Published March, 1975

Glandless Cotton: Susceptibility to *Lygus hesperus* Knight[1]

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ABSTRACT

Field and laboratory methods were used to study population growth and feeding damage of *Lygus hesperus* Knight (a major cotton pest) on isogenic lines of glandless and glanded cotton, *Gossypium* spp. In no-choice field cages, a glandless genotype had 2.5 times more *L. hesperus* and 57% fewer bolls compared to its glanded equivalent. The larger lygus bug population on glandless cotton was attributed to a two-fold increase in growth rate and survival of nymphs. Thus glandless cotton may require more intensive control of *L. hesperus* than normal glanded cotton, to minimize losses in yield and quality.

***Additional index words:* *Gossypium hirsutum* L., *G. barbadense* L., Insect susceptibility, Gossypol, Cottonseed, Antibiosis, Pest management, Lygus bugs.**

PLANTS of the genus Gossypium have epidermal pigment-bearing glands in aerial parts of the plant. Although a number of biologically active compounds have been isolated from the glands (7, 11), the principal component is gossypol, a polyphenolic yellow pigment that may be toxic when ingested by nonruminant vertebrates at levels found in cotton seed (3). Cottonseed of commercial cultivars contains approximately 1% gossypol. Chemical and physical procedures for removing glands and associated pigments from cottonseed oil and meal are expensive and may reduce the protein content of the meal (15).

Following development of cotton genotypes with glandfree seeds (8), the cottonseed industry became extremely interested in the prospects of producing high protein flour at relatively small cost, from glandless cottonseed (4). In many parts of the world there is an acute need by hungry people for sources of high quality, inexpensive protein. Furthermore, smaller refining costs for oil from glandless cottonseed should lower production costs of cottonseed oil.

An evaluation of economic aspects of glandless cottonseed production should include complete consideration of any differential costs to control phytophagous

[1] This research was supported by a grant from the Rockefeller Foundation, New York. The authors are indebted to Dr. E. L. Turcotte for providing glandless and glanded 'Pima S-4' cottonseed. Dr. V. Sevacherian and C. E. Jackson aided in statistical analysis of data. Received Sept. 3, 1974.

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pests. Greater damage to glandless than to glanded cotton by pests such as beet armyworm [*Spodoptera exigua* (Hubner)]; *Spanogonicus albofasciatus* (Reuter); bollworms (Heliothis spp.); and cotton leafworm [*Alabama argillacea* (Hubner)] has been reported (1, 9). Damage by arthropods that only infrequently attack cotton, such as blister beetles (Epicauta spp.); cucumber beetles (Diabrotica spp.); *Maecolaspis flavida* (Say); a chrysomelid [*Gastrophysa cyarea* (Melsheimer)]; and pillbugs (Porcellio spp.) has been described also in glandless cotton (1, 6, 9, 10). Lee (5) reported damage by a wild rodent, probably *Reithrodontomys humulis* Aud. and Bach. We have observed damage to test plots of glandless cotton by field mice and rabbits in the San Joaquin Valley of California. Thus, glandless cotton plants appear to lack a natural fitness against herbivores, as inferred as early as 1905 from the work of Quaintance and Brues (12).

The studies reported here were to determine the susceptibility of glandless and glanded genotypes of cotton (*Gossypium barbadense* L. and *G. hirsutum* L.) to *Lygus hesperus* Knight (a major pest of irrigated cotton in the southwestern United States). All work was done at the U. S. Cotton Research Station, Shafter, Calif.

MATERIALS AND METHODS

Field Cage Experiment

Population growth and feeding damage of *L. hesperus* on isogenic glandless and glanded lines of G1831 cotton were studied in a randomized, complete block experiment of four replications using no-choice field cages. The G1831 glandless and glanded isogenic lines were derived from an F_2 population in 'Acala SJ-1' background. The original cross was made between Acala SJ-1 and bulked pollen from several selected glandless lines. Eight backcrosses were then made to advanced breeding lines which had been selected out of advanced generations of an AxTE 1 × New Mexico 2302 cross. These breeding lines were all closely related to Acala SJ-1, which had also been selected out of the above cross. Five more backcrosses were made onto Acala SJ-1 itself; only plants carrying the gl_2 and gl_3 alleles were used in backcrossing to the recurrent parent. Thirty-two $Gl_2Gl_2Gl_3Gl_3$ plants and 25 $gl_2gl_2gl_3gl_3$ plants were selected at random in the F_2 generation of the last backcross and equal numbers of selfed seed from plants of the same genotype were bulked together for the original seed for the G1831 glanded and glandless lines.

Each Lumite[3] field-cage (1.83 m wide, 1.83 m high, 3.66 m long) enclosed 20 plants in two 3.1-m rows spaced 101.6 cm apart. Prior to infestation, each cage was treated twice with tepp and dicofol to eliminate arthropods. At an early bloom stage 12 weeks after planting, terminals of six plants in each cage were enclosed with a cotton organdy sleeve-cage 20 cm wide × 24 cm long. Soon thereafter, eight females were placed in each sleeve cage for egg laying; after 72 hours, they were released into the Lumite field-cage.

Infested cages were inspected periodically for predators and phytophagous arthropods. Uninfested check cages were monitored for *L. hesperus* and other cotton pests.

Five weeks after the females were released, populations of *L. hesperus* in the cages were determined. Each infested cage was partially covered with a black polyethylene film tarp; one corner was left open. Bugs attracted to the lighted corner were collected from the walls with a portable 12 VDC automobile vacuum. Cages were then sealed with the exterior trap and fumigated using Plantfume 103[3] smoke. Dead bugs were collected from a polyethylene sheet on the floor of the cage. After the bugs were separated from plant debris and soil with the aid of sieves, they were sorted into life stages and counted. Eight plants from each cage, excluding those used for egg laying, were evaluated for growth and fruiting using the plant growth analysis technique described by Davidson (2).

[3] The use of brand names does not imply endorsement by the U. of Calif. or USDA.

Laboratory Bioassay

Growth and survival of nymphs, oviposition, and egg survival were studied using isogenic glandless and glanded lines of *G. hirsutum* (G1831, G8628) and *G. barbadense* (72-4056, 72-4058, 72-4062). The G8628 glandless and glanded isogenic lines were derived from an F_2 population in Acala 4-42-77 background. After an original cross of 'Acala 4-42' onto glandless line 41-63, a backcross was made onto Acala 4-42. Subsequently five backcrosses were made onto Acala 4-42-77. Only plants carrying the gl_2 and gl_3 alleles were used in backcrossing to the Acala 4-42 material. In the F_2 generation of the final backcross, 22 random plants each of $Gl_2Gl_2Gl_3Gl_3$ (glanded) and $gl_2gl_2gl_3gl_3$ (glandless) genotypes were selected. For each genotype, equal numbers of selfed seed from each plant were bulked together to make up the original seed stock for the G8628 glanded and glandless lines. Acala 4-42-77 was one of the several closely related families that comprised the Acala 4-42 cultivar.

Glandless lines 72-4056, 72-4058, and 72-4062 were developed by Dr. E. L. Turcotte, cotton research center, Phoenix, Ariz. and came from backcrosses to 'Pima S-4.' The original cross was glandless line 23B to 'Pima S-2' and then six backcrosses to Pima S-2. The sixth backcross then was crossed to Pima S-4 and this was followed by three backcrosses to Pima S-4. The above glandless lines came from seed that were bulked from F_3 progeny rows.

Oviposition and egg survival were measured as one parameter ("nymphal emergence") using the bagged terminal method (13). Accordingly, the combined effects of ovipositional nonpreference and egg antibiosis were determined. Three females were caged on each plant terminal; 10 days later nymphs were counted. Four to six plants (replications) of each genotype were caged. Growth and survival of nymphs were determined by rearing bugs on floral buds, using dialysis tubing cages (14). In this method, females collected from alfalfa were placed on green beans (*Phaseolus vulgaris* L.) for egg laying. At three days posteclosion, nymphs were individually confined to intact floral buds by dialysis tubing cages 4.8 cm diam. × 15.2 cm long. Two ages of floral buds were used in rearing nymphs (approx. 3 and 6 days preanthesis). One of the former and two of the latter age were caged on each of four plants (replications) of each genotype. Dialysis tubing was used because of its light weight and permeability to water vapor. A polyurethane foam disk (5.1 cm diam. × 2.5 cm thick) slit radially for attachment to the peduncle was used to seal the cage. The opposite end was folded and closed with a paper clip. Nymphs were weighed and survival was recorded 7 days later.

Data were subjected to analysis of variance. Means were compared using the L.S.D. or Student's t-test ($P = 0.05$). When necessary, data were transformed to meet the assumptions of these analyses.

RESULTS

Table 1 presents growth and fruiting responses of cotton plants in the field cage experiment. Numbers of bolls and fruiting points were similar in both genotypes in the check (uninfested) treatment. Both genotypes had less fruit, more fruiting points, and greater

Table 1. Growth and fruiting response of glandless and glanded G1831 cotton after 5 weeks of infestation by *L. hesperus* at Shafter, Calif. (1973).

Genotype	Treatment	Mean no./plant		Fruiting forms shed, %
		Bolls	Fruiting points	
G1831 glandless	Infest	5.4	137.7	91.0
	Check	20.5	107.9	43.9
	% (infest/check)	27.2*	127.1	207.3*
G1831 glanded	Infest	12.6	117.3	79.4
	Check	20.1	100.2	53.8
	% (infest/check)	64.1	118.4	147.6
L. S. D. (5%): infest vs. check		5.3	21.2	8.6

* Significantly different from that of glanded equivalent at P = 0.05 by analysis of variance.

Table 2. Mean number of *L. hesperus* in no-choice field cages of G1831 glandless and glanded cotton after 5 weeks of infestation at Shafter, Calif. (1973).

Genotype	Nymphs	Adults		Total
		Females	Males	
G1831 glandless	52.8*	157.3*	158.6*	370.9*
G1831 glanded	12.3	61.5	74.0	148.7
CV	26.8	17.9	15.2	15.9

* Significantly greater than that of glanded equivalent at P = 0.05 by analysis of variance.

Table 3. Growth, survival, and emergence of *L. hesperus* nymphs on lines of isogenic glandless and glanded *G. hirsutum* and *G. barbadense* at Shafter, Calif. (1973).

Genotype	Growth rate	Survival	Hatching nymphs
	mg/day	%	no./plant
G. hirsutum			
G1831 glandless	0.52*	100.0*	35.0
G1831 glanded	.35	50.0	27.7
G8628 glandless	.28*	90.9*	27.4
G8628 glanded	.15	58.5	28.9
G. barbadense			
Pima S-4 glandless			
(72-4056)	.41*	90.8*	20.0
(72-4058)	.43*	97.7*	27.1
(72-4062)	.43*	94.4*	20.4
Pima S-4 glanded	.19	41.5	19.8

* Significantly greater than that of glanded equivalent at P = 0.05 (Student's t-test).

shedding of fruiting forms when subjected to *L. hesperus;* the glandless genotype had significantly fewer bolls and greater shedding than did its glanded equivalent.

Table 2 summarizes the population response of lygus bugs after 5 weeks in the field cages. The mean number of pooled adults and nymphs per cage was 148.7 and 370.9 for the glanded and glandless genotypes, respectively. When numbers of females, males, and nymphs were compared on both genotypes, numbers of both sexes and life stages were greater on the glandless cotton.

Table 3 presents results of growth, survival, and nymphal emergence bioassays of three glanded genotypes and their isogenic glandless equivalents. Growth rates of nymphs were significantly greater on glandless lines of G1831, G8628, and Pima S-4 than on the glanded cottons. Nymphal survival was significantly greater on all glandless lines compared to glanded lines. Glanded and glandless genotypes did not differ in number of newly-hatched nymphs.

DISCUSSION

Nymphs on glandless cottons had growth rates and survival nearly double those on isogenic glanded lines. Gossypol or other gland-related pigments probably mediate nonpreference for feeding or antibiosis, or both, in *L. hesperus.* Studies of feeding behavior and nutrition are needed to determine the resistance mechanisms.

The larger populations of *L. hesperus* observed in field cages of glandless cotton probably resulted from greater nymphal survival, coupled with a shortened generation time owing to greater growth rate. The 2.5-fold increase in numbers of bugs on glandless G1831 may have been less had predators and parasites been present. Nevertheless, these results indicate a serious possibility for larger populations of *L. hesperus* and greater damage to glandless cotton as most current cotton pesticides are indiscriminate and broadly toxic to entomophagous arthropods. Thus the nearly 60% decrease in bolls on the glandless cotton compared to its glanded equivalent, should be viewed with concern. If intensive control of *L. hesperus* is needed for production of glandless cotton, increased usage of chemical insecticides may be necessary, thus increasing production costs. We suggest that the susceptibility of glandless cotton to lygus bugs be intensively studied using large field plots and production practices similar to those used commercially.

REFERENCES

1. Bottger, G. T., E. T. Sheehan, and M. J. Lukefahr. 1964. Relation of gossypol of cotton plants to insect resistance. J. Econ. Entomol. 57:283-285.
2. Davidson, A. 1973. Computerized plant growth analysis of the interaction of arthropod pests and other factors with the cotton plant. Ph.D. diss. U. of Calif., Berkeley. 182 p.
3. Eagle, E. L., E. Castillon, C. M. Hall, and C. H. Boatner. 1948. Acute oral toxicity of gossypol in cottonseed pigment glands for rats, mice, rabbits, and guinea pigs. Arch. Biochem. 18:271-277.
4. Lambou, M. G., R. L. Shaw, K. M. Decossas, and H. L. E. Vix. 1966. Cottonseed's role in a hungry world. Econ. Bot. 20:256-257.
5. Lee, J. A. 1965. The genomic allocation of the principal foliar-gland loci in *Gossypium hirsutum* and *Gossypium barbadense.* Evolution 19:182-188.
6. Leigh, T. F., and A. H. Hyer. 1971. Susceptibility of glandless cotton to attack by *Diabrotica* beetles. J. Econ. Entomol. 64:319.
7. Lyman, C. M., A. S. El Nockrasky, and J. W. Dallahite. 1963. Gossyverdurin: A newly isolated pigment from cottonseed pigment glands. J. Am. Oil Chem. Soc. 40:571-575.
8. McMichael, S. C. 1959. Hopi cotton. A source of cottonseed free of gossypol pigments. Agr. J. 51:630.
9. Maxwell, F. G., H. N. Lafever, and J. N. Jenkins. 1965. Blister beetles on glandless cotton. J. Econ. Entomol. 58:792-793.
10. Murray, J. C., L. M. Verhalen, and D. E. Bryan. 1965. Observations on the feeding preference of the striped blister beetle, *Epicauta vitatta* (Fabricius) to glanded and glandless cottons. Crop Sci. 5:189.
11. Neelakantam, K., and T. R. Seshadri. 1936. Pigments of cotton flowers Indian Acad. Sci., Proc. 4A:54-58. Pt. 3.
12. Quaintance, A. L., and C. T. Brues. 1905. The cotton bollworm. USDA Bur. Entomol. Bull. 50. 155 p.
13. Tingey, W. M., T. F. Leigh, and A. H. Hyer. 1973. Three methods of screening cotton for ovipositional nonpreference by lygus bugs. J. Econ. Entomol. 66:1312-1314.
14. ———, ———, and ———. 1974. Lygus bugs: growth, survival, and egg laying resistance of cotton genotypes. J. Econ. Entomol. 68:28-30.
15. Vix, H. L. E. 1968. High protein flour products from glandless and glanded cottonseed. Oil Mill Gaz. 72:53-56.