Chapter 9

OVERVIEW OF REGIONAL DEFOLIATION PRACTICES

AND RESULTS OF REGIONAL TREATMENTS CONDUCTED BY THE COTTON DEFOLIATION WORK GROUP

INTRODUCTION

Cotton production and practices, such as defoliation, vary significantly across the U.S. Cotton Belt. Although the five-year study conducted by the Cotton Defoliation Work Group (CDWG) applied a standardized protocol to field research, regional variations in environmental conditions were recognized and evaluated. These environmental variances and a summary of regional treatments conducted by the CDWG are presented in four segments of this chapter. The regions include the Southeast, Midsouth, Southwest, and Far West. The chapter segments also address defoliation variances within regions.

SOUTHEAST[1]

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OVERVIEW

The Southeastern region is, for the purpose of cotton production, Alabama, Georgia, Florida, North Carolina, and South Carolina (Figure 1). The area has a long history of growing cotton, with some fields growing the crop continuously for more than 100 years. Cotton defoliation has been a standard practice in the Southeast for many years and correlates with the rise in machine harvest and use of more modern techniques such as moduling. No two areas of the country are the same with regard to weather patterns and cotton growth, but much of the Southeast is under the dual influences of the Gulf of Mexico and the Atlantic Ocean, which can exacerbate the variability of weather patterns within the area each year. The five-state area currently grows about three million acres of cotton.

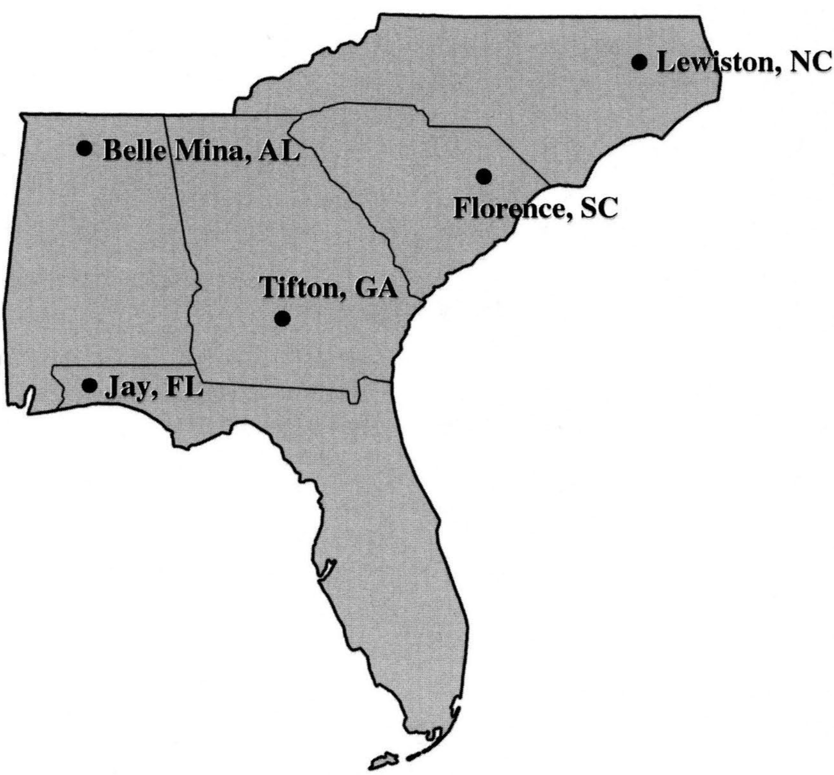

Figure 1. Southeast cotton harvest-aid study locations.

ENVIRONMENTAL CONSIDERATIONS

Weather during the defoliation season in the Southeast is never the same from one year to the next. Examining September weather patterns for temperature and rainfall from 1993 through 1996 will validate this statement (Table 1). September and early October can be very hot and dry or wet and relatively cool. Because the activity of harvest aids is dependent to a large degree on temperature, recommendations seldom are identical from one year to the next. Several soil types and topographies are represented in the Southeast. Although Southeast cotton-growing areas primarily are located on the Coastal Plain, some of the crop is grown in the Tennessee Valley region of Alabama, and some is produced in the Piedmont areas of Georgia and North Carolina. Soil types where cotton is grown range from loamy sands to clay loams.

Yearly rainfall amounts vary significantly within the Southeast. Areas along the Gulf Coast, including the Florida Panhandle and adjacent Alabama Gulf Coast, may average more than 70 inches of precipitation per year. Most areas in the Southeast average from 45 to 50 inches per year (Table 2). A large portion of the southeastern crop is grown without irrigation. The combination of differing soil types and rainfall amounts results in significant differences in crop condition at the end of the season. The same field may have knee-high cotton at the end of the season one year and chest-high cotton the next year. A harvest-aid recommendation that worked well last year may not be as successful this year. Cotton that has gone through an extended summer drought followed by late-season rainfall may exhibit significant regrowth problems.

In the 1990s, the Southeast was victimized by hurricanes with alarming regularity. Cotton growers in the Florida Panhandle, Alabama Gulf Coast region, and eastern North Carolina all incurred losses from mid- to late-season hurricanes between 1993 and 1999. The fear of crop losses from hurricanes has prompted some growers to delay planting from mid-April until mid-May in hopes of not having open bolls in the event of a late summer hurricane. Harvest-aid application, especially with ground equipment, is more difficult in hurricane-damaged cotton; the injured crop may respond differently to harvest aids than a normal crop.

Although the Southeast can experience drought conditions for much of the growing season, relative humidity seldom drops below 40 percent, even during extended dry periods. Relative humidity can influence the activity of most harvest aids, with products generally more active at higher humidities.

Table 1. September temperatures and precipitation for selected sites in the southeastern United States (1993-1996).

Location	Extreme Temperatures (min/max – degrees F)				Precipitation (in)			
	September				September			
	1993	1994	1995	1996	1993	1994	1995	1996
Charlotte, NC	46/96	51/90	48/88	53/90	0.9	1.0	2.5	3.2
Columbia, SC	46/101	52/94	52/94	50/94	3.9	3.3	5.5	2.3
Plains, GA	47/96	54/92	54/93	54/92	4.8	3.4	3.5	2.9
Tifton, GA	52/92	56/89	54/93	55/92	3.9	3.9	0.6	4.0
Belle Mina, AL	43/96	44/90	48/98	46/90	5.3	4.0	7.6	8.0
Brewton, AL	43/96	45/95	50/96	54/93	8.3	3.5	2.0	5.4
Pensacola, FL	53/96	55/94	61/97	57/92	7.2	6.0	5.2	9.7

Source: Agricultural Weather Information Service, 1735 E. University Dr., Auburn, AL 36831-3247.

Table 2. Thirty-year (1961-1990) average temperatures and precipitation for selected locations in the southeastern United States.

Location	September			October			Yearly
	min (F)	max (F)	pcp[1] (in)	min (F)	max (F)	pcp[1] (in)	pcp[1] (in)
Hamlet, NC	60	85	3.6	47	75	3.7	48
Lewiston, NC	58	82	3.8	46	73	3.0	47
Lumberton, NC	60	84	3.9	46	75	3.0	47
Darlington, SC	62	86	3.5	51	77	2.9	47
Manning, SC	61	87	3.5	48	78	2.6	46
McColl, SC	63	85	3.5	51	76	2.8	44
Cordele, GA	65	88	3.0	53	80	1.8	45
Tifton, GA	66	87	3.0	55	79	2.1	48
Waynesboro, GA	61	86	3.0	49	77	3.0	45
Belle Mina, AL	60	83	3.6	47	73	3.2	55
Brewton, AL	63	88	4.5	50	79	3.1	65
Marion Jct., AL	63	86	3.5	50	77	2.8	54
Pensacola, FL	70	86	5.3	59	79	4.2	62

Source: Agricultural Weather Information Service, 1735 E. University Dr., Auburn, AL 36831-3247.
[1] pcp = precipitation.

Air temperatures during September, when a large portion of Southeast acreage is defoliated, often are in the high 80s to low 90s (degrees Fahrenheit; 27 C to 32 C). Harvest-aid activity generally is correlated with temperature a few days before and for several days after application. High temperatures often seen in the Southeast during September can cause defoliants to act much more quickly than normal, causing leaves to stick on the plant rather than dropping. For this reason, lower rates of defoliants often are used in periods of high temperatures. Conversely, when air temperatures drop into the 50s at night and 70s during the day (degrees Fahrenheit; 10 C to 21 C), harvest-aid activity decreases significantly. Higher rates are used under these cooler conditions, and a longer time from application until picking should be anticipated.

STANDARD AND RECOMMENDED PRACTICES

Several cotton varieties are used in different tillage systems throughout the Southeast. Most years, planting dates vary from early April to mid June. Tillage systems ranging from conventional to strict no-till are used, and cotton is grown in various row spacings. Most growers would like a once-over harvest, which usually requires the use of boll-opening products. However, the use of boll-opening products often will depend on a farmer's picker capacity, crop potential, and other economic factors. Thus, no two growers use exactly the same cultural practices. Cotton planted on the same day in adjacent fields may vary significantly in the way it grows and the treatments required to terminate the crop at the end of the season.

University workers and private consultants, as well as agricultural chemical distributors, have offered Southeastern growers cotton harvest-aid recommendations and advice for several years. Until recently, only a handful of products were available for use as harvest aids – primarily Folex®/Def®, Dropp®, Harvade®, and Prep™ (ethephon). Each product has advantages and disadvantages, depending on the crop growth stage and weather during treatment.

Because of the unpredictable nature of growing conditions in the Southeast, product-use recommendations have evolved into a "shotgun" philosophy: Seldom would a grower consider using a single product alone. Application rates generally can be decreased when multiple products are used in mixtures;

different types of activity can be obtained by using products in combination. For example, mixtures of Folex/Def, a poor regrowth inhibitor, with Dropp, a good regrowth inhibitor, provide acceptable defoliation, as well as regrowth inhibition. Ethephon can be added to the mix to provide boll opening; it also increases the level of defoliation obtained. Harvade with Prep is a standard mix for defoliation and boll opening, but it also provides weed desiccation, especially for morningglory. Adding Dropp to this mix will enhance regrowth inhibition. Two- and three-way mixtures are the norm, not the exception.

Most growers would like to make only one application of a harvest aid and then pick; but, in many cases, the best job is obtained with two applications, especially on tall, rank cotton.

Economics plays an important role in the selection of harvest-aid treatments: Any treatment should be evaluated for cost effectiveness as well as for physical activity (something that often is easier to say than to do). The high cost of running a picker over the field has caused many growers to seek treatments that will enable a once-over harvest.

SUMMARY OF RESULTS

During a five-year period, specific Southeast treatments (Table 3) and seven core treatments were applied by the Defoliation Work Group during September (in most cases). Temperatures were warm for the most part; therefore, the activity of the treatments should be considered optimal. Prep + Dropp + Folex, Dropp + Folex, and Harvade + Dropp + crop oil concentrate (COC) were applied in all five years of the study. Quick Pick® + Prep and Quick Pick + Dropp were applied for the first three years of the study (1992-1994), and Prep alone and Finish were applied the last two years of the study (1995 and 1996). Therefore, averages from the last four regional treatments cannot be directly compared to the first three regional treatments or to the core treatments, because they were not tested all five years. Data from Southeast regional treatments containing Quick Pick, Prep alone, and Finish will be discussed, but no direct comparisons with the other regional treatments or core treatments will be made.

FIVE-YEAR REGIONAL AVERAGES

Prep + Dropp + Folex/Def is a treatment widely used in the Southeast (Table 3). This treatment was chosen because it generally provides defoliation, boll opening, and regrowth control in one mixture. Dropp + Folex/Def is another combination often used in our region when boll opening is not needed. Harvade + Dropp with crop oil concentrate was the third regional treatment applied all five years.

Performance Index (PI) is an overall evaluation of the effectiveness of a treatment, including defoliation, boll opening, regrowth, desiccation, and leaf sticking (Anonymous, 1999). PI at 7 days after treatment (DAT) was greater than 78 for Harvade + Prep + Agri-Dex®, Folex + Prep, and Prep + Dropp + Folex (Table 4). PI at 14 DAT was higher than 84 for Folex + Prep, Dropp + Prep, and Prep + Dropp + Folex. All other PIs were less than 82 for this rating period. The addition of Prep tended to increase PI ratings at both 7 DAT and 14 DAT. Combinations also provided generally higher PI ratings than any product applied alone.

Table 3. Southeast regional harvest-aid treatments.

Trt No.	Treatment	Rate Per Acre	Years Studied
8	Prep™ + Dropp® + Folex®	1.33 pt 0.1 lb 1 pt	1992-1996
9	Dropp + Folex	0.125 lb 0.75 pt	1992-1996
10	Harvade® + Dropp + COC[1]	6.5 fl oz 0.125 lb 1 pt	1992-1996
11	Quick Pick® + Prep	1.3 pt 1.33 pt	1992-1994
12	Quick Pick + Dropp	1.3 pt 0.125 lb	1992-1994
13	Prep	1.33 pt	1995, 1996
14	Finish®	2 pt	1995, 1996

Source: Anonymous, 1999.
[1]COC = crop oil concentrate.

Table 4. Influence of harvest-aid treatments on performance, defoliation, and desiccation at Southeast test sites (1992-1996).

Treatment Description	Performance Index[1]		% Defoliation		% Desiccation	
	7 DAT	14 DAT	7 DAT	14 DAT	7 DAT	14 DAT
Untreated Check	31.9	38.7	36.0	47.8	1.6	3.1
Folex®	70.1	75.4	66.2	77.3	15.5	11.6
Dropp®	62.2	74.6	57.6	71.7	5.5	8.7
Harvade® + Agri-Dex®	73.8	77.4	68.9	79.6	18.9	13.0
Harvade + Prep™ + Agri-Dex	78.5	80.2	72.9	82.6	15.4	12.2
Folex + Prep	79.8	84.2	75.0	85.2	15.8	13.6
Dropp + Prep	76.1	84.4	70.2	83.3	7.5	10.0
Prep + Dropp + Folex	79.6	87.6	73.8	88.1	18.1	16.4
Dropp + Folex	72.3	81.7	65.9	79.1	10.4	13.0
Harvade + Dropp + Agri-Dex	75.3	80.9	69.4	80.7	18.0	12.1
LSD ($p<0.05$)	9.9	10.3	6.8	8.5	10.8	5.3

Source: Anonymous, 1999.

[1] Performance Index is an overall evaluation of the effectiveness of a treatment, including defoliation, boll opening, regrowth, desiccation, and leaf sticking, on a 0 to 100 scale.

Defoliation closely paralleled the Performance Indices, with the highest rating given to the three-way mixture of Prep + Dropp + Folex (73.8 at 7 DAT and 88.1 at 14 DAT). Although this was not significantly different from several other treatments, it was higher than three of the core treatments and the Dropp + Folex regional treatment.

Desiccation was lowest at both 7 DAT and 14 DAT for the Dropp alone and Dropp + Prep core treatments. The highest desiccation rates generally were observed for treatments containing Harvade and the Prep + Dropp + Folex treatment, although no desiccation ratings above 19 percent were observed.

Boll opening – The Dropp + Prep regional treatment showed a numerically higher percent open bolls at 7 DAT than all other treatments, but it was not significantly higher than other treatments containing Prep (Table 5). Treatments containing Prep generally provided four to five percent more open bolls than those without Prep at 7 DAT. By 14 DAT, all treatments containing Prep were approximately 89 to 90 percent open, five to 11 percent higher than those treatments without Prep.

Terminal regrowth was significantly lower ($p<0.05$) for the Prep + Dropp + Folex treatment (19.7 percent) than all other treatments except Dropp + Prep, Dropp + Folex, and Dropp alone. Treatments containing Dropp generally had lower terminal regrowth than those without Dropp. Basal regrowth was higher with all treatments than terminal regrowth; although there were differences, all treatments had basal regrowth of 53 percent and higher.

Seed cotton and lint yields were statistically similar for all treatments (Table 6). Percent lint varied between 38.8 and 39.1. Harvade + Prep + Agri-Dex, Folex + Prep, Dropp + Prep, and Prep + Dropp + Folex all provided lint yields of more than 1000 pounds per acre. Gin turnout was similar for most treatments, varying from 36.3 to 36.7 percent.

TWO- AND THREE-YEAR REGIONAL AVERAGES

Additional Southeast regional treatments that were not tested for the entire five-year period include Quick Pick + Prep, Quick Pick + Dropp, Prep alone, and Finish (Table 3). Because these treatments were not tested all five years, the averages for yield, gin turnout, and percent lint cannot be compared fairly to the core treatments or to the three regional treatments tested all five years. Two- and three-year averages for overall performance, defoliation, desiccation, open bolls, and regrowth associated with the additional regional treatments are presented in tables 7 and 8.

Quick Pick + Dropp provided good overall performance and defoliation in the three years this mixture was tested (Table 7). Desiccation was no greater numerically than with the other regional or core treatments. Prep alone did not provide adequate defoliation or overall performance. Finish provided good defoliation and performance as a stand-alone treatment during the two years it was tested. The percentage of open bolls with the Finish treatment was numerically equal to that of core treatments containing Prep (Table 8). Terminal regrowth ratings for Quick Pick and Finish treatments were numerically equal to the three-way regional mix of Prep + Dropp + Folex.

SUMMARY

The three-way regional harvest-aid mixture of Prep + Dropp + Folex/Def performed well across the Southeast over the five-year period of our study. Folex/Def + Prep and Harvade + Prep + Agri-Dex also performed well. Addition of Prep tended to increase overall performance and defoliation. Combinations of harvest aids generally performed better than single products alone. Finish performed well as a stand-alone product during the two years in which it was tested.

Table 5. Influence of harvest-aid treatments on percent open bolls, terminal regrowth, and basal regrowth at Southeast test sites (1992-1996).

Treatment Description	% Open Bolls		% Terminal Regrowth	% Basal Regrowth
	7 DAT	14 DAT	21-28 DAT	21-28 DAT
Untreated Check	65.1	75.8	80.0	64.0
Folex®	65.4	78.2	51.3	63.1
Dropp®	65.7	79.2	30.4	53.2
Harvade® + Agri-Dex®	69.7	83.1	48.4	59.0
Harvade + Prep™ + Agri-Dex	70.8	90.1	42.8	67.7
Folex + Prep	71.6	88.8	39.6	74.7
Dropp + Prep	73.7	89.9	26.6	66.6
Prep + Dropp + Folex	70.4	89.4	19.7	62.4
Dropp + Folex	66.6	82.8	32.1	58.5
Harvade + Dropp + Agri-Dex	66.5	82.2	33.9	55.2
LSD ($p<0.05$)	5.7	4.2	13.7	11.9

Source: Anonymous, 1999.

Table 6. Influence of harvest-aid treatments on seed cotton, lint yield, percent lint, and gin turnout at Southeast test sites (1992-1996).

Treatment Description	Seed Cotton (lb per acre)	Lint Yield (lb per acre)	Lint (%)	Gin Turnout (%)
Untreated Check	2504	980	38.9	36.3
Folex®	2500	985	39.0	36.6
Dropp®	2516	981	38.8	36.3
Harvade® + Agri-Dex®	2495	982	38.9	36.5
Harvade + Prep™ + Agri-Dex	2617	1024	39.1	36.7
Folex + Prep	2581	1018	39.0	36.7
Dropp + Prep	2610	1020	38.9	36.6
Prep + Dropp + Folex	2635	1029	38.9	36.5
Dropp + Folex	2538	997	39.0	36.5
Harvade + Dropp + Agri-Dex	2504	989	39.1	36.7
LSD ($p<0.05$)	120	41	0.2	0.3

Source: Anonymous, 1999.

Table 7. Influence of additional regional harvest-aid treatments on performance, defoliation, and desiccation at Southeast test sites (1992-1996).

Treatment Description	Performance Index[1]		Defoliation (%)		Desiccation (%)		Years Studied
	7 DAT	14 DAT	7 DAT	14 DAT	7 DAT	14 DAT	
Untreated Check		30	36	48	2	3	
Quick Pick® + Prep™	62	81	61	79	7	13	1992-1994
Quick Pick + Dropp®	80	88	71	88	13	11	1992-1994
Prep	56	74	55	71	6	18	1995, 1996
Finish®	80	90	70	88	18	10	1995, 1996

Source: Anonymous, 1999.

[1] Performance Index is an overall evaluation of the effectiveness of a treatment, including defoliation, boll opening, regrowth, desiccation, and leaf sticking, on a 0 to 100 scale.

Table 8. Influence of additional regional harvest-aid treatments on percent open bolls, terminal regrowth, and basal regrowth at Southeast test sites (1992-1996).

Treatment Description	Open Bolls (%)		Terminal Regrowth (%)	Basal Regrowth (%)	Years Studied
	7 DAT	14 DAT	21-28 DAT	21-28 DAT	
Untreated Check	74	87	44	38	
Quick Pick® + Prep™	74	84	18	43	1992-1994
Quick Pick + Dropp®	75	88	20	48	1992-1994
Prep	80	90	40	54	1995, 1996
Finish®	79	90	19	48	1995, 1996

Source: Anonymous, 1999.

LITERATURE CITED

Anonymous. (1999). Uniform harvest aid performance and fiber quality evaluation. *MAFES Information Bulletin* (No. 358, September). Mississippi State: Office of Agricultural Communications; Division of Agriculture, Forestry, & Veterinary Medicine; Mississippi State University.

MIDSOUTH[1]

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OVERVIEW

The Midsouth cotton production region includes the states of Arkansas, Louisiana, Mississippi, Missouri, and Tennessee. This region is a major cotton-production area of the United States, as well as of the world. In 1996, Midsouth states produced 6.1 million bales of cotton, or 33 percent of U.S. production. During the years from 1992 to 1996, cotton harvested in the Midsouth ranged from a high of 4.7 million acres in 1995 to a low of 3.2 million acres in 1992.

Of the five Midsouth states, Mississippi was the highest producer at 1.9 million bales in 1996, followed by Arkansas, Louisiana, Tennessee, and Missouri. When averaged over a five-year period (1992-1996), Arkansas produced the highest yields per acre at 734 pounds per acre, followed by Mississippi (716 pounds per acre), Missouri (694 pounds per acre), Louisiana (690 pounds per acre) and Tennessee (588 pounds per acre) (Anonymous, 1997).

The Midsouth region has many advantages for cotton production because of large areas of relatively flat topography and almost unlimited water availability for irrigation, supplied by underground aquifers during dry summer months (Raney and Cooper, 1968). Cotton is almost 100 percent spindle-harvested; a very high percentage is stored in modules after harvest

[1] Members of the Midsouth team who worked on the Cotton Defoliation Work Group included Merritt Holman, Dan Reynolds, and Steve Crawford - Louisiana State University Agricultural Center, St. Joseph, Louisiana; Charles Snipes - Mississippi State University, Delta Research and Extension Center, Stoneville, Mississippi; Eric Webster and Charles Guy - University of Arkansas at Monticello; C.O. Gwathmey and R.M. Hayes - University of Tennessee, Jackson; and Dave Albers, Gene Stevens, and Bobby Phipps - Delta Research Center, Portageville, Missouri.

(Crawford, 1996). Weather risk is high, however: The production challenge of growing cotton in the Midsouth region is characterized by management of either too much moisture or not enough.

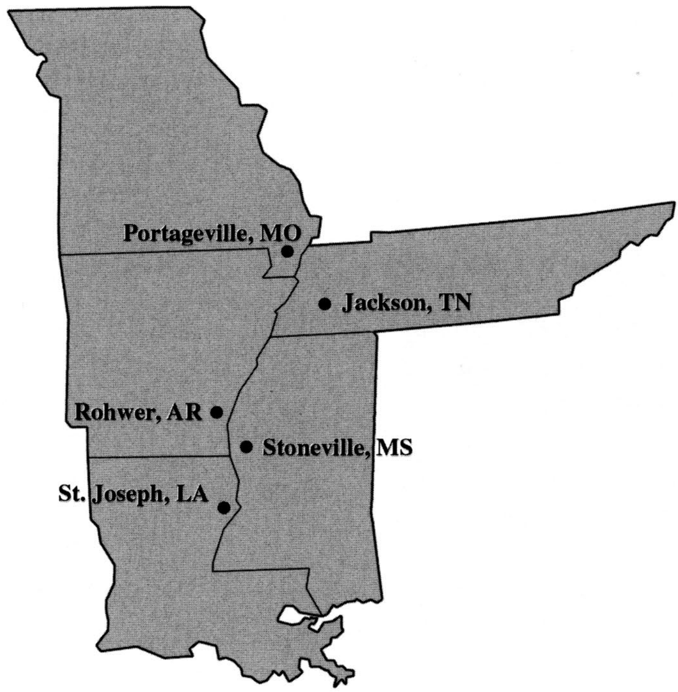

Figure 1. Midsouth cotton harvest-aid study locations.

Cotton production largely is concentrated in the alluvial valley soils and stream bottomlands along the Mississippi River flood plain. These soils are rich in all nutrients, although they can vary widely in texture, structure, depth, frequency of overflow from rivers and bayous, and drainage. The riverbank soils are sandy and well drained, but, as production moves farther from the riverbank soils, clay content increases, resulting in poor drainage (Raney and Cooper, 1968).

Yearly rainfall amounts range from approximately 48 inches in the more northern areas of the region to 56 inches per year as production moves south towards the Gulf coast (Anonymous, 1996). Although rainfall is adequate, much of the rainfall occurs during the months in which cotton is not actively growing. Data collected at Stoneville, Mississippi, over a 30-year period shows that 72 percent of the yearly rainfall occurred from September to April, whereas only 28 percent occurred during May, June, July, and August (Boykin *et al.*, 1995).

This pattern of rainfall distribution, paired with a low to inadequate soil infiltration rate, can result in a crop that is difficult to terminate or in delayed harvest during the fall. In the upper areas of the Midsouth (northeast Arkansas, west Tennessee, and Bootheel of Missouri), weather delays mean fewer days to harvest, insufficient heat to mature late-set bolls, and the threat of freeze damage to unopened bolls. In the lower region of the Midsouth, monsoon-type rains become a threat late in the season because of tropical storms originating near the Gulf Coast.

USE OF HARVEST AIDS

Management of the crop during the dry summer months and timely application of effective harvest aids to terminate the crop are critical for successful cotton production in the Midsouth. Weather patterns and condition of the crop can vary widely across the region. Therefore growers always should consult local Extension agents or crop consultants for regional recommendations. Although use of a single harvest-aid material may be more economical and may result in satisfactory defoliation, more flexibility can be obtained if a mixture is used (Snipes and Cathey, 1992). In order to reduce the risk of poor performance, tank mixtures often are recommended (Brandon *et al.*, 2000).

Folex®/Def®, Dropp® – The phosphate-type products, Folex/Def (tribufos), are effective over a broad range of environmental conditions and promote more rapid leaf drop than Dropp (thidiazuron). These materials, however, are not as effective as Dropp in removing juvenile growth (younger growth that occurs prior to defoliant application) or inhibition of regrowth (growth that occurs after defoliation). Dropp provides defoliation equal to the phosphate materials, but performs best under warm, humid conditions when the minimum daily temperature is 70 F or higher.

Harvade® (dimethipin) provides effective defoliation of mature cotton and usually desiccates mature morningglory (*Ipomoea* sp.) and prickly sida (*Sida spinosa*). Harvade is not effective in removing juvenile growth, nor is it a strong inhibitor of terminal regrowth.

Prep™/Super Boll®/Ethephon 6 (ethephon) are used to both open mature bolls and enhance defoliation. Application of ethephon increases the ethylene synthesis that occurs naturally during boll opening, as well as stimulating ethylene production in the leaf petiole where abscission occurs. Because of the complex plant processes involved with application, ethephon is rate- and temperature-sensitive.

Finish®, a combination of ethephon and cyclanilide, provides boll opening and higher defoliation than with ethephon alone.

CottonQuik® is a combination of ethephon and AMADS (1-Amino-methanamide dihydrogen tetraoxosulfate) and provides substantial defoliation and boll opening activity, as well as mild regrowth inhibition. It is, however, recommended for tankmix combinations with low rates of Dropp or Folex/Def to provide consistent defoliation activity.

Sodium chlorate, paraquat – Defoliants/desiccants such as sodium chlorate and paraquat commonly are used in areas where cotton is mechanically stripped. In the Midsouth, where the majority of cotton is mechanically picked, desiccants generally are avoided, but they are recommended as sequential treatments following defoliants to improve unacceptable first-application results or to remove juvenile growth missed by the first application. Lower rates of sodium chlorate or paraquat deliver a certain level of defoliation without excessive desiccation, whereas higher rates serve as desiccants and are more suited to stripper harvest when used as a first-application method. Paraquat usually is considered a good tankmix partner with Folex or Def during periods of cool, wet weather. Applying Dropp at proper physiological maturity, followed five to seven days later with paraquat plus sodium chlorate, has become a standard practice through much of the Midsouth.

FIVE-YEAR SUMMARY

Experiments were conducted from 1992 through 1996 at the University of Arkansas Southeast Research and Extension Center, Monticello, Arkansas; Louisiana State University Northeast Research Station, St. Joseph, Louisiana; Mississippi State University Delta Branch Experiment Station, Stoneville, Mississippi; University of Missouri-Delta Center, Portageville, Missouri; and West Tennessee Experiment Station, Jackson, Tennessee.

Refer to Table 1 for cotton variety used, soil type, and crop condition at application timing for each location. Summarized weather data from 1992 through 1996 for various locations throughout the Midsouth can be found in Table 2. Table 3 indicates that average heat unit accumulation over the five-year period was much lower in the more northern regions of the Midsouth (Tennessee and Missouri) than for locations in Mississippi, Louisiana, and Arkansas.

Table 1. Cotton variety, soil type, and percent open bolls at application for Midsouth locations.

Location	Variety	Soil Type	% Open Bolls at Application (1992–1996)
Louisiana	Deltapine® 50	Commerce Silt Loam	41-65
Mississippi	DES 119 (1992–1995) Deltapine 50 (1996)	Bosket Very Fine Sandy Loam Bosket Very Fine Sandy Loam	51-63
Missouri	Deltapine 50	Tiptonville Silt Loam	43-56
Tennessee	Deltapine 50	Loring Sandy Loam	49-52
Arkansas	Deltapine 51 (1992–1995) Deltapine 50 (1996)	Loring Sandy Loam Loring Sandy Loam	55-61

Source: Anonymous, 1999.

Table 2. September temperatures and precipitation for selected sites in the Midsouth (1992-1996).

	Average Temperatures (min/max F)					Precipitation (in)				
Location	**1992**	**1993**	**1994**	**1995**	**1996**	**1992**	**1993**	**1994**	**1995**	**1996**
Jackson, TN	60/81	58/81	57/81	59/81	60/80	4.12	4.24	2.02	1.55	7.90
Monroe, LA	64/87	62/89	62/88	62/88	62/85	4.89	2.47	1.60	1.49	3.78
Stoneville, MS	63/84	62/87	61/87	60/87	63/84	2.96	4.34	1.14	1.63	4.39
Stuttgart, AR	62/83	59/86	59/85	59/85	62/83	2.22	0.90	1.55	0.48	5.86
Sikeston, MO	58/80	58/78	60/80	60/79	60/79	3.49	6.42	3.12	2.07	4.25

Source: National Climatic Data Center, Asheville, North Carolina, 2000.

Table 3. Heat units (DD60) from treatment application to first harvest for each Midsouth location.

Location	**1992**	**1993**	**1994**	**1995**	**1996**	**5-Year Average**
Stoneville, MS	90	158	248	272	199	194
Jackson, TN	46	102	85	105	162	100
Portageville, MO	34	85	80	55	90	69
St. Joseph. LA	226	279	290	288	240	265
Rohwer, AR	172	235	144	231	232	203
Midsouth 5-Year Average						166

Source: Anonymous, 1999.

Standard agronomic practices and recommended pest management procedures were followed to ensure normal crop growth at each location. Treatments were applied with standard high-clearance ground application equipment calibrated to deliver 10 to 15 gallons per acre, depending on location. In addition to the seven core treatments used throughout the Cotton Belt, the Midsouth cooperators included eight treatments with specific regional importance (Table 4). Treatments were chosen for anticipated response within the region and were considered regional standards or treatments that were, or have been, in wide use throughout the region. These data have no bearing on performance of the same treatments in other regions.

Criteria for evaluation parameters are defined in Table 5. Performance, defoliation, desiccation, and open boll evaluations were conducted at 7 and 14 days after treatment (DAT). Terminal and basal regrowth was determined as defined in the study's protocol at 21 DAT to 28 DAT except in 1992. In 1992, a visual estimation of general regrowth was recorded. Plots were harvested 14 DAT (±2) with a spindle-type picker modified for plot harvest. Seed cotton was harvested from the two center rows of each plot and sampled for lint percent. Lint yields are reported.

Data from the Midsouth region for the years 1992-1996 were subjected to analysis of variance and means were separated by least significant difference (LSD) ($p<0.05$). Data were averaged over replications and combined across years and locations. Years and location were treated as random environmental effects. Mean comparisons for treatments were performed using appropriate environmental error components. Because of an unequal number of observations per mean, the LSD value reported is not constant for all comparisons of means. Therefore, the LSD reported is the weighted average of all LSDs calculated.

Table 4. Midsouth harvest-aid treatments (1992-1996).

Treatment Description	**Product Rate Per Acre**	**Years Tested**
Untreated Check		
Folex®	1.5 pt	1992-1996
Dropp®	0.2 lb	1992-1996
Harvade® + Agri-Dex®	8 oz + 1 pt	1992-1996
Harvade + Prep™ + Agri-Dex	6.5 oz + 1.33 pt + 1 pt	1992-1996
Folex + Prep (Low)	0.75 pt + 1.33 pt	1992-1996
Dropp + Prep	0.1 lb + 1.33 pt	1992-1996
Harvade + Dropp + Agri-Dex	6.5 oz + 0.125 lb + 1 pt	1992-1996
Dropp + Folex	0.1 lb + 0.75 pt	1992-1996
Sodium Chlorate (47% a.i.)	4.5 lb	1992-1996
Folex + Prep (High)	1 pt + 1 qt	1992-1996
Dropp + Prep	0.125 lb + 5.33 oz	1992-1996
Prep	1.33 pt	1995-1996
Finish® (EXP 31039C)	1 qt	1995-1996
Roundup® + Folex	1 qt + 0.75 pt	1995-1996

Source: Anonymous, 1999.

Table 5. Harvest-aid data collected, 1992-1996.

Term	Timing	Definition
Performance Index	7 DAT and 14 DAT	Overall harvest-aid performance on a scale of 0 to 100, where 0 equals no performance and 100 equals perfect performance. (Evaluated in 1993-1996 only.)
Defoliation (%)	7 DAT and 14 DAT	Visual estimate of percentage of leaves present at time of application that were removed by treatment.
Desiccation (%)	7 DAT and 14 DAT	Visual estimate of leaves remaining on plant that were desiccated as a result of treatment.
Open Bolls (%)	7 DAT and 14 DAT	Determined by counting total bolls and open bolls in a pre-defined 1-meter row segment.
Terminal Regrowth (%)	21-28 DAT	Determined by counting number of plants in a pre-defined 1-meter row segment with new leaves larger than 10 mm in size that had regrowth on stem terminals. (In 1992, visual estimation of overall regrowth was recorded and included with 1993-1996 data.)
Basil Regrowth (%)	21-28 DAT	Determined by counting number of plants in a 1-meter row segment with new leaves larger than 10 mm in size that had regrown from the main stem. (Evaluated in 1993-1996 only).
Lint (%)	After Harvest	From a ginned sample, lint weight divided by seed weight plus lint weight.
Gin Turnout (%)	After Harvest	From a ginned sample, lint weight divided by total sample weight.

Source: Anonymous, 1999.

REGIONAL RESULTS AND DISCUSSION

PERFORMANCE INDEX

Performance Index (PI) is an overall evaluation of the effectiveness of a treatment, including defoliation, boll opening, regrowth, desiccation, and leaf sticking. The PI of the various treatments at 7 DAT and 14 DAT ranged from 48 to 77 and 59 to 84, respectively (Table 6). At 7 DAT, application of the high-rate regime of Folex + Prep resulted in a PI of 77, which improved to 84 by 14 DAT. Other treatments that compared favorably at 7 DAT were Harvade + Prep, the low-rate regime of Folex + Prep, Dropp + Prep, and Finish.

Table 6. Influence of harvest-aid treatments on performance, defoliation, and desiccation at Midsouth test sites (1992-1996).

Treatment Description	Performance Index[1]		Defoliation (%)		Desiccation (%)	
	7 DAT	14 DAT	7 DAT	14 DAT	7 DAT	14 DAT
Untreated Check	6.9	19.9	15.2	25.2	2.5	2.6
Folex®	67.7	76.4	67.4	80.0	9.4	6.0
Dropp®	53.2	69.2	54.1	71.4	7.1	4.4
Harvade® + Agri-Dex®	56.9	70.6	58.7	73.5	11.4	5.8
Harvade + Prep™ + Agri-Dex	67.1	75.7	65.4	77.7	7.2	4.9
Folex + Prep (Low)	74.2	81.3	74.0	85.2	8.9	4.2
Dropp + Prep	67.0	81.5	64.5	81.4	7.5	4.5
Harvade + Dropp + Agri-Dex	61.6	77.8	63.3	80.1	12.3	7.2
Dropp + Folex	58.4	76.5	59.8	79.0	14.7	9.4
Sodium Chlorate	59.1	71.9	60.3	75.8	19.3	9.3
Folex + Prep (High)	76.8	84.6	75.9	87.2	10.4	5.1
Dropp + Prep (5.33 oz per acre)	58.8	74.5	58.4	75.1	5.5	4.0
Prep	48.6	59.0	49.7	62.0	3.7	3.0
Finish® (EXP 31039C)	69.8	79.3	66.6	78.9	4.1	2.9
Roundup® + Folex	60.2	72.8	59.4	75.3	12.3	7.1
ANOVA results F-test Trt (Pr>F)	15.01	18.48	17.67	19.62	7.26	6.11
LSD Trt (p<0.05)[2]	12.40	10.52	9.85	9.67	4.90	2.51

Source: Anonymous, 1999.

[1] Performance Index is an overall evaluation of the effectiveness of a treatment, including defoliation, boll opening, regrowth, desiccation, and leaf sticking, on a 0 to 100 scale.

[2] Because of an unequal number of observations per mean, the LSD value is not constant for all means comparisons. Therefore the LSD given is the weighted average of all LSDs calculated.

By 14 DAT results of several additional treatments were similar to those from the Folex + Prep (high) treatment. In addition to the treatments mentioned previously, they included Folex, Folex + Dropp, Harvade + Dropp, and Dropp + Prep (at 5.33 ounces per acre). Treatments that included Dropp tended to improve more from 7 DAT to 14 DAT than all other treatments.

In general, PI was better when combinations were used than with single treatments. Prep at 1.33 pints per acre did not provide acceptable performance. Tank mixes of Prep with defoliants typically performed better than the defoliant-only treatments.

DEFOLIATION

Generally, defoliation followed the same trend as PI (Table 6). Because defoliation considered only the percentage leaf drop, ratings for treatments were slightly higher, not reflecting other factors considered in PI ratings such as regrowth, desiccation, and boll opening.

Percent defoliation with Folex + Prep (high rate) was 76 percent at 7 DAT, but was not statistically higher than Finish, Folex + Prep (low rate), or Folex. At 14 DAT, the Folex + Prep (high) treatment had the best defoliation at 87 percent, although it was not statistically better than the low rate of Folex + Prep (85 percent), Dropp + Prep (81 percent), Harvade + Dropp (80 percent), Folex (80 percent), Dropp + Folex (79 percent), Finish (79 percent), and Harvade + Prep (78 percent). More treatments were similar at 14 DAT than at 7 DAT, indicating a difference in time to maximum defoliation for certain treatments.

DESICCATION

At 7 DAT, desiccation did not exceed 20 percent with any treatment (Table 6). Desiccation was 19 percent and 15 percent for sodium chlorate and Dropp + Folex, respectively. Other treatments with greater than 10 percent desiccation were Harvade, Harvade + Dropp, Folex + Prep (high), and Roundup + Folex. By 14 DAT, none of the treatments resulted in desiccation levels that exceeded 10 percent. However, the sodium chlorate and Dropp + Folex treatments at nine percent dessication were statistically higher than all other treatments except Harvade + Dropp and Roundup + Folex.

BOLL OPENING

For the Midsouth, boll opening at 7 DAT for all treatments containing ethephon (except Dropp + Prep at 5.33 ounces per acre) was significantly higher than the check (Table 7). Open bolls at 7 DAT averaged 5.8 percentage points higher than the check where ethephon was used and ranged from 65.6 percent in the check to 76.1 percent for Finish, which contains ethephon. At 14 DAT, the highest percentage of open bolls resulted from six treatments containing ethephon and from Harvade + Dropp (Table 7). At 14 DAT, Finish resulted in 91.3 percent open bolls, which was statistically higher than all other treatments except Dropp + Prep and Folex + Prep (high rate).

REGROWTH

Terminal regrowth was 51.8 percent in the untreated control (Table 7). Terminal regrowth was reduced by all harvest-aid treatments although several treatments reduced regrowth more than others. Roundup + Folex and Dropp + Folex were the best treatments, with only 0.6 percent and 15.1 percent terminal regrowth, respectively. Treatments with statistically higher percentages of regrowth were Folex alone, Harvade alone, Harvade + Prep, sodium chlorate, Prep alone, and Finish. As a general trend, treatments that contained Dropp had better terminal regrowth inhibition than treatments that did not contain Dropp.

The Roundup + Folex treatment resulted in excellent terminal regrowth inhibition. Roundup's mode of action is herbicidal, and it primarily is recommended for late-season weed control. However, Roundup does not have any defoliation activity; its regrowth inhibition properties generally are considered secondary to its use for late-season weed control. Use of Roundup to inhibit terminal regrowth would be desirable in areas with cooler temperatures where Dropp may perform poorly. However, without the economic benefits of weed control from the Roundup application, rates of Roundup necessary for high levels of regrowth inhibition may be cost prohibitive.

Basal regrowth was higher than terminal regrowth for all treatments (Table 7). Dropp at the full use rate and Roundup + Folex were the only treatments that reduced basal regrowth below that of the untreated check ($p<0.05$). Basal regrowth with several treatments, including Folex + Prep (both low and high rates) and Finish, actually was significantly higher than the untreated check

TREATMENTS PROTECTED QUALITY

Average seed cotton and lint yields, percent lint, and percent gin turnout for the Midsouth from 1992 through 1996 are shown in Table 8. Defoliation treatments evaluated and described in this chapter did not adversely influence yields, lint percent, or gin turnout.

Table 7. Influence of harvest-aid treatments on percent open bolls, terminal regrowth, and basal regrowth at Midsouth test sites (1992-1996).

Treatment	**Open Bolls** (%)		**Terminal Regrowth** (%)	**Basal Regrowth** (%)
Description	**7 DAT**	**14 DAT**	**21-28 DAT**	**21-28 DAT**
Untreated Check	65.5	79.3	51.8	49.2
Folex®	68.3	83.0	36.2	51.6
Dropp®	65.7	81.0	22.3	36.2
Harvade® + Agri-Dex®	67.8	81.4	32.3	42.3
Harvade + Prep™ + Agri-Dex	72.5	86.9	31.8	57.4
Folex + Prep (Low)	70.9	86.8	27.2	64.7
Dropp + Prep	72.2	88.2	17.7	54.1
Harvade + Dropp + Agri-Dex	67.8	84.5	20.1	41.2
Dropp + Folex	68.0	83.4	15.1	46.3
Sodium Chlorate	68.1	82.8	30.0	53.9
Folex + Prep (High)	72.6	88.6	23.0	64.4
Dropp + Prep (5.33 oz per acre)	67.7	82.4	24.2	46.3
Prep	72.4	87.7	36.2	59.3
Finish® (EXP 31039C)	76.1	91.3	30.7	66.5
Roundup® + Folex	66.9	82.2	0.6	21.0
ANOVA results				
F-test Trt (Pr>F)	4.48	8.60	5.72	8.93
LSD Trt ($p<0.05$)[1]	3.96	3.28	13.37	10.59

Source: Anonymous, 1999.

[1] Because of an unequal number of observations per mean, the LSD value is not constant for all means comparisons. Therefore the LSD given is the weightened average of all LSDs calculated.

Table 8. Influence of harvest-aid treatments on seed cotton, lint yield, percent lint, and gin turnout at Midsouth test sites (1992-1996).

Treatment Description	Seed Cotton (lb per acre)	Lint Yield (lb per acre)	Lint (%)	Gin Turnout (%)
Untreated Check	3016	1073	35.92	33.25
Folex®	2963	1058	36.09	33.80
Dropp®	2983	1063	36.02	33.60
Harvade® + Agri-Dex®	2994	1069	36.10	33.81
Harvade + Prep™ + Agri-Dex	3022	1077	36.01	33.57
Folex + Prep (Low)	2998	1070	36.08	33.78
Dropp + Prep	3008	1076	36.11	33.84
Harvade + Dropp + Agri-Dex	2966	1060	36.10	33.75
Dropp + Folex	2968	1058	35.91	33.53
Sodium Chlorate	2928	1041	35.93	33.45
Folex + Prep (High)	3006	1076	36.10	33.90
Dropp + Prep (5 33 oz per acre)	2941	1048	36.00	33.65
Prep	3119	1110	35.91	33.35
Finish® (EXP 31039C)	3001	1072	36.09	33.78
Roundup® + Folex	2948	1051	36.05	33.98
ANOVA results				
F-test Trt (Pr>F)	1.08	0.99	0.78	1.62
LSD Trt (p<0.05)[1]	111.54	42.72	0.27	0.47

Source: Anonymous, 1999.

[1]Because of an unequal number of observations per mean, the LSD value is not constant for all means comparisons. Therefore the LSD given is the weightened average of all LSDs calculated.

SUMMARY

Harvest-aid practices in the Midsouth region may differ widely because of variations in weather patterns as production moves from areas along the warm, humid Gulf Coast to the more northern, cooler boundaries of the Midsouth in Missouri and Tennessee. This region is exclusively picker-harvested; therefore, effective use of harvest aids to terminate the crop is crucial for successful cotton production.

Results from a five-year study conducted by Midsouth cooperators of the Cotton Defoliation Work Group indicated that overall harvest-aid performance is best when tank mixtures are used rather than single products; boll opening is enhanced by the inclusion of ethephon in the tank mixture; and terminal regrowth is reduced by the use of Dropp.

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SOUTHWEST[1]

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OVERVIEW

Southwest (Texas, Oklahoma, and a portion of northeastern New Mexico) farmers plant in excess of five million acres of cotton annually. Cotton production in the Southwest occurs in several relatively distinct areas, as illustrated in Figure 1. These areas represent a broad range of soil types, elevations, climatic conditions, irrigation capabilities, pest complexes, and cropping systems. Cotton planting typically is initiated in the Lower Rio Grande Valley in February, with harvest in July and August; in the Rolling Plains, planting occurs in late May and early June, with harvest in October and November. About 10 percent of the planted acreage is abandoned annually (mainly on the High and Rolling Plains) because of drought or other adverse weather conditions.

Year-to-year production fluctuates widely (Figure 2) because of variations in acreage planted, moisture availability, and seasonal growing conditions. Since the early 1970s, the number of active gins has declined, while the capacity of the remaining facilities has expanded. The percent of bales that are moduled has increased significantly since the module builder was introduced in 1974 (Supak, 1996).

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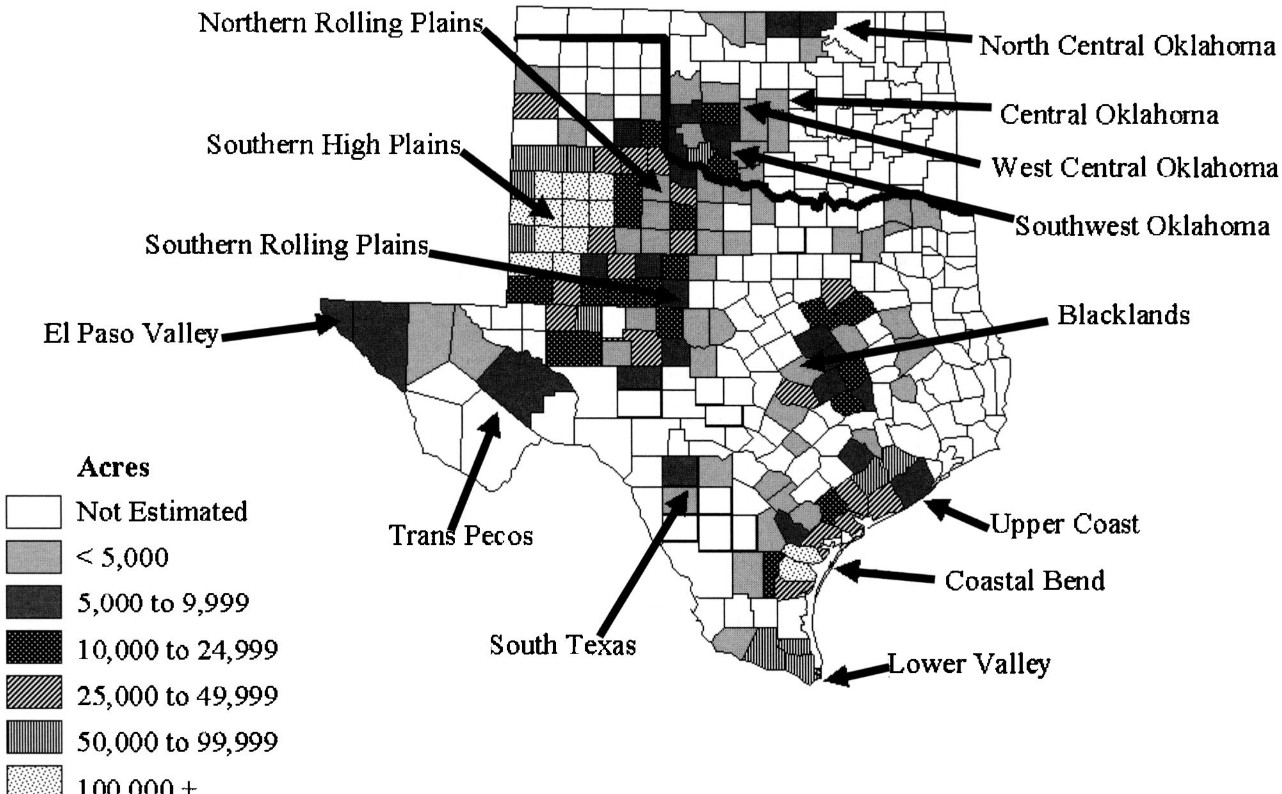
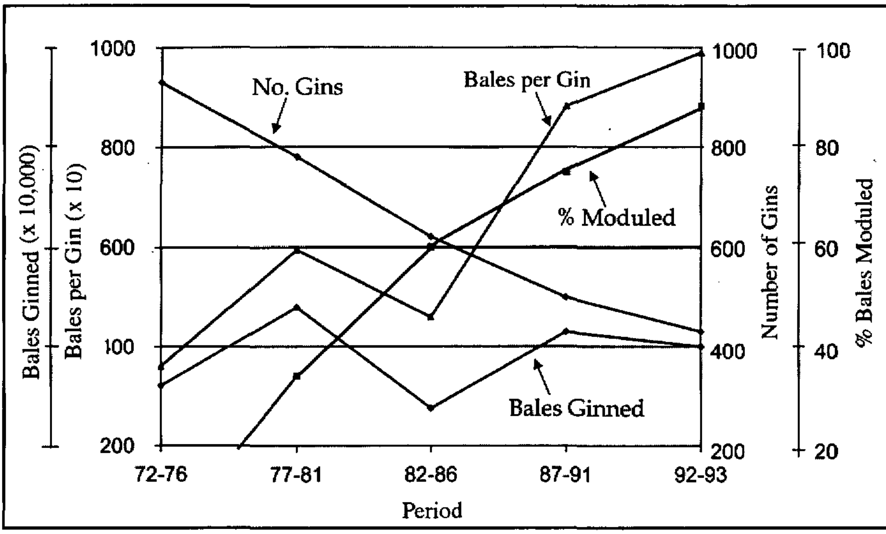
[1] Members of the Southwest team who participated in the Cotton Defoliation Work Group project included Tom Cothren, Texas A&M University at College Station; Wayne Keeling, Texas Agricultural Experiment Station at Lubbock; J.C. Banks, Oklahoma Cooperative Extension Service at Altus; and John Bremer and James Supak, Texas Agricultural Extension Service at Corpus Christi and College Station, respectively.



Source: Adapted from USDA National Agricultural Statistics Service, 2000.

Figure 1. Acres of upland cotton harvested by county in Texas and Oklahoma during 2000.



Source: Supak, 1996.

Figure 2. Cotton production and ginning trends in Texas, 1972-1993.

Early acceptance of high-volume instrument (HVI) fiber testing by Southwest growers stimulated a strong emphasis on producing and maintaining fiber quality. This led to the adoption of varieties that produce better-quality fibers and also helped expand and optimize the use of harvest aids.

Since the adoption of mechanical harvesters in the 1950s and 1960s, cotton harvest aids have been used extensively in the southern and central sections of the Southwest. But prior to the mid 1980s, growers in the High and Rolling Plains of Texas and portions of Oklahoma tended to rely as much or more on freezing temperatures (typically in early November) as on harvest aids to condition crops for mechanical harvest.

Since then, the emphasis on preservation of yield, lint and seed quality, management of insect pests, and other considerations has led to more widespread use of cotton harvest aids in the northern sections of the Southwest. Throughout the region, growers also have become more knowledgeable and conscientious about properly using and timing harvest-aid applications to minimize reductions in yield or quality and to use these products in a safe and environmentally conscientious manner.

ENVIRONMENTAL CONSIDERATIONS

Water – The primary factor limiting cotton production in the Southwest is water. Annual rainfall varies from 40 inches or more in the Upper Gulf Coast of Texas, to 15 or 20 inches on the Plains, to less than 10 inches in the Far West (Dugas, 1983). Only 35 to 40 percent of Texas cotton acreage is irrigated. Because both underground and surface water resources are limited, most irrigation water is used strictly to supplement rainfall; in drier years, crop water requirements may not be met fully, even with the combined utilization of rainfall and irrigation water.

Seasonal rainfall patterns vary substantially, but the probability of receiving precipitation at some point during the harvest season is relatively high throughout the Southwest. In the southern areas, late rains often are associated with tropical storms and hurricanes in the Gulf of Mexico. Rains disrupt harvest activities, but the storms also can cause extensive damage if they make landfall in the cotton production areas.

Temperature is another important variable that heavily influences cotton growth and development, especially in the Southwest. Heat unit (DD60) accumulations during the typical growing season range from more than 2600 in southern Texas to less than 2000 in the northern portions of Texas and Oklahoma (Dugas and Heuer, 1984). The southern and central sections have the longer growing season; but, high temperatures, coupled with dry conditions that typically occur during the bloom period, often create stress conditions that contribute to early cutout, excessive fruit shed, toughening of leaves, and high potential for regrowth should late-season rains occur. In contrast, the growing season is much shorter in the northern areas; low nighttime temperatures, which slow boll maturation, are more likely to be a concern during the latter stages of boll development.

Such variations in temperatures and crop conditions are important considerations in the selection and use of the most appropriate harvest-aid options for the area and the season. For example, Dropp® frequently is used to defoliate cotton in southern Texas (from the Rio Grande Valley to the southern Blacklands/Brazos River Valley), but rarely is used alone in the central and northern regions, where both maximum and minimum temperatures tend to be lower during the defoliation season. Results of trials conducted near College Station in 1995 show that Dropp, used alone, provided good defoliation and some regrowth suppression; the test showed no advantage from using a tank mix of Dropp + Prep™ (Table 1). In a similar test conducted at Prosper, Texas (200 miles north of College Station), Dropp alone resulted in very poor defoliation, whereas the combination of Dropp + Prep was among the better treatments seven days after application (Table 2). In contrast, Ginstar® exhibited less temperature sensitivity than other defoliants and provided levels of defoliation comparable to the best treatments in "Uniform Harvest Aid Performance and Quality Evaluation Trials" (Table 3).

CROP YIELD POTENTIAL

Potential crop yields and quality also are important considerations in the selection of harvest-aid programs in the Southwest, where yields in a given year may range from less than 0.25 bale per acre to more than 2.5 bales per acre. Because so many factors – water (rainfall and irrigation), length of growing season, seasonal growing conditions, pest pressures, and management, etc. – have a significant impact on yield potential in any given year, harvest-aid programs have to be specifically adjusted for each area and even for individual farms (Stichler *et al.*, 1995).

Harvesting cotton as soon as practical after all harvestable bolls are open minimizes the potential for weather-related deterioration of yield and quality. If properly used, defoliants, boll openers, and desiccants can prepare crops for earlier harvest with no detrimental effects on yield or quality. Defoliation removes leaves and thus can contribute to better leaf grades by reducing the trash content in the fiber, even in stripper-harvested cotton. The use of boll openers (ethephon) can accelerate opening of mature bolls and lead to earlier harvest. Frequently, a combination of treatments, including both a defoliant and a boll opener, is more effective than a single product in preparing cotton for harvest, by both increasing and accelerating the rate of boll opening and defoliation. Desiccants often are needed to dry leaves and other plant tissues to allow stripper harvesting.

The potential gains from the harvest-aid program are dependent on cost and crop yield potential as well as efficacy. Anderson (1995) illustrates the relationship between yields and harvest-aid costs in Table 4, with the premise that chemical and application costs are limited to $0.05 per pound of lint produced. His analysis shows that as much as $30 per acre could be expended

Table 1. Defoliation and regrowth suppression obtained in 1995 with core treatments at College Station, Texas.

Treatment	Rate (per acre)	Defoliation (%)		Terminal Regrowth (%)
		7 DAT	14 DAT	
Untreated Check	—	29	54	100
Folex®/Def®	1.5 pt	50	71	100
Dropp®	0.2 lb	83	87	44
Harvade® + COC	0.5 pt 1.0 pt	45	65	100
Harvade + Prep™ + COC	0.4 pt 1.3 pt 1.0 pt	59	70	100
Folex/Def + Prep	0.75 pt 1.3 pt	62	74	97
Dropp + Prep	0.1 lb 1.3 pt	71	80	91

Source: Anonymous, 1999.

Table 2. Defoliation, desiccation, and regrowth suppression obtained in 1995 with core treatments at Prosper, Texas.

Treatment[1]	Rate (per acre)	Defoliation (%)		Defoliation + Desiccation (%)	Basal Regrowth (%)
		7 DAT	14 DAT	14 DAT	21 DAT
Untreated Check	-	4	5	100	6
Folex®/Def®	1.5 pt	40	48	100	9
Dropp®	0.2 lb	9	13	96	11
Harvade® + COC	0.5 pt 1.0 pt	21	21	99	12
Harvade + Prep™ + COC	0.4 pt 1.3 pt 1.0 pt	37	35	99	13
Folex/Def + Prep	0.75 pt 1.3 pt	56	77	100	11
Dropp + Prep	0.1 lb 1.3 pt	49	61	99	12

Source: Anonymous, 1999.

[1] Followed by 2.0 pints Cyclone® at five to seven DAT.

Table 3. Defoliation and regrowth suppression obtained in 1995 with "best" core treatment and with Ginstar®.

Treatment	Rate (per acre)	Defoliation (%)		Terminal Regrowth (%)
		7 DAT	14 DAT	
Weslaco, Texas				
Dropp®+ Prep™	0.1 lb 1.3 pt	63	52	
Ginstar®	0.5 pt	78	82	
College Station, Texas				
Dropp	0.2 lb	83	87	44
Ginstar	0.5 pt	83	93	24
Prosper, Texas[1]				
Folex®+ Prep	0.75 pt 1.30 pt	56	77	0
Ginstar	0.50 pt	62	90	0
Lubbock, Texas[1]				
Folex + Prep	0.75 pt 1.30 pt	79	93	0
Ginstar	0.50 pt	67	93	0

Source: Anonymous, 1999.

[1] Followed by 2.0 pints Cyclone® at five to seven DAT.

Table 4. Harvest-aid chemical and application costs per pound of lint produced for five yield levels.

Cost ($ per acre)	Yield (lb per acre)				
	200	300	400	500	600
	¢ per lb of lint produced				
10	5.00	3.33	2.50	2.00	1.67
15	7.50	5.00	3.75	3.00	2.50
20	10.00	6.67	5.00	4.00	3.33
25	12.50	8.33	6.25	5.00	4.17
30	15.00	10.00	7.50	6.00	5.00

Source: Anderson, 1995.

in fields with yield potential of 600 pounds per acre, but only $10 per acre could be spent in fields yielding only 200 pounds per acre. In the latter case, harvest-aid options would be determined largely by the cost of achieving the level of defoliation or desiccation needed for efficient harvest and safe field storage, and less by the desire to accelerate boll opening and eliminate potential sources of fiber contaminants.

HARVEST METHODS

The Southwest is somewhat unique in that both spindle picking and stripping are used widely to harvest cotton. Data compiled by the Commodity Economics Division, ERS, USDA, shows that approximately 71 percent and 72 percent of the bales harvested in Texas and Oklahoma, respectively, during the period 1993-1994 were stripper-harvested (Anonymous, 1996).

Stripper harvesters have several advantages, including lower equipment purchase and operating costs, higher harvesting capacity, and the capability to efficiently harvest short-stature, low-yielding crops. A disadvantage is that stripping is a once-over harvest method that collects more trash (leaves, burs, and fragments of limbs) than spindle picking. Consequently, stripped cotton requires more cleaning at the gin, entails higher ginning costs, and frequently results in reduced leaf grades because of contaminants embedded in the lint. Additionally, preparation of cotton for once-over stripper harvesting requires that all harvestable bolls are open and that the crop is desiccated either with chemicals or by a killing freeze. This ensures that the moisture content of stripped cotton is less than 12 percent, minimizing the possibility of heating during field storage in modules or trailers.

In contrast, the primary requirements for preparing cotton for spindle picking are boll opening and defoliation. Boll openers may be used in conjunction with defoliants to prepare cotton for once-over picker harvest.

Often the factors that determine choice of harvest method include crop yield potential, harvest-aid costs, seasonal conditions, plant size and condition, acres to be harvested, and equipment availability. Of these, yield potential may be the most important. Results of field trials indicate that spindle picking becomes an economically viable option when yields reach or exceed approximately one bale per acre (Anderson, 1995).

COMMON HARVEST-AID PRACTICES

Selection of the most effective harvest-aid treatment(s) varies somewhat by year, by region, and even by community. Growers and consultants are encouraged to review the most current harvest-aid guidelines developed by local Extension and research personnel and by industry to identify treatments, especially those involving tankmix combinations, recommended for specific areas. The following general recommendations are based on harvest method and apply to the Southwest region.

STRIPPER HARVEST

Producers typically have three basic options to consider in preparing cotton for stripper harvesting. These include: 1) use of only a desiccant (currently, paraquat is the primary material registered for this use) as a single treatment or in sequential applications; 2) application of a defoliant (or tankmix combination of two or more defoliants) followed by a desiccant; or, 3) application of a defoliant + boll opener tankmix combination followed by a desiccant.

The single application of a desiccant (paraquat) is most applicable for use on short-stature cotton with limited yield potential. Typically, this treatment results in very little defoliation (20 percent or less) but provides adequate desiccation of leaves and other plant tissues. The use of sequential applications of the desiccant (e.g., 0.125 pound a.i. per acre of paraquat at 60 to 70 percent open bolls, followed by 0.375 pound a.i. per acre five to seven days later) is a lower-cost alternative to option 2, above, and primarily is applicable in the northern regions of the Southwest. The low rate of paraquat in the sequential treatment results in some defoliation (usually 40 to 60 percent) and conditions the crop for more complete desiccation with the second treatment.

The desiccating effects of paraquat are the result of a light-activated reaction that produces superoxide radicals that rupture plant cell membranes. Limited paraquat penetration into stressed, toughened leaves under sunny conditions results in rapid death of tissues in the immediate vicinity of droplet deposition, eliminating potential for further translocation. Studies have confirmed that late-afternoon and early-evening applications result in better desiccation than morning or midday treatments (Bremer, 1995; Biles and Cothren, 1996).

With option 2, defoliation prior to desiccation removes most leaves and also conditions the crop for more complete desiccation with the second (desiccant) treatment. Removal of most leaves reduces the amount of trash in the harvested cotton, which can contribute to better leaf and, possibly, color grades. Tank-mixing a boll opener with the defoliant (option 3) hastens the opening of mature bolls and may further improve defoliation.

In situations where the treatments (options 2 and 3) remove 95 percent or more of the leaves, it may be possible to strip the crop without applying the desiccant treatment. Also, in the northern sections, only the initial treatment (no desiccant) may be applied and used as a means of conditioning the crop for a killing freeze. The use of harvest aids prior to a hard freeze can speed defoliation, allow more mature (or nearly mature) bolls to open, and, ultimately, result in earlier harvest.

PICKER HARVEST

In most instances, a single application of a proven defoliant or defoliant tank-mix combination is sufficient to prepare cotton for spindle picking. Fields with tall, rank cotton may warrant sequential applications of defoliants to induce sufficient leaf shedding to minimize green leaf fragments and lint staining during harvest. Preparation of cotton for once-over harvest with pickers also can be accomplished with a single tankmix application of a defoliant + boll opener, especially in high-yielding cotton and in areas where cooler temperatures occur at the time of defoliation. In fields with tall, often-lodged plants and dense foliage, a defoliation treatment followed by subsequent application of a boll opener + defoliant may be needed to prepare cotton for once-over picking.

Typically, desiccants are not used in preparing cotton for spindle-type harvest. Occasionally, however, low rates of paraquat are mixed with a defoliant to enhance leaf shedding. Full labeled rates of paraquat alone or in combination with other harvest aids also may be used to desiccate weeds and remaining cotton leaves that otherwise would interfere with harvesting operations.

REGROWTH CONTROL

Control of regrowth may be a consideration in fields intended for either picker or stripper harvest, especially in the southern regions of Texas. Some defoliants (e.g., Dropp, Ginstar) will suppress regrowth, but only for limited periods (two weeks or less in South Texas). Landivar *et al.* (1994) have shown that relatively low rates of Roundup® (0.375 to 0.5 pound a.i. per acre) applied at approximately 40 percent open bolls to conventional (not Roundup Ready®) cotton provided extended regrowth control (55 days or more) with no adverse effects on yield or quality. Applying Roundup in combination with defoliants also can be effective in suppressing regrowth, but requires higher rates of the herbicide and does not impart defoliation activity. This combination treatment is less effective in heavily drought-stressed cotton and can result in decreased levels of defoliation (compared to a defoliant-only treatment).

REGIONAL TRIALS

Uniform cotton harvest-aid field trails were conducted at five locations in the Southwest region during the period 1992-1996 (Figure 3). Test plots at Weslaco, Texas (Rio Grande Valley), and College Station, Texas (Brazos River Valley), were picker-harvested, whereas those located at Prosper, Texas (northern Blacklands), Lubbock, Texas (Southern High Plains), and Altus, Oklahoma (Southwest Oklahoma), were stripper-harvested. Standard production

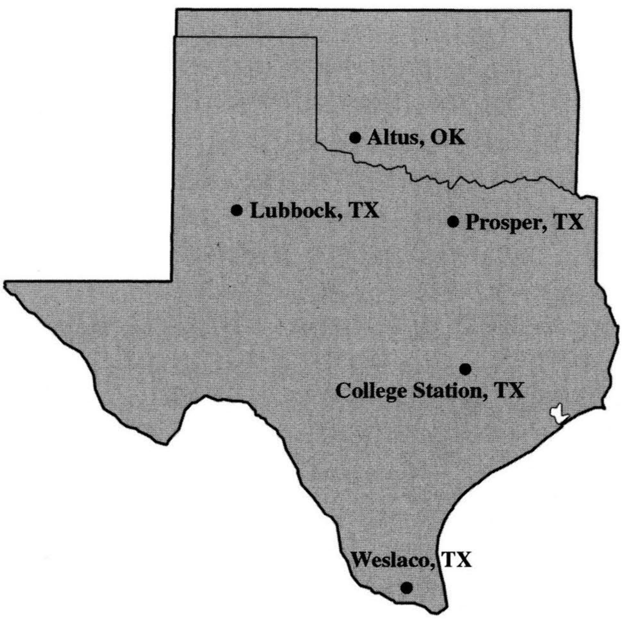


Figure 3. Southwest cotton harvest-aid study locations.

and pest management practices were used at all test locations. Cotton at Prosper was grown under dryland conditions, whereas irrigation was used at the other locations. Common treatments (which included seven core and five to seven regional standards) and standardized application timings and rating procedures were used at all locations. Geographically, the picker tests were located in the southern end of the Southwest region, whereas the stripper trials were more in the northern sections. In the stripper tests, all plots were treated with a desiccant (paraquat) five to seven days before harvest; only designated plots were desiccated at the picker test sites.

Core treatments remained constant, while the regional standards (Table 5) were modified three times during the five-year study. The regional treatments noted in Table 5 were those used during the last two years of the study. A

Table 5. Core and regional harvest-aid treatments used in the stripper-harvested trials in the Southwest region, 1992-1996.[1]

Core Treatments:
Untreated Check[2]
Folex®/Def®(1.5 pt per acre)[2]
Dropp® (0.2 lb per acre)[2]
Harvade® + Agri-Dex® (0.5 + 1.0 pt per acre)[2]
Harvade + Agri-Dex + Prep™(0.4 + 1.0 + 1.33 pt per acre)[2]
Folex/Def + Prep (0.75 + 1.33 pt per acre)[2]
Dropp + Prep (0.1 lb + 1.33 pt per acre)[2]
Regional Treatments:
Cyclone® + NIS (0.5 pt per acre + 0.25% v/v) followed by Cyclone + NIS (0.5 pt per acre + 0.25% v/v)
Folex/Def or Dropp (1.5 pt per acre or 0.2 lb per acre followed by glufosinate-ammonium (0.5 lb a.i. per acre)[2]
Ginstar® (0.5 pt per acre)[2]
Folex/Def + Dropp (0.75 pt + 0.1 lb per acre)[2]
Folex/Def + Roundup® (1.5 + 1.0 pt per acre)[2]
Prep (1.33 pt per acre)[2]
Ginstar + Prep (0.4 pt + 1.33 pt per acre)[2]

Source: Anonymous, 1999.

[1] Regional standard treatments varied slightly among the five test locations. These variations are noted in the summary report (Anonymous, 1999).

[2] In stripper-harvest tests, all plots were treated with Cyclone® + NIS (non-ionic surfactant) (2.0 pints per acre + 0.25% v/v) five to seven days after the initial harvest-aid application.

regional summary for the picker and stripper trials follows. The harvest-aid efficacy, fiber quality, and yield data collected during the course of this study are too extensive to be included in this chapter, but are contained in the overall project summary report (Anonymous, 1999). In addition, the harvest-aid evaluation results from these and other trials have been extensively used to develop cotton harvest-aid recommendations for specific areas within the Southwest region and are, for the most part, updated annually (e.g., Banks and Kelley, 1998; Boman et al., 1999; Bremer, 1997; Lemon et al., 1999).

PICKER TRIALS

Of the seven core treatments, Dropp was the most consistent and received the highest Performance Index (PI) ratings at 7 days after treatment (DAT) at both picker-harvested test locations. The average PI ratings consistently were above 80 and 70 at College Station and Weslaco, respectively. At College Station, PI ratings also were above 80 for Ginstar and for all treatments containing Dropp in tank mixes with other products. At Weslaco, Ginstar and Ginstar tank-mixed with Prep were the best treatments based on PI scores, which typically were 70 or higher.

At 14 DAT, Dropp had the highest PI ratings of all the core treatments at both College Station and Weslaco (multiyear averages of 90 and 81, respectively). With the exception of Prep, all regional treatments averaged PI ratings of 85 or higher at College Station. A similar trend was observed at Weslaco, with average PI ratings of 70 or higher for the better treatments. While acceptable PI ratings were recorded for the treatments that included Cyclone® (paraquat), as much as 15 percent desiccation was noted in those plots at both locations.

At College Station, Dropp was the only core treatment to provide defoliation ratings above 70 percent in all five years at seven DAT. Dropp also was the best defoliation treatment at Weslaco, with an average rating of 68 percent; but, on a year-by-year basis, defoliation ranged from 46 percent in 1995 to 94 percent in 1994. At both College Station and Weslaco, Ginstar was the only regional standard treatment that resulted in 85 percent or more defoliation at seven DAT.

Dropp and Dropp + Prep, with defoliation ratings of 75 percent and 74 percent, respectively, were the best core defoliation treatments in Weslaco at 14 DAT. In contrast, at College Station, all core treatments received defoliation ratings between 82 and 89 percent. In the regional standard treatments, the follow-up desiccant application at five to seven days after the initial treatment resulted in defoliation levels ranging from 84 to 95 percent at both locations.

Overall, tank mixes that included defoliants + Prep did not consistently improve boll opening over that achieved with the defoliant-only treatment at 7 DAT or 14 DAT at either location. None of the treatments had an impact on lint yield or fiber quality at either location.

STRIPPER TRIALS

Of the seven core treatments evaluated, Folex® generally was more effective than Dropp with regard to overall Performance Index and percent defoliation at seven DAT at all locations. At Lubbock and Altus, the PI for the Harvade® treatment was approximately the same as that of Folex, whereas, at Prosper, Harvade and Dropp received lower PI and defoliation ratings than Folex. The Folex + Dropp treatment was consistently more effective than either defoliant used alone at all locations. Applying Prep in combination with defoliants (Dropp, Folex, or Harvade) improved PI and defoliation ratings over those obtained with only the defoliants. The Folex + Prep combination was the best overall core treatment at Prosper and Lubbock, whereas all three defoliant + Prep treatments received similar PI and defoliation ratings in Oklahoma. The use of Prep in combination with the respective defoliants tended to increase boll opening at seven DAT, but the improvements generally were not statistically significant.

At 14 DAT, ratings reflected the effect of the defoliants + boll opener and of the desiccant (Cyclone) that was applied five to seven days after the initial treatment. Among the seven core treatments, the highest PIs and best defoliation ratings at all locations were achieved with the defoliant + Prep combinations. Of the regional standards, Ginstar and Ginstar + Prep received the highest PI and percent defoliation ratings during the 1995-1996 testing period (the only years the treatments were included in the study). Overall, Ginstar tended to be more effective than the other defoliants; Prep combined with Ginstar did not further improve PI ratings, percent defoliation, or percent boll opening. The Folex + Dropp combination treatment provided better defoliation than either product used alone at all locations. At 14 DAT, split applications of Cyclone resulted in 40 percent and 80 percent defoliation, whereas single application (0.5 pound a.i.

per acre) resulted in only 6 percent and 30 percent defoliation at Prosper and Lubbock, respectively. The split application of Cyclone also provided better desiccation than the single (0.5 pound a.i. per acre) application.

Terminal regrowth rarely exceeded 20 percent and was not regarded as a serious problem in most years. In contrast, basal regrowth was an every-year occurrence and ranged from 50 to 100 percent in most test plots by 21 DAT. Plants treated by Prep, defoliant + Prep, and Cyclone followed by Cyclone consistently were among the first to develop new leaves and generally had the most extensive new foliage. A tankmix treatment of defoliant + Roundup followed by Cyclone was the most effective in suppressing both basal and terminal regrowth. Also, treatments that contained Dropp (alone or in combination with Prep or another defoliant) provided some suppression of terminal regrowth. Ginstar was notably less consistent than Dropp in suppressing development of new leaves, but generally was more effective than the other defoliants.

Harvest-aid treatments had little or no effect on yield or lint quality at any location in any given year even though pronounced differences in overall performance, defoliation, and desiccation ratings were noted among treatments. On occasion (usually in conjunction with prolonged wet conditions during the crop termination-harvest period), poor grades and high levels of leaf trash were observed in all lint samples from a given test location. Leaf grade and trash parameters exhibited surprisingly little variation, even though there were pronounced differences in PI and in defoliation and desiccation ratings from treatment to treatment.

Although plots were machine-harvested to simulate farm conditions, the harvested cotton was loosely packed and stored in paper, cotton, or burlap bags; thus, these conditions were not representative of those inside trailers or tightly packed modules. Subsequent ginning and lint cleaning undoubtedly helped normalize variations in trash content (just as occurs at commercial gins). Nevertheless, the failure of the varied harvest treatments to affect leaf grades and trash content in the lint, coupled with little variation in fiber quality parameters at a given location (but often with considerable variation among locations), suggests that environmental conditions have a major influence on how much foreign matter ultimately ends up in the lint.

These observations suggest that good desiccation is by far more critical than defoliation in preparing cotton for stripper harvesting.

SUMMARY

The primary reason for using harvest aids is to increase grower profits. This objective is achieved by enabling growers to harvest their crops in a timely manner, which allows them to better schedule harvest equipment and labor. This also improves harvesting and ginning efficiencies and reduces the risk of heat and microbial damage to fiber and seed during field storage. Producers have a range of harvest-aid options. The most appropriate, cost-effective option for each producer's operation largely will be determined by the production region, environmental conditions, crop yield potential, and harvest method. Additional data are needed to establish how much defoliation is economically justifiable, especially in stripper areas. Results from the Uniform Harvest Aid Performance and Fiber Quality Evaluation trials in the Southwest region (Anonymous, 1999) indicate that defoliation may have a relatively small effect on leaf grades and HVI trash content.

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FAR WEST[1]

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OVERVIEW

The Far West Region of the United States Cotton Belt includes California, Arizona, and portions of New Mexico. In New Mexico, the production of Pima cotton and of the Acala™ varieties developed for that state are concentrated in the El Paso Valley. The predominant portion (70 percent) of Arizona's production is located in Maricopa and Pinal Counties, with additional acreage in the Parker, Yuma, and Safford areas. California's 1995 cotton production – 1.3 million acres – predominately was concentrated in six counties of the southern San Joaquin Valley. This acreage represents 97 percent of California's total production. The other areas of production are Imperial and Riverside Counties and, more recently, acreage planted in the Sacramento Valley (Anonymous, 1995). In addition, a significant percentage of U.S. Pima is produced in this two-state region.

[1] Members of the Far West team who participated in the Cotton Defoliation Work Group project were from the University of California Cooperative Extension Service, including Gerardo Banuelos, Brett Allen, and Steve Wright, Tulare County; Joe Padilla and Bruce Roberts, Kings County; and Tome Martin-Duvall and Ron Vargas, Madera County.

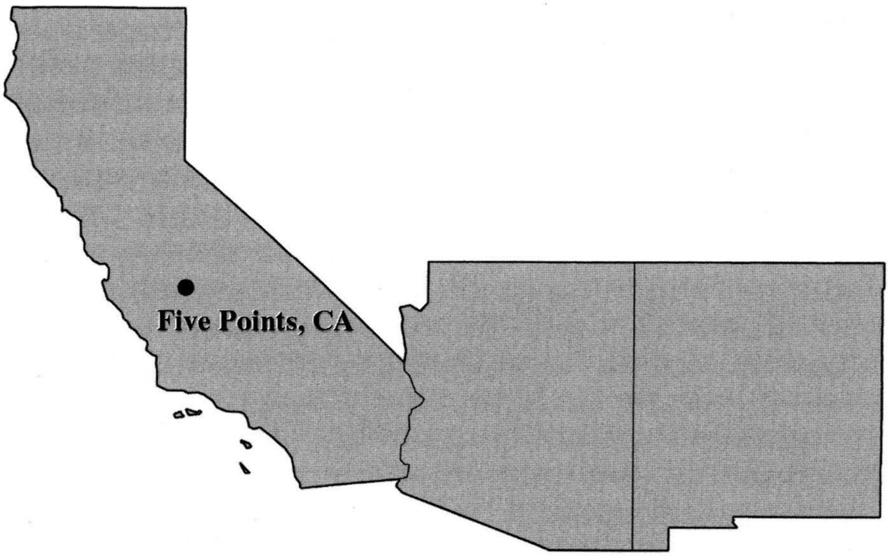

Figure 1. Far West cotton harvest-aid study location.

The Far West's cotton production is characterized by a hot, arid growing season; the entire acreage is irrigated. This lends some advantage in preparing the crop for defoliation because of greater control of soil moisture and nitrogen by terminating irrigation. The low desert areas of both Arizona and California experience a monsoon period with elevated humidity during late July, extending through August. Following this humid period, weather in both states is ideal for defoliation. Temperatures usually are above 80 F well into October.

Harvest of the Far West crop is performed with spindle-type harvesters (Roberts *et al.*, 1996). Therefore, defoliation practices play an important pre-harvest role. Although similar materials are used in both Arizona and California, recommended rates differ in each area. Combinations of materials and application methods vary from farm to farm.

Normal defoliation usually requires two applications: The first may be a treatment of ethephon or ethephon in combination with a phosphate defoliant (Folex®/Def®). Sodium chlorate is used extensively for cleanup applications. Additives like paraquat and cacodylic acid are included to enhance the desiccation of remaining leaves. Ginstar® provided the highest percent defoliation from a single application. (Wright *et al.*, 2000; Hutmacher *et al.*, 2001).

The trends in harvesting, storage, and ginning of seed cotton described in other regions are very evident in the Far West. The shift to using modules for field storage and seed cotton handling has increased. More than 80 percent of the entire region's harvested cotton is moduled (Glade *et al.*, 1995). The convenience and economics of this handling system also have led to many changes at the processing level.

The number of active gins in both Arizona and California has decreased by 40 percent during the past 10 years. Although acreage has remained relatively constant, the decreasing number of active gins has been offset by a 40-percent increase in ginning capacity during this same period (Glade *et al.*, 1995).

The current harvesting and handling system using modules has allowed cotton growers to take advantage of other production changes that have led to greater benefits from earliness and helped preserve fiber quality. This system also places greater emphasis on pre-harvest preparation and timely harvest of well-defoliated cotton for safe storage and handling (Curley *et al.*, 1988).

The results of a standard set of treatments in the San Joaquin Valley clearly indicate that rate adjustments are necessary for adequate defoliation. Treatments that produced 80 percent or greater leaf drop in other regions had only minor effect (30 percent or less) in the San Joaquin Valley. These same treatments produced acceptable defoliation in the desert areas of California and Arizona.

One cause of this difference is the *Verticilium* wilt-tolerant Acala varieties grown in the San Joaquin Valley. Results of a "variety by defoliation" trial conducted at the University of California West Side Research and Extension Center are presented in Table 1. In this comparison, the higher-wilt-tolerant Acala varieties were much less affected by two applications of sodium chlorate than less-wilt-tolerant varieties.

ENVIRONMENTAL CONSIDERATIONS

Western pre-harvest and harvest practices have been criticized for their impact on air quality. The production areas of this region are located in fertile valleys that are experiencing significant urban growth. These valleys ("closed air" basins) are becoming more aware of the various activities that affect air quality; environmental and regulatory interest is increasing.

Besides urban encroachment, the cropping rotations within this region offer an additional challenge in managing cotton defoliation. Late-summer and fall vegetables are important alternate crops that are actively growing when cotton is being defoliated. Nontarget drift of cotton defoliants onto an adjacent field of leafy vegetables can be costly.

An important objective for cotton defoliation in the Far West is to continue to emphasize crop monitoring for effective late-season management that enhances defoliation. The crop requires good water and nitrogen management from cutout to termination and defoliation. Producers must continue screening for new materials or combinations that improve crop defoliation and harvestability. From this effort, environmentally acceptable practices will be available to assist western cotton growers to harvest, store, and deliver to the gin the highest-quality seed cotton.

Table 1. Defoliation comparison for Acala™ varieties – 1992.[1]

Variety	*Verticillium* wilt rating	% Defoliation (14 DAT)
Maxxa	High	43
GC-510	High	25
DP6166	High	38
SJ-2	Mod	60
DP6100	Low	78
DP90[2]	Low	90

Source: Roberts, 1996.
[1] Defoliated with sodium chlorate (4.5 pounds a.i. per acre) on Sept. 28 and Oct. 9.
[2] DP90 is not approved for San Joaquin Valley production.

CALIFORNIA HARVEST-AID PRACTICES AND PERFORMANCE

Defoliation of upland Acalas grown in the California's San Joaquin Valley is accomplished by using two applications of harvest-aid materials. Standard practices include applications of Prep™, combinations of chemical defoliants with Prep, or defoliants alone as first treatments applied at the recommended stage of maturity (i.e., nodes above cracked boll). This initial treatment is followed by a second application of harvest-aid materials to assist the further defoliation and complete desiccation of remaining leaves. Although a single application would be desirable, the norm for this production region of California is two applications of harvest-aid materials.

In 1992, a five-year study was initiated to uniformly assess various defoliation treatments across the U.S. Cotton Belt. An objective of the "Beltwide Harvest Aid Performance and Fiber Quality Evaluation" was to test a set of uniform core treatments across a range of climatic conditions and production practices.

After the first year of this Beltwide study, the efforts were expanded to include a Far West region. California's San Joaquin Valley was selected to represent this region; it was added to the study in 1993. The arid climate and high *Verticillium* wilt-tolerant Acala varieties grown in this area contributed to the diversity of locations for the Beltwide study. Because of these regional differences, California's standard core treatments have not performed as well as treatments in the other regional locations.

MATERIALS AND METHODS

The trials were conducted from 1993 to 1996 at the University of California Research and Extension Center, Five Points, California. The soil type was a Panoche clay loam. Standard regional cultural practices and recommended pest-management procedures were followed to ensure normal crop growth. Yearly planting, treatment, and harvest dates, along with other agronomic information, are shown in Table 2. Plots were four 40-inch rows, 60 to 65 feet long.

Variety selection was based on grower preference and valley-wide acreage. In 1993, Acala GC-510 was the predominant variety planted in the San Joaquin Valley. From 1994 to 1996, Acala Maxxa was used in the study, because this variety was planted in more than 65 percent of the San Joaquin Valley acreage.

Defoliation treatments were applied with a modified Hagie 470 "High Cycle" applicator. The treatments were applied with a broadcast boom (TXV 10, hollow cones) with nozzle spacing of 20 inches. Harvest-aid materials were applied with 20 gallons per acre water at a pressure of 55 psi. One pint of Agri-Dex® per acre was added to all treatments that had a surfactant as part of the manufacturer's recommendation.

Evaluations for performance, defoliation, desiccation, and open bolls were conducted at 7 and 14 days after treatment (DAT). Terminal and basal regrowth was determined as defined in the standardized protocol, between 21 DAT to 28 DAT. Plots were harvested after 14 DAT with a John Deere® 9910 two-row spindle-type picker modified for plot harvest. Seed cotton was harvested from the two center rows of each plot. Plot yields were recorded and samples collected for percent lint and fiber quality (High-Volume Instrumentation) and spun-fabric evaluations.

Table 2. California planting, treatment, and harvest dates, and percent open bolls at treatment, 1993-1996.

Dates	1993	1994	1995	1996
Planting	4/7	4/5	4/10	4/4
Treatment	9/20	9/12	9/27	9/19
Harvest	10/21	10/10	10/18	10/8
Crop Condition at Treatment				
Open bolls (%)	65	55	55	55

Source: Anonymous, 1999.

RESULTS AND DISCUSSION

PERFORMANCE INDEX

Performance Index (PI) is an overall evaluation of the effectiveness of a treatment, including defoliation, boll opening, regrowth, desiccation, and leaf sticking, on a 0 to 100 scale. PI of the standard core treatments varied from year to year. In general, the core treatments were less effective than the recommended "western" application rate of the same materials. Because the differences among core treatments was so subtle, no efforts were made to discriminate between PI and defoliation ratings. Therefore, for the Far West region, defoliation ratings only reflect overall performance of the various treatments.

Evaluation ratings are from the 14 DAT observations if not otherwise noted.

DEFOLIATION

Defoliation ratings were based on visual evaluations of "leaf drop." The values are expressed as a percent of leaves present at time of application that were removed by the treatment. Although ratings were recorded at both 7 DAT and 14 DAT, the only data presented are from 14 DAT. This information is presented in Table 3.

Table 3. Percent defoliation at 14 days after treatment – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	4	0	4	0	2
Folex® @ 1.5 pt	50	38	26	14	32
Dropp® @ 0.2 lb	8	14	11	9	11
Harvade® @ 8.0 pt	32	35	6	3	19
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	17	12	11	4	11
Folex @ 0.75 pt + Prep @ 1.33 pt	42	10	37	17	26
Dropp @ 0.1 lb + Prep @ 1.33 pt	17	21	13	8	15
Folex @ 2.0 pt + Prep @ 2.0 pt		69	54	22	51
LSD ($p<0.05$)	9.934	8.987	8.114	7.577	

Source: Anonymous, 1999.

In 1993, the Folex treatments (Folex alone at 1.5 pints per acre and a combination of Folex and Prep at 0.75 and 1.33 pints per acre, respectively) performed better than the other core treatments. The highest level of defoliation achieved at the 14 DAT evaluation was only 50 percent. The 1993 trial, using Acala GC-510, was the only time the core Folex treatments performed as well as a standard treatment. After shifting to Acala Maxxa in 1994, the core Folex treatments (Folex alone and in combination with Prep) produced, on average, half the leaf drop of the higher "western" rates of Folex and Prep.

Defoliation performance results from 1996 are low – even for the higher regional rates. An extreme heat spell through August is thought to have produced a late-season canopy of leaves with a thicker cuticle layer. This was noticed in the overall lower performance of all harvest-aid treatments throughout the San Joaquin Valley during this season.

The Folex + Prep combination (2 pints per acre of each product) in 1994 was the only treatment during this study that would have received no additional cleanup application prior to harvest under standard grower practices.

DESICCATION

Desiccation values are visual evaluations of percent of total remaining leaves on the plant that are damaged or desiccated as a result of the treatment. The data use a relative scale of 0 to 100, where 0 equals no remaining desiccated leaves and 100 indicates all leaves remaining on the plant are desiccated. This information is presented in Table 4. This parameter is significant for a harvest system, because it relates to the potential amount of green leaf material that could be harvested with the seed cotton. Green leaf trash adds to the overall moisture content of the harvested seed cotton and can result in storage problems once moduled.

Although there were differences among the various treatments, final desiccation values at 14 DAT all were relatively low. When these values are combined with the overall low defoliation at 14 DAT, the results for the standard core treatments reflect poorly defoliated and "green" fields.

Table 4. Percent desiccation at 14 days after treatment – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	2	0	1	0	1
Folex® @ 1.5 pt	30	12	12	16	18
Dropp® @ 0.2 lb	5	8	7	10	7
Harvade® @ 8.0 oz	25	12	2	4	11
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	12	5	5	3	6
Folex @ 0.75 pt + Prep @ 1.33 pt	20	8	9	14	12
Dropp @ 0.1 lb + Prep @ 1.33 pt	8	12	5	10	9
Folex @ 2.0 pt + Prep @ 2.0 pt		11	12	22	15
LSD (p<0.05)	11.461	6.142	4.136	5.805	

Source: Anonymous, 1999.

BOLL OPENING

Boll opening was determined by counting total bolls and open bolls in 1 meter of row. This value is represented as Percent Open Bolls (Table 5). With the exception of the 1996 results and a few treatments in 1995, defoliation treatments resulted in significantly greater boll opening than the untreated control. At 14 DAT, the Harvade® treatments performed as well as the Prep combinations. Dropp® alone was the least effective at opening bolls. Overall, even slight defoliation enhanced boll opening.

Most of the core treatments produced satisfactory boll opening each year of the study, reflecting the seasonal management and climatic conditions of this trial location. Pests were controlled to maintain good top boll retention; the final irrigation was scheduled to allow the top bolls to fully open. However, some leaf drop and leaf desiccation was helpful in allowing more light to penetrate the canopy and aid in boll opening.

Table 5. Percent Open Bolls at 14 days after treatment – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	86	88	89	84	87
Folex® @ 1.5 pt	90	94	92	91	92
Dropp® @ 0.2 lb	89	94	86	85	88
Harvade® @ 8.0 oz	90	97	97	89	93
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	89	94	86	89	90
Folex @ 0.75 pt + Prep @ 1.33 pt	90	92	90	88	90
Dropp @ 0.1 lb + Prep @ 1.33 pt	90	93	94	87	91
Folex @ 2.0 pt + Prep @ 2.0 pt		96	95	93	95
LSD ($p<0.05$)	2.103	3.897	7.546	ns[1]	

Source: Anonymous, 1999.
[1] ns = not significant.

REGROWTH

Terminal regrowth was determined by counting the number of plants in a 1-meter row segment with new leaves larger than 10 millimeters in size on the main stem tips. The values, presented in Table 6, are the percentages of plants with terminal regrowth; they were collected post-harvest between 21 DAT and 28 DAT. Patterns for regrowth are associated with severity of the initial defoliation treatment. An abrupt shock from a strong defoliant or desiccant usually will produce greater and earlier regrowth.

Basal regrowth (Table 7) was determined by the same means as terminal regrowth, except that these values represent the percent of plants with new leaves (larger than 10 millimeters) at the base of the main stem. Basal regrowth was slightly higher than terminal regrowth but followed a similar pattern among treatments. The higher regrowth was from the Folex rates of 1.5 pints and 2 pints per acre, and from the Harvade treatment of 8 ounces per acre.

Regrowth data for 1996 are not available. The overall lower defoliation observed during this year's trial also caused little regrowth.

Table 6. Percent terminal regrowth at 21 to 28 days after treatment – California.

TREATMENT	1993	1994	1995	Mean
Untreated	58	15	40	38
Folex® @ 1.5 pt	58	31	77	55
Dropp® @ 0.2 lb	55	17	49	40
Harvade® @ 8.0 oz	76	42	44	54
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	63	8	56	42
Folex @ 0.75 pt + Prep @ 1.33 pt	57	6	63	42
Dropp @ 0.1 lb + Prep @ 1.33 pt	62	10	41	38
Folex @ 2.0 pt + Prep @ 2.0 pt		34	62	48
LSD ($p<0.05$)	ns[1]	19.047	ns[1]	

Source: Anonymous, 1999.
[1] ns = not significant.

Table 7. Percent basal regrowth at 21 to 28 days after treatment – California.

TREATMENT	1993	1994	1995	Mean
Untreated	10	26	40	25
Folex® @ 1.5 pt	49	61	77	62
Dropp® @ 0.2 lb	20	22	49	30
Harvade® @ 8.0 oz	44	85	44	58
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	20	66	56	47
Folex @ 0.75 pt + Prep @ 1.33 pt	67	16	63	49
Dropp @ 0.1 lb + Prep @ 1.33 pt	22	38	41	34
Folex @ 2.0 pt + Prep @ 2.0 pt		71	62	67
LSD ($p<0.05$)	35	42	37	

Source: Anonymous, 1999.

LINT YIELDS

Lint yields for 1993-1996 are shown in Table 8. Defoliation treatments did not adversely influence final lint yields. The purpose of these defoliation trials was to preserve the yield and quality of the cotton in the field at the time of harvest. The guideline of Nodes Above Cracked Boll (NACB) was used to schedule each year's defoliation to ensure there would be no effect on lint yield or quality because of the treatment itself. Therefore, differences among the various treatments were not expected.

It is important to note, however, that the samples collected for HVI analysis and the larger bulk samples that were to be spun into fabric were not stored in a module prior to ginning. At harvest there was noticeable difference among the defoliation treatments' seed-cotton moisture levels. This is because of handling the harvested seed cotton while collecting the sub-samples.

Preparing a field for efficient machine harvest is only part of today's harvest requirements. The Beltwide use of the module system for field storage, transporting, and handling at the gin make harvesting dry, well-defoliated seed cotton more important in preserving final quality of the lint. Continued reliance on harvest-aid materials to assist in the pre-harvest preparation will be necessary to effectively use these systems.

Table 8. Total lint yield (lb per acre) – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	1794	1949	1517	2046	1826
Folex® @ 1.5 pt	1852	1869	1506	2060	1822
Dropp® @ 0.2 lb	1849	1926	1433	1985	1798
Harvade® @ 8.0 oz	1758	1904	1532	1938	1783
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	1746	1898	1506	2064	1804
Folex @ 0.75 pt + Prep @ 1.33 pt	1762	1870	1462	1994	1772
Dropp @ 0.1 lb + Prep @ 1.33 pt	1798	1886	1477	2073	1809
Folex @ 2.0 pt + Prep @ 2.0 pt		1828	1487	2053	1789
LSD ($p<0.05$)	ns[1]	ns[1]	ns[1]	91.162	

Source: Anonymous, 1999.
[1] ns = not significant.

FIBER QUALITY DATA

HVI fiber data are shown in Tables 9 through 15. The HVI fiber quality analysis was performed by Cotton Incorporated, Raleigh, North Carolina. Overall, the fiber quality data do not show a strong relationship to any effect of the various defoliation treatments.

Scheduling of the defoliation treatments using NACB would have ensured the absence of negative effects on fiber development and quality as measured by length, strength, and micronaire. The differences in color grade and leaf trash were not directly related to defoliation efficacy. As mentioned in the desiccation section (above), these samples were handled differently from field-harvest seed cotton, which would have been stored in a module prior to ginning.

Table 9. Fiber length (in) – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	1.15	1.14	1.14	1.18	1.15
Folex® @ 1.5 pt	1.12	1.13	1.13	1.17	1.14
Dropp® @ 0.2 lb	1.13	1.13	1.15	1.19	1.15
Harvade® @ 8.0 oz	1.12	1.14	1.14	1.19	1.15
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	1.14	1.12	1.14	1.18	1.14
Folex @ 0.75 pt + Prep @ 1.33 pt	1.10	1.12	1.14	1.19	1.14
Dropp @ 0.1 lb + Prep @ 1.33 pt	1.14	1.12	1.13	1.17	1.14
Folex @ 2.0 pt + Prep @ 2.0 pt		1.13	1.14	1.19	1.15
LSD (p<0.05)	0.039	ns[1]	0.019	ns[1]	

Source: Anonymous, 1999.
[1] ns = not significant.

Table 10. Fiber strength (g/tex) – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	32.60	30.08	30.77	33.35	31.70
Folex® @ 1.5 pt	30.85	30.42	29.45	32.27	30.75
Dropp® @ 0.2 lb	32.92	30.38	29.63	33.67	31.65
Harvade® @ 8.0 oz	31.43	30.48	30.57	33.67	31.54
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	32.08	29.70	30.52	33.95	31.56
Folex @ 0.75 pt + Prep @ 1.33 pt	30.65	30.45	30.15	33.95	31.30
Dropp @ 0.1 lb + Prep @ 1.33 pt	31.67	29.63	30.40	33.83	31.38
Folex @ 2.0 pt + Prep @ 2.0 pt		29.92	29.97	33.08	30.99
LSD (p<0.05)	1.52	ns[1]	0.73	1.29	

Source: Anonymous, 1999.
[1] ns = not significant.

Table 11. Micronaire – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	4.70	3.92	4.18	4.10	4.22
Folex® @ 1.5 pt	4.70	3.90	4.13	4.24	4.24
Dropp® @ 0.2 lb	4.65	3.97	4.14	4.17	4.23
Harvade® @ 8.0 oz	4.65	3.92	4.16	4.16	4.22
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	4.58	3.90	4.02	4.12	4.16
Folex @ 0.75 pt + Prep @ 1.33 pt	4.58	3.88	4.10	4.15	4.18
Dropp @ 0.1 lb + Prep @ 1.33 pt	4.60	3.92	4.07	4.06	4.16
Folex @ 2.0 pt + Prep @ 2.0 pt		3.95	4.12	4.13	4.07
LSD (p<0.05)	0.12	ns[1]	ns[1]	ns[1]	

Source: Anonymous, 1999.
[1] ns = not significant.

Table 12. Color grade – reflectance (Rd) – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	75.0	74.88	76.90	74.58	75.34
Folex® @ 1.5 pt	77.0	74.93	77.07	76.93	76.48
Dropp® @ 0.2 lb	74.8	74.42	77.35	76.22	75.70
Harvade® @ 8.0 oz	76.5	74.05	77.28	75.22	75.76
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	74.5	74.30	77.45	74.77	75.26
Folex @ 0.75 pt + Prep @ 1.33 pt	76.5	74.10	77.58	76.04	76.06
Dropp @ 0.1 lb + Prep @ 1.33 pt	75.8	74.57	77.42	74.70	94.30
Folex @ 2.0 pt + Prep @ 2.0 pt		74.47	78.00	76.38	76.28
LSD (p<0.05)	1.48	ns[1]	ns[1]	1.29	

Source: Anonymous, 1999.
[1] ns = not significant.

Table 13. Color grade – yellowness (+b) – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	9.20	9.38	8.88	9.02	9.12
Folex® @ 1.5 pt	8.92	8.98	8.67	8.88	8.86
Dropp® @ 0.2 lb	9.40	9.10	8.60	8.85	8.99
Harvade® @ 8.0 oz	8.95	9.30	8.77	8.92	8.99
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	9.23	9.13	8.73	8.98	9.02
Folex @ 0.75 pt + Prep @ 1.33 pt	8.82	8.95	8.58	8.73	8.77
Dropp @ 0.1 lb + Prep @ 1.33 pt	8.95	9.08	8.53	9.02	8.90
Folex @ 2.0 pt + Prep @ 2.0 pt		9.02	8.43	8.70	8.72
LSD (p<0.05)	0.23	0.327	0.252	0.27	

Source: Anonymous, 1999.

Table 14. Percent trash – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	0.43	0.29	0.27	0.43	0.33
Folex® @ 1.5 pt	0.25	0.24	0.22	0.24	0.24
Dropp® @ 0.2 lb	0.43	0.38	0.17	0.28	0.33
Harvade® @ 8.0 oz	0.30	0.29	0.22	0.37	0.27
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	0.50	0.30	0.21	0.46	0.36
Folex @ 0.75 pt + Prep @ 1.33 pt	0.25	0.37	0.16	0.38	0.26
Dropp @ 0.1 lb + Prep @ 1.33 pt	0.35	0.30	0.26	0.38	0.30
Folex @ 2.0 pt + Prep @ 2.0 pt		0.31	0.12	0.33	0.21
LSD (p<0.05)	0.148	ns[1]	ns[1]	0.188	

Source: Anonymous, 1999.
[1] ns = not significant.

Table 15. Fiber length uniformity – California.

TREATMENT	1993	1994	1995	1996	Mean
Untreated	84.8	81.30	82.85	83.25	83.05
Folex® @ 1.5 pt	83.5	80.78	81.55	83.73	82.39
Dropp® @ 0.2 lb	84.5	80.73	82.53	84.15	82.98
Harvade® @ 8.0 oz	84.0	81.20	82.33	83.00	82.63
Harvade @ 6.5 oz + Prep™ @ 1.33 pt	84.8	81.18	81.57	83.13	82.67
Folex @ 0.75 pt + Prep @ 1.33 pt	84.0	80.63	82.20	82.99	82.46
Dropp @ 0.1 lb + Prep @ 1.33 pt	85.0	80.82	81.45	83.40	82.67
Folex @ 2.0 pt + Prep @ 2.0 pt		80.57	81.47	83.35	81.80
LSD (p<0.05)	1.08	ns[1]	1.125	ns[1]	

Source: Anonymous, 1999.
[1] ns = not significant.

SUMMARY

Far West cotton production is characterized by a hot, arid growing season; the entire acreage is irrigated. This lends some advantage in preparing the crop for defoliation, because the season's final crop irrigations can be scheduled to afford greater control of soil moisture and nitrogen. Harvest of this acreage is performed with spindle-type harvesters, so defoliation practices play an important pre-harvest role. Although effective defoliation is the primary goal, a sequential application often is required to fully desiccate the remaining leaves and help open any green bolls. This practice is particularly important in the preparation of Pima cotton for harvest.

Although similar materials are used in Arizona and California, each production area has specific labeled rate differences. Within each production area, material combinations and application methods vary from farm to farm. Initial defoliation treatments include harvest-aid materials such as Folex, Def, or Ginstar in combination with Prep (ethephon). These materials have provided the most consistent results over a range of climatic conditions.

Sodium chlorate is used extensively for cleanup applications. Additives such as paraquat or cacodylic acid are included to enhance the desiccation of remaining leaves.

In cooperation with the Beltwide Harvest-Aid Performance and Fiber Quality Evaluation, California's San Joaquin Valley was selected to represent the Far West production area. Far West conditions represent a unique environment for comparing the effects of pre-harvest practices. As the Far West representative, California participated in the last four years of the five-year study to uniformly assess various defoliation treatments. The "standard" core treatments did not perform as well in the California trials as they did in other regions of the Cotton Belt. The overall lower treatment response is attributed to the San Joaquin Valley's arid climate and the high *Verticillium* wilt-tolerant Acala varieties grown in this region of California. The Far West location provided a more challenging environment to test the performance of the standard treatments, thus providing an important contribution to the final Beltwide database.

Regional objectives for improved cotton defoliation in the Far West continue to emphasize seasonal crop monitoring for effective management that enhances defoliation. This includes good water and nitrogen management from cutout to termination and defoliation. Research must continue screening new materials or combinations that improve crop defoliation and harvestability. The growing environmental concerns, urban encroachment, and crop rotation requirements continue to make cotton pre-harvest preparation one of the most visible and challenging aspects of cotton production in the Far West. Success in this effort will provide western growers with environmentally acceptable practices to harvest and deliver the highest-quality seed cotton.

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APPENDICES

Appendix 1. Standard harvest-aid treatments.[1]

Untreated check
Folex® @ 1.5 pt per acre
Dropp® @ 0.2 lb per acre
Harvade® @ 8 oz per acre + Agri-Dex® @ 1 pt per acre
Harvade @ 6.5 oz per acre + Prep™ @ 1.33 pt per acre + Agri-Dex @ 1 pt per acre
Folex @ 0.75 pt per acre + Prep @ 1.33 pt per acre
Dropp @ 0.1 lb per acre + Prep @ 1.33 pt per acre
Folex @ 2 pt per acre + Prep @ 2 pt per acre[2]

Source: Anonymous, 1999.
[1] Standard treatments varied slightly in different regions. These variations are noted in the summary report (Anonymous, 1999).
[2] Regional standard.

Appendix 2. Harvest-aid performance data collected each year.

Term	Timing[1]	Definition
Defoliation (%)	7 DAT and 14 DAT	Percent of leaves present at time of application that were removed by treatment, on a scale of 0 to 100.
Desiccation (%)	7 DAT and 14 DAT	Percent of total leaf number remaining on the plant that were desiccated as a result of the treatment. Relative scale of 0 to 100, where 0 equals no remaining desiccated leaves and 100 indicates all leaves desiccated and remaining on the plant.
Terminal Regrowth (%)	21 DAT	Determined by counting the number of plants in a 1-meter row segment with new leaves larger than 10 mm in size that had regrowth on stem tips.
Basal Regrowth (%)	21 DAT	Determined by counting the number of plants in a 1-meter row segment with new leaves larger than 10 mm in size that had regrowth from the main stem.
Open Bolls (%)	7 DAT and 14 DAT	Determined by counting total bolls and open bolls in a 1-meter row segment.

Source: Anonymous, 1999.
[1] DAT = Days After Treatment.