Bemesia (Homoptera: Aleyrodidae) Honeydew and Sticky Cotton Relationships

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ABSTRACT

Sticky cotton caused by insect honeydew contamination is a major issue in the cotton industry. Bemisia tabaci (Gennadius) Strain B (= B. argentifolii Bellows and Perring) honeydew contributes to cotton lint stickiness. Increases in thermodetector sticky cotton counts and trehalulose and melezitose were correlated to increasing Bemisia nymph and adult populations. Effective chemical control reduced whitefly populations and sticky cotton levels. Thermodetector counts did not reach levels ≥ 5 until average Bemisia adult leaf-turn counts were 11.7 or nymphs were 1.7 per cm^2 of leaf disk during the open mature cotton boll period.

Introduction

Hector and Hodkinson (1989) highlighted cotton lint stickiness as a significant problem in the textile industry. Whitefly or aphid honeydew deposits remain localized on lint and adhere to machinery surfaces during harvest, ginning and lint processing (Bourley *et al.*, 1984). In Arizona, cotton stickiness may result in discounts up to 18 cents per kilogram of cotton (Anon., 1996). Spinning mills report monetary loss, increased machinery maintenance, refusal to process sticky cotton and price reduction differentials above 10% for sticky cottons (Hector and Hodkinson, 1989). The cotton ginning output may be reduced up to 25% by sticky cotton (Khalifa and Gameel, 1982).

Identifying Sugars Associated with Lint Stickiness

The detection and quantification of the carbohydrates in cotton lint and their relationships to cotton lint stickiness has been investigated for many years. A number of chemical oxidation-reduction methods, chemical and/or heat-induced colour formation reactions and other methods that detect sugars *in situ* extracted from cotton lint were reviewed by Perkins (1993). The most commonly used are oxidation-reduction reactions that measure total reducing components of cotton lint extracts. Some of the components extracted from contaminated lint are not reducing sugars and are not detected by these methods. Furthermore, they do not identify specific sugars and thus have limitations relating lint stickiness to insect honeydew. Honeydew secreted by different insect species differs in sugar composition (Hendrix *et al.*, 1992, 1996). Despite these limitations, the potassium ferricyanide method (Perkins, 1971) is used to detect reducing substances in cotton lint as a measure of potential lint stickiness problems in processing. Cotton lint with reducing sugar content < 0.35% rarely causes problems while reducing sugars of 0.5% are likely to cause residua accumulation on machinery parts, necessitating stoppages to clean machinery (Perkins, 1993).

More definitive information on the carbohydrate composition of *Bemisia* honeydew has been obtained using high performance liquid chromatography (HPLC). Tarczynski *et al.* (1992) reported that sucrose (10.1%), glucose (5.3%), fructose (11.7%), trehalulose (43.1%), and oligosaccharides (primarily stachyose and raffinose) (29.5%) were the major honeydew carbohydrates for *Bemisia* feeding on cotton. Similarly, Hendrix *et al.* (1992) found that honeydew from *Bemisia* feeding on cotton contained 18.9% monosaccharides, 16% sucrose, 1% turanose, 43.8% trehalulose, 16.8% melezitose, approximately 3% of a novel trisaccharide later identified and named *Bemisiose* (Hendrix and Wei, 1994), and several other oligosaccharides. The authors suggested that more than 20 sugars occur in *Bemisia* honeydew, but unlike Tarczynski *et al.* (1992) they did not find either stachyose or raffinose in these excretions. Also, using an evaporative light-scattering detector and HPLC, Wei *et al.* (1996) reported that oligosaccharides larger than trisaccharides comprised greater than 13% of the total carbohydrates in the honeydew. The larger saccharides may play a significant role in the honeydew physical and chemical characteristics and in osmotic regulation of insect body fluids (Hendrix and Salvucci, 1998). Wei *et al.* (1996, 1997) identified additional oligosaccharides from honeydew produced by *Bemisia* feeding on cotton as bemisiotetrose, maltosucrose and diglucomelezitose as well as substantial amounts of the quaternary amine glycine betaine. The currently known sugars (Hendrix and Salvucci, 1998) and their percent composition of honeydew (Wei *et al.*, 1996) produced by *Bemisia* feeding on cotton are shown in Fig. 1 and Table 1, respectively. Several unidentified sugars remain. The carbohydrate aspect of the *Bemisia*-cotton host interaction is complex. An understanding of this interaction and knowledge of the carbohydrate composition of honeydew may help develop potential approaches to *Bemisia* control and/or chemically (or enzymatically) reducing cotton lint stickiness in harvested cotton (Hendrix *et al.,* 1993, 1996). Normal plant physiological sugars (fructose, glucose, and sucrose) also occur in lint. The impact and/or additive contributions of each source to sticky cotton cannot be separated with current methodology.

Cotton Lint Stickiness Measurement

The International Committee on Cotton Testing Methods of the International Textile Manufacturer's Federation adopted the thermodetector method as the international standard for measuring cotton lint stickiness (Perkins and Brushwood, 1994). Thermodetector counts of individual sticky spots measure the overall contribution of all sugar components in the cotton lint. Less than 5 sticky spots indicates non-sticky cotton, 5-14, light stickiness, 15-24, moderate stickiness and above 24, heavy stickiness (Perkins and Brushwood, 1994). Automated variations of this device now exist (Hequet and Frydrych, 1997; Mor, 1997).

Progress in Cotton Lint Stickiness Research

Bemisia-produced sugars trehalulose and melezitose on cotton lint and thermodetector counts, were more highly correlated than glucose and fructose to *Bemisia* adult and nymph numbers on cotton leaves (Henneberry *et al.,* 1995). The trehalulose and melezitose content of tagged open bolls also increased in *Bemisia*-infested fields with increasing lengths of exposure (Henneberry *et al.,* 1996).

The most direct solution to the sticky cotton problem is development of methods to reduce whitefly populations below levels causing stickiness. The most common approach to whitefly control is insecticides alone or in mixtures. Effective, integrated pest management, insecticide-based control has been developed for cotton in Arizona (Ellsworth *et al.,* 1997). The whitefly population sampling levels developed to protect cotton yield (Naranjo and Flint, 1994, 1995; Ellsworth *et al.,* 1997) are 5 adults per leaf turn for conventional insecticides and 3 to 5 adults per leaf turn with 0.5 to 1.0 large whitefly nymphs per 3.88 cm leaf disk for insect growth regulators. Reduced insecticide use is accompanied by reduced costs; conservation of natural enemies is encouraged and insecticide resistance slowed.

A series of replicated field trials has determined relationships between whitefly adult and nymph populations and sticky cotton (Henneberry *et al.,* 1998a, 1998b). Insecticide treatments were used to create different whitefly population levels. Adult whiteflies were counted weekly (Naranjo and Flint, 1994, 1995) during the open boll period. Lint samples at harvest were analyzed for stickiness using the thermodetector (Perkins and Brushwood, 1994). In the results reported here, *Bemisia* adult and nymph populations increased during the season and were highest during the open boll period (Figure 2A, B). Approximately 95% of open bolls for the first cotton fruiting cycle occurred by 15 September (Figure 2A, B, C). Thermodetector counts were below 5 in insecticide-treated plots (Figure 2C) compared to 9 to 12 for untreated plots. There were significant correlations between increasing average adults (Fig. 3A) or nymphs (Fig. 3B) populations during the open cotton boll period and increasing thermodetector counts. The thermodetector count threshold (5) for sticky cotton (Perkins and Brushwood, 1994) occurred at 11.7 adults/leaf and 1.7 nymphs/cm^2 of leaf area under the population densities that occurred, suggesting that whitefly action thresholds that protect cotton yields also protect against sticky cotton.

Discussion

Results in these and other studies (Henneberry *et al.,* 1995, 1996) suggest that trehalulose and melezitose are major contributors to stickiness. The role of all the individual honeydew sugars, plant physiological sugars and combinations thereof in the total problem need to be defined. Standardized lint sampling protocols and thermodetector counts related to the problem at the textile mill are needed. Whitefly populations normally rise during the season to peak in September and early October when a high percentage of the total boll production is exposed and subject to honeydew contamination. Careful attention to crop phenology, date of last insecticide application and identification of late-season whitefly populations can be important in cotton crop management to avoid sticky cotton. Most cotton growers opt for maximum yield to maximize gross profit. A less popular option is sub-maximum yield with lower gross profit but reduced production input and potential for equal or higher net profit. Late-season decisions to extend the season where whiteflies are a problem involves the obvious risk of sticky cotton. This is particularly true if insecticide-treatments are terminated. If the cotton becomes contaminated with honeydew in excess of acceptable textile mill thresholds, a penalty may be imposed at a cost equal to or greater than the increased value of the cotton yield. Added incentives to reduce the risk of sticky cotton by early harvest, may be savings in cost of additional water, insecticide and other production costs to realize the additional yield. This oversimplification does not consider all factors and intangibles that concern each grower but the rationale suggests that formal economic analysis and risk assessment might be revealing and informative to growers needing to make such decisions.

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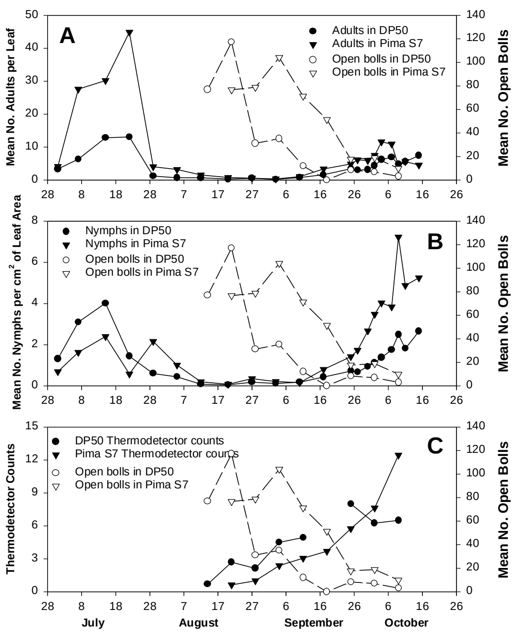
Table 1. Elution of honeydew sugars from amino HPLC column.

Peak	Retention Time (min)	% Total (peak area)
fructose	16.22	10.48
glucose	17.42	5.63
glycine betaine	19.87	2.72
sucrose	21.63	5.38
turanose	23.13	1.29
trehalulose	25.53	36.59
melezitose	32.83	21.73
bemisiose	39.07	2.83
bemisiotetrose	48.33	4.67
all other peaks		8.68

Source: From Wei *et al.* 1996

Figure 2. Seasonal distributions of the mean numbers of *Bemisia argentifolii* adults (A), nymphs (B), and thermodetector counts (C) in relation to the seasonal development of open cotton bolls.



Insecticide applications on 25 July, 2, 8, 22 August and 6 September.

silverleaf whitefly honeydew. Amer. Chem. Soc. 45:3481-3486.Table 1. Elution of Honeydew sugars from Amino HPLC Column.

Figure 1. Anion exchange HPLC profile of *B. argentifolii* honeydew. Dashed arrow indicates elusion time of sorbitol (From Hendrix and Salvucci, 1998).

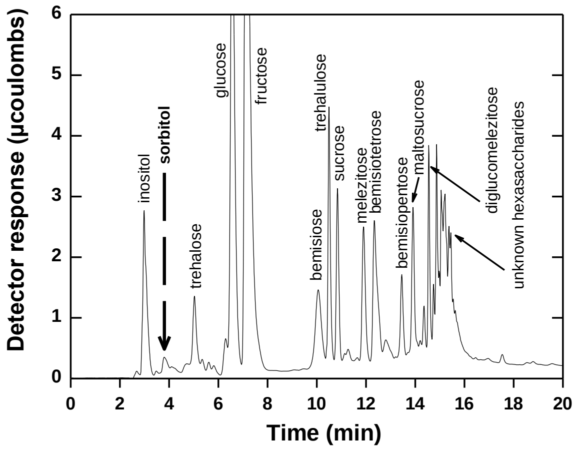


Figure 3. Relationships between thermodetector sticky cotton counts and numbers of *Bemisia argentifolii* adults (A) and nymphs (B).