002).

Harvest-aid performance can be influenced by certain adjuvants. The earliest documentation of adjuvant additions to defoliants was in the 1950s with nonionic surfactant additions (NIS) to sodium chlorate and monosodium cyanamide (Brown 1957). These surfactants were found to increase the amount of leaf fall and the speed of defoliation under limiting conditions, including wilted, toughened, and inactive leaves; immature leaves and bolls; cool temperatures; and conditions resulting from excessive nitrogen applications. More modern harvest aids such as Harvade require the addition of a crop-oil concentrate (COC) as an adjuvant in order to achieve consistently desirable results. Defoliation resulting from Folex/Def or Dropp applications was found to be enhanced by including the combination of Prep, a nonionic surfactant, and ammonium sulfate in the harvest-aid appli-

Table 1. Harvest-aid products available and operations performed.

			Harvest-aid Operations Performed		
Harvest-aid Trade Name	**Harvest-aid Chemical(s)**	**Mode of Action**	**Defoliation**	**Boll Opening**	**Regrowth Inhibition**
Harvade 5 F	dimethipin	contact	X		
Folex/Def 6 EC	tribufos	contact	X		
Finish 6 Pro	cyclanilide + ethephon	hormonal	X	X	
CottonQuik	AMADS + ethephon	hormonal	X	X	
Dropp 4 SC	thidiazuron	hormonal	X		X
Free Fall 50 WP	thidiazuron	hormonal	X		X
Leafless 4 F	thidiazuron + dimethipin	hormonal	X		X
Ginstar 1.5 EC	thidiazuron + diuron	hormonal	X		X
Aim 2 EC	carfentrazone	contact	X		
ET 0.208 EC	pyraflufen	contact	X		
Prep 6 L	ethephon	hormonal		X	
Super Boll 6 L	ethephon	hormonal		X	
Ethephon 6 L	ethephon	hormonal		X	
Boll'd 6 L	ethephon	hormonal		X	

cation (Jones et al. 1999). Leaf drop within seven days after application can be achieved by the addition of Accelerate or Flair (endothall) to either Folex/Def or Dropp (Thead 1997). Cotton generally can be harvested two to three days earlier with adjuvant additions to harvest-aid applications when compared to the harvest interval if applications are made without adjuvants.

There are other advantages to applying harvest aids besides defoliation, boll opening, and regrowth inhibition. Boll rot and lodging can be significantly reduced in cotton with the bottom portion of the plants defoliated (Brown 1953, Cathey 1986). With producers commonly using Pix (and other mepiquat chloride products) to control excessive vegetative growth, the defoliation of rank and lodged cotton has become less problematic (Benedict 1984). Because the application of harvest-aids in cotton is influenced by many conditions and goals, it is one of the most complex and inconsistent management practices.

Drought Stress

Dry-land cotton producers are often faced with defoliating drought-stressed cotton. When soil moisture conditions become low enough for plants to wilt and daytime temperatures exceed 90°F, cotton can quickly become stressed. Because drought-stressed cotton often has thick leaf cuticles that inhibit the uptake of many defoliants, its response to defoliants can be less than desirable. Recommended harvest aids and appropriate rates for defoliation under drought-stress conditions are listed in Table 2. Residual nitrogen and early cutout often lead to regrowth following harvest-aid applications in drought-stressed cotton, thus Dropp (thidiazuron at 0.05 – 0.10 lb ai/A) can be added to recommended harvest aids for effective defoliation and regrowth control. The uptake of certain thidiazuron containing products (i.e. Leafless, Ginstar) can be higher in drought-stressed cotton than thidiazuron alone (Dropp). The addition of a surfactant, ammonium sulfate, or Def/Folex can increase the uptake of Dropp on drought-stressed cotton. However, the use of adjuvants such as crop-oil concentrate or ammonium sulfate in high temperatures will increase the probability of leaf sticking. If regrowth is not a concern, Def/Folex is often an adequate defoliant choice. If only Leafless or Ginstar is utilized, high rates of these defoliants should be avoided.

Table 2. Harvest-aid rates for application under adverse conditions.
(Refer to label for specific tank-mix[1] information concerning rates.)

	Recommended Rates for Defoliation			
Harvest-aid	**Drought-stress**	**Cool Temperatures (High <80, Low <60)**	**Rank Growth 1st Application**	**Rank Growth 2nd Application**
Harvade	Not Recommended	6.5 – 10 fl. oz/A + COC (1 pt/A)	6.5 – 10 fl. oz/A + COC (1 pt/A) **(Avoid if High >80)**	Not Recommended
Folex/Def	1.5 pt/A	1.5 pt/A	1.5 pt/A	Not Recommended
Finish 6 Pro	1.33 – 2.67 pt/A	2.0 – 2.67 pt/A	1.33 – 2.67 pt/A	Not Recommended
CottonQuik	2 – 3 qt/A	2 – 3.5 qt/A	2 – 3.5 qt/A	Not Recommended
Dropp SC	Not Recommended	Not Recommended	3.2 – 6.4 fl oz/A	Not Recommended
Free Fall	Not Recommended	Not Recommended	0.2 – 0.4 lb/A	Not Recommended
Leafless	10 – 12 fl oz/A + COC (1 pt/A)	10 – 12 fl oz/A + COC (1 pt/A)	10 – 12 fl oz/A + COC (1 pt/A)	Not Recommended
Ginstar	6 – 11 fl oz/A	4 – 8 fl oz/A	4 – 8 fl oz/A	Not Recommended
Aim	Not Recommended	1.0 fl oz/A + NIS (0.25%v/v)	Not Recommended	1.0 – 1.5 fl oz/A + NIS (0.25%v/v)
ET	Not Recommended	1.5 fl oz/A + NIS (0.25%v/v)	Not Recommended	1.5 – 2.0 fl oz/A + NIS (0.25%v/v)

[1] Tank mixtures are recommended to achieve complete and optimal harvest-aid management (i.e. defoliation, boll opening, and regrowth inhibition). Refer to *Cotton Harvest Aid Selection and Application Timing*, Virginia Cooperative Extension publication 424-201.

Cool Temperatures

Because of their geographic location, Virginia producers often have concerns about defoliating cotton when temperatures are cool (highs less than 80°F and lows less than 60°F). Most harvest aids are temperature sensitive and do not perform as well when temperatures are cool. Harvade traditionally has been recommended in most states as a good cool-weather defoliant. Though Harvade is the least sensitive chemical to low temperatures at normal use rates, high rates of Def/Folex can also be used to effectively defoliate mature cotton in cool weather (Table 2). The recently labeled Aim and ET also can be used to defoliate cotton when temperatures are low. Because of the leaf sticking potential at high temperatures, Aim and ET are probably better suited for use when high temperatures are below 80°F. Adjuvants are essential for achieving successful defoliation with many of these products. A crop-oil concentrate must be added to Harvade and a nonionic surfactant to Aim or ET. For boll opening, higher rates of Prep are needed as temperatures decrease. Because the potential for regrowth is often less when temperatures are cool, Dropp can sometimes be omitted if temperatures are likely to remain below 70°F.

Rank Growth

The most important aspect to defoliating rank cotton is spray coverage. This is challenging and growers tend to increase the rate of chemical applied. However, rate increases are not advised since higher rates increase the possibility of leaf desiccation and sticking. In most situations, excessively rank cotton will require a two-application defoliation program (Table 2). The first application should be made as normal with the goal of knocking off all the leaves except for a skirt around the base of the plant. A product such as Aim or ET works well as an affordable second application. If a boll opener is used in this program, it will be more effective with the second application as coverage will be better. Rank cotton is more prone to damage from boll-rot pathogens, and a close examination of the crop prior to defoliation can be beneficial in determining boll-rot levels. The best solution for avoiding late season difficulties with rank cotton is the proper management of plant growth regulators and soil nitrogen levels.

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