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RELATIONSHIP OF PLANT SUGARS AND ENVIRONMENT TO STICKINESS IN WEST TEXAS COTTON

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Abstract

In West Texas, sticky cotton (*Gossypium hirsutum*) may occasionally occur with contamination from aphid (*Aphis* gossyppi) honeydew or excess plant sugars in the fiber due to cool night temperatures and/or late maturity. If fiber stickiness were due to plant sugars, the potential might be reduced by selecting cultivars and lines that produce fibers with low residual sugar content (<0.3 % reducing sugars) at harvest.

Field experiments were conducted over a five-year period with cultivars and lines varying in maturity class (early, mid-, and full-season). Experimental design was a split-plot with four replications, with genotypes as main plots, and harvest aids as subplots. Harvest aid treatments were ethephon (Prep®), paraquat (Cyclone®), and desiccation by a killing frost. At harvest, bolls were hand-picked from three fruiting zones. Seed cotton was ginned and cleaned once with a lint cleaner. In the first two years, reducing sugars were determined for all fruiting zones (top, middle, and bottom), genotypes, and harvest aids treatments, while in the final three years, glucose and sucrose were determined. In all years, 2.2 lb. samples of ginned lint were carded and rated for stickiness.

Fiber stickiness was found only occasionally. In years when there was substantial rainfall prior to harvest, fiber stickiness was not detected and sugar content on fiber was very low. Contrary to expectations, neither reducing sugars nor glucose correlated well with stickiness ratings based on carding; however, fiber stickiness ratings and sucrose levels were frequently well correlated. Stickiness potential was most frequently observed in bolls harvested from the uppermost fruiting zone in comparison to levels found in the middle and bottom zones. Stickiness potential was most often found when cotton was harvested following a killing frost, compared to treatment with ethephon or paraquat. Fiber stickiness and sugar levels varied between years and genotypes. There was no association between stickiness potential and maturity classes of genotypes.

Introduction

The term stickiness is used to describe adhesion of cotton fiber to moving parts in harvesting, ginning, or textile processing. Typically, stickiness creates the greatest problem during the carding process in the textile mill. In certain severe instances carding operations can be stopped in less than an hour. In recent years, by far the greatest cause of stickiness has been from insect honeydew. In West Texas, stickiness sometimes occurs due to contamination of open bolls by cotton aphid honeydew, but an accumulation of plant sugars on cotton fiber is another common source of contamination.

Testing for stickiness is not part of the cotton grading system. There is no widely accepted method of quantifying stickiness that is capable of testing samples at a rate equivalent to that of the high volume instrumentation (HVI) system. Stickiness generally is first discovered at the textile mill. Fiber purchasers then suffer financial losses and discount future risk by reducing the price they are willing to pay for cotton produced in areas with a history of sticky cotton.

The relationship between sugars and sticky cotton is well documented (Perkins, 1971; Roberts et al., 1978; Heuer and Plaut, 1985; Miller et al., 1994). Common causes of immature fiber in West Texas are early applications of harvest aids, drought stress, and low temperature. If many immature bolls are present when cotton is terminated with harvest aids, lint yield and fiber properties may be compromised (Cathey et al., 1982; Snipes and Baskin, 1994). Micronaire, a partial indicator of fiber maturity, can be reduced when harvest aids are applied when fewer than 25% of bolls are open. Fiber development is governed by temperature and substrate availability (Conner et al., 1972). Low temperatures, especially at night, result in cotton producing

immature fiber (Gipson and Joham, 1968b). Cellulose synthesis and respiration respond differently to cool night temperatures (Roberts et al., 1992). Both processes are impaired by sub-optimum temperature, but cellulose synthesis is slower to recover.

Hessler et al. (1959), and later Conner et al. (1972), detected increase in soluble sugars in developing cotton bolls as temperature decreased. Cotton genotypes also appear to be a factor in sticky cotton. Effect of temperature on rate of fiber development differs among genotypes. Those cultivars best adapted to the High Plains production area exhibit less reduction in fiber development when affected by low temperatures than do non-adapted cultivars (Gipson and Joham, 1968a).

Plant sugars are abundant in developing cotton bolls but decline with maturity (Hessler et al., 1959, Conner et al., 1972). Thus, fiber maturity and sugar content are inversely related. Rapid tests used by textile mills to screen for stickiness are based on reducing substance assays. Glucose, the most prevalent sugar in developing cotton fiber, is a reducing sugar and the standard in most reducing sugar tests. In practice, each textile mill will determine by experience the maximum concentration of reducing substances in lint, usually <0.3%, that can be processed without loss of operating efficiency. Then, if stickiness is suspected, the mill will screen suspect bales to ascertain the level of reducing substances and adjust the number of bales with higher than desired reducing substance concentrations included in individual lay-downs. Stickiness potential of cotton is not determined wholly by total sugar content (Miller et al., 1994). Rather, the types of sugars are more of a determinant of stickiness. Sucrose, a non-reducing sugar, has two to three times greater cotton stickiness potential than does glucose.

Objectives of this research were to determine if reducing substances can be used as a selection criterion for reducing stickiness potential among cotton genotypes, and identify boll sampling zones and harvest treatments to facilitate such selection.

Materials and Methods

Field experiments were conducted at the Texas A&M Research and Extension Center at Lubbock from 1994 to 1998. Cultivars and breeding lines were grown using recommended practices. The plots were managed for an intermediate crop maturity. The experiment was conducted using a split-plot design with four replications. Main plot treatments were genotypes and subplot treatments were harvest aids. In 1994, 1995, 1996, 1997, and 1998 there were 20, 20, 11, 12, and 12 genotypes, respectively, included in experiments. Plots were 28 feet in length and 18 feet in width containing six equally spaced rows. In 1994, there were two harvest aid treatments: an early harvest following application of the boll opener ethephon at 4.5 a.i. lb acre^{-1}, and a harvest soon after a killing frost (temperatures below 32°F for a minimum of 4 hours resulting in general plant desiccation). In 1995 and subsequent years, paraquat at 1.5 a.i. lb acre^{-1} was included as a crop desiccant, applied at about two weeks after five nodes above white flower (NAWF).

Following each crop termination treatment, bolls were hand harvested and partitioned based on three fruiting node equivalency zones, bottom=fruiting node equivalents 1-4, middle=fruiting node equivalents 5-8, and top=fruiting node equivalents 9-12. Approximately 5 lb. of seed cotton was harvested from each fruiting zone. Seed cotton samples were ginned on a ten-saw laboratory gin with one lint cleaning. A 2.2 lb. sub-sample was assayed for stickiness on a Hollingsworth® carding machine at Texas Tech University International Textile Center. Fiber was fed through the carding machine for approximately one minute. Visual ratings were made on a scale based on amount of sticking points (0=not sticky, 1=slightly sticky, 2=moderately sticky, and 3=very sticky). Additional sub-samples were assayed for reducing sugars using the Perkins' method (Perkins, 1971) in 1994 and 1995; while glucose and sucrose were measured using a YSI 2700 Sugar Analyzer in 1996-1998 (YSI, 1996) (Table 1).

Results and Discussion

Neither reducing sugar nor glucose assays were good indicators of fiber stickiness as measured by card ratings (Table 2). The sucrose assay was a better predictor of card stickiness ratings. These results are consistent with findings of Miller et al. (1994) who determined sucrose has a greater stickiness potential than the reducing sugar, glucose. In 1994, fiber from plots treated with ethephon had significantly greater concentrations of reducing substances than plots left to a killing freeze; however, the card stickiness rating analyses indicated there was less stickiness potential from cotton treated with ethephon (Table 3). Similar results were observed in 1996, but this time glucose was significantly higher in treatments with significantly lower card ratings (Table 4). The exception to this trend was found in 1998. Plots left to a killing freeze were exposed to rainfall that likely removed sugars and detectable levels of card stickiness.

The greatest amount of stickiness generally was found from bolls produced in the uppermost portion of the plant in age-equivalent fruiting nodes 9-12 (Tables 3 and 4). Not only did these bolls develop when plants were stressed with heavy boll loads, but bolls developed during late summer and early autumn when night temperatures were frequently sub-optimum for cotton growth and development. Moreover, bolls from lower fruiting sites opened sooner. The longer cotton bolls remain exposed, the more likely events, such as heavy rainfall, will remove sticky sugars. Nevertheless, it was possible to detect

some low levels of card stickiness from all fruiting zones at least once during the course of this research project. Whereas the top fruiting zone may be the optimum diagnostic sampling site for research purposes, lower fruiting positions can also produce sticky cotton, which suggests that selection against fruiting in the uppermost zone, i.e, early cutout, may not be a viable strategy for avoiding stickiness.

Stickiness was most often found in cotton harvested after a killing freeze in comparison to cotton harvested following use of ethephon or desiccated with paraquat (Tables 3 and 4). Cotton harvested following a killing frost had significantly higher card stickiness ratings from 1994 to 1996. Fiber from plants treated with ethephon was generally not significantly different than cotton desiccated by paraquat. The exception was in 1996, when fiber from bolls in the top fruiting zone that had been treated with ethephon had higher card stickiness ratings than did the fiber from those treated with paraquat.

Card stickiness and sugar content on fiber varied between years and harvest aid treatments. There was no concordance of maturity class of genotype with stickiness potential. Rather, differences in stickiness were most readily associated with harvest aid treatments across genotypes. Cotton harvested following early fall treatment with ethephon or paraquat very seldom indicated any potential for stickiness. In contrast, when the same genotypes were harvested after termination by a killing frost, stickiness potential was often indicated in card ratings in those years when little or no rainfall occurred before harvesting.

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Table 1. Sugars determined from cotton fibers.

Harvest Treatment	Year				
	1994	1995	1996	1997	1998
Ethephon	RS[1]	RS	Gluc,Suc[2]	Rain[3]	Gluc, Suc
Paraquat	Not Tested	RS	Gluc, Suc	Rain	Gluc, Suc
Freeze	RS	RS	Gluc, Suc	Rain	Rain

1. Reducing sugars (Perkins, 1971)
2. Glucose and sucrose, separately by YSI Model 2700 Sugar Analyzer (YSI, 1996)
3. Determinations were performed but rainfall before sampling reduced contents to undetectable levels

Table 2. Correlation of card ratings and sugar determinations for harvest treatments within zones 1994-1998.

Harvest Treatment	Harvest Zone	1994 RS[1]	1995 RS	1996 Glucose	1996 Sucrose	1998 Glucose	1998 Sucrose
				R-square[2]			
Ethephon	Top	.00	NST	.02	.48**	.12*	.03
	Middle	NST[3]	.00	NST	NST	.06	.21*
	Bottom	NST	NST	NST	NST	.01	.66**
Paraquat	Top	ND[4]	NST	NST	NST	.01	.07
	Middle	ND	NST	.02	.08	.01	.13*
	Bottom	ND	NST	NST	NST	.00	.07
Freeze	Top	.02	.05**	.06	.63**	Rain[5]	Rain
	Middle	.11**	.00	.04	.01	Rain	Rain
	Bottom	.00	NST	NST	NST	Rain	Rain
$df_{(error)}$		78	78	42	42	46	46

Reducing substances

1. * p-value $\leq$ 0.05; ** p-value $\leq$ 0.01
2. No stickiness found when carding
3. Treatment not done in 1994
4. Substantial rainfall occurred before harvesting; sugar concentration was below the level of detection, and stickiness not found at carding

Table 3. Mean card stickiness ratings and reducing sugar concentrations of harvest treatments in 1994 and 1995.

	Harvest Zone					
	Top		Middle		Bottom	
Harvest Treatment	Card[1]	RS[2]	Card	RS	Card	RS
1994						
Ethephon	0.00 b	.872 a	0.00 b	.575 a	0.00 b	.462 a
Freeze	2.38 a	.534 b	0.77 a	.436 b	0.17 a	.365 b
Mean	1.19	.703	0.38	.506	0.08	.413
L.S.D. (0.05)	0.17	.059	0.13	.042	0.08	.026
1995						
Ethephon	0.00 b	.324 a	0.01 a	.259 c	0.00 a	.270 b
Paraquat	0.00 b	.275 b	0.00 a	.321 b	0.00 a	.286 b
Freeze	0.51 a	.348 a	0.01 a	.391 a	0.00 a	.351 a
Mean	0.11	.316	0.01	.324	0.00	.314
L.S.D. (0.05)	0.20	.035	ns	.021	ns	.041

1. Card rating (0= not sticky, 1= slightly sticky, 2=moderately sticky, 3=very sticky)
2. Reducing sugars reported as fraction of fiber weight

Table 4. Mean card stickiness ratings, glucose and sucrose concentrations of harvest aid treatments in 1996, 1998.

Harvest Treatment	Harvest Zone: Top			Middle			Bottom		
		mg/g			mg/g			mg/g	
	Card[1]	Glu[2]	Suc[3]	Card	Glu	Suc	Card	Glu	Suc
1996									
Ethephon	.142b	0.52a	0.17a	.000b	0.05a	0.08a	.000	0.12b	0.26ab
Paraquat	.000c	0.66a	0.12a	.011b	0.05a	0.08a	.000	0.11b	0.25b
Freeze	.540a	0.10b	0.18a	.502a	0.05a	0.04a	.000	0.14a	0.31a
Mean	.227	0.42	0.15	.171	0.05	0.06	.000	0.13	0.27
L.S.D. $_{(0.05)}$	.110	0.30	ns	.218	ns	ns	ns	0.02	0.06
1998									
Ethephon	.215a	3.50a	0.95a	.161a	1.40a	0.54a	.076a	1.13a	0.17a
Paraquat	.208a	2.08a	0.54a	.092a	0.91a	0.30ab	.043a	0.71b	0.14a
Freeze[4]	.000b	0.58a	0.17a	.000b	0.36c	0.15b	.000b	0.20c	0.10a
Mean	.141	2.05	0.55	.084	0.89	0.33	.040	0.68	0.14
L.S.D. $_{(0.05)}$	.132	ns	ns	.070	0.24	0.27	.067	0.20	ns

1. Card rating (0=not sticky, 1=slightly sticky, 2= moderately sticky, 3=very sticky)
2. Glucose concentration from fiber sample
3. Sucrose concentration from fiber sample
4. Three-inches of rain fell between the harvest date of ethephon and paraquat treatments and harvest date of treatment killed by freeze