SWEET POTATO WHITEFLIES, COTTON APHIDS, AND STICKY COTTON

T. J. Henneberry, L. Forlow Jech and D. L. Hendrix
USDA-ARS
Western Cotton Research Laboratory
Phoenix, AZ

Abstract

Sweetpotato whitefly (SPW), *Bemisia tabaci* (Gennadius) Strain B (=*B. argentifolii*) and cotton aphid (CA), *Aphis gossypii* Glover, are the two most common honeydew producing insect species that occur on cotton. Honeydew contaminated lint is a serious problem in lint processing at the textile mill. It can also be difficult to harvest and gin. The major sugar components of the honeydew of both insect species are glucose, fructose, sucrose, trehalulose, and melezitose. Trehalulose and melezitose are insect-produced sugars. SPWs produce more trehalulose in relation to melezitose and the opposite is true for CAs. We exposed clean cotton lint to SPW or CA in the laboratory. The total sugar contents of water extracts of honeydew-contaminated lint after exposure to the insects were significantly correlated to increasing thermodetector counts (a measure of stickiness) that occurred as a result of increasing durations (days) of exposure. Higher concentrations of total sugars measured in these extracts occurred following exposures to SPW compared with CA. However, numbers of SPW and CA were different and the results are therefore not directly comparable. Research is continuing to further define differences and similarities in cotton lint stickiness as a result of honeydew lint contamination by SPW or CA.

Introduction

Sticky cotton is a problem throughout many cotton production areas of the world (Hector and Hodkinson 1989). Although many factors have been suggested as contributing to the problem, results of studies by various research institutes show that 80 to 90 % of the reported instances of cotton stickiness were associated with the occurrence of insect honeydew contamination of lint (Sisman and Schenck 1984). The sweetpotato whitefly (SPW), *Bemisia tabaci* (Gennadius) (also called *B. tabaci* Strain B = *B. argentifolii*), and the cotton aphid (CA), *Aphis gossypii* Glover, are the main honeydew-producing insects infesting cotton. Honeydew from SPW, on a worldwide basis, has been regarded as the most frequent cause of sticky cotton (Watson et al. 1982, Rimon 1982). However, CAs were reported to be a factor in sticky cotton problems in Israel from 1983 to 1985 (Broza 1986) and in California in 1977 and 1986 (Perkins 1983, Perkins and Basset 1988). With increasing CA problems on a worldwide basis (King et al. 1987), the increasing probability of CA related sticky cotton problems is of concern.

In this paper we briefly review the published information on the sugar composition of SPW and CA honeydews. We also compare the sugars extracted from cotton lint exposed SPW and CA under laboratory conditions and compare their effects on cotton lint stickiness as measured by thermodetector counts.

Sugar Components of SPW and CA Honeydews

Using High Performance Liquid Chromatography (HPLC), Hendrix et al. (1992) and Tarczynski et al. (1992) identified sucrose, glucose, fructose, trehalulose and a number of oligosaccharides in honeydew produced by SPW feeding on cotton. Trehalulose with lesser amounts of melezitose were the major sugar components. Hendrix and Wei (1994) also reported a novel trisaccharide in SPW honeydew that was later identified and named *Bemisiose*. Wei et al. (1996, 1997) identified additional oligosaccharides from honeydew produced by SPW feeding on cotton as bemisiotetrose, maltosucrose and diglucomelezitose as well as substantial amounts of the quaternary amine, glycine betaine. A summary of the sugars found in SPW honeydew taken from Hendrix (1999) is shown in Figure 1A.

For the cotton aphid feeding on cotton, Hendrix et al. (1992) and Hendrix (1999) found that melezitose was the dominant insect-produced sugar with lesser amounts of trehalulose (Fig. 1B). Other sugars found that were common to both SPW and CA honeydew were fructose, glucose, and sucrose. A greater relative abundance of monosaccharides was found in CA honeydew as compared to SPW honeydew and greater relative abundance of sucrose was found in SPW honeydew compared with CA honeydew. The significance of these differences, if any, remain unknown. Continuing efforts to define the carbohydrate chemistry of SPW and CA honeydews is an essential step in developing chemical, microbial, or other agents that may be used to treat cotton lint to degrade or inactivate honeydew sugars that cause sticky cotton lint.

The presence of trehalulose and melezitose in water extracts of cotton lint is distinctive evidence of insect honeydew contamination. However, a direct projection from this information to the extent of the problem in processing the lint at the textile mill is not possible. The problem in making such a prediction occurs because other honeydew sugars and plant physiological sugars are also found on the cotton lint. Water extracts of clean cotton lint may contain as many as 10 sugars, but the most prevalent of these are glucose, fructose, sucrose and trehalulose, in that order of magnitude (Brushwood and Perkins 1996, Brushwood 1997). Unlike honeydew sugars, plant sugars are evenly distributed on lint

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1160-1162 (2000)
National Cotton Council, Memphis TN

and do not normally cause sticky cotton when they occur in amounts of 0.35% or less (Perkins 1993). However, their additive effect to the stickiness caused by honeydew sugars cannot be separated.

Direct Measurement of Cotton Lint Stickiness

Several methods have been developed for directly measuring cotton stickiness (Hector and Hodkinson 1989). The international standard, at present, is the thermodetector method (Brushwood and Perkins 1993). A 2.5-gram sample of cotton lint is spread into a thin mat and layered between two sheets of aluminum foil and heated under pressure. Thereafter, the foil sheets are separated and the number of sticky spots on the foil counted. Four or fewer spots are negative for stickiness, 5 to 14 spots = light stickiness, 15 to 24 = moderate stickiness, and > 24 = heavy stickiness. Thermodetector counts have been shown to be more highly correlated to trehalulose and melezitose extracted from honeydew-contaminated lint than for the glucose and fructose extracged from the same lint or to the number of SPW adults and nymphs on cotton leaves (Henneberry et al. 1995). However, limited information exists for CA honeydew and thermodetector counts.

SPW and CA Induced Lint Stickiness in the Laboratory

Hinged, rectangular, transparent plastic boxes (30.5 cm long x 12.7 cm wide x 12.7 cm deep) were modified to enclose four to six leaf stage cotton seedlings growing in soil filled pots. Two, 5 cm diameter muslin covered holes provided ventilation. A 0.63 cm, cork-plugged hole provided an entrance for adult SPW. Openings of 0.63 cm wide x 1.00 cm long were cut in the middle and opposite each other in each of the bottom halves of the boxes to accommodate cotton-wrapped seedling stems when the hinged box halves were closed. Cotton lint samples (2.5 g) were spread into a thin layer and equally distributed over the bottoms of the boxes. Five hundred SPW adults were introduced into each cage at the start of each experiment. Fifty additional whiteflies were introduced into each cage on each day for 8 d to allow for mortality and escapes during lint removal.

For CA, four- to six-leaf stage cotton plants were infested by pinning CA infested leaves from a colony onto uninfested leaves. After 50 to 60 aphids crawled onto the uninfested leaves, the plants were held until there were 300 to 400 aphids mixed ages and life stages.

Boxes with SPW were placed in randomized complete block designs in a 26.7° C constant temperature box under 14:10 light:dark conditions. Cotton lint was removed from each of 10 boxes after 0 (controls), 3, 7, and 9 d exposure periods. The lint from five of the boxes for each sampling date was analyzed by thermodetector. Honeydew sugars were extracted from lint of the five remaining samples, on each date. Extracts ofcotton lint were made following the methods of Hendrix et al. (1993) which were approximately 98% efficient for sugar removal. A 2.5 g lint sample was packed into a plastic 30 cm long by 3.5 cm wide (inside diameter) cylinder. One 50 ml rinse of hot (ca 90°C) water was drawn through the cotton with a vacuum into a collection container. Water in the extract was removed by lyophilization. The resulting residue was suspended in a few ml of 80% ethanol and centrifuged through a small bed of activated charcoal and a 0.2 μm filter (Hendrix and Peelen, 1987). An aliquot of the filtered ethanol was dried, taken up in a small amount of water, and analyzed by HPLC (Hendrix and Wei 1994). Each experiment replicated five times was repeated on five occasions.

Water extracts of honeydew from cotton lint exposed to SPW for different numbers of days in the laboratory contained the greatest concentration of trehalulose (33.5%), followed by melezitose (22.2%), glucose (20.8%), fructose (14.8%), and sucrose (8.7%) (Table 1). Percentages are of total amounts of measured glucose, fructose, sucrose, trehalulose and melezitose. Means of the totals of the individual sugars for each exposure period were significantly correlated to numbers of thermodetector counts ($r = 0.99$, $P \leq 0.001$, Fig. 2A). In contrast, water extracts from lint exposed to CA for different numbers of days contained 30.6, 26.9, 21.1, 16.6 and 4.8% glucose, fructose, melezitose, sucrose and trehalulose, respectively (Table 1). The means of the totals of the individual sugars for each exposure period were also significantly correlated to thermodetector counts ($r = 0.96$ $P \leq 0.001$, Fig. 2B.

Discussion

The most abundant sugars found in SPW and CA honeydews were fructose, glucose, sucrose, melezitose, and trehalulose. Additionally, a number of oligosaccharides were found in the honeydew of each species. The most obvious differences in the composition of honeydews when comparing the two species, is the dominance of trehalulose for SPW and the dominance of melezitose for CA and differences in the largest sugars. The largest oligosaccharides in SPW honeydew are hexasaccharides, the largest sugars in CA honeydew are larger than decasaccharides (Hendrix 1999). It is unknown whether or not these differences occur consistently and are biologically significant. In any event, all of the mentioned sugars, obtained commercially and sprayed individually on clean cotton, resulted in some level of stickiness as measured by the thermodetector (Henneberry et al. 1999, In Press). In general, trehalulose, melezitose and sucrose on cotton lint are more sticky than glucose or fructose. However, the thermodetector measures the overall lint stickiness effect of all the sugars in honeydew. Additional research is being conducted to define SPW and CA lint stickiness parameters.

References

Broza, M. 1986. An aphid outbreak in cotton fields in Israel. Parasitica 14: 8 1-8.

Brushwood, D. E. and H. H. Perkins. 1993. Cotton stickiness potential as determined by minicard thermodetector and chemical methods, pp. 1132-1135. *In* D. J. Herber and D. Richter [eds.], Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council Am, Memphis. TN.

Brushwood, D. E. and H. H. Perkins, Jr. 1996. Cotton plant sugars and insect honeydew characterized by high performance liquid chromatography, pp. 1310-1313. *In* P. Dugger and D. A. Richter [eds.], Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council Am, Memphis. TN.

Brushwood, D. E. 1997. Measurement of sugar on raw cotton by HPLC, individual carbohydrate concentrations and their relationship to stickiness potential, pp. 1656-1658. *In* P. Dugger and D. A. Richter [eds.], Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council Am, Memphis. TN.

Hector, D. J. and I. D. Hodkinson. 1989. Stickiness in cotton. CAB. International, Oxon, UK, 43 pp.

Hendrix, D. L. 1999. Sugar composition of cotton aphid and silverleaf whitefly honeydews, pp. 47-51. *In* P. Dugger and D. Richter [eds.] Proc. Beltwide Cotton Res. Conf., National Cotton Council Am, Memphis, TN.

Hendrix, D. L., B. Blackledge, and H. H. Perkins, Jr. 1993. Development of methods for the detection and elimination of insect honeydews on cotton fiber, pp. 1600-1602. *In* D. J. Herber and D. A. Richter [eds.], Proc. Beltwide Cotton Res. Conf., National Cotton Council Am, Memphis, TN.

Hendrix, D. L. and K.K. Peelen. 1987. Artifacts in the analysis of plant tissues for soluble carbohydrates. Crop Sci. 27: 710-715.

Hendrix, D. L., and Y-A. Wei. 1994. Bemisiose: An unusual trisaccharide in *Bemisia* honeydew. Carbohydrate Res. 253: 329-334.

Hendrix, D. L. and Y. Wei, and J. E. Leggett. 1992. Homopteran honeydew sugar composition is determined by both insect and plant species. Comp. Biochem. Physiol. 101B: 23-27.

Henneberry, T. J., D. L. Hendrix, H. H. Perkins, S. E. Naranjo, H. M. Flint, D. H. Akey, L. Forlow Jech, and R. A. Burke. 1995. *Bemisia argentifolii* (Homoptera: Aleyrodidae) populations and relationships to sticky cotton and cotton yields. Southwestern Entomol. 20: 255-271.

Henneberry, T. J., L. Forlow Jech, D. L. Hendrix, and T. Steele. 1999. *Bemisia argentifolii* (Homoptera: Aleyrodidae) honeydew and honeydew sugar relationships to sticky cotton. Southwestern Entomol. (In Press).

King, E. G., J. R. Phillips, and R. B. Head. 1987. 40th annual conference report on cotton insect research and control, pp. 171-193. *In* D. J. Herber, and D. A. Richter [eds.], Proc. Beltwide Cotton Res. Conf., National Cotton Council Am, Memphis, TN.

Perkins, H. H., Jr., and D. M. Bassett. 1988. Variations in stickiness of variety test cottons – San Joaquin Valley, California, 1986, pp. 135-136. *In* J. M. Brown and D. A. Richter [eds.], Proc. Beltwide Cotton Res. Conf., National Cotton Council Am, Memphis, TN.

Perkins, H. H., Jr. 1993. A survey of sugar and sticky cotton test methods. pp. 1136--1141. *In* D. J. Herber, and D. A. Richter [eds.] Proc. Beltwide Cotton Res. Conf., National Cotton Council Am, Memphis, TN.

Perkins, H.H. Jr. 1983. Identification and processing of honeydew contaminated cotton. Textile Research J. 53:508-512.

Rimon, D. 1982. Chemical methods for the evaluation of stickiness in cotton fibers: *Bemisia tabaci* as a factor in contamination by sugars in fiber stickiness. Phytoparasitica 10:296-297.

Sisman, S., and A. Schenek. 1984. 'Bremen honeydew test' – new method for testing the sticky tendency of cotton. Melliand Textileberichte (English Edition). 13:593-595.

Tarzcynski, M.C., D.N. Byrne, and W.B. Miller. (1992). High performance liquid chromatography analysis of carbohydrates of cotton phloem, sap and of honeydew produced by *Bemisia tabaci* feeding on cotton. Plant Physiol. 98: 753--756.

Watson, J. S., B. L. Hopper, and J. D. Tipton. 1982. Whitefly and the problem of sticky cotton. Span. 25:71-73.

Wei, Y., D.L. Hendrix, and R. Nieman. (1996). Isolation of a novel tetrasaccharide, Bemisiotetrose, and glycine betaine from silverleaf whitefly honeydew. Amer. Chem. Soc. 44: 3214--3218.

Wei, Y., D.L. Hendrix, and R. Nieman. (1997). Diglucomelezitose, a novel pentasaccharide in silverleaf whitefly honeydew. Amer. Chem. Soc. 45: 3481--3486.

Table 1. Mean (± SE)[1/] mg/g of individual sugars and percentages to total sugars extracted from CA or SPW honeydew contaminated cotton lint in the laboratory.

	CA (Expt 1)		SPW (Expt 2)	
Sugar	Mg/g of lint	% of the total	Mg/g of lint	% of the total
Glucose	0.26 ± 0.02	30.6 ± 1.4	0.29 ± 0.02	20.8 ± 1.7
Fructose	0.25 ± 0.03	26.9 ± 1.2	6.27 ± 0.04	14.8 ± 0.6
Trehalulose	0.04 ± 0.01	4.8 ± 0.7	0.94 ± 0.23	33.5 ± 4.2
Sucrose	0.16 ± 0.02	16.6 ± 1.3	0.13 ± 0.02	8.7 ± 0.9
Melezitose	0.16 ± 0.01	21.1 ± 1.6	0.31 ± 0.03	27.2 ± 1.8
Total	0.87 ± 0.06	100.0	1.94 ± 0.31	100.0

[1/] Means and standard errors of 10 replications.

[2/] Total for glucose, fructose, trehalulose, sucrose, and melezitose in honeydew.

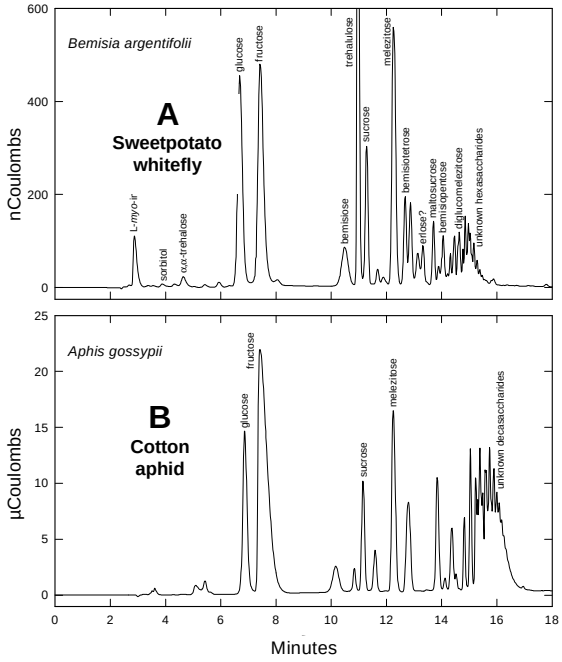

Figure 1. HPLC analysis of honeydew produced by sweetpotato whitefly (A) and cotton aphid (B) feeding on cotton. (Hendrix 1999)

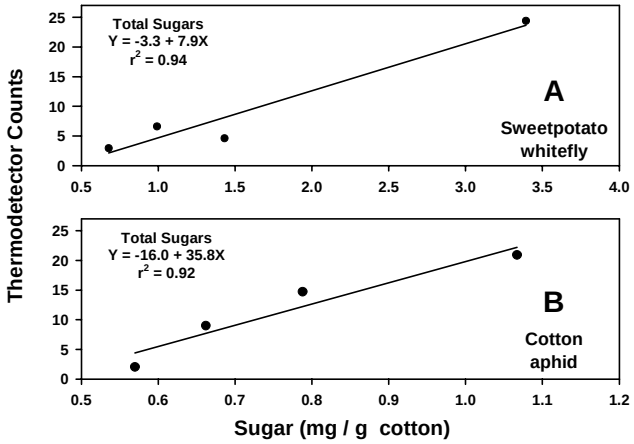

Figure 2. Mean numbers of mg/g of selected honeydew sugars (March 29, 2000glucose, fructose, sucrose, trehalulose and melezitose) extracted from cotton lint after 0 (control), 3, 7, or 9 day exposure of lint to sweetpotato whitefly (A) or cotton aphid (B) in cages.