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AGRONOMY & SOILS

Impact of Pima Defoliation Timings on Lint Yield and Quality

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ABSTRACT

Chemical defoliation is a necessary pre-harvest practice in Pima cotton (*Gossypium barbadense* L.) production in the San Joaquin Valley of California. Cotton growers are advised to begin defoliation as early as possible with both Pima and Upland cotton, but not so early that it results in yield and quality loss Potentially harvestable bolls often fail to reach full maturity due to the recommended defoliation timing. Applying harvest aids before the recommended maturity can advance the start of harvest, avoiding late-season pests and adverse weather that can damage lint quality. The objective of this research was to compare different rates of Ginstar ® (thidiazuron/diuron, Research Triangle Park, NC) or Ginstar plus Finish ® (ethephon/cyclanilide, Research Triangle Park, NC) on defoliation, yield, and fiber quality of Pima cotton when applications began at an earlier timing, six to seven NACB (nodes above cracked boll), versus the common four to five NACB timing. 'Delta Pine DP-340' (Monsanto Company, St. Louis, MO) was treated with harvest aid materials in field trials and was analyzed as a factorial split-plot design with four replications. Starting the defoliation of Pima at six to seven NACB rather than four to five NACB brought about a potential seven to ten day earlier harvest and did not significantly affect yield or cotton fiber quality characteristics except for micronaire in one year of the study. These data indicate that earlier defoliation could be beneficial when later-maturing crops or worsening harvest-season weather necessitate the initiation of an earlier harvest.

Although Pima cotton only represents three percent of the world's cotton production, it is considered to be the commercial cotton that gives the highest quality fiber (Supima Website, 2013). Major production areas include Egypt, the western and southwestern United States, and the Chinese province of Xinjiang (Stahel, 2012). Ninety-four percent of the Pima that is produced in the United States, as of the 2012 production season, is grown in California's San Joaquin Valley, with the remaining production in Arizona, New Mexico, and Texas (Supima Website, 2013). Defoliation is the final pre-harvest step in the production of a cotton crop. Because of Pima cotton's high-grade fiber, efficient defoliation is a matter of utmost concern in order to produce acceptable quality and economic value. Unfortunately, Pima cotton is generally recognized as more difficult to defoliate than most Upland cottons, showing lower leaf desiccation levels and lower levels of defoliation than Acala and non-Acala Upland cotton varieties when treated by the same number of harvest aid product applications at the same rates (Cathey, 1986; Hutmacher et al, 2003;Wright and Hutmacher, 2012). To cope with the difficult defoliation associated with Pima, Arizona Pima growers have been observed to use as many as six applications of defoliant (Silvertooth, 1988). More commonly, two or three harvest aid applications may be needed when grown under full irrigation conditions and deep soil areas such as those in the San Joaquin Valley, particularly if there is poor fruit set or high nutrient or water availability causing vigorous growth. (Wright and Hutmacher, 2012). Harvest aid product selection as well as application rate and timing can be a strong influence on the profitability of a cotton crop. Chemical harvest aids are necessary in most irrigated cotton production regions like California to promote leaf desiccation and abscission, boll opening, restraining plant re-growth (Hutmacher

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et al, 2003; Roberts et al, 1996) and ensuring a plant ready for uniform harvesting (Copur, 2010). Determining the appropriate time for application of a harvest aid cannot be done effectively by selecting a specific date or growth period because conditions vary between different years and fields. In managing a Pima crop for defoliation, optimal timing requires the consideration of multiple factors, namely weather conditions, crop maturity, cultivar, plant vigor, soil characteristics impacting soil water and nutrient status, and harvest aid material used (Faircloth et al, 2004a; Faircloth et al, 2004b). Most importantly, there must be a compromise when anticipating the maturity of later-developing bolls and the degradation of the earlier-developed bolls in Acala and Pima (Snipes, 1999; Snipes and Baskin, 1994). There are three main techniques available to assist the grower or advisor in determining when to apply harvest aids while retaining good quality and near-maximum yields: the percent of open boll and assessment of mature bolls technique, the sharp knife technique, and the NACB technique (Hutmacher et al, 2003; Roberts et al, 1996). These approaches help determine the best time to apply harvest aids, but do not provide information to help determine harvest aid application rates (Hutmacher et al, 2003).

Previous harvest aid studies on Upland cotton in various United States cotton production areas found that first defoliant applications prior to 60 % open boll (or four to five NACB) can result in decreased lint yields, reduced fiber micronaire, and increased likelihood of re-growth (Bynum and Cothren, 2008; Copur et al, 2010; Craig, 2010; Gwathmey et al, 2004; Larson et al, 2002). However, waiting too long to defoliate can also reduce lint quality and yield due to the onset of adverse late-season weather conditions (Collins et al, 2007). Other previous defoliation studies in Acala cotton indicated that applications at six to seven NACB instead of at four to five NACB did not significantly affect yield or cotton HVI (high volume instrument) fiber quality characteristics (Karademir et al, 2007), however this timing did slightly reduce micronaire (Wright et al, 2012).

The San Joaquin Valley's Mediterranean-type climate exemplifies the adverse conditions that can arise from weather alone. In California's central valley, the risk of rainfall increases as harvest extends into late-October and November. Also, already-open bolls can be contaminated with honeydew excreted from late-season insect pests such as aphids and whiteflies, causing growth of sooty mold, resulting in sticky cotton and reduced market grade (Leigh et al, 2002). Many of these adverse conditions and their effects can be avoided with earlier, defoliant-induced harvest.

Under warmer conditions, physiological activity in cotton is higher, so defoliant effects may be more pronounced and rapid when compared with cooler conditions (Silvertooth and Howell, 1988). Harvest aids like thidiazuron/diuron and ethephon/cyclanilide have optimal activity when maximum and minimum daily temperatures are above 27°C degrees and above 10°C, respectively. In the San Joaquin Valley, these higher temperatures are characteristic of late summer and early fall, but the likelihood of continuing warm weather becomes lower and more variable as harvest aid applications are delayed. Earlier completion of harvest operations also allows more time for post-harvest tillage practices and land preparation for subsequent crops to be completed before ideal weather conditions are replaced by rain and fog (Roberts et al, 1996).

Crop fruit load and the relative vigor of vegetative growth of plants can play a major role in the success of defoliation efforts. Plants with low to moderate early- and mid-season fruit retention should be evaluated early to determine need for aggressive plant growth regulator applications or use of delayed irrigations and water stress to lessen problems of rank growth and excessive leaf area (Hutmacher et al, 2003; Supak and Snipes, 2001). Such management can potentially increase yield as well as the efficacy of defoliant applications at the end of the season.

First applications of harvest aid chemicals are usually made when the majority of Pima cotton fields have reached 60 to 65 % open bolls, or at three to five NACB (Collins et al, 2007; Craig, 2010; Roberts et al, 1996; Robertson et al, 2004). However, first harvest aid applications at six to seven NACB may allow harvesting to be spread out over more days, potentially reducing picking costs and allowing earlier harvests (Long and Bange, 2008).

The objectives of the following research were to compare the impact of timing and rate of early harvest aid applications at six to seven NACB versus four to five NACB of thidiazuron/diuron and ethephon/cyclanilide on defoliation, yield, and select fiber quality characteristics in Pima cotton in California.

MATERIALS AND METHODS

Studies were conducted in 2009 and 2010 at the University of California West Side Research and Extension Center (36°20’27.00”N, 120°07’03.38”W) near Five Points, CA. The soil at the field site is a Panoche clay loam (fine-loamy, superactive, thermic typic haplocambids) with a pH of 7.6 to 7.8 in the top meter of the soil profile (O’Geen et al., 2005). The Pima cultivar used in this study was ‘Delta Pine DP-340’ (Monsanto Company, St. Louis, MO), which is characterized as having moderately indeterminate growth habit and moderate vigor.

The study was analyzed as a factorial split-plot design with four replications. Cotton was planted on 20 April 2009 and the following year on 3 May 2010 with both years planted at a seed rate of 20.2 kg/ha (78,500 seeds/ha). Plots consisted of four 1 m wide rows that were 19.5 m in length. To better manage plant vigor during the irrigation season, irrigations were delayed until leaf water potential measurements were in the range of -1.8 to -1.9 MegaPascals (MPa) for the first within-season irrigation and -2.0 to -2.1 MPa for remaining irrigations. Leaf water potential was determined generally early to mid-afternoon (between 1300 and 1530 hours) using a Model 600 Pressure Chamber Instrument (PMS Instrument Company, Albany, Oregon). The pre-plant irrigation was 20 cm each year of the study. The field was irrigated three times each year after planting, typically in early June, early to mid-July and mid-August both years, receiving a total of approximately 48 cm of additional irrigation water. Two harvest aid application timings were tested: an early application at six to seven NACB and an application more typical for San Joaquin Valley growers, at four to five NACB. In 2009, there were 2316 heat units accumulated by the six to seven NACB timing and 2464 heat units accumulated by the four to five NACB timing. In 2010, there were 2198 heat units accumulated by the six to seven NACB timing and 2264 heat units accumulated by the four to five NACB timing (Table 1). Timing for initial harvest aid applications was determined using NACB measurements, which are defined as the number of main stem nodes with machine-harvestable bolls above the most recent first-fruiting position boll that had matured, dried and started to crack open. Three chemical combinations for harvest aid treatments (Table 2) were used for comparison at each time of application compared to an untreated control. Depending on the prevailing temperatures prior to first harvest aid applications, the number of days between six to seven NACB and four to five NACB typically averages between seven and ten. In this study, the measured time period was 13 days in 2009 and eight days in 2010. Treatments were applied using a high clearance sprayer with a drift guard; the travel speed of the sprayer was 5.6 km/hr. Flat Fan broadcast nozzles (Model 8002 VS, TeeJet) were used to apply 142.5 L/ha with boom pressure at 2.72 atmosphere (atm) Application dates, relative humidity, air temperature, and wind were noted at the time of defoliant application for each treatment and at each development stage in 2009 and 2010 (Table 3).

Table 1. Heat units accumulated during the 2009 and 2010 growing season.

Days after planting	Accumulated heat units – base 60F *	
	2009	2010
10	64	51
20	144	114
30	282	183
40	419	323
50	510	438
60	616	618
70	776	801
80	954	1019
90	1165	1193
100	1378	1355
110	1537	1526
120	1712	1670
130	1900	1811
140	2085	1931
150	2223	2071
155	2316 (Sept. 22)	
160	2411	2160
163		2198 (Oct. 13)
169	2464 (Oct. 6)	
170	2465	2260
171		2264 (Oct. 21)
182	2540 (Oct. 19)	
190		2336 (Nov. 9)

*heat units calculated using air temperature measurements from weather station located 300 m from trial site at the Univ. CA West Side Research and Extension Center. The threshold value used was 60°F, and calculations were done using the single triangle method.

Table 2. Percent defoliation of Pima Delta Pine 340 for 2009 and 2010, following application of harvest aid treatments at two different crop stages.

Treatment[z]	Rates (kg ai/ha)	Timing	2009				2010			
			29-Sep 7 DAT	6-Oct 14 DAT	13-Oct 21 DAT		19-Oct 7 DAT	26-Oct 14 DAT	2-Nov 21 DAT	
			Percent Defoliation							
1. Thidiazuron[y] + Ethephon[x] B[w]. Thidiazuron + Ethephon	.075 + .468 .101 + .786	6-7 NACB	48	81	90		11	35	84	
2. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .126 + .786	6-7 NACB	48	83	91		11	40	84	
3. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786	6-7 NACB	39	80	89		9	36	84	
				6-Oct 7 DAT	13-Oct 14 DAT	19-Oct 21 DAT		26-Oct 7 DAT	2-Nov 14 DAT	9-Nov 21 DAT
			Percent Defoliation							
4. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .101 + .786	4-5 NACB		48	88	88		11	64	81
5. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .1226 + .786	4-5 NACB		55	88	88		10	60	81
6. Thidiazuron B. Thidiazuron + Ethephon	0.075 .101 + .786	4-5 NACB		39	81	81		7	48	80
7. Untreated				25	55	68		7	26	44
LSD 0.05		Treatment		8.5	5.4	-		2.8	3.9	-
LSD 0.05		Timing		6.0	NS	-		2.0	2.8	-

[z] COC (Crop oil concentrate): was added to all treatments at .202 (kg ai/ha).

[y] Thidiazuron: Thidiazuron/Diuron.

[x] Ethephon: Ethephon/cyclanilide.

[w] Treatment B. Indicates the second application used at 7 d (2009) and 7 d (2010) after first Treatment.

Table 3. Dates of applications and temperature and wind conditions at timing of harvest aid treatment applications in 2009 and 2010.

	2009		2010	
Planting Date	April 20, 2009		May 10, 2009	
Growth stage	6-7 NACB	4-5 NACB	6-7 NACB	4-5 NACB
1st application[z]	September 22	October 6	October 13	October 21
Temperature, high-low (°C) Day of Applications	29-17	24-2	26-14	26-12
Wind (km/h)	0-1	2-5	0-1	0-1
2nd application[z]	October 1	October 13	October 19	October 26
Temperature, high-low (°C) Day of Applications	77	78	80	75
Wind (km/h)	0-1	2-5	0-1	2-4

[z] Date air temperature, wind registered at the time of application of defoliants at each developmental stage for 2009 and 2010.

Plant samples were pulled from ten random locations within the test plot field on three separate dates in July, August and September of 2009 and 2010 to provide basic descriptions of crop growth and development. Plant height, number of vegetative nodes and fruiting nodes, first position fruit retention and nodes above first position yellow flowers for each of the three sample dates is shown in Table 4. Defoliation, desiccation, and open boll ratings were evaluated from the center two rows in the middle portion of the plot to avoid rating the beginning and ends of plots that could possibly have been affected by sprayer speed. Treatment effects were evaluated by following standard evaluation guidelines for cotton harvest aid research (Kerby and Hake, 1996; Snipes et al., 1994) by counting total nodes and bolls in a predefined 1-m row segment and relating this at the time of application with a visual estimate of percent of leaves that were removed by the treatment, an estimate of leaves remaining on the plant that were desiccated as a result of the treatment, and an estimate of percentage of harvestable open bolls.

Plots were harvested using a two-row commercial-type spindle picker on 19 October 2009 and 9 November 2010. All data was collected from the center two rows of each plot leaving the outer rows to act as buffers between plots. Two to three kg seed cotton sub-samples from each plot were sent to a commercial saw gin at the Shafter, California research station to determine lint percentage (turnout), and to provide fiber samples for HVI analyses. Lint yield, color grade, micronaire, fiber length, strength, uniformity, HVI color, HVI trash, reflectance (Rd), and yellowness (+b) were determined by the United States Department of Agriculture Agricultural Marketing Service (USDA AMS) Cotton Program Visalia Classing Office (Visalia, CA).

Data for all parameters were tested to verify if the assumptions of analysis of variance (ANOVA) were met using Shapiro-Wilk's test. Data that failed to meet the assumptions of ANOVA were log transformed and analyzed using generalized linear model (GLM) procedure in SAS (version 9.3; SAS Institute Inc., Cary, NC). The ANOVA method is relatively robust to violations of assumptions, so even though data failed to meet assumptions after log transformation, analyses of variation were run at the significance level of $\alpha = 0.05$ and means were separated using Fisher's Least Significant Difference test. Interactions between timing and treatments were tested, and whenever these interactions were significant ($P<0.05$) analysis was conducted separately for each year. Statistical analysis for defoliation (Table 2), desiccation (Table 5), and open boll (Table 5) were performed by date rather than days after treatment (DAT) in order to determine if starting defoliation at six to seven NACB could allow for an earlier start to harvest based on the time of the year or date.

RESULTS AND DISCUSSION

Efficacy of harvest aids can be strongly affected by the relative size/number and distribution of the cotton fruit load and overall plant vigor (Table 4). In 2010, the later planting date combined with cooler early-season temperatures (Table 1, shown as reduced heat units) compared with 2009 early-season tended to produce more vigorous vegetative growth, as evidenced by increased plant heights at the mid-September plant measurement dates (Table 4). In addition, higher early and mid-season lygus bug pressure resulted in reduced lower and mid-canopy fruit retention in 2010 when compared with 2009. The delay in plant maturity and tendency toward later vegetative cutout in 2010 compared with 2009 can also be seen in the late-August averages for nodes above first position yellow flower shown in Table 4. By the mid to late September plant measurement timing, the increased plant heights were evident in the 2010 plants, but the nodes above white flower counts were similar in September readings in 2009 and 2010 (Table 4).

The combination of later planting date, more vigorous vegetative growth, and lower early-season fruit retention and lower yields in 2010 meant that those plants exhibited more vigorous plant growth characteristics. Under the scenario experienced in 2010, a crop that is more difficult to defoliate would typically be expected when compared with the plant characteristics in 2009 (better fruit retention, moderately smaller plants, higher yields) (Hutmacher et al, 2003; Wright et al, 2013).

Table 4. Plant mapping data for 2009 and 2010 cotton fields at the University of CA West Side REC, Pima defoliation trial.

Year	Date	Plant Height (cm)	# Vegetative Nodes	# Fruiting Nodes	Fruit Retention (# out of 5)			Nodes Above FP1 yellow flower
					1 to 5	6 to 10	11 +	
2009	17-Jul	69 (2)^z	6.5 (0.5)	12.3 (0.7)	3.3 (0.7)	-	-	7.6 (0.5)
	18-Aug	92 (2)	6.3 (0.5)	17.9 (0.9)	3.1 (0.7)	3.1 (0.7)	2.1 (0.7)	4.1 (0.7)
	22-Sep	96 (2)	6.4 (0.7)	18 (0.9)	-	2.9 (0.7)	1.5 (0.9)	2.8 (0.5)
2010	20-Jul	72 (1)	7.2 (0.6)	10.6 (0.5)	2.1 (0.7)	-	-	7.8 (0.7)
	21-Aug	97 (2)	7.2 (0.4)	15.4 (0.7)	2.2 (0.6)	2.9 (1.0)	1.8 (0.8)	5.6 (0.5)
	15-Sep	112 (2)	6.9 (0.6)	18.9 (0.7)	-	2.5 (0.7)	1.4 (0.7)	2.6 (0.7)

^{z} Values shown are the mean (and standard deviation shown in parentheses following each mean) for plant mapping done plants (n=10) in the test plot area on each of the dates shown.

Table 5. Percent desiccation of Pima 'Delta Pine 340' for 2009 and 2010, following application of various harvest aid treatments at two different crop stages.

Treatment[z]	Rates (kg ai/ha)	Timing	2009			2010		
			29-Sep 7 DAT	6-Oct 14 DAT	13-Oct 21 DAT	19-Oct 7 DAT	26-Oct 14 DAT	2-Nov 21 DAT
			Percent Desiccation					
1. Thidiazuron[y] + Ethephon[x] B[w]. Thidiazuron + Ethephon	.075 + .468 .101 + .786	6-7 NACB	28	56	73	14	74	89
2. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .126 + .786	6-7 NACB	33	45	68	19	81	88
3. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786	6-7 NACB	18	60	65	8	78	93
			6-Oct 7 DAT	13-Oct 14 DAT	19-Oct 21 DAT	26-Oct 7 DAT	2-Nov 14 DAT	9-Nov 21 DAT
			Percent Desiccation					
4. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .101 + .786	4-5 NACB	25	56	60	21	58	85
5. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .1226 + .786	4-5 NACB	24	53	55	28	51	86
6. Thidiazuron B. Thidiazuron + Ethephon	0.075 .101 + .786	4-5 NACB	14	49	55	13	39	83
7. Untreated			8	14	25	6	13	6
LSD 0.05		Treatment	12.3	8.8	--	6.4	3.7	--
LSD 0.05		Timing	8.7	3.2	--	4.5	2.6	--

[z] COC (Crop oil concentrate): was added to all treatments at .202 (kg ai/ha).

[y] Thidiazuron: Thidiazuron/Diuron.

[x] Ethephon: Ethephon/cyclanilide.

[w] Treatment B. Indicates the second application used at 7 d (2009) and 7 d (2010) after first treatment.

Treatment effects on percent defoliation, desiccation, and open boll at multiple measurement dates for six to seven and four to five NACB application timing are shown in (Tables 2, 5 and 6). Under ideal conditions in the San Joaquin Valley, harvest aid chemicals give acceptable defoliation, desiccation, and open bolls within approximately 14 DAT. In 2010, cotton did not reach six to seven NACB until 13 October; this was due in part to cooler temperatures after planting which set the cotton off to a slower start than in 2009 when more heat units were accumulated after planting (Table 1). Beginning about 120 days after planting, it was also evident that the late-maturation period was also cooler in 2010 than in 2009, accumulating fewer heat units during that period (Table 1).

By 13 October 2009, there were significant differences due to treatment in percent defoliation and desiccation, with the lowest harvest aid application rate giving the lowest percentage defoliation and desiccation (Tables 2 and 5). Harvest aid application timing (four to five versus six to seven NACB) in general did not significantly affect percent defoliation by October 13, 2009, but there were significant differences in percent desiccation and open boll, with the six to seven NACB timing achieving significantly higher percentages in both cases (Tables 5 and 6). In 2009, the untreated check was lower than the harvest aid treatments in both application timings (four to five versus six to seven NACB) in percent defoliation and desiccation, but not in percent open bolls at the 14 and 21 DAT evaluations (Tables 2, 5, and 6). This lack of treatment differences in percent open bolls and generally high open boll percentage in 2009 reflects a boll set that is earlier and more mature at the time of harvest aid application than in 2010.

By 2 November in the 2010 evaluations, there were significant differences in percent defoliation, desiccation, and open boll due to both treatment and timing, with the cotton treated at six to seven NACB achieving higher percentages in all three parameters (Tables 2, 5, and 6). In 2010, the untreated check was significantly lower across all parameters compared to other treatments.

Table 6. Percent open boll of Pima 'Delta Pine 340' for 2009 and 2010, following application of various harvest aid treatments at two different crop stages.

Treatment[z]	Rates (kg ai/ha)	Timing	2009				2010			
			29-Sep 7 DAT	6-Oct 14 DAT	13-Oct 21 DAT		19-Oct 7 DAT	26-Oct 14 DAT	2-Nov 21 DAT	
			Percent Open Boll							
1. Thidiazuron[y] + Ethephon[x] B[w]. Thidiazuron + Ethephon	.075 + .468 .101 + .786	6-7 NACB	66	80	90		30	60	94	
2. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .126 + .786		65	80	89		29	58	90	
3. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786		61	75	86		28	56	91	
				6-Oct 7 DAT	13-Oct 14 DAT	19-Oct 21 DAT		26-Oct 7 DAT	2-Nov 14 DAT	9-Nov 21 DAT
				Percent Open Boll						
4. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .101 + .786	4-5 NACB		61	83	88		30	74	93
5. Thidiazuron+ Ethephon B. Thidiazuron + Ethephon	.075 + .468 .1226 + .786			64	80	88		33	79	94
6. Thidiazuron B. Thidiazuron + Ethephon	0.075 .101 + .786			60	79	84		29	66	88
7. Untreated				63	81	89		28	64	77
LSD .05		Treatment		3.2	NS	--		NS	3.0	--
LSD .05		Timing		2.2	2.9	--		2.9	2.1	--

[z] COC (Crop oil concentrate): was added to all treatments at .202 (kg ai/ha).

[y] Thidiazuron: Thidiazuron/Diuron.

[x] Ethephon: Ethephon/cyclanilide.

[w] Treatment B. Indicates the second application used at 7 d (2009) and 7 d (2010) after first treatment.

There were significant differences in prevailing lint yields across all treatments in 2009 versus 2010, with all treatments showing much higher yields in 2009 (Table 7). The higher yields observed in 2009 likely reflect the earlier planting date, higher earlier heat units and higher earlier fruit retention in 2009. Untreated plant yields were greatly reduced in 2010, reflecting many unopened or unharvestable bolls in the later-maturing 2010 crop. In 2009 and 2010 alike, there were no significant differences in gin turnout or lint yield due to timing of the initiation of harvest aid applications, but there were differences in gin turnout both years due to treatment, with gin turnouts generally improved by most defoliation treatments when compared with untreated (Table 7). In 2010, the micronaire was significantly higher in the four to five NACB treatment than in the six to seven NACB treatment (Table 7), but in both years, crops gave micronaire in the acceptable range. Since percent open bolls on the last evaluation dates were quite high (over 90 percent) and not significantly different between timing treatments, it was unclear why micronaire values would be slightly higher in the four to five NACB treatments. Improvements in gin turnout with most defoliation treatments imply less trash and perhaps more open bolls than in samples from untreated (no harvest aids) plants. The HVI trash values in final harvest seed cotton samples were not significantly different than values for any defoliation treatments or timings (Table 8), but percent open boll on the final two measurement dates were generally higher in all defoliation treatments when compared with untreated plots (Table 6). There were no differences in fiber length or strength in either year for any treatment or timing (Table 8). Similarly, there were no differences in uniformity or yellowness (+b) in either year between harvest aid application timings or treatments, although in 2010, the reflectance (Rd) ratings were significantly higher with the six to seven NACB timing (Table 9).

Table 7. Effects on Pima 'Delta Pine 340' of defoliation timing on Micronaire, Gin Turn Out Percent and Lint Yield for 2009 and 2010.

Treatments[z]	Rates (kg ai/ha)	Timing	2009 Mic	2009 Gin T.O %	2009 Lint Yield LBS/A	2010 Mic	2010 Gin T.O %	2010 Lint Yield LBS/A
1. Thidiazuron[y] + Ethephon[x] B[w]. Thidiazuron + Ethephon	0.075 + 0.468 0.101 + 0.786	6-7 NACB	4.0	34.5	1635	3.8	32.7	1306
2. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .126 + .786		4.0	33.9	1601	3.8	32.6	1269
3. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786		4.0	34.4	1616	3.8	32.7	1224
4. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .101 + .786	4-5 NACB	4.0	34.4	1610	4.0	32.2	1201
5. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .1226 + .786		3.9	34.0	1633	4.2	32.2	1274
6. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786		4.0	34.6	1658	4.2	31.3	1249
7. Untreated			4.1	33.4	1610	4.3	28.8	891
LSD .05		Timing	NS	NS	NS	0.1	NS	NS
LSD .05		Treatment	0.1	0.8	NS	0.2	1.4	117.1

[z] COC (Crop oil concentrate): was added to all treatments at .202 (kg ai/ha).

[y] Thidiazuron: Thidiazuron/Diuron.

[x] Ethephon: Ethephon/cyclanilide.

[w] Treatment B. Indicates the second application used at 7 d (2009) and 7 d (2010) after first treatment.

Table 8. Effects of defoliation timing and treatment on fiber quality* of Pima 'Delta Pine 340' for Length, Strength, and HVI Trash for 2009 and 2010.

Treatments[z]	Rates (kg ai/ha)	Timing	Length (cm) 2009	Length (cm) 2010	Strength 2009	Strength 2010	HVI Trash 2009	HVI Trash 2010
1. Thidiazuron[y] + Ethephon[x] B[w]. Thidiazuron + Ethephon	.075 + .468 .101 + .786	6-7 NACB	3.53	3.53	40.7	39.3	3.53	3.53
2. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .126 + .786		3.50	3.53	70.9	38.6	3.50	3.53
3. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786		3.53	3.53	41.3	38.6	3.53	3.53
4. Thidiazuron B. Thidiazuron + Ethephon	.075 + .468 .101 + .786	4-5 NACB	3.45	3.53	42.1	39.5	3.45	3.53
5. Thidiazuron B. Thidiazuron + Ethephon	.075 + .468 .1226 + .786		3.50	3.56	41.3	38.7	3.50	3.56
6. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 .101 + .786		3.50	3.56	41.1	39.6	3.50	3.56
7. Untreated			3.56	3.56	42.6	39.3	3.56	3.56
LSD .05		Timing	NS	NS	NS	NS	NS	NS
LSD .05		Treatment	NS	NS	NS	NS	NS	NS

*Over a multi-year period (2000-2010), the average micronaire of San Joaquin Valley Acala cultivars included in University of California cultivar trials is about 4.2.

[z] COC (Crop oil concentrate): was added to all treatments at .202 (kg ai/ha).

[y] Thidiazuron: Thidiazuron/Diuron.

[x] Ethephon: Ethephon/cyclanilide.

[w] Treatment B. Indicates the second application used at 7 d (2009) and 7 d (2010) after first treatment.

Table 9. Effects of defoliation timing and treatment on fiber quality* of Pima 'Delta Pine 340' on Uniformity, Color Rd (color reflectance), and Color +b (color yellow present) for 2009 and 2010.

Treatments[z]	Rates (kg ai/ha)	Timing	Uniformity		Color Rd		Color +b	
			2009	2010	2009	2010	2009	2010
1. Thidiazuron[y] + Ethephon[x] B[w]. Thidiazuron + Ethephon	075 + .468 .101 + .786		87.1	86.4	71.3	69.0	11.9	12.2
2. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 + .468 .126 + .786	6-7 NACB	87.7	85.8	71.2	69.6	11.9	12.0
3. Thidiazuron B. Thidiazuron + Ethephon	.075 .101 + .786		88.0	86.2	71.5	69.5	11.9	12.0
4. Thidiazuron B. Thidiazuron + Ethephon	.075 + .468 .101 + .786		86.7	86.5	71.4	68.9	11.9	12.1
5. Thidiazuron B. Thidiazuron + Ethephon	.075 + .468 .1226 + .786	4-5 NACB	87.4	86.5	71.1	68.1	12.0	12.2
6. Thidiazuron + Ethephon B. Thidiazuron + Ethephon	.075 .101 + .786		87.0	86.3	70.9	65.4	11.7	12.8
7. Untreated			88.4	86.3	70.1	63.2	12.1	13.4
LSD .05		Timing	NS	NS	NS	1.3	NS	NS
LSD .05		Treatment	0.6	NS	0.	1.8	0.1	0.5

*Over a multi-year period (2000-2010), the average micronaire of San Joaquin Valley Acala cultivars included in University of California cultivar trials is about 4.2.

[z] COC (Crop oil concentrate): was added to all treatments at .202 (kg ai/ha).

[y] Thidiazuron: Thidiazuron/Diuron.

[x] Ethephon: Ethephon/cyclanilide.

[w] Treatment B. Indicates the second application used at 7 d (2009) and 7 d (2010) after first treatment.

The results demonstrate that when the defoliation process of Pima variety 'Delta Pine DP-340' was started at the six to seven NACB stage, there were no major impacts on measured HVI quality parameters when compared to fiber quality of plants treated beginning at the four to five NACB stage. An exception observed was fiber micronaire in 2010, which was higher in the cotton treated at four to five NACB. Most of the minor differences in fiber quality parameters observed during the two years were associated with different harvest aid treatments, and not necessarily associated with differences in initiation of treatments. As exemplified in the second year of this study, in the event of a later-developing crop, an earlier initiation of harvest aid applications at six to seven NACB (40% open boll) could be beneficial to California Pima cotton growers who wish to reduce the risks of late season adverse weather conditions, rather than waiting for four to five NACB (60% open boll).

In future years, changing production conditions and environmental constraints may make it useful to investigate potential benefits and problems with the initiation of harvest aid applications even earlier than at 40% open boll. Limited irrigation water supplies or late developing insect pests with potential to impact fiber quality (aphids, silverleaf whitefly) in some years could provide scenarios where harvest aid applications even earlier than those reported

...paragraph that starts with "s reference on page 6 after the discussion of Upland cotton responses to harvest aid timing in could be considered.

Since this study reports on responses of a moderately determinant, earlier maturing Pima cotton variety (DP-340) to targeted earlier harvest aid applications, other studies have recently been initiated with Phytogen-802RF (Dow AgroSciences, Indianapolis, Indiana), which is a more vigorous Pima variety with more indeterminate growth habit. This variety is more typical of the growth habit of most of the planted Pima varieties in recent years in California.

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DISCLAIMER

Mention of any trade name or product does not imply endorsement by the University of California Cooperative Extension. Any details on materials or products used in the course of this study are presented to give more complete experimental details.

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