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Performance of Cottons when Infested with Tobacco Budworm[1]

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ABSTRACT

Thirteen germplasm lines of cotton, *Gossypium hirsutum* L., including seven cultivars were grown for 3 years with and without tobacco budworm, *Heliothis virescens* F. There is a paucity of information available on the performance of cotton germplasm when grown under tobacco budworm infestation. Development of insecticide resistance in this insect or a loss of effective insecticides from the market would pose substantial problems for the cotton industry. Objectives of this study were i) to determine the performance of 13 diverse germplasm lines when grown under controlled, uniform levels of tobacco budworm infestation, ii) to identify germplasm useful to breeders for use in developing cultivars resistant to tobacco budworm, iii) to identify germplasm lines with different levels of resistance useful for studies on how or why cotton germplasm resist tobacco budworm and iv) to develop information useful for improving breeding practices in cotton. Plots were grown on a Leeper silty clay loam, fine montmorilloritic, non-acid, thermic, chromondertic, Haplaquept, 0 to 2% slope. Infested plots were inoculated with first instar tobacco budworm larvae five to six times at weekly intervals beginning about the second week of squaring as determined in 'Stoneville 213'. Worm-free plots were sprayed weekly with fenvalerate [cyano(3-phenoxyphenyl)methyl 4-chloroalpha-(1-methylethyl)benzeneacetate]. Resistance was measured as the ability to resist yield loss when continually infested with tobacco budworm larvae for 5 to 6 weeks. Resistance was identified in 'Stoneville 506' and confirmed in PEE DEE 875, PEE DEE 8619 and 'Tamcot CAMD-E'. Because two are cultivars and are presently being grown, information on them can immediately be put to use. Each of the four germplasms should be useful to breeders as parental lines to increase resistance to tobacco budworm. Regression analyses on one year's data suggest that about 65% of the resistance is associated with early, rapid fruiting. However, additional unidentified factors are also involved.

***Additional index words:* *Heliothis virescens* F., *H. zea* (Boddie), Plant resistance, Cotton genetics, Cotton breeding, *Gossypium hirsutum* L.**

THE *Heliothis* complex comprised of tobacco budworm, *H. virescens* F., and cotton bollworm, *H. zea* Boddie, is a major pest in upland cotton, *Gossypium hirsutum* L. Most cultivars are susceptible to the *Heliothis* complex and require extensive use of insecticides when the complex is present in commercial production areas. Cotton breeders normally develop cotton germplasm lines into cultivars using a "protective canopy" of insecticides. Thus, they develop widely adapted cultivars capable of high production when grown with production practices normally used by most producers. A major problem would immediately develop if the *Heliothis* complex develops resistance to insecticides or if the insecticides were removed from the market. There is a paucity of information on the performance of currently used cultivars without insecticides.

Most researchers are interested in developing resistance to the *Heliothis* complex in cotton or are actively monitoring the activities of others because effective insecticides may be lost from the market and the *Heliothis* complex has developed resistance to previously used insecticides. However, no commercial breeders are actively pursuing studies to measure field resistance to *Heliothis* spp. under controlled conditions. Modest efforts to increase gossypol level and to develop smooth leaf, nectariless, early maturing germplasm lines are the most widely used approaches to increase resistance to insects.

Jenkins et al. (1982) have recently developed techniques for uniformly infesting large numbers of field plots with first instar tobacco budworm larvae, then measuring resistance of these cotton germplasm lines to tobacco budworm. This resistance is expressed as the ability to resist yield loss when infested with this insect. Using this system in our research we have developed and released five germplasms resistant to tobacco budworms, MHR-1, DH-118, DH,121, DH-126 and DH-128 (Jenkins et al, 1984; Mahill et al, 1984). This technique is presently feasible for a cotton breeder to use in large breeding programs. The objectives of this research were i) to determine the performance of 13 diverse germplasm lines of cotton when grown under controlled levels of tobacco budworm infestation, ii) to identify germplasm lines useful to breeders for developing cultivars resistant to tobacco budworm, iii) to identify germplasm lines with different levels of resistance useful for studies of how or why cotton germplasm resist tobacco budworm and iv) to develop information useful for improving breeding strategies or practices.

MATERIALS AND METHODS

Thirteen cultivars or advanced strains were used in our experiments: 'Stoneville 213' (ST 213), 'Stoneville 825' (ST 825), 'Stoneville 506' (ST 506), Stoneville 857 (ST 857), Stoneville 517 (ST 517), Stoneville 7A glandless (ST 7A Gl), 'Deltapine 61' (DPL 61), 'Deltapine 41' (DPL 41), 'Tamcot CAMD-E' (Bird 1979), 'Delcot 311' (Sappenfield, 1980), PEE DEE 8619 (Culp, 1979b), PEE DEE 875 (Culp, 1979a) and DPL-16 AD_3 nectariless. These cottons represent a diverse group and include the most widely grown cultivars in the Delta cotton production region.

These germplasms were grown for 3 years under two levels of tobacco budworm. Measured resistance was expressed as the relative ability to resist yield loss when larvae of this insect were present in large numbers during most of the fruit set period. Plots were located on a Leeper silty clay loam, fine, montmorillonitic, non-acid, thermic, chromondertic, Haplaquept, 0 to 2% slope. In 1980, plots were planted solidly two rows by 10 m, spaced 0.97 m apart and replicated four times. In 1982 and 1983, plots were single rows, spaced 0.97 m by 10 m and replicated six times. The planting pattern in 1982 and 1983 was two rows planted to cotton followed by a blank row: This pattern is referred to as 2×1 planting. Yields each of the 3 years were calculated on the basis of 1 ha of land. Solid planted plots had 10 352 row m ha^{-1} and the 2×1 plots had 6905 row m ha^{-1}.

The experimental design was a two-way whole split plot.

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Table 1. Lint yields and estimates of *Heliothis virescens* resistance of 13 cotton strains and cultivars.

Strain	3-year means				
	Lint yield		Mean productivity	Loss	Percentage of potential
	With *Heliothis*	Without *Heliothis*			
	kg ha^{-1}				
St 213	621	1129	875	509	54.3
St 825	647	1204	925	558	53.7
St 506	759	1039	899	280	75.1
St 517	666	1174	920	507	56.8
St 857	467	862	664	395	56.2
St 7A G1	367	962	664	595	38.1
DPL 61	572	1157	864	585	49.0
DPL 41	659	1142	901	483	57.7
CAMD-E	785	796	791	11	104.6
Delcott 311	652	1085	868	433	60.7
PD 8619	584	875	729	290	68.8
PD 875	764	1038	901	274	74.9
DPL 16 AD3	639	1048	843	408	61.1
LSD 0.05	123	123	84	132	12.5

The whole plots were levels of tobacco budworm infestation: i) five to six infestations of first instar tobacco budworm larvae and ii) insecticide sprays to prevent tobacco budworm and other insects from damaging cotton. The split plots were germplasm lines. To minimize field variability and to facilitate spraying the whole plots were paired eight row strips of cotton. The split plots were arranged as paired (worm vs. worm free) randomized complete blocks. This design resulted in the whole plot effect being confounded within a year with replications; however this was not a problem in interpretation of the results because we were primarily concerned with the treatment-germplasm interaction in this experiment. Data were analyzed using the (GLM) General Linear Model from (SAS) Statistical Analysis System. The calculated values of (MP) mean productivity (mean yield of an entry with and without worm), loss and (PP) percentage of potential (yield of an entry with worms/yield of that entry without worms expressed as a percentage) were analyzed across years. The LSD (0.05) was calculated to use in comparing means.

Plots were planted with a cone planter between 5 and 9 May in each year. Terrachlor super-x (5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole) plus disulfoton [0,0-Diethyl S-2-(ethylthio)ethyl phosphorodithioate] was applied in-furrow with the seed.[3] All plots within a year were planted on the same day. Plots were harvested one time using a mechanical spindle harvester modified with a sacking arrangement for plot harvesting. Twenty-five open bolls were harvested from each plot from four replications to determine lint percentages.

Plot without tobacco budworm were sprayed once or twice weekly with azinphosmethyl {0,0-Dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl methyl]phosphorodithioate} plus fenvalerate [cyano(3-phenoxyphenyl)methyl 4-chloroalpha-(1-methylethyl)benzeneacetate] beginning at pinhead square stage. Plots with tobacco budworm were sprayed with azinphosmethyl one time before larvae were applied to eliminate parasites and predators. Thereafter, they were sprayed with this insecticide throughout the growing season to control all insects except tobacco budworm. Beginning about 20 August, all plots in both treatments were sprayed with azinphosmethyl plus fenvalerate. First instar tobacco budworm larvae were applied to plants by mixing with corn (*Zea mays* L.) cob grits and applying the mixture to plant terminals according to the method of Jenkins et al. (1982). Larvae were applied weekly for 5 to 7 weeks beginning the second or third week of squaring as determined in ST 213 (25 June, 21 June, 5 July) in each of the years.

In 1982, previous day and current day blooms were counted in each plot twice each week beginning about the first week of blooming (59 days after planting) and continuing for 5 weeks. All squares on five randomly selected plants per germplasm line were counted in each replication on days 39, 46, 53, 59 and 66 after planting in the plots that did not have tobacco budworms applied. Forward stepwise regression using SAS was used to determine the relationships between numbers of blooms or squares and PP. Bloom data from worm treated plots as cumulative blooms to days 66, 84, and 90 and square data from worm-free plots as counts on days 39, 53, and 66 were used in the regression analysis.

RESULTS AND DISCUSSION

Mean squares for lint yield showed year, treatment, germplasm line, and germplasm line by treatment were significant (0.05 level). The year-by-treatment-by-germplasm line and the year-by-treatment mean squares were not significant. Mean squares for lint yield for the calculated values MP, loss and PP were significant (0.05 level) for germplasm lines. Germplasm-by-year terms were nonsignificant for MP and loss. For PP this term was significant due to the cultivar CAMD-E, which was higher in yield in 1980 in the treatment with tobacco budworms. Thus, the 3-yr mean values generally provide valid estimates of performance of the germplasm lines under the two treatments. Yield data for germplasm line by treatment means are shown in Table 1. Four germplasms, ST 506, CAMD-E, PD 875, and PD 8619 tend to resist yield loss more than others. Each is significantly more resistant than ST 213 using PP as a measure of resistance. The ST 7A G1 germplasm is significantly more susceptible than ST213. These strains were different from ST 213 in each of 3 years and each had the same trend over years thus the differences appear to be real. In addition to the resistance value of these germplasms, it is important to consider their yield performance when no tobacco budworms are present. The CAMD-E and PD 8619 germplasms produced significantly less lint, whereas ST 506 and PD 875 were similar in yields to ST 213. Thus, even though CAMD-E and PD 8619 show resistance to tobacco budworm they need improvements in yield when grown in the environments we tested. The DPL 16 AD_3 germplasm contains *G. tomentosum* Nutt. ex Seem. cytoplasm and Meredith et al. (1979) reported tobacco budworms grown on this germplasm were 25% smaller than those grown on *G. hirsutum* cytoplasm. These authors also reported higher yields on germplasm with *G. tomentosum* cytoplasms. We also found in our studies that DPL 16 AD_3 was 25% more resistant than DPL-61 [(61.1−49.0)/49.0 = 25%].

We conducted several regression analyses to develop a value which measures resistance and is not closely related to yield potential of the germplasm lines. We regressed yield with and without tobacco budworms as the independent variable against lint loss, MP and PP. The value, PP vs. yield under sprayed

[3] 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.

Table 2. Parameters from regression analysis of various aspects of lint yields.

Variable				
Dependent	Independent	r	Intercept	b
			kg ha^{-1}	
Yield infested	Yield spray	0.33**	271	0.34
Lint loss	Yield infested	0.50**	1083	−0.80
Lint loss	Yield spray	0.61**	−465	1.00
Mean productivity	Yield infested	0.67**	515	1.02
Mean productivity	Yield spray	0.81**	−124	1.23
Percentage of potential	Yield infested	0.74**	8	0.08
Percentage of potential	Yield spray	0.30**	99	−0.03
Percentage of potential	Lint loss	0.84**	97	−0.05

** Statistically significant at 0.01 level of probability.

conditions gave the lowest value, $r = 0.30$ (significant at the 0.01 level), which was statistically significant though very small (Table 2). Based upon these data, PP represents a value that can be used to measure resistance and is nearly independent of yield potential of a germplasm.

Forward stepwise regression of cumulative number of blooms in 1982 in plots with worms on PP gave a r^2 value of 0.65 at day 66 after emergence. In worm-free plots the r^2 value was 0.53 at day 66. Including data from days 80 or 94 did not improve the r^2 value. A similar analysis for number of squares in worm free plots on day 39 and 53 gave r^2 values of 0.53 and 0.63. Thus these regression values on 1 year's data suggest that resistance is not entirely due to earliness. Only 65% could be accounted for by this parameter which leaves 35% due to some other cause.

The CAMD-E and ST 506 germplasms had more blooms at day 66 in worm-invested plots than the other germplasm lines and they maintained this advantage through final counts. The PD 8619 and ST 7A Gl lines were not different from ST 213 at final count yet PD 8619 was significantly more resistant and ST 7A Gl more susceptible than ST 213. The ability to produce squares and blooms at an earlier and faster rate accounts for part of the resistance of these cottons to tobacco budworm; however, it is evident that other mechanisms not yet elucidated are also involved.

The CAMD-E, ST 506, PD 875, and PD 8619 lines have some common characteristics. The first is highly resistant to seedling pathogens and has a shorter vertical flowering interval than standard Delta types, such as ST 213. A high percentage of plants of CAMD-E produce early blooms. It is resistant to Fusarium wilt root-knot complex (incited by *Fusarium oxysporum* F. sp. *vasinfectur* (Atk.) synd. and Hans and *Meloidogyne incognita* (Kofoid and White) (Chitwood), respectively (Bird, 1979). The PD 8619 line was developed by selections from the cross PD 4461 and 'Mo-Del'. In the backgrounds of these parental strains are a *G. barbadense* L. strain, 'Earlistaple', 'Coker 100 Wilt', and 'Auburn 56'. The PD 875 line involved PD 8619 in its parentage and both PD 8619 and PD 875 were reported to possess an unidentified form of resistance to damage by *Heliothis* spp. (Culp, 1979a, b; Culp et al. 1981).

The ST 506 has a sister line of Auburn 56, a fusarium wilt nematode-resistant cultivar, in its parentage (Manning, 1985, personal communication). Four *Heliothis* resistant germplasms in our study have either Auburn 56, a sister line of Auburn 56, or resistance to the fusarium wilt root-knot nematode complex in common. This result may indicate a common physiological-genetic system related to the resistance we measured to tobacco budworm.

These four germplasm lines represent two cultivars, CAMD-E and ST 506, and two related PEE DEE strains. The cultivars are presently being grown in their areas of adaptation. There was no previous knowledge that ST 506 possessed any genetic resistance to tobacco budworm. Each are available for use as parental lines in crosses. By using the techniques we used in this research a breeder should be able to identify resistant progeny lines from crosses involving resistant by susceptible parents. The data indicate that some progress in selecting for increased levels of resistance to tobacco budworm can be made by selecting for early and rapid fruit formation and set. None of the four lines identified as resistant in this study was selected under uniform levels of infestation by tobacco budworm. The resistance may be serendipity as the germplasm lines were developed for other reasons. Our data suggest that growing presently available germplasm from breeding programs with the techniques we used in this research can yield information previously unknown relative to genetic resistance to tobacco budworm. It should also be possible to increase resistance to tobacco budworm by direct selection for the ability to resist yield loss when progeny are uniformly infested with tobacco budworm. We suggest that our techniques have wide applicability and should be used as a routine part of cotton breeding programs. Information from this research should enhance development of cotton cultivars with genetic resistance to tobacco budworm.

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