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Antixenosis of Smooth Leaf Cotton to the Ovipositional Response of Tobacco Budworm[1]

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ABSTRACT

Cottons (*Gossypium* spp.) ranging from glabrous (Smooth leaf) to Pilose were compared to determine their effects on the ovipositional response of the tobacco budworm moth, *Heliothis virescens* (F.). The numbers of trichome branches/cm on the margin, midrib, secondary vein, and petiole, and in an area of the lamina of young fully expanded cotton leaves were positively correlated with the number of eggs laid on cotton plants. Tobacco budworm moths laid fewer eggs on leaves of cottons with no more or fewer trichome branches than those found on 'Deltapine Smooth Leaf' than on the normally pubescent cultivar 'Stoneville 213' or on the densely pubescent (Pilose) line. Stoneville 213, a pubescent near-isoline, and a Smooth leaf near-isoline (Sm_2) in Stoneville 213 background, were tested in solid and mixed plantings. Significantly fewer eggs were laid on the Smooth leaf cotton than on the pubescent cottons whether or not the tobacco budworm had a choice of hosts. In a laboratory test, bond paper, synthetic net, rayon, cheesecloth, and muslin fabrics were compared in no-choice and free-choice tests as ovipositional surfaces. Those with textures that had fibers with the highest numbers of loose ends (cheesecloth and muslin) were preferred by tobacco budworm females.

***Additional index words:* Gossypium hirsutum L., Heliothis virescens (F.), Insect resistance, Trichomes, Preference, Non-preference, Pilose, Glabrous.**

LUKEFAHR et al. (1971) reported that the tobacco budworm moth, *Heliothis virescens* (F.) when given a choice, laid significantly more eggs on pubescent than on glabrous (Smooth leaf) cottons, *Gossypium* spp. They also observed that *Heliothis* spp. females restricted to glabrous lines did not always lay a full complement of eggs. They stated that Smooth leaf varieties had a normal number of trichomes on the growing points but that these trichomes abscised as the leaf expanded. Lee (1971) described Smooth leaf as a condition in Upland cotton in which leaves have fewer trichomes than normal. Smith (1964) suggested that the cultivar 'Deltapine Smooth Leaf' be used as a standard for the Smooth leaf or glabrous condition.

Our objectives were to determine: 1) whether smoothness, irrespective of its source, was antixenotic (Kogan and Ortman, 1978) to the ovipositional response of tobacco budworm females; 2) whether antixenosis was shown when these moths were restricted to Smooth leaf cottons or when they were offered a choice of cottons ranging from glabrous to Pilose; 3) the level of smoothness necessary to show a significant reduction in numbers of eggs when compared to a normally pubescent standard. To complement this study, we determined the ovipositional response of tobacco budworm moths to fabrics of various textures.

MATERIALS AND METHODS

In 1976, 30 or more fully expanded terminal leaves (8 to 10 cm) of nine cottons were picked from plants growing in the field, and an equal number was picked from cotton growing in a screened cage. The trichome branches were counted with the aid of a binocular microscope for 1 cm along the leaf margin and midrib, along and around the petiole, and on a cm^2 area of the lamina between primary veins on the upper and the lower leaf surfaces (Fig. 1). In 1977 and 1978, the same method was used for two near-isolines of 'Stoneville 213' (ST-213), one smooth and one pubescent. Also, 30 leaves were picked from each of those lines on which eggs had been deposited. The locations of the eggs were mapped on the upper and the lower leaf surfaces, and the numbers of trichome branches were counted that contacted each egg.

In 1976, nine cottons were planted in 10 randomized complete blocks in the field and in six blocks in a 12 × 50 m field cage. Plots were 3 m long and 1 m wide. The two cultivars tested were ST-213 and Deltapine Smooth Leaf. The experimental cotton lines tested were Coker 413 Sm_1 Sm_1 (the Sm_1 gene was transferred into 'Coker 413' by J. A. Lee, AR, SEA, USDA, Raleigh, N.C.); Carolina Queen Sm_2 Sm_2, Carolina Queen Sm_3 Sm_3, and Carolina Queen Sm_1 Sm_2 Sm_3 (transferred into 'Carolina Queen' by J. A. Lee); Pilose, carrying the H_2 gene; 542, devel-

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Table 1. Number of trichome branches at several locations on upper (U) and lower (L) leaf surfaces of 11 cottons and number of eggs/plant on 9 cottons.

Cotton	Trichome branches: Margin	Midrib U	Midrib L	Petiole	Lamina U	Lamina L	Eggs/plant
		No./cm ± SD			No./cm² ± SD		No.
			Pilose				
Pilose	117 ± 43	310 ± 100	316 ± 94	320 ± 75	318 ± 98	327 ± 86	22 a*
			Normal				
La 73-36 *H*	36 ± 12	41 ± 18	38 ± 26	64 ± 36	5 ± 7	35 ± 43	-
ST-213	35 ± 12	37 ± 18	33 ± 18	49 ± 26	6 ± 7	23 ± 22	18 ab
			Moderately Smooth				
Carolina Queen Sm_2 Sm_2	35 ± 16	34 ± 21	28 ± 18	19 ± 20	4 ± 8	13 ± 11	15 bc
Carolina Queen Sm_3 Sm_3	19 ± 9	28 ± 15	22 ± 10	24 ± 14	3 ± 7	5 ± 9	13 bc
			Smooth				
Deltapine Smooth Leaf	23 ± 10	25 ± 18	7 ± 6	15 ± 11	5 ± 7	0.4 ± 1	8 c
Coker 413 Sm_1 Sm_1	25 ± 8	15 ± 7	8 ± 7	11 ± 10	2 ± 5	0.4 ± 1	10 c
			Very Smooth				
La 73-36 Sm_2	5 ± 0.4	2 ± 3	0.2 ± 0.7	1 ± 2	0	0.1 ± 0.4	-
LAMSL-8-62-3-2-1	7 ± 6	0.1 ± 0.6	0.3 ± 0.7	0.3 ± 0.7	0	1 ± 2	11 c
Carolina Queen Sm_1 Sm_2 Sm_3	6 ± 7	0	0.3 ± 1.8	0.06 ± 0.4	0	0	12 bc
542	1 ± 1.7	0.2 ± 0.7	0.5 ± 1.4	1 ± 2	0	0	9 c

* Numbers followed by different letters are significantly different at the 0.05 level of probability (Duncan's Multiple Range Test).

oped by F. D. Wilson, AR, SEA, USDA, Phoenix, Ariz.; and LAMSL-8-62-3-2-1, developed by G. A. Niles, TAES, College Station, Tex.; both 542 and the LAMSL cottons carry a Smooth leaf gene transferred from a primitive stock of *G. hirsutum* known as race *yucatanense*.

In the field plots, all leaves on five plants of each test cotton were examined for tobacco budworm eggs on 15 dates. In the cage, as soon as two or more squares/plant were present, 25 to 200 pairs of laboratory-reared tobacco budworm moths were released about three times weekly until mid-August. All the leaves on 12 plants of each test cotton were examined on 11 dates for tobacco budworm eggs.

The curvilinear regression analysis $Y = ae^{bx}$, because it gave the best fit, was used to relate numbers of trichomes (X) on the margin, midrib, lamina and petiole of the cotton leaf with the number of eggs (Y) found on the leaves.

In 1977, the Smooth leaf and moderately pubescent near-isolines La 73-36 Sm_2 and La 73-36 *H* (Jones et al., 1977) were planted in alternate rows in three 12 × 19 m field cages. Similar cages contained solid plantings of each line, replicated twice. After the plants began to square (produce flower buds), about 100 pairs of tobacco budworm moths/cage were released two

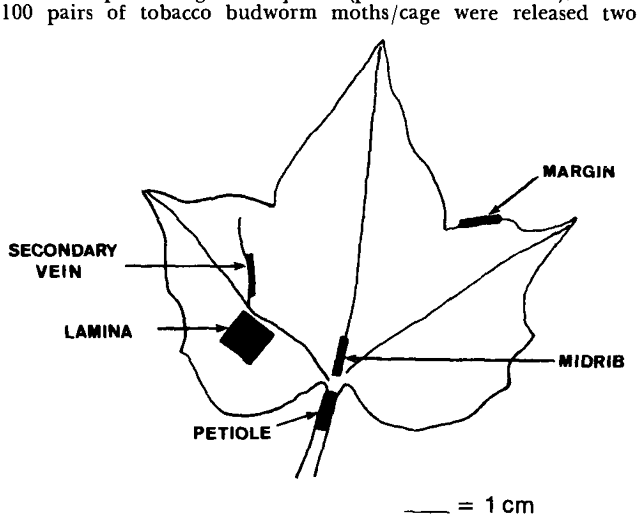

Fig. 1. Locations on cotton leaf at which counts of trichome branches were taken.

or three times weekly. Records were kept of numbers of eggs, larvae, and fruiting forms undamaged and damaged by tobacco budworms. Four to 12 plants of each cotton in each cage were examined on 11 dates. Open and green bolls were counted at the end of the test. Trichome branches were counted on five sampling dates.

In 1978, ST-213 was compared with the two near-isolines tested in 1977. Ten 12 × 19 m field cages were planted as follows: two cages of solid plantings of each cotton and four cages, two of which were designated as uninfested checks, of mixed plantings of the three cottons. After the plants had commenced to square, about 35 pairs of tobacco budworm moths were released two to three times weekly in each of the eight test cages. Thirty-two plants of each cotton were inspected for eggs, larvae, and damaged and undamaged fruiting forms on each of 30 sampling dates. Trichome branches were counted on five sampling dates. Open and green bolls were counted on every plant on 9 August.

Various fabrics were tested as ovipositional substrates for tobacco budworm moths. In a no-choice test, 15 single pairs of newly emerged tobacco budworm moths were caged in 0.5-liter cartons covered with one of the following fabrics; muslin, cheesecloth, rayon, synthetic netting, or bond paper. In a free-choice test, 10 pairs of moths were caged in cartons with covers having equal-sized sections of the four cloth fabrics. Covers were changed and eggs were counted daily. After 7 days, the bursa copulatrix of each female was removed, and spermatophores were counted to determine mating frequency. The cloth fibers were selected because the loose-ended fibers that protruded from the woven threads resembled trichome branches and ranged in density from an estimated 2,000/cm² on the muslin to about 10/cm² on the net; the bond paper had no visible loose fibers.

RESULTS AND DISCUSSION

Numbers of trichome branches are shown for 11 cottons, and numbers of tobacco budworm eggs/plant are shown for nine cottons (Table 1). The field and cage results were averaged because analyses showed no differences between these two environments in trichome-branch density. Numbers of trichome branches on leaves of the Pilose cotton were approximated by averaging two or more counts because these branches were matted and overlapped. Pilose leaves had as many as 700 branches in 1 cm along the midrib and

Table 2. Distribution of tobacco budworm eggs on upper (U) and lower (L) surfaces of leaves of a pubescent cotton and of a Smooth leaf cotton, and numbers of trichome branches that contacted those eggs.†

Location on leaf surface	Eggs found		Trichome branches in contact with an egg	
	La 73-36 *H*	La 73-36 Sm_2	La 73-36 *H*	La 73-36 Sm_2
	No.			
Primary veins				
U	50	26	6	1.4
L	10	6	6	1
Secondary veins				
U	22	4	3	1
L	8	2	3	0
Lamina				
U	14	7	0.5	0
L	32	6	3	0.5

† 135 eggs and 51 eggs on 30 leaves each of pubescent and Smooth leaf cottons, respectively.

600 in a cm² area on the lamina. At the other extreme, the very smooth cottons had 0 to 10 trichome branches at the same sites (Table 1).

Populations of tobacco budworms were very low in the field plots in 1976. Numbers of eggs found on the plants were not significantly different for any of the cottons. All eggs observed were believed to be tobacco budworm eggs because no adult bollworms, *Heliothis zea* (Boddie), were seen. The seasonal average number of eggs/plant ranged from 0.0 to 0.2. Egg deposition was heavy in the cages, however. Correlation coefficients were significant for numbers of eggs × trichome branch numbers on the margin, midrib, lamina, and petiole (r ranged from 0.66 to 0.79).

The moths laid significantly more eggs on Pilose than on the moderately to very smooth cottons, but not more than on the normally pubescent ST-213. The moths laid significantly more eggs on ST-213 than on some, but not all, Smooth leaf lines. Numbers of eggs laid on the leaves of moderately to very smooth cottons did not differ significantly. Antixenosis was shown for four of the five cottons that were as glabrous as Deltapine Smooth Leaf but for none of the moderately glabrous cottons when compared with ST-213.

Table 2 shows that the order of preference for oviposition by the moths was primary veins, leaf lamina, and secondary veins for both pubescent and Smooth leaf cottons. The moths also preferred to deposit their eggs on the upper rather than on the lower leaf surface, with one exception. That exception was that 24% of the eggs found on the pubescent line were laid on the lower surface of the leaf lamina.

The number of trichome branches in contact with an egg averaged 3.6 in the pubescent cottons and 0.7 in the Smooth leaf cotton. In the former, this number did not vary on the leaf veins on either surface but was higher on the lower surface of the lamina. In the latter, the number of branches was slightly higher on the upper leaf surface along the veins, but lower on the upper surface of the lamina.

In 1977, antixenosis of Smooth leaf on the ovipositional response was shown again. The smooth line La 73-36 sm_2 had significantly fewer eggs in both solid and mixed plantings and significantly more undamaged squares per plant in solid plantings than its pubescent sister line La 73-36 *H* (Table 3). There were no significant differences in damage to squares between the two lines in either solid or mixed plantings. The smooth line produced significantly more bolls/plant in the solid planting but not in the mixed plantings.

Table 3. Tobacco budworm eggs, undamaged and tobacco budworm-damaged squares and bolls/plant on one Smooth leaf and two normally pubescent cottons.

Cotton	Eggs/plant	Squares/plant: Undamaged	Squares/plant: Damaged	Bolls/plant
	no.	no.	%	no.
		1977		
		Solid Planting		
La 73-36 *H*	13 a*	4 b	13.8 a	3 b
La 73-36 Sm_2	3 b	8 a	10.4 a	6 a
		Mixed Planting		
La 73-36 *H*	12 a	4 a	22.5 a	4 a
La 73-36 Sm_2	8 b	6 a	18.0 a	6 a
		1978		
		Solid Planting		
ST-213	9 a	16 b	1.4 a	12 c
La 73-36 *H*	7 a	15 b	1.0 a	16 b
La 73-36 Sm_2	3 b	19 a	0.7 a	19 a
		Mixed Planting		
ST-213	10 a	16 a	1.5 a	14 c
La 73-36 *H*	9 a	17 a	1.4 a	16 b
La 73-36 Sm_2	4 b	19 a	0.7 a	20 a

* Numbers followed by different letters are significantly different at the 0.05 level of probability (Duncan's Multiple Range Test) when compared within each column, year, and planting type.

Table 4. Tobacco budworm ovipositional and mating responses to surfaces with various textures in a no-choice and a free-choice situation.

Surface	Threads/cm²	Loose ends on fibers/cm²	Matings†	Eggs/cm² of surface: No-choice	Eggs/cm² of surface: Free-choice
	no.	no.		no.	no.
Muslin	24 × 24	2,000	3.1 a*	13 a	12 a
Cheesecloth	10 × 12	1,000	3.6 a	12 a	11 a
Rayon	30 × 30	500	3.4 a	11 ab	8 b
Synthetic net	12 × 15	10	3.0 a	5 bc	4 c
Bond paper	–	0	0.6 b	0.1 c	–

* Numbers with different letters are significantly different at the 0.05 level of probability (Duncan's Multiple Range Test), within columns.
† Average for no-choice pairs; average for free-choice pairs was 2.9 (as indicated by spermatophores per female).

In 1978, significantly fewer eggs were laid on La 73-36 Sm_2 than on the two pubescent cottons, ST-213 and La 73-36 *H*, whether or not the tobacco budworm female had a choice of these hosts. Few eggs hatched throughout the test period, larval infestation was light, and no significant differences in damage to fruiting forms were found. The Smooth leaf line had more undamaged squares than the two pubescent entries in the solid planting, and produced significantly more bolls/plant than did the pubescent cottons in both solid and mixed plantings (Table 3).

Among the cottons tested, we established that the level of smoothness characteristic of Deltapine Smooth Leaf reduced oviposition by the tobacco budworm moth. We also found that a Smooth leaf version of

ST-213 expressed antixenosis for oviposition by the tobacco budworm whether alone or in combination with a pubescent cotton.

Direct comparisons could not be made between the textures of the test fabrics and pubescent and smooth cotton leaves but there were certain similarities. Properties of the fabrics and results of insect behavior are presented in Table 4. The moths laid fewer eggs on smooth fabrics, but the correlation coefficient (r = 0.63) was not significant between numbers of fabric fibers and eggs. However, significantly fewer matings took place in cages with bond paper covers. Females offered a choice of surfaces laid significantly more eggs on muslin and cheesecloth than on the smoother fabrics. When no choice was possible, significantly more eggs were laid on the muslin and cheesecloth than on the net or bond paper. Thus, results of the tests with fabrics, like those with cotton leaves, showed that the tobacco budworm female preferred surfaces with abundant hairlike protrusions over smooth surfaces for oviposition.

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