Published September, 1983

Genotype × Environment Interaction of Cottons Varying in Insect Resistance[1]

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ABSTRACT

Insect resistance and glandless traits were introgressed, usually by the backcross method, into agronomically acceptable genetic backgrounds of cotton, *Gossypium hirsutum* L. The yield potential and adaptability of nine nectariless-nectaried pairs of cottons were evaluated for 1 to 3 years, 1978 to 1980, at six locations with and without early season insect control. Five of these pairs were in conventional Coker, Deltapine, Stoneville, or DES genetic backgrounds. The others were backcross-derived strains that combined nectaried or nectariless with the frego bract, Okra leaf, Smooth leaf, high gossypol, or glandless traits. Significant strain × location interactions were detected for first harvest (earliness) and total lint yields. Nectariless cottons had significantly higher first harvest yields than nectaried ones in 1978 and 1979. Over 3 years, nectariless cottons averaged 5.7% higher total yields than nectaried cottons, 887 vs. 827 kg/ha, respectively when grown without early season insect control. However, no differences in total yield were detected between the nectaried/nectariless cottons when grown with early season insect control. The environmental index used for the 18 environments studied was determined by the average performance of two nectaried cottons, 'Stoneville 213' and 'Deltapine 61', and two nectariless ones, 'Stoneville 825' and Deltapine 7146N. The average regression coefficient for the nectariless cottons was not different from the nectaried ones (b = 0.81 vs. b = 0.79, respectively) when grown with early season insect control. However, when grown without early season control the average regression coefficient for nectariless was significantly higher than nectaried ones (b = 0.86 vs. b = 0.76, respectively). The average regression coefficient, with and without early season insect control, for the glandless, high gossypol, Okra leaf, and frego bract traits were 0.64, 0.70, 0.76, and 0.43, respectively. This study suggests that the nectariless cottons used had high adaptability potentials, but the other traits investigated did not.

***Additional index words:* *Gossypium hirsutum* L., Host-plant resistance, Lint yield, Nectariless, Frego bract, Okra leaf, Smooth leaf, Glandless.**

THE economic production of cotton, *Gossypium hirsutum* L., usually requires the use of multiple insecticide treatments to control various insect pests. One method proposed to reduce the dependence of the crop on insecticides is to develop insect resistant cotton. Some of the characteristics backcrossed into agronomically usable cottons for this purpose are frego bract, Okra leaf, Smooth leaf, high gossypol, earliness, and nectariless. The use of these and other host plant resistance traits in cotton have been reviewed by Maxwell et al. (1972), Jones et al. (1978), Niles (1980), and Maxwell (1980).

The frego bract and Okra leaf traits confer resistance to the boll weevil, *Anthonomus grandis* Boh. In addition, Okra leaf cottons carry resistance to the banded-wing whitefly, *Trialeurodes abutilonea* (Haldeman), and pink bollworm, *Pectinophora gossypiella* (Saunders). Smooth leaf cottons result in a reduction in oviposition by *Heliothis* spp. and pink bollworm. High gossypol strains produce adverse effects on cotton fleahoppers, *Pseudatomoscelis seriatus* (Reuter), and *Heliothis* spp. larvae. Glandless cotton plants have virtually no gossypol and consequently are susceptible to numerous insects. However, glandless cotton seeds hold potential as a source of high protein food for ruminant as well as nonruminant animals. Earliness as an escape mechanism has long been proposed as a pest management strategy.

Nectariless cottons are earlier maturing than their nectaried counterparts and result in reduced *Heliothis* spp. oviposition, reduced pink bollworm damage, and reduced numbers of tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois). The nectariless trait has been introduced into the following types of cotton: frego bract, Okra leaf, Smooth leaf, high gossypol, glandless, early, and conventional cultivars.

However, the adaptability of cottons carrying these traits to variable environments and genotype × environment interactions have not been investigated. The objective of this study was to compare the performance and adaptability of insect resistant strains, as measured by lint yield, over a range of environments.

MATERIALS AND METHODS

Insect resistant strains and cultivars of cotton were evaluated in 1978, 1979, and 1980 at each of six locations in Mississippi with and without early season insect control. Location 1 was in Oktibbeha County 6 km northwest of Mississippi State Univ. Locations 2 and 3 were in Panola County, approximately 15 km northwest and 6 km west of Batesville, respectively. Locations 4, 5, and 6 were in the Delta at or near Stoneville. The soil types for the six locations are as follows: location 1: Marietta silty clay loam (fine-loamy, siliceous, thermic Fluraquentic Eutrochrepts); location 2: Falaya silt loam (coarse, silty, mixed, acid, thermic Aeric Fluraquent); location 3, 4, and 5: Memphis silt loam, 2-5% slopes, eroded (fine-silty, mixed, thermic Typic Hapludalfs); and location 6: Bosket very fine sandy loam, nearly level phase (fine-loamy, mixed thermic Mollic Hapludalfs). Nine nectariless-nectaried pairs of cotton strains, some also having other insect resistance or glandless traits, were evaluated for 1 to 3 years. These were 'Stoneville 825' nectariless (ST-825N); 'Stoneville 213' (ST-213); Deltapine 7146 nectariless (DPL-7146N); 'Deltapine 61' (DPL-61); Coker 420 Smooth, nectariless (C-420N); 'Coker 420' (C-420); DES-56 nectariless (DES-56N); 'DES 56'; Stoneville glandless, nectariless (ST-glN); Stoneville glandless (ST-gl); Stoneville Okra leaf, nectariless (ST-L°N); Stoneville Okra leaf (ST-L°); high gossypol, nectariless (HGBR-8N); high gossypol (HGBR-8); Stoneville frego, nectariless (ST-fgN); Stoneville frego (ST-fg); DES-24 nectariless (DES-24N); and 'DES-24'. Standard cultural practices were carried out at each location.

The experimental design at all locations was a split-split-plot arrangement with five replications in 1978 and 1979,

[1] Cooperative investigations of USDA-ARS and the Mississippi Agric. and For. Exp. Stn. Journal paper 5246 of the Mississippi Agric. and For. Exp. Stn., Mississippi State. Received 7 Sept. 1982.

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Table 1. Mean squares† for first and total lint yield for nectaried/nectariless strains and cultivars of cotton grown at six locations during 1978 to 1980.

Source	1978‡			1979			1980		
	df	1st harvest	Total	df	1st harvest	Total	df	1st harvest	Total
Location	5	1 988**	11 131**	5	2 682*	3 364**	5	3 953*	3 834**
Replication (L)	24	189	296	24	673	719	30	30	131
Aldicarb Trt.	1	788**	1 430**	24	3 337**	3 806**	1	136*	198
T × L	5	285	947**	5	79	188*	5	89**	32
Pooled error a	24	119	112	24	89	68	30	18	83
Nectar	1	296*	41	48	1 214**	522*	1	6	13
N × L	5	89	108	5	197*	105	5	3	6
N × T	1	27	77	1	462**	637*	1	68**	24
N × T × L	5	80	89	5	75	118	5	9	13
Pooled error b	48	44	67	48	62	89	60	6	9
Strain	5	688**	1 410**	8	580**	828**	3	32**	70**
S × L	25	173**	138**	40	115**	189**	15	21**	27**
S × T	5	45	55	8	38*	46	3	23*	23
S × N	5	42	16	8	68**	132**	3	46**	85**
S × L × T	25	30	28	40	24*	34	15	8	12
S × T × N	25	32	51	40	64**	63**	15	11	18
S × T × N	5	31	49	8	16	41	3	16	4
S × L × T × N	25	31	31	40	26	38*	15	5	12
Pooled error c	480	24	37	768	17	25	360	8	11

*,** Significant at the 0.05 and 0.01 levels, respectively.
† × 10^{-3}.
‡ If any one of the nectaried/nectariless entries was missing, the pair was dropped from the analysis.

and six replications in 1980. Whole plots were early and no early season insect control, split plots were nectaried/nectariless, and split-split plots were strain or cultivar type. Early season insect control was none and a side-dress application of 2.4 kg/ha ai of aldicarb [2-methyl-2-(methylthio)propionaldehyde *O*-(methylcarbamoyl) oxime] applied when pinhead squares were present.[4] The field plots were scouted each week and insecticides were applied as needed for late season control. Plots which received aldicarb were treated with conventional insecticides. Late season insect control for plots which did not receive aldicarb consisted of a biological agent, *Bacillus thuringensis* plus an ovicide, chlordimeform [*N'*-(4-chloro-*o*-tolyl)-*N, N*-dimethylformadine], to control *Heliothis* spp.

Lack of adequate amounts of seed prevented certain strains from being planted at all locations in 1978. All strains and cultivars were planted with the exception of the following: locations 1, 2 and 3—DES-56N, DES-24N, and ST-fgN; location 4—DES-56N and DES-24N. During 1979 all 18 strains and cultivars were grown at each location. Based on data from the 2 years before, the eight best strains and cultivars (DPL-61, DPL-7146N, C-420, C-420N, ST-213, ST-825N, DES-56, and DES-56N) were planted at each of six locations in 1980.

The plots were 12 rows, 1 m × 13.7 m long. At location 1, the two center rows from each plot were machine harvested twice for yield determination. At the other locations, a 7.6-m section of row was hand harvested twice from each plot for yield determination. Boll samples were hand picked at all locations and ginned to determine lint percentage which was used in calculating lint yields. The data for lint yields were analyzed over locations within a year. If any one of the nectaried/nectariless entries was missing, the pair was dropped from the analysis.

Analysis of variance and regression were used to estimate strain and cultivar yield performance over years and locations. Each year/location was considered a separate environment. The yield of individual strains was designated as the dependent variable (Y) and the mean yield of DPL-61, DPL-7146N, ST-213, and ST-825N as the independent variable (X), i.e. environmental index. Three of these cultivars are widely grown (Anonymous, 1981) and should represent a good standard for environmental adaptability.

[4] Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

A simple linear regression analysis was used to estimate the regression coefficient (b), coefficient of determination (r^2), and the standard deviation from regression (s_d). The hypothesis of no significant difference between a line of unit slope and the slope of the regression line, Ho: $\beta = 1$, was tested for the regression line of each strain to compare yield performance.

RESULTS AND DISCUSSION

The largest mean squares within a year's analyses were for locations, suggesting that a wide range of environments was sampled each year (Table 1). Early season insect control (aldicarb treatment) resulted in significantly higher yields for first and total harvest in 1978 and 1979, and first harvest in 1980. All locations did not have early season insects. Nectariless cottons produced significantly earlier yields than nectaried cottons in 1978 and 1979, reinforcing previous studies by Meredith et al. (1973). The average yield of nectariless and nectaried cottons was 520 and 471 kg/ha for first harvest and 830 and 802 kg/ha over the season, respectively. However, total yield of nectariless cotton was significantly higher than nectaried only in 1979. Location × nectaried type interactions were significant for first harvest only in 1978. Nectaried type × aldicarb treatment was significant for first harvest in 1979 and 1980, and for total yield in 1979. The with aldicarb treatment resulted in no differences between the nectaried/nectariless cottons; however, the nectariless types yielded significantly more than the nectaried types in the no aldicarb treatment.

Large differences were detected among strains for first and total yield for each year. The strain × location interaction was significant for first harvest and total yield all 3 years. The strain × nectary type interaction was significant for first and total yield in

Table 2. Estimates of performance of cotton strains and cultivars grown with and without early season insect control based on regression analysis.

		With early season insect control					Without early season insect control				
Strain or cultivar	n	Mean yield entry	Mean yield index†	b‡	s_d	r^2	Mean yield entry	Mean yield index†	b‡	s_d	r^2
		kg/ha	kg/ha				kg/ha	kg/ha			
DPL-61	18	1064	1044	1.16*	0.129	0.96	876	932	1.01	0.218	0.86
SPL-7146N	18	1044	1044	1.02	0.114	0.96	946	932	1.05	0.153	0.93
ST-213	18	1057	1044	0.94	0.142	0.92	904	932	0.86	0.153	0.90
ST-825N	18	1011	1044	0.89	0.127	0.93	1002	932	1.08	0.208	0.88
C-420	18	883	1044	0.80	0.382	0.55	769	932	0.87	0.466	0.50
C-420N	18	958	1044	0.79	0.286	0.68	832	932	0.80	0.398	0.53
DES-56	18	1002	1044	0.96	0.235	0.82	867	932	0.93	0.388	0.62
DES-56N	14	968	1035	1.00	0.161	0.94	882	906	1.03	0.252	0.87
DES-24	12	1037	1085	0.75*	0.225	0.84	886	964	0.82*	0.156	0.93
DES-24N	8	993	1090	0.91	0.367	0.86	941	934	1.12	0.287	0.93
ST-gl	12	882	1085	0.67**	0.230	0.81	751	964	0.50**	0.339	0.52
ST-glN	12	844	1085	0.64**	0.222	0.80	829	964	0.74	0.308	0.74
HGBR8	12	910	1085	0.59**	0.189	0.83	782	964	0.62*	0.321	0.65
HGBR8N	12	950	1085	0.91	0.227	0.89	863	964	0.71	0.392	0.62
ST-Okra	12	1008	1085	0.76*	0.232	0.84	906	964	0.79	0.319	0.76
ST-Okra N	12	1046	1085	0.73*	0.252	0.81	927	964	0.78	0.254	0.82
ST-Frego	12	943	1085	0.46**	0.310	0.52	704	964	0.40*	0.504	0.24
ST-Frego N	9	836	1113	0.40**	0.187	0.76	673	934	0.45**	0.369	0.52

*,** Significantly different from 1.0 at the 0.05 and 0.01 levels of probability, respectively.
† Environmental index is the mean of DPL-61, DPL-7146N, ST-213, and ST-825N.
‡ Regression of strain or cultivar mean on environmental index.

1979 and 1980. In an unbalanced analysis for 1978 this interaction was also significant. In 1978 the nectariless types outyielded the nectaried types except for the frego bract and glandless nectaried strains, which yielded more than their nectariless counterpart. Again in 1979 the frego nectaried strain yielded more than its nectariless comparison. Also in 1979 DES-24 produced more than DES-24N. In 1980 DES-56 yielded significantly more than DES-56N. The strain by aldicarb interaction was significant for first harvest in 1979 and 1980.

Eberhart and Russell (1966) proposed the use of an environmental index to measure general adaptability and genotype × environment interactions. Pedersen et al. (1978) used regression techniques in describing cultivar response over a series of environments where entries were not kept constant from year to year or site to site. Since all cultivars were not included in all the tests of this study, we used four widely adapted cultivars as a measure of the environmental index. Bilbro and Ray (1976) used a similar approach in their studies of the adaptability of cotton cultivars in western Texas.

Mean lint yields over environments and regression parameters, with and without early season insect control, are given in Table 2. The four check cultivars used as the environmental index averaged 1044 kg/ha lint and their average regression coefficient was 1.00, when grown with early season insect control. The average regression coefficient for the nine nectariless cottons, b = 0.81, was not different from that of the nectaried cottons, b = 0.79. However, when grown without early season insect control the average regression coefficient for the nectariless cottons, b = 0.86, was significantly higher than that of the nectaried cottons, b = 0.76. In the absence of early season insect control the nectariless types yielded 5.7% more than the nectaried types. The primary early season insect pest present was the tarnished plant bug. It has been previously reported (Meredith et al. 1973, Schuster and Maxwell 1974) that the nectariless character is effective in reducing plant bug damage.

In 1981, a nectariless cultivar was grown on a larger hectarage than any other cultivar in the USA (Anonymous, 1981). The linear correlation between mean yield of cultivar type and the regression coefficient was highly significant. This indicates that the higher yielding types responded better to favorable environments than the lower yielding cottons. Except for the nectariless strains and cultivars, all of the insect-resistant cottons and the glandless ones had lower yields and general adaptability indices than the conventional cultivars. The average regression coefficient of the five nectariless cottons that carried no other mutant traits was 0.92 and 1.02, compared to 0.92 and 0.90 for the five conventional (nectaried) cultivars that were tested when grown with and without aldicarb, respectively. The average regression coefficients for glandless, high gossypol, Okra leaf, and frego bract cottons were 0.65, 0.75, 0.74, and 0.43, respectively, when grown with aldicarb and 0.62, 0.66, 0.78, and 0.43, respectively, when grown without early season insect control. The average coefficient for the four standards, as mentioned, was 1.00.

The glandless and high gossypol cottons were both developed by backcrossing into a 'Stoneville 7A' background. It is interesting that both high gossypol and glandless (gossypol free) cottons had low adaptability indices. Cottons having the frego bract trait had the lowest yields and adaptability indices.

ACKNOWLEDGMENTS

We thank the following who provided seed: C.W. Manning, Stoneville Pedigreed Seed Co.; Keith Jones, Delta and Pine Land Co.; and H.W. Webb, Coker Pedigreed Seed Co. M.J. Lukefahr, USDA-ARS, developed the high gossypol strains. Thanks are also extended to William M. Thomas for computer assistance during data analyses. This research was supported by pilot test funds provided by USDA.

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