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Impact of Defoliation Timings and Leaf Pubescence on Yield and Fiber Quality of Cotton

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ABSTRACT

Defoliation is an important management practice of cotton production. Field experiments were conducted for exploring response of cotton to defoliant application times at various percentages of boll opening on seed cotton yield and fiber quality. Experiments were arranged in split-plot design with defoliation times (control, 40, 60, and 80% open boll) as the main plots and cultivars (hairy leaf, semi-smooth leaf, and smooth leaf) as subplots, with three replicates. The pooled results indicated that early application of harvest aid products significantly reduced seed cotton yield, boll number per plant, micronaire and fiber length. Significant reductions in seed cotton yield occurred with defoliant applications both prior to and after 60% open boll application timing. Application at 40% followed by boll opening had the maximum number of the green leaves remaining on the plant at 14, 21, and 28 days after treatments and a corresponding high trash content and high leaf grade. However, except for the leaf grade, the number of green leaves remaining on the plant after defoliation and the trash content, varietal differences were non-significant. Smooth leaf cultivar (SG 125) had the highest number of green leaves left on the plant after treatment (79.2) compared with hairy (71.9) and semi-smooth leaf (77.1) cultivars. It was concluded that cotton cultivars with varying levels of leaf hairiness impacted the defoliation efficacy of the harvest aid products.

Keywords: Harvest aids, Leaf hairiness, Micronaire, Open boll percentage, Trash content.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) plant is perennial with an indeterminate growth habit (Oosterhuis, 1999). Cotton accounts for 98.9% of fiber plant coverage in Turkey and fiber production has increased significantly (Copur *et al.,* 2010). Cotton is an important agricultural product for the general economy because it provides fiber for textiles (Cetin *et al.,* 2015). Maintaining fiber quantity and quality is one of the great challenges (Lokhande and Reddy, 2015). Defoliants have been widely used in developed countries in cotton production for adjusting plant growth and improving lint yield (El-Kassaby and Kandil, 1985) as well as fiber quality (Larson *et al.,* 2002). Cotton growers are always keen to improve profit margins by adopting improved cotton production practices while maintaining yield (Singh *et al.,* 2013). Advantages associated with harvest aid applications prior to cotton harvest include: reduction in leaf trash content in harvested lint, quicker drying of dew and early boll opening due to full exposure to sunlight (Awan *et al.*, 2012). Cotton growers are advised to begin defoliation as early as possible with both pima and upland cotton, however, too early defoliation may results in loss of yield and quality. Applying harvest aids before the recommended maturity can advance the start of harvest, avoid late-season pests and adverse weather that can damage lint quality (Wright *et al.,* 2014). Delaying defoliation increases the risks of yield loss due to damaging early frosts and late season rainy weather, both of which are possible in the cotton growing areas

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(Bange and Milroy, 2001). However, delaying defoliation allows immature bolls to develop, which may enhance yields. Defoliation timing also impacts various cotton fiber quality characteristics. Defoliating too late or early can negatively impact fiber quality, including micronaire and fiber length (Samani *et al.*, 1999). The harvest aid chosen may affect the response of defoliation at different dates because of possible temperature differences during application (Gwathmey and Hayes, 1997). However, Kelley (2002) reported insignificant reductions in yield and fiber quality due to harvest aids application under ideal weather conditions. Cotton plant characteristics such as leaf hairiness may affect leaf grade and harvest aid efficacy. Several agronomic factors are believed to negatively influence the leaf grade values, including cotton defoliation, late-season weather conditions, and some cotton cultivar characteristics (Anthony and Rayburn, 1989; Morey *et al.*, 1976). Cotton cultivars can be distinctive from one another in terms of leaf size, hairiness, and growth habits and may also detrimentally impact cotton leaf grade values (Novick *et al.*, 1991). Leaf grade is a measure of the leaf content in cotton. Higher cotton leaf grade values have a detrimental impact on cotton industry with increased ginning cost for ginners. Therefore, keeping the above points in view, the present study hypothesized that cotton cultivars, particularly differing in leaf hairiness, may responded differently to harvest aid applications, and these treatments could result in higher leaf grades, yield and fiber quality. Therefore, it was intended to study the effect of harvest-aid defoliants on yield and monetary parameters, identify ideal time of application to realize high productivity and fiber quality.

MATERIALS AND METHODS

Plant Material and Culture Conditions

Field experiments were conducted at Cotton Research Center, Cukurova University, Adana, Turkey during 2013 and 2014. Cotton was planted on 7 May 2013 and 3 May 2014. Monthly maximum and mean temperatures, heat units and precipitation are given in (Table 1). Cultivars were selected to provide a range of leaf hairiness, i.e. smooth to hairy based on the cultivar descriptions provided by seed companies. The cultivar leaf hairiness groups included a smooth leaf (SG 125, early maturing with very broad adaptation and high yield potential), semi-smooth leaf (DP 396, medium maturing cultivar with high yield potential), and hairy leaf cultivar (ST 468, medium maturing cultivar with high yield potential). All cotton cultivars were certified for Mediterranean region. Four row plots were established and re-randomized each year for the application of harvest-aid treatments at 40% (early), 60% (mid) and 80% (late) open boll (OB) stages and control. Plots contained four rows 10 m long, spaced 0.80 m apart. The experimental design was a split-plot arranged as a randomized complete block design with three replications. The main plot comprised of the timing of harvest aid chemicals and the sub-plots were allocated to the cultivars. In two years, mixtures of Finish (ethephon+cyclanilide) at the rate of 1.75 L

Table 1. Monthly maximum, minimum, and mean temperatures, heat units, and precipitation at Adana, Turkey, in 2013 and 2014.

Month	2013					2014				
	Mean (°C)	Max (°C)	Min (°C)	Heat units[a]	Precipitatio (mm)	Mean (°C)	Max (°C)	Min (°C)	Heat units[a]	Precipitatio (mm)
May	22.7	29.4	16.3	224.4	57.4	21.2	27.8	14.8	190.0	22.4
June	25.3	31.4	19.1	284.5	0.3	24.8	30.9	18.9	272.0	50.0
July	28.2	33.9	22.2	386.4	0.0	28.2	32.9	23.4	375.0	0.25
August	28.6	35.1	22.1	404.0	0.0	29.1	34.5	23.7	420.0	0.25
September	25.3	32.0	18.5	291.0	15.0	25.9	31.8	20.2	310.1	80.4
October	19.5	27.5	11.5	122.8	16.5	20.9	27.1	15.0	171.5	67.8

[a] Heat units were calculated as $\sum$ [(Daily high temperature+Daily low temperature)/2]-15.6°C.

per hectare with Dropp Ultra (thidiazuron+diuron) at the rate of 0.60 L per hectare were applied to allow for the possibility of a once-over harvest with spindle pickers. Both chemicals were mixed with water (300 L ha^{-1}) and delivered uniformly using a knapsack sprayer. Each trial contained a control plot, where water was applied. General agronomic practices for fertilization, irrigation, and pest control were followed as per recommendation.

Plant Sampling and Measurements

Timing for the initial harvest aid applications were determined using percent open boll, which was calculated by counting the total number of open bolls per plant and dividing by the total number of bolls per plant and expressed as percentage. Defoliation and open bolls were evaluated for the two-centered rows in the middle portion of the plot to avoid evaluation of the foliage in the control plots and defoliated plots were individually conducted. Prior to treatment application, 10 plants were randomly tagged from the two rows at the center of each plot for visual observations. Treatment effects were detected by counting and recording the number of green leaves remaining on the same tagged plants 14, 21, and 28 Days After Treatment (DAT). Number of leaves just before treatment was counted in the control treatments. No desiccation was measured. Opened bolls were also determined on the same tagged plants. Three weeks after application of the last defoliation treatments, seed cotton yield was determined in plots by manual harvesting of the center two rows of each plot. Seed cotton from each plot was weighed, and approximate 1 kg sub-sample of seed cotton was ginned on an experimental rollergin to determine lint turnout. The samples were not subjected to lint cleaners that would be used in commercial cotton gins. Boll weight and opened boll per plant were determined from 20 randomly selected plants in the central two rows from each plot at harvest. Fiber properties were measured using the High Volume Instrumentation (HVI) method.

Statistical Analysis and Evaluation

The experimental data were subjected to Analysis Of Variance (ANOVA) using MSTAT-C software (MSTATC, 1989) and treatment means were compared using the Least Significant Difference (LSD) at the 5% probability level.

RESULTS

Analysis of variance in relation to cotton parameters among defoliation timings and cultivars is presented in Table 2. The main effects of defoliation timing and cultivar was significant for trash content and number of green leaves remaining on the plant after defoliation by 14, 21 and 28 DAT. The defoliation timing by cultivar interactions were significant for lint turnout, uniformity, trash content, leaf grade, number of green leaves remaining on the plant after defoliation by 14 and 21 DAT. Year×defoliation timing interactions were significant for seed cotton yield, number of bolls per plant, boll weight, micronaire, fiber length, uniformity, fiber strength and number of green leaves remaining on the plant after defoliation by 21 and 28 DAT. Year×cultivar interactions were significant for uniformity and leaf grade. Year x defoliation timing×cultivar interaction was significant for boll weight.

Seed Cotton Yield and Lint Turnout

Defoliation timing treatments significantly affected seed cotton yields, but they did not affect lint turnout. No significant cultivar effect on seed cotton yield and lint turnout was observed. Defoliation timing did not influence seed cotton yield in 2013. Greatest seed coton yields were achieved by defoliation at 60% OB and the control treatments when compared with early and late treatments in 2014. The pooled results also revealed the same tendency(Table 3).

Table 2. ANOVA mean squares for cotton yield, yield components and trash area, grade fiber properties, green leaves remaining on the plant after 14, 21, and 28 DAT..

SOV	*Df*	Seed cotton yield	Lint turnout	Boll number/Plant	Boll weight	Trash area	Leaf grade	*df*	Mic	UHM	UI	Strength	Green leaves/Plant 14 DAT	21 DAT	28 DAT
Replicate	2	8997.5	17.64	0.282	0.469	0.04	1.43	2	0.006	1.711	0.593	2.568	24.88	33.92	13.74
Year (Yr)	1	1643.5	0.005	15.21*	7.437*	0.36	0.5	1	0.068	1.201	8.473	1.417	28.50	532.**	118.8
Error	2	2099	1.86	0.682	0.136	0.03	0.04	2	0.067	0.322	0.858	0.73	29.64	8.161	14.48
Defoliation timing	3	15954.2**	6.619	197.6**	0.29	4.33**	25.6**	2	2.05**	14.0**	6.46**	12.8**	4104.**	5650.**	4019.**
Yr×Defoliation timing	3	18508.2**	5.669	1.326*	0.332*	0.08	1.5	2	0.31**	7.32**	30.9**	15.3**	28.16	80.2**	74.55*
Error	12	2011.6	3.046	0.369	0.093	0.05	1.42	8	0.036	0.319	0.8	1.534	8.168	12.03	13.27
Cultivar (Cv)	2	147.68	5.822	2.623	0.068	2.35**	1.85	2	0.014	0.061	0.162	0.267	335.**	323.**	96.4**
Year×Cultivar	2	378.59	1.712	0.808	0.161	0.01	3.79**	2	0.036	1.164	4.71**	1.602	5.724	21.89	4.392
Defoliation timing ×Cultivar	6	3021.9	5.951*	1.245	0.088	0.24*	1.61*	4	0.052	0.973	2.39**	1.626	71.60**	56.2**	20.72
Yr×Defoliation timing ×Cv	6	1532	3.231	0.976	0.172*	0.09	0.51	4	0.033	0.709	1.96	0.734	8.988	16.63	4.598
Error	32	2467.1	2.058	1.086	0.062	0.09	0.6	24	0.024	0.563	0.864	0.959	13.14	8.742	12.01

* Denotes significance at the 0.05 level of probability, **Denotes significance at the 0.01 level of probability.

Table 3 . Yield and lint turnout as affected by defoliation timing and cultivar.[a]

Treatments	Seed cotton yield (kg ha^{-1})			Lint turnout (%)		
Defoliation timing	2013	2014	Pooled	2013	2014	Pooled
Control	6193	6352 a	6273 a	44.9	44.3	44.6
40% OB	6131	5323 b	5727 b	45.7	44.8	45.3
60% OB	5812	6473 a	6143 a	43.7	43.9	43.8
80% OB	5873	5479 b	5676 b	43.5	45.1	44.3
Mean	6002	5907	5955	44.5	44.5	44.5
LSD $_{(0.05)}$	Ns	631.1	325.8	ns	ns	ns
Cultivar	2013	2014	Pooled	2013	2014	Pooled
ST 468	5956	5897	5926	44.8	45.3	45.0
DP 396	5987	5946	5966	44.7	44.2	44.5
SG 125	6065	5878	5972	44.0	44.1	44.0
Mean	6003	5907	5955	44.5	44.5	44.5
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns

[a] Means within a column followed by the same letter are not significantly different according to *LSD* test at 0.05 level of significance

Boll Number per Plant and Boll Weight

Significant differences among defoliation timing main effect means were observed for number of bolls per plant and boll weight (Table 4). Data for 2013 indicated significant reductions (30.7%) in boll number per plant from the 40% OB application timing as compared to the 60% OB application timing (Table 4). The reduction in total bolls at 40% application timing is attributed to lower early season fruit retention and boll set in first position bolls and square shed from lygus damage. The control and the 60% OB application timing resulted in the highest number of bolls per plant. In 2014, boll numbers per plant were 17.1, 24.6 and 20.2 for the 40, 60, and 80% OB application timings, respectively. The 60% OB application timing increased boll number by 6.5% over control. The pooled results indicated that boll number per plant was significantly reduced by the 40% OB application timing. In 2013, boll weight for the 40% OB application timing was not significantly different from the boll weight of the control treatment. Boll weights for the 60

Table 4. Boll number and boll weight as affected by defoliation timing and cultivar.[a]

Treatments	Boll number per plant			Boll weight (g)		
Defoliation timing	2013	2014	Pooled	2013	2014	Pooled
Control	22.8 a	23.0 b	22.9 b	5.35 c	6.21	5.78
40% OB	16.0 c	17.1 d	16.5 d	5.42 bc	6.28	5.84
60% OB	23.1 a	24.6 a	23.9 a	5.78 ab	6.33	6.05
80% OB	19.3 b	20.2 c	19.8 c	5.84 a	6.14	5.99
Mean	20.3	21.2	20.8	5.60	6.24	5.92
LSD $_{(0.05)}$	0.72	0.73	0.44	0.39	ns	ns
Cultivar	2013	2014	Pooled	2013	2014	Pooled
ST 468	19.8	21.2	20.5	5.44	6.27	5.86
DP 396	20.4	21.0	20.7	5.67	6.22	5.94
SG 125	20.8	21.5	21.1	5.68	6.23	5.95
Mean	20.3	21.2	20.8	5.6	6.24	5.92
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns

[a] Means within a column followed by the same letter are not significantly different according to *LSD* test at 0.05 level of significance.

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and 80% OB application timings were significantly greater than the 40% OB application timing and the control. Boll weight significantly increased by delaying application timing from 40 to 80% OB in 2013. This translates into a 7.2% decrease in boll weight from the 40% OB application timing as compared to the 80% OB application timing. No significant differences were observed among application timing means for boll weight in 2014 and averaged across two years.

Micronaire and Fiber Length

Micronaire and fiber length values for defoliation timing were significantly different. But the interaction effects between application timing and cultivar on micronaire and fiber length were not significant (Table 2). No variations were observed among the cultivars main effect means for these two parameters. The 40% OB application timing had a significantly lower micronaire values than the 60 and 80% OB application timings and also over the control during both study years. The pooled results revealed that the early applications resulted in lower micronaire values as compared to all treatments (Table 5). Fiber length values were also significantly reduced under all defoliation timing treatments over control.

Uniformity and Fiber Strength

Significant variations were observed among defoliation timings for uniformity and strength. No significant differences were observed among cultivars for uniformity and strength. In 2013, the 80% OB application timing and control treatments resulted in significantly greater uniformity values than the 40 and 60% OB application timings. On the other hand, the 40% OB application resulted in a significantly greater uniformity value in 2014 (Table 6). The pooled results showed that the control and the 40% OB application timing treatments resulted in significantly greater uniformity values. This may be due to the shedding of immature, lower-strength bolls due to early harvest aid applications. The pooled results revealed that the later applications significantly reduced strength values.

Trash Content and Leaf Grade

Effects of defoliation timing, cultivars, and their interaction were significant on the trash content and the leaf grade. Trash content values for the 40 and 60% OB applications were significantly higher than the 80% OB application timing in both years. In 2013, 60 and 80% OB application timings were at par. The control produced a significantly lower

Table 5. Micronaire and fiber length as affected by defoliation timing and cultivar.[a]

Treatments	Micronaire			Fiber length (mm)		
Defoliation timing	2013	2014	Pooled	2013	2014	Pooled
Control	5.24 a	5.29 a	5.27 a	29.2 a	29.6 a	29.4 a
40% OB	4.60 b	4.42 c	4.51 c	27.3 d	28.1 b	27.7 b
60% OB	5.19 a	4.84 b	5.02 b	27.6 c	27.5 b	27.5 b
80% OB	5.05 a	5.29 a	5.17 a	28.6 b	26.5 c	27.6 b
Mean	5.02	4.85	4.89	28.2	27.9	28.0
LSD $_{(0.05)}$	0.29	0.11	0.14	0.21	0.89	0.41
Cultivar	2013	2014	Pooled	2013	2014	Pooled
ST 468	5.06	4.96	5.01	28.0	28.1	28.0
DP 396	4.98	5.00	4.99	28.1	27.9	28.0
SG 125	5.02	4.91	4.97	28.5	27.5	28.1
Mean	5.02	4.96	4.99	28.2	27.8	28.0
LSD $_{(0.05)}$	Ns	ns	ns	ns	ns	ns

[a] Means within a column followed by the same letter are not significantly different according to *LSD* test at 0.05 level of significance.

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Table 6. Uniformity and fiber strength as affected by defoliation timing and cultivar.[a]

Treatments	Uniformity (g tex^{-1})			Fiber strength (g tex^{-1})		
Defoliation timing	2013	2014	Pooled	2013	2014	Pooled
Control	82.5 ab	83.6 b	83.1 ab	30.7	30.8 b	30.8 a
40% OB	81.2 c	85.1 a	83.1 a	28.8	31.0 a	30.2 ab
60% OB	82.4 b	82.6 b	82.5 bc	29.5	29.4 c	29.5 bc
80% OB	83.1 a	80.6 c	81.8 c	29.7	27.9 d	28.8 c
Mean	82.2	82.9	82.6	29.7	29.9	29.8
LSD $_{(0.05)}$	0.63	1.31	0.65	ns	0.79	0.9
Cultivar	2013	2014	Pooled	2013	2014	Pooled
ST 468	81.7	83.4	82.6	29.2	30.3	29.9
DP 396	82.5	82.7	82.6	29.3	29.9	29.8
SG 125	82.6	82.8	82.7	29.5	29.6	29.7
Mean	82.3	83	82.6	29.3	29.9	29.8
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns

[a] Means within a column followed by the same letter are not significantly different according to LSD test at 0.05 level of significance.

Table 7. Trash content and leaf grade as affected by defoliation timing and cultivar.[a]

Treatments	Trash content (% area)			Leaf grade		
Defoliation timing	2013	2014	Pooled	2013	2014	Pooled
Control	0.44 c	0.44 c	0.44 c	3.9 b	4.1 b	4.0 c
40% OB	1.47 a	1.54 a	1.51 a	6.7 a	6.5 a	6.6 a
60% OB	1.30 ab	1.59 a	1.45 a	6.2 a	5.2 ab	5.7 b
80% OB	1.07 b	1.27 b	1.17 b	4.3 b	4.5 b	4.4 c
Mean	1.08	1.47	1.14	5.3	5.0	5.2
LSD $_{(0.05)}$	0.3	0.07	0.16	1.35	1.4	0.87
Cultivar	2013	2014	Pooled	2013	2014	Pooled
ST 468	1.40 a	1.55	1.48 a	5.8 a	4.8	5.3
DP 396	1.01 b	1.17	1.09 b	5.4 a	5.3	5.4
SG 125	0.80 b	0.91	0.86 c	4.6 b	5.2	4.8
Mean	1.07	1.21	1.14	5.3	5.1	5.2
LSD $_{(0.05)}$	1.24	1.21	0.18	0.51	ns	ns

[a] Means within a column followed by the same letter are not significantly different according to *LSD* test at 0.05 level of significance.

trash content value than defoliation treatments. Over the two years, applications at 40, 60, and 80% OB resulted in trash contents of 1.51, 1.45 and 1.17% , respectively (Table 7). Trash content of the variety ST 468 was 42.8 and 27.8% higher than that of SG 125 and DP 396, respectively. ST 468 and DP 396 varieties produced significantly greater average leaf grade values (5.8 and 5.4, respectively) as compared to SG 125 (4.6). Trash content and leaf grade values from the present study demonstrated that increased leaf hair of a cultivar increases the propensity for higher trash and leaf grade values. Leaf grade values for the 40 and 60% OB application timings were significantly greater in both years. The pooled data revealed that the early application resulted in the highest leaf grade values than the late. Considering interaction effects, the percentage of trash content in the control with the three cultivars was significantly lower than in all other treatments. ST 468 produced the highest trash contents regardless of application timings. Leaf grades for the 40% OB application timings for the three cultivars and the 60% OB application timing for ST 468 were significantly higher among all the combination and the cultivars had lower leaf

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grade values under control condition (data not shown).

Number of Green Leaves Remaining on the Plant

Effect of defoliation timings on the amount of the green leaves remaining on the plant, measured at 14, 21 and 28 DAT, were found significant (Table 8). In both years, number of green leaves remaining on the plant was significantly higher in the control plots than that of the harvest aid treated plots. The average number of leaves in the control plot just before defoliation was 93 leaves per plant in 2013 and 92.3 leaves per plant in 2014. At 14, 21 and 28 DAT, the 40% OB application timing had higher number of green leaves remaining on the plant compared to other treatments and a corresponding high trash content. The number of green leaves remaining on the plant following treatments progressively decreased as compared to the control after 14 DAT, in both the years (Table 8). Averaged across two years, smooth leaf cultivar (SG 125) had the highest number of green leaves remaining on the plant (79.2) than hairy (ST 468) and semi-smooth leaf cultivars (DP 396) of 71.9 and 77.1, respectively. The number of green leaves remaining on the plant for 40, 60, and 80% OB after 28 DAT were 37.8, 29.0 and 23.4, respectively, while they were 84.2, 68.1 and 59.4 for 40, 60, and 80% OB after 14 DAT, respectively. The 80% OB application timing resulted in significantly lower number of green leaves remaining on the plant among OB application timings after 21 DAT (Table 8). After 28 DAT, the 40% OB application timing provided a high number of green leaves remaining on the plant (37.8), averaged across two years.

DISCUSSION

In the present study, significant reductions in seed cotton yield occurred with defoliant applications, both prior to and after 60% OB. The increased seed cotton yield with 60% OB application timing was due to improved boll number per plant and boll weight, indicating better boll retention and, consequently, less shedding under mid application. Results from this study differ from those of Larson *et al.* (2005) and Wright *et al.* (2014). The control had significantly higher seed cotton yield compared with the early and late applications of harvest aids. Since the removal of leaves typically stops all plant processes, the control

Table 8. Number of green leaves remaining on the plant 14, 21 and 28 Days After Application (DAT) of harvest aid treatments.[a]

Treatment	Number of green leaves at 14 DAT			Number of green leaves at 21 DAT			Number of green leaves at 28 DAT		
Defoliation timing	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Control	93.0 a	92.3 a	92.7 a	78.1 a	78.2 a	78.2 a	58.7 a	56.3 a	57.5 a
40% OB	82.0 b	86.4 b	84.2 b	57.8 b	68.2 b	63.0 b	34.5 b	41.0 b	37.8 b
60% OB	66.9 c	69.1 c	68.1 c	44.9 c	51.5 c	48.2 c	26.4 c	31.6 c	29.0 c
80% OB	59.8 d	58.9 d	59.4 d	35.3 d	39.8 d	37.6 d	22.9 c	23.9 d	23.4 d
Mean	75.4	76.7	76.1	54	59.4	56.7	35.6	38.2	36.9
LSD $_{(0.05)}$	3.74	2.79	2.08	3.19	4.67	2.52	3.54	4.77	2.65
Cultivar	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
ST 468	71.2 b	72.6 b	71.9 c	50.1 b	56.7 b	53.4 c	33.2 b	36.8 b	35.0 b
DP 396	76.0 a	78.1 a	77.1 b	52.9 b	59.4 ab	56.2 b	35.6 ab	37.9 b	36.8 b
SG 125	79.1 a	79.3 a	79.2 a	59.1 a	62.3 a	60.7 a	38.1 a	39.5 a	39.0 a
Mean	75.4	76.7	76.1	54	59.5	56.7	35.6	38	36.9
LSD $_{(0.05)}$	3.25	3.02	2.13	2.99	2.03	1.74	2.02	2.02	2.04

[a] Means within a column followed by the same letter are not significantly different according to LSD test at 0.05 level of significance.

had additional developmental time relative to the treated plots, resulting in higher seed cotton yields. In the present study, the reduction in seed cotton yield with late defoliant application (80% OB) is attributed to adverse late-season weather conditions, especially late season rainfall just before harvest which resulted in weathering losses and delayed harvest. Similarly, Faircloth (2002) found that rainfall greater than 0.5 cm was strongly correlated with seed cotton losses and approximately 50 mm of rainfall can reduce yields. Kelley *et al.* (2002) concluded that the threshold where yield and quality reductions begin is 7.6 cm of precipitation during the later harvest period. Yield reductions from the 40% OB application timing may be attributed to premature opening of smaller bolls located higher up on the plants as well as the aborting of some small bolls brought on by harvest aid applications and reduced photosynthesis during the later stage of boll development. Contrary to our results, Ogunlela and Odion (2006) found that mild defoliation (20% OB) enhanced yield, while severe defoliation (60% OB) significantly reduced cotton yield. Singh *et al.* (2014) found reduced seed cotton yield and severe shedding of young squares and young bolls by early application of Dropp Ultra. Buttar and Singh (2013) observed significant seed cotton yield increases by late application of ethephon compared with early application. Kelley (2011) also reported reduced seed cotton yields by extreme early defoliation and more beneficial effects of defoliation after 60% OB. One possible explanation is that delaying defoliation allows for more carbon assimilation and partitioning of photoassimilates to developing bolls. However, late defoliation also increases the possibility that leaf drop will be diminished by lower temperatures (Copur *et al.,* 2010). Delaying defoliation from 40 to 60% OB across cultivars resulted in yield increases (Faircloth et *al.,* 2004a). Defoliating before 60% OB may help to stop micronaire growth while avoiding yield losses (Faircloth *et al*., 2004b). However, Sarlach *et al.* (2010) observed that ethrel applied at 145 and 160 DAP was found to be associated with improved boll opening percentage. Yield attributing components such as boll number per plant and boll weight was significantly affected by defoliation timing. These results agree with those obtained by Larson *et al.* (2002), Cicek *et al.* (2003) and Copur et *al.* (2010). However, Singh *et al.* (2014) reported that application of Dropp ultra at 200 mL ha^{-1} led to the highest open bolls per plant and the control resulted in the highest boll weight. Once set, bolls usually remained attached to the plant, continued to accumulate dry matter, and eventually opened. Early defoliated plants were often observed with full loads of green bolls attached. Higher boll number per plant with the 60% OB application timing might be due to extended physiological period of time for fruiting sites set without the premature loss of leaves. On the other hand, it may reduce boll weight by opening small bolls prematurely and further decrease yield (Smith *et al.,* 1986). In the present study, the effect of the application timings on micronaire, length, uniformity, and strength were inconsistent between years. Quality differences from year to year is due to the variability between environmental conditions (temperature, precipitation, light) during the experimental years. Lower micronaire by early defoliation can be explained by the longer boll maturation period resulting from the later application timings. When harvest aid products are applied too early, micronaire development can be arrested and low micronaire can result because of immaturity. Conversely, if those products are applied too late, high micronaire can result. These results are consistent with Snipes and Baskin (1994), Larson *et al.* (2002) and Gwathmey *et al.* (2004). The most notabe and significant reductions observed in fiber quality when harvesting was delayed were strength and length (Kelley *et al.,* 2012). Defoliation enhancement with ethephon may cause low micronaire, especially when applications are made prior to maximum physiological crop maturity (Valco and Snipes, 2001). In the present study, inconsistent impact of defoliation timing on uniformity is attributed to abundant late season precipitation during harvest season in 2014. A total rainfall of 14.82 cm fell in September and mid-October (Table 2). Decrease in uniformity after 70% OB is due to crop weathering (Bednarz *et al.,* 2002). Open boll which has weathered due to abundant rainfall (5 cm or more) deteriorates (Hake *et al.*, 1992). Bednarz *et al.* (2002) found that uniformity decreased when defoliation was applied after 90% OB and fiber length was greatest when defoliation was applied before 80% OB. The pooled data revealed that early application resulted in significantly greater strength values and this can possibly be explained by the shedding of less-mature, lower fiber strength bolls, leaving higher strength bolls for sampling due to premature applications of harvest aids. Most cellulose deposition that determines fiber strength occurs within 35 to 45 days after bloom, but, if environmental conditions are suitable and nutrients and photosynthate are ample, it can continue for much longer until the embryo matures and bolls prepare to open (Mauney and Stewart, 1986). Low strength can be associated with weathering of open bolls in the field prior to harvest. Early application of defoliation (approximately 60 days after flowering) might negatively affect the fiber index values due to incomplete fiber maturation. Early application of defoliation had a negative effect on fiber development, probably causing contraction of fibers. In the meantime, there were no significant differences in fiber strength due to defoliants and application times (Copur *et al.*, 2010). Early defoliation and boll opening can shorten the period of secondary wall deposition and also lead to reduction in the strength. Fiber length is largely determined within the first 20 to 25 days after pollination and it can be reduced by stresses during boll maturation. In general, fiber length is relatively insensitive to other environmental conditions (Mauney and Stewart, 1986) and usually impacted little by harvest aid applications. Hairy leaf varieties had significantly higher trash content at harvest, presumably because the leaf hairs prevent harvest aid materials from reaching the leaf tissue. Cotton defoliation and cultivar characteristics can negatively influence the leaf grade values (Anthony and Rayburn, 1989; Morey *et al.,* 1976). Harvest aid treatments had no impact on leaf grade values, while the hairy variety had higher leaf grades than a smooth variety (Eder, 2013). In a leaf hairiness by defoliation trial, Kelley *et al.* (2012) found that cotton leaf grade was not influenced by the defoliation levels. Leaf grade is the visual estimate of the quantity of leaf and bract material in the ginned lint sample submitted for HVI analysis. It is assumed that higher percentages of defoliation cause a lower leaf grade and hairy leaf varieties amplify leaf trash, resulting in higher leaf grades. In our study, lower number of green leaves left on the plant at late defoliation application after 14, 21, and 28 DAT corresponded to the lowest leaf grade values obtained from the late application timing.

CONCLUSIONS

The success of a defoliation program is strongly dependent on favorable environmental and crop conditions that prevail during and following defoliation. The pooled data from this study indicate that early defoliation had higher uniformity, strength, trash area and leaf grade values, although there was no significant difference between this application and the control for uniformity and strength. Late defoliation had higher micronaire value (undesirable effect), which is not different from the control. The number of green leaves remaining on the treated plants gradually decreased with later defoliation. The results of this study indicated that trash content and leaf grade were consistently impacted by the timing of defoliation, while there was a varietal impact on trash content and leaf grade values in one of the study years. Ultimately, there were no individual treatments that, consistently over years, provided higher yield and better quality, except for micronaire, trash area, and leaf grade. Year to year variations in seed cotton yield and some fiber properties emphasizes the differences in environmental and crop conditions. It can be concluded that level of leaf hairiness of cultivars may impact efficacy of harvest aid products, corresponding to the number of green leaves left on the plant after treatments.

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تاثیر زمان برگ زدایی و کرک داشتن برگ روی عملکرد و کیفیت تار پنبه

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چکیده

برگ زدایی یکی از عملیات مدیریتی مهم در تولید پنبه است. در این زمینه، آزمایشی صحرایی برای بررسی واکنش عملکرد و کیفیت تار پنبه به مصرف مواد برگ زدا در زمان باز بودن درصد های مختلف غوزه اجرا شد. آزمایش با طرح کرت های خرد شده پیاده شد که در آن کرت اصلی به زمان های مصرف ماده برگ زدا(شاهد، و ۴۰٪، ۶۰٪، و ۸۰٪ غوزه های باز) و کرت فرعی به کولتیوارها (برگ کرکدار، برگ نیمه نرم، و برگ نرم) اختصاص داشت. نتایج کلی چنین حکایت داشت که

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مصرف زود هنگام مواد برگ زدا عملکرد وش، تعداد غوزه در بوته، میکرونر و طول تار(طول الیاف) را به طور معناداری کاهش داد. همچنین، عملکرد وش در شرایطی که ماده برگ زدا (برگ ریز) قبل یا بعد از باز شدن ۶۰٪ غوزه ها مصرف شده بود به طور معناداری کم شد. در ۱۴، ۲۱، و ۲۸ روز پس از مصرف ماده برگ زدا، بیشترین تعداد برگ سبز باقیمانده روی بوته ها در تیمار کاربرد ماده مزبور در زمان باز شدن ۴۰٪ غوزه ها مشاهده شد که محتوای ضایعات آشغال (trash) آن و درجه بندی(leaf grade) آن بالا بود. اما، اثر نوع کولتیوار روی خصوصیات مختلف به غیر از درجه بندی، تعداد برگ سبز باقیمانده روی بوته بعد از مصرف ماده برگ زدا، و محتوای ضایعات معنی دار نبود. بعد از تیمار مصرف ماده برگ زدا، کولتیوار دارای برگ نرم (SG 125) بیشترین تعداد برگ سبز باقیمانده روی بوته راداشت (79.2) در مقایسه با کولتیوار کرک دار(71.9) و کولتیوار دارای برگ نیمه نرم (77.1). نتیجه گیری این بود که کولتیوارهای پنبه دارای مقادیر مختلف کرک، سودمندی مواد برگ زدا (برگ ریز) را تحت تاثیر قرار دادند.