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AGRONOMY AND SOILS

Leaf Pubescence and Defoliation Strategy Influence on Cotton Defoliation and Fiber Quality

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ABSTRACT

Proper defoliation of cotton is critical to maximize both harvest efficiency and fiber quality. Increased levels of leaf grade or trash resulting from inadequate defoliation can lead to decreases in fiber quality and value. Inherent characteristics of cultivars, such as leaf pubescence levels and defoliation practices influence the efficacy of cotton defoliation. This study aimed to determine the impact of leaf pubescence and defoliation strategies on defoliation success and fiber quality in cotton. Treatments included a factorial of four cultivars and two defoliation treatments. Cultivars included two smooth-leaf cultivars and two cultivars with greater leaf pubescence ratings. Defoliation treatments included a standard program and an aggressive program with increased rates of the same defoliant mixture and the addition of a desiccant. There were few instances of a cultivar-by-defoliation strategy interaction, however, both cultivar and defoliation strategy had a significant effect on defoliation ratings. The aggressive defoliation treatment decreased defoliation and increased desiccation in all three locations but did not influence yield or fiber quality. In two of three locations, cultivars with higher leaf pubescence ratings resulted in increased leaf grades and HVI trash ratings compared with the smooth leaf cultivars. The results of this study suggest that the defoliation strategy can impact efficacy of defoliation, whereas leaf pubescence characteristics influence fiber quality parameters.

Application of harvest aids is often required for producers of indeterminate crops such as cotton. Proper defoliation is critical to maximizing the yield and profitability of the crop. Because cotton is a perennial crop that is grown and managed as an annual for agronomic benefits, eliminating green, live plant material and minimizing the amount of dead plant material contaminating harvested seed cotton is crucial to optimize harvest efficiency and lint quality (Colwick et al., 1984). Proper defoliation has numerous benefits including reducing the amount of leaf and other plant material (referred to as trash) in harvested seed cotton (Brecke et al., 2001; Valco and Snipes, 2001), reducing damage to fiber in the ginning process by lessening the amount of cleaning required for achieving marketable lint (Valco and Snipes, 2001), reducing losses to boll rot (Brown, 1953), and allowing for earlier harvest to avoid weathering (Cathey et al., 1982; Siebert and Stewart, 2006). Although many factors influence the effectiveness of cotton defoliation (Brecke et al., 2001; Siebert and Stewart, 2006), leaf pubescence and defoliation practices are of specific interest in this experiment.

Reduced leaf pubescence has been an important goal of cotton breeding to improve lint quality (Colwick et al., 1984). Leaf pubescence can influence cotton production and ginning practices by reducing defoliation efficacy and reducing lint quality due to increased trash content because the pubescent plant material can become entangled in the lint. A reduction in motes (Novick et al., 1991), greater lint cleaning efficacy (Bechere et al., 2011; Colwick et al, 1984; Novick et al., 1991), and a reduction in trash or nonlint material in ginned lint has been observed in cultivars with reduced leaf pubescence compared to hairier cultivars (Novick et al., 1991; Ramey, 1962; Smith, 1964; Wanjura et al., 1976).

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Defoliants are a common category of harvest-aid products utilized in cotton and achieve leaf removal through the formation of an abscission layer at the base of the petiole (Cathey, 1986). Defoliants function optimally when applied to mature, healthy leaves at appropriate rates (Brecke et al., 2001). Plant tissue must be alive for the formation of an abscission layer to occur, thus optimal defoliation could be prevented if cell and tissue death occur too rapidly, inhibiting the formation of the abscission layer (Cathey, 1986; Clark and Carpenter, 1997; Stahler, 1953; Stichler et al., 1995). Leaf removal typically occurs 7 to 17 d after the application of defoliants (Colwick et al., 1984; Clark and Carpenter, 1997).

Herbicidal defoliants or desiccants also are used as harvest aids in cotton. The use of a desiccant as a harvest aid can lead to dead leaves remaining on the plant, termed leaf stick, due to the inhibition of the formation of an abscission layer as a result of rapid plant tissue death (Bovey and Miller, 1968; Brecke et al., 2001; McMeans et al., 1966; Shaw, 2002; Stahler, 1953). Leaf stick resulting from desiccation can lead to an increase of trash in ginned lint because dead leaves are present on the plant at harvest and are removed by the cotton harvester along with the seed cotton (Shaw, 2002). Death of leaves resulting from the utilization of desiccants as a harvest aid has been observed to occur 6 to 7 d after application (Bovey and Miller, 1968; Clark and Carpenter, 1997). Often herbicidal defoliants are used when late-season rainfall results in excessive regrowth, or on fields that are deemed to be lower priority and harvest aids are not applied in a timely fashion in relation to harvest, such as cotton grown on nonirrigated or marginal land.

Increased levels of trash in lint decrease the quality of the lint and potentially could lead to discounted returns to the producer. Both leaf pubescence levels and defoliation strategy have been shown to influence the efficacy of defoliation in cotton as well as fiber quality characteristics, namely leaf or trash grade. Recently, leaf grade has become more of a concern due to environmental extremes across the Cotton Belt during harvest, leading to higher leaf grades than typically are seen in many regions. Determining how variety selection and defoliation strategy influence leaf grade would provide information on how to best manage the crop at the end of the season to minimize leaf grade and perhaps improve other fiber quality parameters. The objectives of the current study were to determine the influence of leaf pubescence and defoliation practices on the effectiveness of defoliation and related fiber quality parameters.

MATERIALS AND METHODS

Experiments were conducted at the University of Georgia's Gibbs Farm in Tifton, GA (31° 26′ N, 83° 35′ W) in 2013 and 2014 and at North Carolina State University's Peanut Belt Research Station in Lewiston, NC (36° 07′ N, 77° 10′ W) in 2014. Planting occurred on 25 April 2013 and 28 April 2014 in Tifton at a seeding rate of 11 seed m^{-1}. Cotton was planted on 12 May 2014 at the Lewiston location at a rate of 10 seed m^{-1}. Plot lengths at all locations were 9 m and contained four rows spaced 91 cm apart. The center two rows served as treatment rows that received defoliant applications and were utilized for defoliation ratings and harvest, with the outer two rows of each plot serving as borders. All other crop management practices followed state extension recommendations (Collins et al., 2015; Edmisten et al., 2015). A split-block design with four replications was utilized. Main plots included two defoliation treatments and subplots included four cultivars. Cultivars included the smooth-leaf cultivars (Anonymous, 2016a) Deltapine 1028 B2RF (DP 1028) and Deltapine 1137 B2RF (DP 1137) (Monsanto Company, St. Louis, MO), the semi-smooth cultivar (Anonymous, 2016b) PhytoGen 499 WRF (PHY 499) (Dow AgroSciences, Indianapolis, IN), and the hairy-leaf cultivar (Anonymous, 2013) Stoneville 5288 B2F (ST 5288) (Bayer CropScience, Research Triangle Park, NC). Leaf pubescence ratings for three of the four varieties used in this study were reported for multiple years of the Arkansas Cotton Variety Test (Bourland et al., 2011, 2012, 2013, 2014, 2015, 2016). On a scale from one to nine, with one being a smooth leaf and nine being very hairy, the DP 1028 cultivar was rated 1.1 in the 2010 and 2011 report (Bourland et al., 2011, 2012). Appearing in the study from 2011 to 2015, the ratings for PHY 499 ranged from a low of 3.5 in 2014 (Bourland et al., 2015) and a high of 5.2 in 2015 (Bourland et al., 2016). Leaf pubescence ratings for ST 5288 were taken in 4 yr of the study and ranged from a low of 5.3 in 2013 (Bourland et al., 2014) to 6.9 in 2011 (Bourland et al., 2012). Two defoliation treatments were included: one targeted defoliation of the crop using recommended rates (Whitaker and Collins, 2015) appropriate for prevailing temperatures (recommended defoliation treatment) and one included a higher rate of the same defoliants plus the addition of a herbicidal defoliant or a desiccating treatment (aggressive defoliation treatment). The recommended treatment included 0.73 L ha^{-1} of tribufos (Folex, Amvac Chemical

Corporation, Newport Beach, CA) for defoliation, 2.34 L ha^{-1} of ethephon (Prep, Bayer CropScience, Research Triangle Park, NC) for boll opening, and 0.23 L ha^{-1} of thidiazuron (Freefall, Nufarm Americas, Inc., Alsip, IL) for regrowth control. The aggressive treatment included 1.17 L $ha^{-1}$of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl (ET, Nichino America Inc., Wilmington, DE), a herbicidal defoliant/desiccant. Applications were made using a CO_2 pressurized backpack sprayer calibrated to deliver 140.3 L ha^{-1} at 4.8 km h^{-1}. At the Tifton, GA location, XR8002 nozzles (TeeJet Technologies, Glendale Heights, IL) were used, whereas XR11002 nozzles were used at Lewiston, NC. Applications were made when plants reached a maximum of four nodes above cracked boll, a recommended defoliation time (Collins et al., 2015).

Treatment results were evaluated at 1, 2, and 3 wk after defoliation treatments (WAT) were applied for visual ratings of percentage of open bolls, percentage defoliation, percentage desiccation, percentage regrowth from the terminal of the plant (RG_T), and percentage basal regrowth (RG_B). At the North Carolina location, basal and terminal regrowth were combined into one total regrowth (RG) rating. After the three intervals of visual inspections of defoliation were completed, cotton was harvested with a John Deere 9930 (John Deere, Moline, IL) two-row plot harvester equipped with bagging attachments for small-plot harvest. Seed cotton from all plots from all locations was weighed prior to ginning at the University of Georgia Micro Gin in Tifton, GA for determination of lint percentage and lint yield (Li et al., 2011). After ginning, approximately 230 g of lint from each plot were sent to the USDA Classing Office in Macon, GA for both classing and high volume instrumentation (HVI) measurements of fiber quality.

Data were analyzed with the use of PROC MIXED with the pdmix 800 macro included (Saxton, 1998) in SAS 9.4 software (SAS Institute, Cary, NC) with the fixed effect of defoliation treatment as the main plot factor and the fixed effect of cultivar as the subplot factor. Treatment means were separated by Fisher's Protected LSD at $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

The effect of site year was significant for seed cotton yield, lint yield, and leaf grade with *p* values < 0.0001 for all three variables. Thus, locations were analyzed and are reported independently. Weekly weather data for all three locations from the application of defoliants until the final rating date are included in Table 1.

Table 1. Weather data from Tifton, GA, 2013, 2014, and Lewiston, NC, 2014 locations from defoliation treatment application to harvest

Measurement	Tifton, GA, 2013		
	1 WAT[Z]	2 WAT	3 WAT
Min. Temperature (°C)	19.7	15.7	17.6
Max. Temperature (°C)	26.8	25.7	28.0
Average Temperature (°C)	22.7	20.3	22.0
Rainfall (cm)	3.5	0.0	1.0
	Tifton, GA, 2014		
	1 WAT	2 WAT	3 WAT
Min. Temperature (°C)	21.6	22.2	18.8
Max. Temperature (°C)	31.3	32.5	29.7
Average Temperature (°C)	25.0	25.9	23.4
Rainfall (cm)	8.6	1.9	1.2
	Lewiston, NC, 2014		
	1 WAT	2 WAT	3 WAT
Min. Temperature (°C)	12.9	8.6	5.9
Max. Temperature (°C)	24.6	20.3	23.8
Average Temperature (°C)	18.3	14.0	14.5
Rainfall (cm)	2.6	0.1	0.0

[Z] Temperature averages and rainfall totals for each week after treatment (WAT) defoliation ratings were conducted.

Defoliation Ratings. *Tifton, GA, 2013.* The interaction of cultivar by defoliation was significant at 3 WAT (Table 2), where the percentage of open bolls was lower in the recommended defoliation of ST 5288 than all other cultivar and defoliation combinations with the exception of aggressive defoliation on DP 1137 (Fig. 1). However, the actual difference in the range between all treatments (98.5100% open bolls) does not reflect any biological or applied difference between the treatments. Cultivar had a significant effect on open bolls, defoliation, and desiccation at 1 WAT and on open bolls at 2 WAT across both defoliation treatments. However, the differences in cultivar did not follow the leaf pubescence categories, as PHY 499, a semi-smooth cultivar, resulted in greater percentages of open bolls at 1 and 2 WAT, defoliation at 1 WAT, and lower desiccation at 1 WAT than the smooth-leaf cultivar, DP 1137, and the hairy-leaf cultivar, ST 5288 (Table 3). A significant difference between the smooth-leaf cultivars occurred at 2 WAT, when the percentage of open bolls was greater in DP 1028 than DP 1137. A greater percentage of open bolls at 1 WAT, as well as greater percentage defoliation and reduced desiccation at 1 WAT, was observed in smooth-leaf DP 1028 compared to hairy-leaf ST 5288. Cultivar had no effect on regrowth at any rating date. The differences observed in defoliation are likely due to differences between the cultivars independent of leaf pubescence levels, as no observations of leaf pubescence influencing open boll, defoliation, desiccation, or regrowth have been reported. Defoliation treatment had a significant effect on percentage desiccation at 1 WAT and percentage defoliation and desiccation at 2 WAT across all cultivars. The aggressive defoliation method resulted in increased desiccation at 1 and 2 WAT and reduced defoliation at 2 WAT. Increased desiccation and reduced defoliation is to be expected because the inclusion of the desiccants promotes rapid drying out of the leaf tissue, which results in more rapid leaf death and prevents the formation of an abscission layer compared to the recommended defoliation treatment (Bovey and Miller, 1968; Brecke et al., 2001). There was no difference in regrowth due to defoliation strategy.

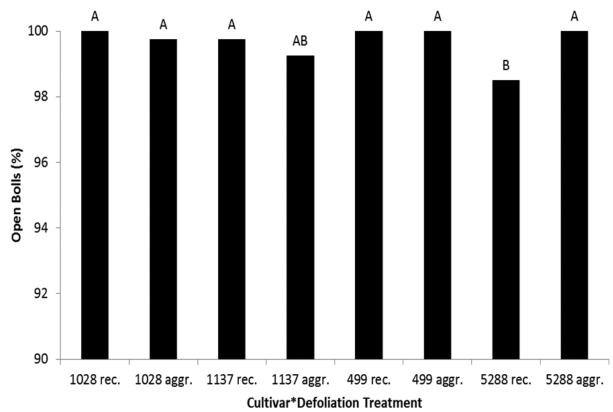

Figure 1. Percent open bolls as influenced by the interaction of cultivars DP 1028 (1028), DP 1137 (1137), PHY 499 (499), and ST 5288 (5288) and the recommended (rec.) and aggressive (aggr.) defoliation treatments at 3 wk after treatment in Tifton, GA, 2013.

Table 2. Analysis of variance (ANOVA) results (*p* values) for cotton defoliation evaluations in Tifton, GA, 2013. Factors include four cultivars, two defoliation treatments, and the interaction of cultivar by defoliation

Factors	df	Open Bolls[Z]	Defoliation	Desiccation	RG_T	RG_B
1 WAT						
Cultivar[Y]	3	0.0062	0.0028	0.0296	N/A[W]	N/A
Defoliation[X]	1	0.5632	0.7471	0.0328	N/A	N/A
Cultivar*Defoliation	3	0.8607	0.6088	0.8947	N/A	N/A
2 WAT						
Cultivar	3	0.0157	0.0616	0.0594	0.4155	0.1097
Defoliation	1	0.3176	0.0326	0.0346	0.3910	1.0000
Cultivar*Defoliation	3	0.0864	0.9282	0.9132	0.4155	0.7002
3 WAT						
Cultivar	3	0.0959	0.0523	0.0523	0.7826	0.3080
Defoliation	1	0.4558	0.0754	0.0754	0.2152	0.6497
Cultivar*Defoliation	3	0.0205	0.624	0.624	0.7826	0.8062

[Z]**Measurements include the percentage of open bolls, defoliation, desiccation, terminal regrowth (RG_T), and basal regrowth (RG_B).**

[Y]**Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).**

[X]**Defoliation treatments included a recommended defoliant mix (0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron) and an aggressive (1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl) defoliant mix.**

[W]**No terminal or basal regrowth was recorded in any plots at 7 DAT.**

Table 3.Means for cultivar and defoliation treatment evaluations in Tifton, GA, 2013

Factor	Open Bolls[Z] (%)	Defoliation (%)	Desiccation (%)	RG_T (%)	RG_B (%)
1 WAT					
Cultivar[Y]					
PHY 499	92	89	8	0	0
DP 1028	90	81	9	0	0
DP 1137	86	73	12	0	0
ST 5288	84	66	15	0	0
$PLSD_{0.05}$	5	11	5	NS[W]	NS
Defoliation[X]					
Light	89	78	8	0	0
Aggressive	88	76	14	0	0
$PLSD_{0.05}$	NS	NS	5	NS	NS
2 WAT					
Cultivar					
PHY 499	100	94	6	0	0
DP 1028	98	92	8	0	1
DP 1137	98	90	10	0	0
ST 5288	97	88	12	0	0
$PLSD_{0.05}$	2	NS	NS	NS	NS
Defoliation					
Light	98	94	6	0	0
Aggressive	99	88	12	0	0
$PLSD_{0.05}$	NS	5	5	NS	NS
3 WAT					
Cultivar					
PHY 499	100	97	3	0	4
DP 1028	100	97	3	0	7
DP 1137	100	95	5	0	4
ST 5288	99	93	8	0	5
$PLSD_{0.05}$	NS	NS	NS	NS	NS
Defoliation					
Light	100	98	3	0	5
Aggressive	100	94	6	0	5
$PLSD_{0.05}$	NS	NS	NS	NS	NS

[Z] Parameters include percentages of open bolls, defoliation, desiccation, terminal regrowth (RG_T), and basal regrowth (RG_B).

[Y] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X] Recommended defoliation treatment applied 0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron. The aggressive treatment applied 1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl.

[W] No significant difference.

Tifton, GA, 2014. Cultivar had no effect on open boll, defoliation, or RG_T percentages but did impact desiccation at 3 WAT and RG_B at 1 and 2 WAT across both defoliation treatments (Table 4). Cotton desiccation was lower in ST 5288 compared to all other cultivars, although the range of desiccation was only from 4 to 7% (Table 5). Greater RG_B was observed in the smooth-leaf cultivar DP 1028 than all other cultivars at 1 WAT. By 2 WAT, RG_B was greatest in the two smooth-leaf cultivars. These differences are likely not attributed to leaf pubescence and given the range of regrowth observed (3-6%) are not significant biologically from a crop management standpoint. When comparing cultivars pooled over defoliation treatments, desiccation differences were noted only at 3 WAT. When pooled over cultivars, a significant effect of defoliation treatment occurred for cotton leaf defoliation at 2 WAT as well as for desiccation at all three rating dates. Differences observed included 5% less defoliation and 6 to 10% more desiccation with the aggressive defoliation strategy. There was no significant interaction between cultivars and defoliation strategy at this location.

Lewiston, NC, 2014. The interaction of cultivar-by-defoliation treatment was significant for open bolls at 1 WAT (Table 6), where the aggressive defoliation treatment on DP 1137 resulted in a lower percentage of open bolls than the recommended defoliation treatment on DP 1028 and ST 5288 regardless of defoliation treatment (Fig. 2). The open boll percentages between all treatments ranged from 95 to 98%, thus it is unlikely that this difference is significant biologically and would impact crop management. Cultivar had a significant effect on both defoliation and desiccation at 1 and 2 WAT. The separation in both defoliation and desiccation was at most 4% among cultivars. At 1 WAT, defoliation in the hairy-leaf ST 5288 was significantly lower than the smooth-leaf DP 1028, whereas greater desiccation was observed in ST 5288 than in the two smooth-leaf cultivars DP 1028 and DP 1137 (Table 7). At 2 WAT, defoliation in PHY 499 and ST 5288 was lower than the two smooth-leaf cultivars, whereas desiccation ratings in the two cultivars with greater levels of leaf pubescence were higher than DP 1137. Defoliation treatment did not have a significant effect on any of the parameters measured by defoliation ratings at Lewiston, NC, 2014.

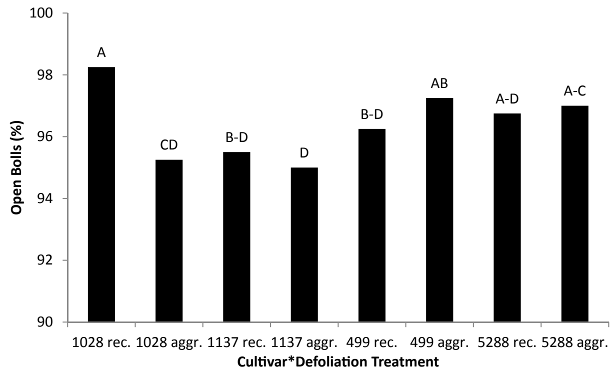

Figure 2. Percent open bolls as influenced by the interaction of cultivars DP 1028 (1028), DP 1137 (1137), PHY 499 (499), and ST 5288 (5288) and the recommended (rec.) and aggressive (aggr.) defoliation treatments at 1 wk after treatment in Lewiston, NC, 2014.

Over all locations, when significant differences were present, the aggressive defoliation treatment resulted in reduced defoliation and increased desiccation. This was expected because defoliation methods that desiccate plant tissues often lead to sticking of desiccated leaves to the plant because the abscission layer that is necessary for proper defoliation is not formed (Bovey and Miller, 1968; Brecke et al., 2001). At the two Georgia site years, there was no observed pattern between leaf pubescence characteristics and defoliation practices for open bolls, defoliation, or desiccation percentages. At Lewiston, NC, 2014, defoliation ratings were lower in the two cultivars with higher leaf pubescence ratings, PHY 499 and ST 5288, when significant differences were present. Similar results were present for desiccation ratings where the cultivar with the highest leaf pubescence rating, ST 5288, had increased percentages of desiccation at 1 and 2 WAT.

Lint Percentage and Yield. Cultivar had a significant effect on lint percentage at Tifton, GA in 2013 and 2014 and on lint yield at Tifton in 2013 (Table 8). Lint percentage is typically dependent on specific cultivar characteristics, primarily seed size (Miller and Rawlings, 1967), which is most likely the primary cause behind the differences in lint percentage observed among the cultivars. A greater lint percentage was present in cultivars PHY 499 and DP 1028 compared to DP 1137 and ST 5288 at Tifton in 2013, whereas lint yield at this site year was higher in DP 1028 and PHY 499 than ST 5288 (Table 9). At Tifton in 2014, a significant difference in lint percentage was observed between all cultivars with the highest and lowest lint percentage present in PHY 499 and ST 5288, respectively.

Table 4. Analysis of variance (ANOVA) results (*p* values) for cotton defoliation evaluations in Tifton, GA, 2014. Factors include four cultivars, two defoliation treatments, and the interaction of cultivar by defoliation

Factors	df	Open Bolls[Z]	Defoliation	Desiccation	RG_T	RG_B
1 WAT						
Cultivar[Y]	3	0.2393	0.7093	0.9770	0.0536	0.0260
Defoliation[X]	1	0.3368	0.9377	0.0435	0.4444	0.6376
Cultivar*Defoliation	3	0.2894	0.3130	0.8732	0.0992	0.8443
2 WAT						
Cultivar	3	0.3819	0.9909	0.2098	0.6765	0.0277
Defoliation	1	0.1705	0.0298	0.0081	0.8839	0.2619
Cultivar*Defoliation	3	0.7770	0.2359	0.2923	0.4265	0.3370
3 WAT						
Cultivar	3	N/A[W]	0.2343	0.0095	0.1181	0.1362
Defoliation	1	N/A	0.1272	0.0066	0.2773	0.4152
Cultivar*Defoliation	3	N/A	0.5068	0.3182	0.0781	0.4141

[Z] Measurements include the percentage of open bolls, defoliation, desiccation, terminal regrowth (RG_T), and basal regrowth (RG_B).

[Y] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X] Defoliation treatments included a recommended defoliant mix (0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron) and an aggressive (1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl) defoliant mix.

[W] All plots had reached 100% open bolls at 3 WAT.

Table 5. Effect means for cultivar and defoliation treatment evaluations in Tifton, GA, 2014

Factor	Open Bolls[Z] (%)	Defoliation (%)	Desiccation (%)	RG_T (%)	RG_B (%)
1 WAT					
Cultivar[Y]					
PHY 499	97	77	14	0	0
DP 1028	94	73	15	1	0.5
DP 1137	94	74	15	0	0
ST 5288	95	73	15	0	0.13
$PLSD_{0.05}$	NS[W]	NS	NS	NS	0.36
Defoliation[X]					
Light	94	74	10	0	0
Aggressive	96	74	20	0	0
$PLSD_{0.05}$	NS	NS	10	NS	NS
2 WAT					
Cultivar					
PHY 499	100	90	8	0	4
DP 1028	99	89	11	1	6
DP 1137	99	89	10	0	6
ST 5288	99	90	8	1	3
$PLSD_{0.05}$	NS	NS	NS	NS	2
Defoliation					
Light	99	92	6	0	4

(Table 5 continued next page)

(Table 5 continued)

Factor	Open Bolls[Z] (%)	Defoliation (%)	Desiccation (%)	RG_T (%)	RG_B (%)
Aggressive	100	87	12	0	6
$PLSD_{0.05}$	NS	4	3	NS	NS
3 WAT					
Cultivar					
PHY 499	100	94	6	1	11
DP 1028	100	93	7	2	12
DP 1137	100	83	7	1	13
ST 5288	100	95	4	1	9
$PLSD_{0.05}$	NS	NS	2	NS	NS
Defoliation					
Light	100	96	3	1	10
Aggressive	100	87	9	1	13
$PLSD_{0.05}$	NS	NS	3	NS	NS

[Z] Parameters include percentages of open bolls, defoliation, desiccation, terminal regrowth (RG_T), and basal regrowth (RG_B).

[Y] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X] Recommended defoliation treatment applied 0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron. The aggressive treatment applied 1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl.

[W] No significant difference.

Table 6. Analysis of variance (ANOVA) results (*p* values) for cotton defoliation evaluations in Lewiston, NC, 2014. Factors include four cultivars, two defoliation treatments, and the interaction of cultivar by defoliation

Factors	df	Open Bolls[Z]	Defoliation	Desiccation	RG
1 WAT					
Cultivar[Y]	3	0.0760	0.0420	0.0289	N/A[W]
Defoliation[X]	1	0.4338	0.1273	0.0563	N/A
Cultivar*Defoliation	3	0.0399	0.7197	0.4362	N/A
2 WAT					
Cultivar	3	0.2642	0.0096	0.0475	N/A
Defoliation	1	0.1027	0.0685	0.0675	N/A
Cultivar*Defoliation	3	0.3381	0.7179	0.7654	N/A
3 WAT					
Cultivar	3	N/A[V]	0.7708	0.7708	N/A
Defoliation	1	N/A	0.2113	0.2113	N/A
Cultivar*Defoliation	3	N/A	0.3308	0.3308	N/A

[Z] Measurements include the percentage of open bolls (OB), defoliation (DEF), desiccation (DES), and regrowth (RG).

[Y] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X] Defoliation treatments included a recommended defoliant mix (0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron) and an aggressive defoliant mix (1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl).

[W] No regrowth was recorded at any evaluation date.

[V] All plots had reached 100% open bolls at 3 WAT.

Table 7. Effect means for cultivar and defoliation treatment evaluations in Lewiston, NC, 2014

	Open Bolls[Z] (%)	Defoliation (%)	Desiccation (%)	RG (%)
1 WAT				
Cultivar[Y]				
PHY 499	97	95	3	0
DP 1028	97	97	2	0
DP 1137	95	96	3	0
ST 5288	97	94	5	0
$PLSD_{0.05}$	NS[W]	2	2	NS
Defoliation[X]				
Light	97	96	2	0
Aggressive	96	95	4	0
$PLSD_{0.05}$	NS	NS	NS	NS
2 WAT				
Cultivar				
PHY 499	98.88	94	6	0
DP 1028	99	97	3	0
DP 1137	98.63	98	2	0
ST 5288	99	94	6	0
$PLSD_{0.05}$	0.44	3	3	NS
Defoliation				
Light	99.06	97	2	0
Aggressive	98.69	94	6	0
$PLSD_{0.05}$	NS	NS	NS	NS
3 WAT				
Cultivar				
PHY 499	100	97	3	0
DP 1028	100	98	2	0
DP 1137	100	97	3	0
ST 5288	100	97	3	0
$PLSD_{0.05}$	NS	NS	NS	NS
Defoliation				
Light	100	98	2	0
Aggressive	100	96	4	0
$PLSD_{0.05}$	NS	NS	NS	NS

[Z] Parameters include percentages of open bolls, defoliation, desiccation, and regrowth (RG).

[Y] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X] Recommended defoliation treatment applied 0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron. The aggressive treatment applied 1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl.

[W] No significant difference.

Table 8. Analysis of variance (ANOVA) results (*p* values) for cotton yield parameters in Tifton, GA, 2013 and 2014, and Lewiston, NC, 2014. Factors include four cultivars, two defoliation treatments, and the interaction of cultivar by defoliation

Factors	Df	Seed Cotton Yield[Z]	Lint Percentage	Lint Yield
Georgia 2013				
Cultivar[Y]	3	0.3185	0.0077	0.0336

(Table 8 continued next page)

(Table 8 continued)

Factors	Df	Seed Cotton Yield[Z]	Lint Percentage	Lint Yield
Defoliation[X]	1	0.2378	0.5644	0.3071
Cultivar*Defoliation	3	0.6461	0.9850	0.6597
Georgia 2014				
Cultivar	3	0.0513	<.0001	0.1131
Defoliation	1	0.4915	0.7381	0.4415
Cultivar*Defoliation	3	0.9750	0.8554	0.9688
North Carolina 2014				
Cultivar	3	0.6461	0.3457	0.2100
Defoliation	1	0.9013	0.3674	0.4471
Cultivar*Defoliation	3	0.4478	0.5025	0.5933

[Z]Measurements include the seed cotton yield, lint percentage, and lint yield.

[Y]Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X]Defoliation treatments included a recommended defoliant mix (0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron) and an aggressive defoliant mix (1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl).

Table 9. Effect means for cultivar on cotton yield parameters in Tifton, GA, 2013 and 2014, and Lewiston, NC, 2014. Cultivar means are pooled over defoliation treatments

Cultivar[Z]	Seed Cotton Yield (kg/ha)[Y]	Lint Percentage (%)	Lint Yield (kg/ha)
Tifton, GA, 2013			
PHY 499	4755.71	41.3	2201.26
DP 1028	4663.02	40.8	2133.05
DP 1137	4765.14	39.2	2090.2
ST 5288	4522.73	39.5	2002.51
$PLSD_{0.05}$	NS[X]	1.3	130.11
Tifton, GA, 2014			
PHY 499	2964.5	43.2	1434.46
DP 1028	2622.68	42.2	1239.79
DP 1137	2920.13	41.1	1344.3
ST 5288	3418.6	40.1	1530.55
$PLSD_{0.05}$	NS	1.0	NS
Lewiston, NC, 2014			
PHY 499	1601.7	44.2	794.46
DP 1028	1537.27	44.1	760.32
DP 1137	1500.49	37.9	630.95
ST 5288	1521.06	42.3	719.97
$PLSD_{0.05}$	NS	NS	NS

[Z]Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[Y]Parameters include seedcotton yield, lint percentage, and lint yield.

[X]No significant difference.

Table 10. Analysis of variance (ANOVA) results (*p* values) from lint quality parameters from Tifton, GA, 2013 and 2014, and Lewiston, NC, 2014. Factors include cultivar, defoliation treatment, and the interaction of cultivar by defoliation

Factors	df	Staple[Z]	Mic	Strength	Leaf Grade	Rd	+B	HVI trash	HVI length	Uniformity
Georgia 2013										
Cultivar[Y]	3	0.0249	0.0014	0.0010	0.5302	0.0852	0.8043	0.6793	0.0363	0.4561
Defoliation[X]	1	0.1817	0.0679	0.8185	0.3966	0.7952	0.7244	0.7827	0.3659	0.4829
Cultivar*Defoliation	3	0.7272	0.1564	0.6689	0.9738	0.4277	0.8348	0.9141	0.8852	0.9993
Georgia 2014										
Cultivar	3	0.0004	<.0001	0.0021	<.0001	0.0356	<.0001	<.0001	<.0001	0.0114
Defoliation	1	0.5456	0.1470	0.7099	0.8116	0.7483	0.8601	0.3132	0.6209	0.4446
Cultivar*Defoliation	3	0.1541	0.9798	0.8249	0.5581	0.6976	0.5180	0.9051	0.1777	0.5882
North Carolina 2014										
Cultivar	3	0.0895	0.0221	<.0001	<.0001	<.0001	<.0001	<.0001	0.0436	<.0001
Defoliation	1	0.3563	0.9675	0.2587	0.6069	0.2255	0.4729	0.8760	0.1768	0.6736
Cultivar*Defoliation	3	0.6871	0.5513	0.5721	0.6194	0.3933	0.2501	0.8993	0.2137	0.0411

[Z] Measurements include color grade, staple, micronaire (Mic), strength, leaf grade, reflectance (Rd), yellowness (+B), HVI trash, HVI length, and uniformity.

[Y] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[X] Defoliation treatments included a recommended defoliant mix (0.73 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, and 0.23 L ha^{-1} of thidiazuron) and an aggressive defoliant mix (1.17 L ha^{-1} of tribufos, 2.34 L ha^{-1} of ethephon, 0.23 L ha^{-1} of thidiazuron, and 0.15 L ha^{-1} of pyraflufen ethyl).

Table 11. Effect means of cultivar on of fiber quality characteristics from Tifton, GA, 2013 and 2014, and Lewiston, NC, 2014. Cultivar means are pooled over defoliation treatments

Cultivar[Z]	Staple[Y] (32nds of an in)	Mic	Strength (g/tex)	Leaf Grade	Rd	+B	HVI Trash (% area)	HVI Length (in)	Uniformity (%)
Tifton, GA 2013									
PHY 499	36.25	4.76	30.94	3.88	74.61	7.84	0.613	1.13	83.26
DP 1028	37	4.59	28.51	3.13	75.94	7.95	0.44	1.15	82.91
DP 1137	36.63	4.49	28.89	4	76.29	7.71	0.64	1.14	82.59
ST 5288	37	4.41	28.92	3.63	76.51	7.73	0.56	1.15	82.79
$PLSD_{0.05}$	0.536	0.159	1.11	NS[X]	NS	NS	NS	0.02	NS
Tifton, GA 2014									
PHY 499	35.63	4.89	31.78	3	75.05	8.85	0.38	1.11	82.95
DP 1028	36.75	4.75	29.80	2.17	76.29	8.93	0.24	1.14	83.4
DP 1137	37	4.6	29.89	2.13	76.25	8.73	0.28	1.15	82.85
ST 5288	36.38	4.91	29.44	3.88	75.51	7.78	0.6	1.13	81.94
$PLSD_{0.05}$	0.55	0.1	1.18	0.48	0.95	0.26	0.1	0.01	0.86
Lewiston, NC 2014									
PHY 499	36.5	4.85	31.88	3.25	76.79	7.76	0.49	1.14	84.41
DP 1028	36.88	4.79	28.86	1.57	79.43	7.89	0.17	1.15	84.24
DP 1137	36.75	4.83	28.92	2	79.58	7.76	0.21	1.14	84.31
ST 5288	36.25	4.61	29.34	4	78.96	7.08	0.63	1.13	82.74
$PLSD_{0.05}$	NS	0.16	1.07	0.45	0.97	0.19	0.14	0.01	0.57

[Z] Cultivars include PhytoGen 499 WRF (PHY 499), Deltapine 1028 B2RF DP 1028), Deltapine 1137 B2RF (DP 1137), and Stoneville 5288 B2F (ST 5288).

[Y] Measurements include color grade, staple, micronaire (Mic), strength, leaf grade, reflectance (Rd), yellowness (+B), HVI trash, HVI length, and uniformity.

[X] No significant difference.

Although lint percentage differences were significant among cultivars at Tifton in 2013 and 2014, the range was relatively small with 2.1 and 3.1% difference among the highest and lowest cultivars in 2013 and 2014, respectively. In the only instance in which cultivar had a significant effect on lint yield (Tifton, 2013), all cultivars yielded in excess of 2,000 kg ha^{-1} of lint with a difference of 198.75 kg ha^{-1} of lint between the highest and lowest yielding cultivars.

Fiber Quality. Previous studies have reported that the timing of defoliation can impact fiber quality properties such as length, strength, micronaire, and uniformity (Brown and Hyer, 1956; Faircloth et al., 2004; Karademir et al., 2007; Snipes and Baskin, 1994), whereas the selection of defoliation products has no effect on these fiber properties (Larson et al., 2005; Snipes and Baskin, 1994). Thus, the significant effect of cultivar on fiber quality properties such as staple, micronaire, strength, HVI length, and uniformity are reflective of the inherent genetic differences associated with the cultivars evaluated, as defoliation was timed appropriately to avoid premature defoliation and was uniform across all locations. The goal of this study was to determine the effect of leaf pubescence characteristics of cultivars and defoliation practices on the fiber quality properties such as leaf grade, color characteristics, and trash, thus these parameters are the focus of the results. However, differences in additional fiber quality parameters, primarily resulting from genetic cultivar effects, are also included.

There was no defoliation-by-cultivar interaction or defoliation main effect observed for any fiber quality parameters (Table 10). In contrast, cultivar main effects were noted for nearly every fiber quality property measured. Significant effects on the reflectance (Rd) and yellowness (+B) of the lint were observed at Tifton, GA, 2014, and Lewiston, NC, 2014. Although differences were noted, all results fell into the middling or strict low middling Rd categories, with the exception of one low middling sample from Tifton, GA, 2013 and one strict middling sample from Lewiston, NC, 2014 (data not shown). Additionally, all individual plot samples were in the white +B category (data not shown).

Cultivar also had a significant effect on HVI trash (a measure of percentage surface area occupied by nonlint material in a sample, analyzed digitally) and leaf grade (visual evaluations of leaf content in a sample) (United States Department of Agriculture, 1995). The cultivar with the highest leaf pubescence rating in the study, ST 5288, had an increased leaf grade and HVI trash values above all other cultivars at Tifton, GA, 2014, and Lewiston, NC, 2014 (Table 11). With the exception of HVI trash in Tifton, GA, 2014, PHY 499 resulted in greater leaf grade and HVI trash values than the two smooth-leaf cultivars, though not as high as ST 5288.

The study results illustrate that open boll, defoliation, and desiccation percentages are influenced primarily by defoliation strategy or cultivar with minimal interaction. Subsequently, these results suggest leaf pubescence level has little influence on these factors; however, leaf pubescence characteristics of the cultivars were directly responsible for nearly all effects on fiber quality. Producers should therefore be mindful of inherent leaf pubescence characteristics of cultivars and their potential influence on fiber quality and potential discounts or premiums for lint.

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