RELATIONSHIP BETWEEN DAYS OF OPEN COTTON BOLL EXPOSURE TO WHITEFLY POPULATIONS AND DEVELOPMENT OF STICKY COTTON

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

Abstract

Trehalulose and melezitose produced by *Bemisia argentifolii* Bellows and Perring and thermodetector counts in cotton lint increased with increasing numbers of days of exposure of open cotton bolls in infested cotton plots. Thermodetector counts were significantly correlated to amounts of trehalulose and melezitose. Rainfall of 0.5 inch reduced trehalulose and melezitose in cotton lint within 5 h following the rain. The results suggest dissolution of the sugars followed by runoff as opposed to microbial degradation.

Introduction

The role of *Bemisia argentifolii* Bellows and Perring as a contributing factor to the sticky cotton problem has been well documented (Husain and Trehan 1942, Hector and Hodkinson 1989). *Bemisia* spp. feeding on cotton produce honeydew that may contain as many as 20 different sugars (Wei et al. 1996, 1997). Extensive research has been conducted to identify and quantify these sugar components (Tarczynski et al. 1992; Hendrix et al. 1992, 1993; Wei et al. 1996, 1997). Sticky cotton as measured using minicard and thermodetector methods have been shown to be highly correlated to the *Bemisia* sugars, trehalulose and melezitose, extracted from cotton lint (Henneberry et al. 1995, 1996, 1998a, 1998b). The minicard method was accepted by the textile industry as the international standard for measuring cotton lint stickiness in 1988, but was recently replaced by the more readily available, more rapid, and less cumbersome thermodetector method (Brushwood and Perkins 1993). Thermodetector lint stickiness measurement is accomplished by manipulating a 2.5 g sample of cotton lint into a fine mat, which is placed between two sheets of aluminum foil and heated under pressure. The foil sheets are separated and the number of sticky spots counted. Thermodetector counts do not distinguish between the contributions of the different sugars in honeydew or plant physiological sugars. However, the counts are an overall assessment of cotton lint stickiness (Brushwood and Perkins 1993).

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We used thermodetector analysis to determine the effect on lint stickiness of different numbers of days of exposure of open cotton bolls to whitefly populations. We also studied the effect of rainfall on sticky cotton.

Materials and Methods

Experiment 1

Honeydew accumulation on cotton lint in an untreated field was studied by tagging petioles of all open bolls on day 5 following the first open boll observed in each of 5 randomly selected 0.5 acre plots within a 2.5-acre Deltapine (DPL) 90 cotton field at Phoenix, AZ. Lint in open bolls was assumed to have been exposed to *B. argentifolii* honeydew accumulation for <1-5 d (average of 3 d) when tagged. Twenty open tagged bolls in each plot were collected at weekly intervals during a 59-d period following tagging.

Adult whitefly populations were estimated weekly in each of the 5 plots using the black pan sampling technique (Butler et al. 1986). Black pan counts were converted to adults/leaf turn using the relationship described by Naranjo et al. (1995b). Nymphs were counted weekly on 3.88-cm^2 leaf disks taken on the same sampling dates from the lower left quadrant of each of 20 leaves per plot as described by Naranjo and Flint (1994).

Experiment 2

We picked 1,000 open Deltapine 90 mature cotton bolls along with petioles and bracts from the same 2.5 acre cotton field at Phoenix, AZ, infested with *B. argentifolii.* Open bolls were again assumed to have been exposed for <1 to 5 days prior to harvest. Two hundred bolls were randomly selected from the 1,000 harvested bolls and divided into 10 samples of 20 bolls each. Of the remaining 800 bolls, 80 were placed in each of 10 open-top wire trays. One tray was placed at each of 5 randomly selected locations in untreated or insecticide-treated 12-acre Deltapine 90 cotton fields at the University of Arizona, Maricopa Agricultural Research Center, Maricopa, AZ. The untreated field was heavily infested with *B. argentifolii* with reduced infestations occurring in the insecticide-treated field. Trays of bolls were placed within the cotton canopy and suspended 16 to 18 inches above the ground between cotton plants. The trays were secured in place with wires attached from each tray corner to cotton plant stems. A canopy of *B. argentifolii*-infested cotton leaves over each tray was made by wrapping string around plant stems 10 inches below the top of the plant and pulling the plants toward the center of the tray. Boll samples (20 in each case) were taken from each tray after 6, 9, 14 or 20 days of exposure. *B. argentifolii* adult and nymph counts were made weekly as previously described.

Rainfall

We determined the effects of rainfall on honeydew sugars by picking seed cotton samples approximately 12 h prior to and 5 h following a 0.5 inch rainfall. Seed cotton samples

prior to rainfall (40 bolls per sample) were picked from each of four randomly selected areas in a 2.5 acre cotton field. Samples, from each area, were divided and seed cotton from 20 bolls were air-dried for 24 h in the greenhouse. Seed cotton from the remaining 20 bolls was weighed and oven-dried at 77° C for 14h and reweighed to determine seed cotton moisture content. For seed cotton picked from each of the sampling areas ≈ 5 h following the end of rainfall, sugars were extracted from the wet lint of seed cotton of 20 bolls immediately after harvest. Seed cotton from the remaining 20 bolls were weighed, oven-dried at 77° C for 14 h and reweighed to determine seed cotton moisture.

Lint Sugar and Cotton Stickiness

All seed cotton was ginned and seed and lint weighed. Thermodetector lint stickiness ratings were determined by the method of Brushwood and Perkins (1993) at the USDA-ARS, Cotton Quality Research Laboratory, Clemson, SC. Determination of the individual sugars, trehalulose and melezitose in cotton lint were determined by high performance liquid chromatography (HPLC) methods described by Hendrix and Wei (1994) after extraction with deionized water (Hendrix et al. 1993).

Statistical Analysis

All data were analyzed using ANOVA methodology. Means were separated, following a significant *F* test, using the method of least significant differences ($P \leq 0.05$). Correlation and regression analyses were conducted, where appropriate, to determine relationships between numbers of whiteflies and thermodetector counts.

Results

Experiment 1

Adult whiteflies/leaf over the 59 day period ranged from 13 on day 3 to a peak of 63 on day 31 and decreasing thereafter to 35/leaf on day 59 (Fig. 1A). Nymphs during the same time period ranged from 0.11/cm^2 of leaf disk on day 3 to a peak of 40 on day 52 and decreasing to 35 on day 59 (Fig. 1B). Average numbers of adults and nymphs over the experimental 59-day period were 31 and 17, respectively. Amounts of trehalulose (Fig. 1C) and melezitose (Fig. 1D) on cotton lint increased with increasing days of exposure up to day 49, thereafter decreasing on days 52 and 59. Similarly, thermodetector (Fig. 1E) lint stickiness counts increased with increasing days of exposure to day 45, decreasing on days 52 and 59. Thermodetector counts were correlated to trehalulose ($r = 0.82$, $P \leq 0.01$) and melezitose ($r = 0.72$, $P \leq 0.01$). Regression relationships for thermodetector counts and trehalulose ($y = 8.07 + 3.97\ x$, $r^2 = 0.67$, $P \leq 0.01$) (Fig. 2A) and for thermodetector counts and melezitose ($y = 8.60 + 3.55\ x$, $r^2 = 0.51$, $P \leq 0.01$) (Fig. 2B) were highly significant.

Experiment 2

In untreated cotton, adult whitefly numbers/leaf during the 20 days of open boll exposure ranged from 112 to 325 and averaged 240 (Fig. 3A). Numbers of nymphs/cm^2 of leaf disk ranged from 57 to 129 and averaged 81 (Fig. 3B). For insecticide-treated cotton, numbers of adults ranged from 13 to 45/leaf and averaged 24/leaf (Fig. 3A). Numbers of nymphs ranged from 1 to 10/cm^2 of leaf disk and averaged 5.7 (Fig. 3B).

Thermodetector counts in untreated cotton were 3.4, 7.8, 16.0 and 12.0 after 3, 6, 9 and 14 days of open boll exposure, respectively (Fig. 3E). Accumulated rainfall of 0.5 inch on days 16 and 17 decreased thermodetector counts to 1.0. Trehalulose and melezitose from untreated cotton increased prior to the rainfalls and decreased to 0.0 and 0.15 mg/g of lint, respectively, following the rainfall (Fig. 3C and D). Amounts of trehalulose and melezitose, and thermodetector counts were higher in untreated cotton compared with insecticide-treated cottons on all sampling dates except for those following rainfall. The differences were not always statistically significant (Fig. 3C, D and E).

Thermodetector counts were significantly correlated to mg/g of lint for trehalulose ($r = 0.74$, $P \leq 0.01$) and melezitose ($r = 0.72$, $P \leq 0.01$). Also, regression relationships for thermodetector counts and trehalulose ($y = 3.34 + 9.32\ x$, $r^2 = 0.55$) (Fig. 4A) and melezitose ($y = 0.63 + 13.24\ x$, $r^2 = 0.53$) (Fig. 4B) were highly significant ($P \leq 0.01$).

Rainfall and Bemisia Sugars

Seed cotton moisture prior to the 0.5 inch cm rainfall was 3.2% and 9.9% following the rainfall (Table 1). After air-drying in an uncooled greenhouse for 168 h, the moisture content of seed cotton picked following the rainfall decreased to 4.6%. The amounts of trehalulose and melezitose in lint prior to rainfall were 1.45 and 0.46 mg/g, respectively. Following the rainfall, the amounts decreased to 0.02 and 0.00 mg/g for trehalulose and melezitose. After air-drying (ave. 26.7° C) for 168 h, the amounts of trehalulose and melezitose from rain exposed seed cotton were 0.02 and 0.11 mg/g of lint, respectively.

Discussion

The results of these studies demonstrate increasing amounts of the whitefly sugars, trehalulose and melezitose on cotton lint, with increasing exposure of open cotton bolls in whitefly infested cotton. The increasing lint sugar content was reflected in increasing lint stickiness as determined by thermodetector counts. Non-sticky cotton (≤ 5 thermodetector counts) from tagged cotton bolls on plants became lightly sticky (9-10 thermodetector counts) in about 14 days when whitefly adults averaged 18 per leaf and nymphs 1/cm^2 of leaf disk. In a second experiment, with open cotton bolls on trays and prior to rainfall, this occurred in about 6 days when adults averaged over 240/leaf and nymphs 81/cm^2 of leaf disk. The results from tagged bolls on plants and open bolls in trays are not comparable since open bolls on trays were all at one level within the plant canopy and in close proximity to whiteflies whereas tagged

bolls were distributed as normally occurs at different levels on the cotton plant. They were protected by foliage and the probability of encountering honeydew excretions from whiteflies was, therefore, lower.

The effect of rainfall on reduction of cotton lint stickiness and honeydew sugars has been previously reported (Henneberry et al. 1995) and verified in this study. Hendrix et al. (1993) suggested that increasing seed cotton lint moisture may stimulate microbial activity accounting for the degradation in sugars. The results of the present study show that reductions in sugars ranged from 68 to 100% within 5 h following the termination of rainfall. This strongly suggests that rainfall dissolved sugars followed by runoff from contaminated lint. Stimulation of microbial activity in bolls is not completely ruled out, but under laboratory conditions reduced cotton stickiness following increased seed cotton moisture content did not occur for more than 5 days and seed cotton moisture must be maintained at 10-12% (Henneberry et al. 1997). The rapid decline ($\approx$ 5 h) in *Bemisia* sugars following rainfall under field conditions appears to preclude microbial activity as the causative factor.

References

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

Butler, G.D., Jr., T. J. Henneberry, and W. D. Hutchinson. 1986. Biology, sampling, and population dynamics of *Bemisia tabaci*. *In* Agric. Zool. Rev. (G. E. Russell, ed) pp. 167-195. Intercept Ltd., London, UK.

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

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

Hendrix, D. L., 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.

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.

Henneberry, T. J., B. Blackledge, H. H. Perkins, D. L. Hendrix, R. L. Nichols, and T. Steele. 1997. Preliminary evaluations of an enzyme approach to reduce cotton lint stickiness, pp. 430-436. *In* P. Dugger and D. Richter [eds.], Proc. Beltwide Cotton Res. Conf., National Cotton Council Am, Memphis, TN.

Henneberry, T. J., L. Forlow Jech, D. L. Hendrix, and D. E. Brushwood. 1998b. *Bemisia argentifolii* (Homoptera: Aleyrodidae) population relationships to cotton and lint stickiness in long and short staple cottons. J. Econ. Entomol. 91:1196-1207.

Henneberry, T. J., L. Forlow Jech, and D. L. Hendrix. 1998a. Seasonal distribution of *Bemisia argentifolii* (Homoptera: Aleyrodidae) honeydew sugars on Pima and upland cotton lint and lint stickiness at harvest. Southwest. Entomol. 23:105-121.

Henneberry, T. J., D. L. Hendrix, H. H. Perkins, L. Forlow Jech, and R. A. Burke. 1996. *Bemisia argentifolii* (Homoptera: Aleyrodidae) honeydew sugars and relationships to sticky cotton. Environ. Entomol. 25: 551-558.

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. Southwest. Entomol. 20: 255-271.

Husain, M. A. and K. N. Trehan. 1942. The nature and extent of damage caused by *Bemisia gossypiperda* M & L, the whitefly of cotton in the Punjab. Indian J. Agric. Sci. 12: 793-821.

Naranjo, S. E., and H. M. Flint. 1994. Spatial distribution of preimaginal *Bemisia tabaci* (Homoptera: Aleyrodidae) in cotton and development of fixed-precision sequential sampling plans. Environ. Entomol. 23: 254-266.

Naranjo, S. E., H. M. Flint, and T. J. Henneberry. 1995. Comparative analyses of selected sampling methods for adult *Bemisia tabaci* (Homoptera: Aleyrodidae) in cotton. J. Econ. Entomol. 88: 1666-1678.

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.

Wei, Y-A., D. L. Hendrix, and R. Nieman. 1996. Isolation of a novel tetrasaccharide, bemisiotetrose, and glycine betaine from silverleaf whitefly honeydew. J. Agric. Food Chem. Soc. 44: 3214-3218.

Wei, Y-A., D. L. Hendrix, and R. Nieman. 1997. Diglucomelezitose, a novel pentasaccharide in silverleaf whitefly honeydew. J. Agric. Food Chem. 45: 3481-3486.

Table 1. Effects of rainfall on whitefly honeydew sugars and percent seed cotton moisture.

Seed cotton samples taken[a]	Sugars (mg/g of cotton lint Trehalulose	Melezitose	% moisture
Before rain[b] air dried 24 h	1.45 a	0.46 a	3.2 c
After rain[c] extracted wet	0.02 b	0.00 c	9.9 c
Extracted after air drying (168 h)	0.02 b	0.11 b	4.6 b

[a] 0.5 inch rain, means of 4 replications, 4 observations per replication in the same column not followed by same letter are significantly different. Method of least significant differences $P \leq 0.05$.
[b] Samples picked 12 h before rain.
[c] Picked ≈ 5 h after rainfall stopped.

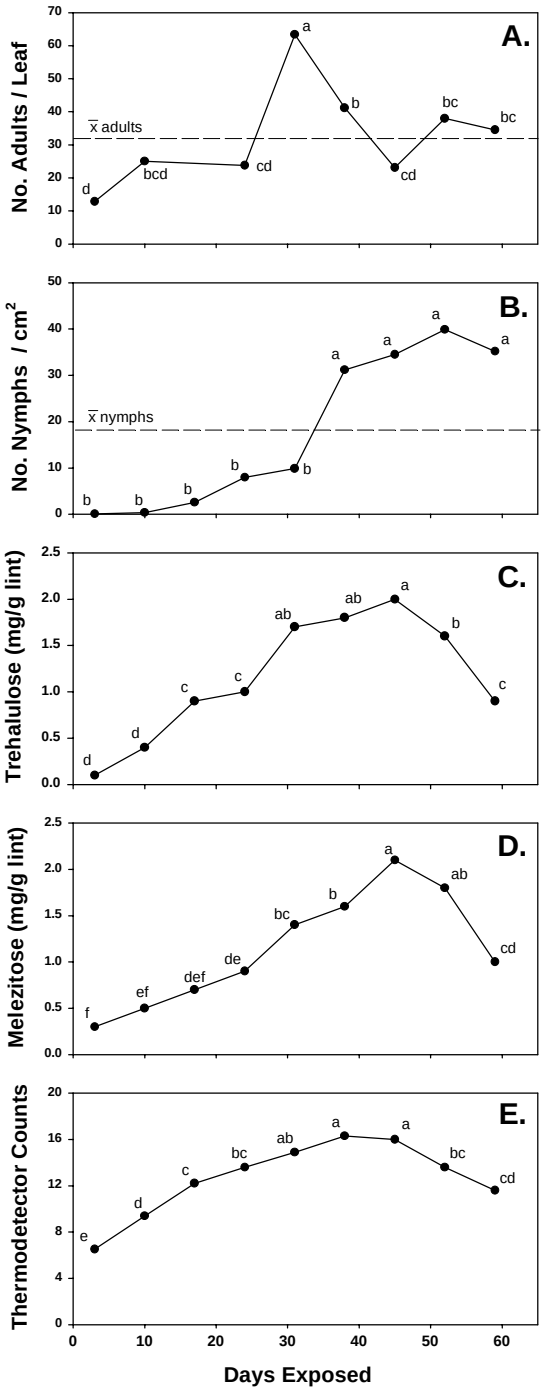

Figure 1. Mean number of *B. argentifolii* adults and nymphs, mg/g of trehalulose and melezitose / gram of cotton lint and lint thermodetector counts after different days of exposure of tagged open cotton bolls in whitefly infested plots. Means, in each graph, followed by the same letter are not significantly different at $P \leq$_0.01.

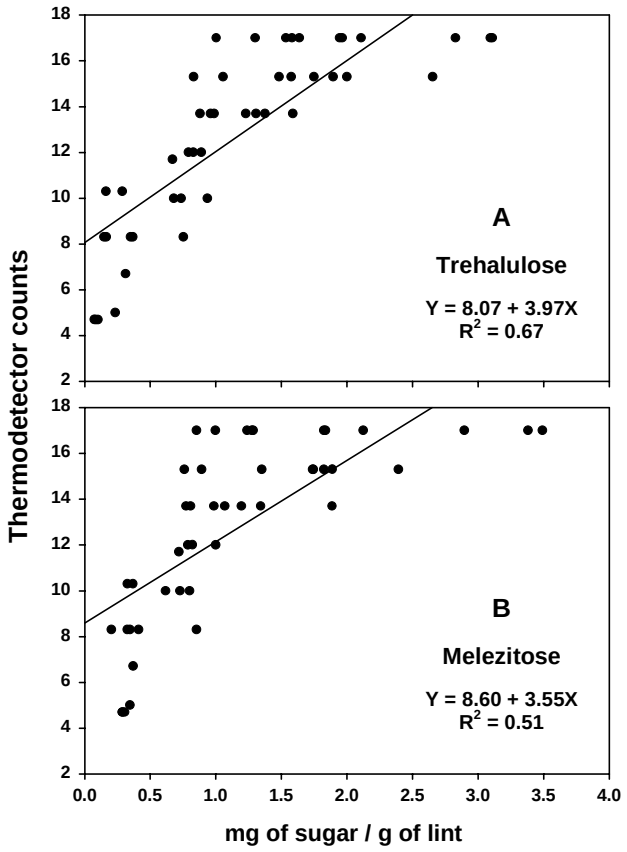

Figure 2. Relationship of thermodetector counts to trehalulose (A) and melezitose (B) extracted from lint of tagged open bolls in *B. argentifolii* infested cotton plots.

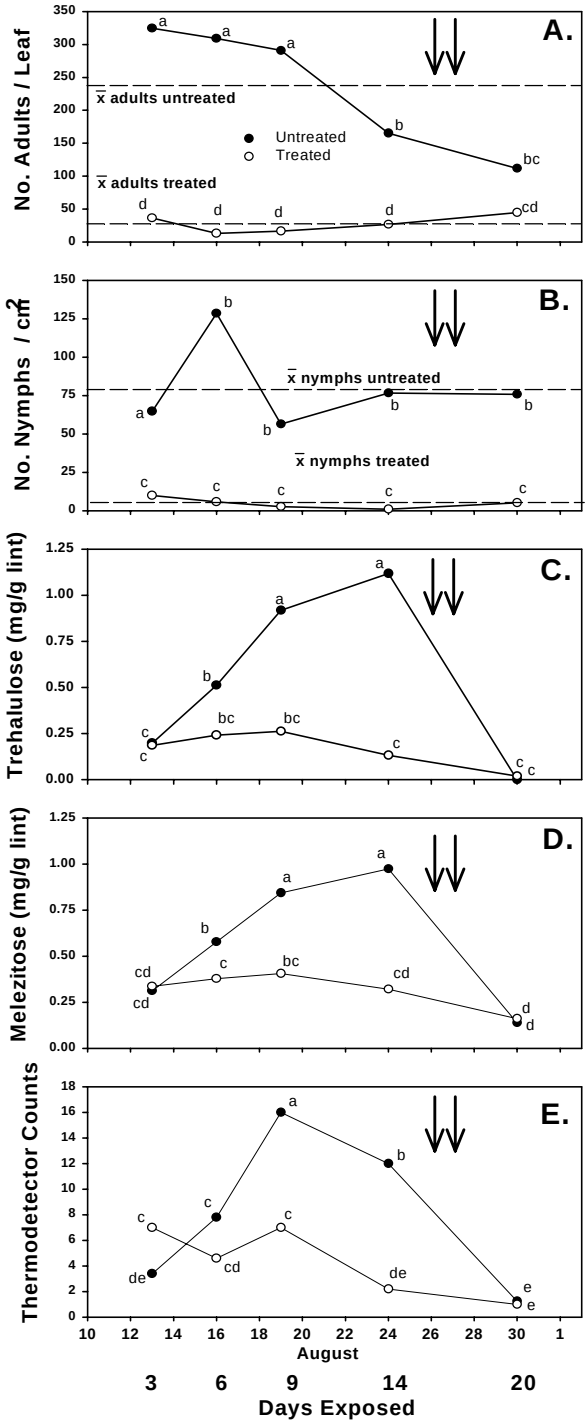

Figure 3. Mean number of *B. argentifolii* adults and nymphs, mg/g of trehalulose and melezitose/gram of cotton lint and lint thermodetector counts after different days of exposure in trays suspended in whitefly infested cotton plants. Means, in each graph, followed by the same letter are not significantly different at $P \leq 0.01$. Arrows indicate rainfall.

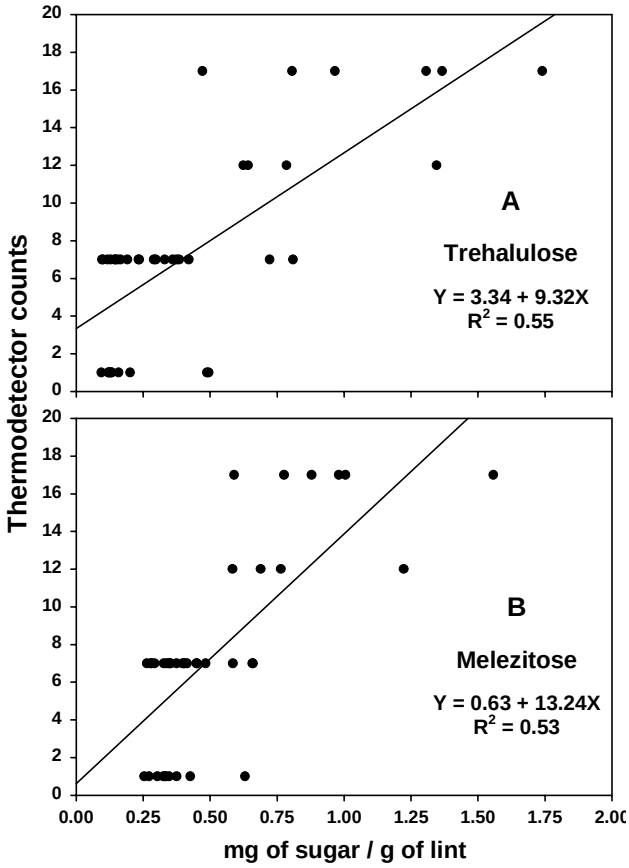

Figure 4. Relationship of thermodetector counts to trehalulose (A) and melezitose (B) extracted from lint of open bolls exposed in trays suspended in *B. argentifolii* infested cotton plants.