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Pink Bollworm Genetic Studies

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Collections of pink bollworm larvae or adults from Indio, Meloland, and El Centro, CA; Tempe, Phoenix, and Gila Bend, AZ; and St. Croix, VI were examined for genetic variability in 18 enzyme systems. Over 60% of the examined loci were polymorphic and distributions generally conformed to Hardy-Weinberg equilibrium values. Thus, across this short range of the geographic distribution of the pink bollworm, the species can be considered highly polymorphic. The St. Croix strain was the most heterozygous of those examined.

Sex-linked recessive lethal mutations are readily induced in the pink bollworm by ionizing radiation and several strains carrying such induced lethals are now being maintained. These tests produced the unexpected result of demonstrating crossing over within the X-chromosome of the male pink bollworm, illustrating the value of genetic markers in research on economically important species.

A successful test of the ability of the sooty pink bollworm strain to enter a natural field population was conducted. In 2 separate fields (ASU farm - sooty females released; Rainbow Valley - sooty males released), F_1 progeny were recovered in large numbers. Emergence of the sooty F_1 progeny was in synchrony with the native moths, and F_1 progeny were recovered in both pheromone traps and from bolls. Performance of the released sooty adults appeared normal. A similar test using the mutant stock purple was not successful and suggested that purple does not behave normally in the field.

Pink Bollworm and Heliothis Behavioral Studies

P. D. Lingren, Research Entomologist

A monocular night vision scope has been adapted to a mobile TV system and one can obtain relatively clear pictures of Heliothis spp. moths at night. Viewing films and photographs of adults responding to pheromone traps show that the male orients the distal one-quarter of its antennae at a 90° angle to the source upon contacting a pheromone plume and orients toward the source. Claspers are extended less than 1 meter from the source.

Vapona strips placed in pink bollworm catch containers of live traps were found to be a good killing agent. Scale accumulation was reduced by one-half. However, vapors from the Vapona were absorbed and released differently by 5 different plastics in the live trap. One component of the trap continued to kill pink bollworms for more than a month after being exposed only to vapors of Vapona for 1 week in the field. The other plastic components exposed to Vapona vapors killed pink bollworms for 1 to 3 weeks.

Three new formulations (water base microencapsulation, solvent base microencapsulation, and PVC extrusion) were tested at 1, 5 and/or 20 mg load rates as gossyplure baits in live traps for pink bollworm. One mg load rate of the solvent base formulation captured as many pink bollworms and for as long as 1 mg load of gossyplure in a rubber septa (standard bait). The other load rates and formulations, except for 1 mg powder formulation of PVC, captured fewer pink bollworms but lasted as long as the standard.

The gossyplure vapors from these formulations were absorbed in the plastic trap and traps exposed in the field to vapors from the baits captured significantly more adults for 1 week than baited traps or the standard trap. This indicates inhibition from solvents or impurities in the bait and may offer a new technique for determining solvent or impurity inhibition in pheromone baits or formulations used for confusion.

Applications of the water soluble formulation at 3 gm AI/a and the solvent base formulation at $3\pm$ gm AI/a against a high density population reduced trap capture by over 90% for 8 days after treatment. in the field, mating was reduced by 69%. Mating increased by 50% in the check. Trap capture was reduced by 100% at a distance of 446 ft from the application of the solvent base formulation on the first night of treatment, but in the field, mating was not reduced. These results indicate a rapid release of the pheromone from the carrier and this test was conducted in late season at a time when temperatures were relatively cool. Applications of the formulations in hot weather likely would not last as long. However, these results clearly show the weakness of using trap capture information to assess the impact of a pheromone on the actual mating in a population. The results also show that development of relatively long lasting formulations applied by conventional spray equipment are likely feasible for pink bollworm.

Nocturnal observations of mating in plots treated with virelure in Hercon sandwiches applied at a rate of 7 to 14 gm AI/ha at 1 to 2-week intervals showed about 80% reduction in mating on the night of treatment, but overall mating was not reduced between applications. This indicates a rapid breakdown or adaptation of the insects to the virelure, but it also indicates a definite reduction in mating for at least 1 night after treatment.

Pink Bollworm Control with Gossyplure

T. J. Henneberry, L. A. Bariola, H. M. Flint, G. D. Butler, Jr., and P. D. Lingren, Res. Entomologists

Studies were conducted in approximately 263 ha of cotton involving 16 fields of about 16 ha each and 1 field of about 4 ha in Rainbow Valley, AZ. Groups of 4 fields each were randomly assigned to each of 4 treatments: (1) gossyplure plus TF (1-tetradecenal formate), (2) gossyplure plus virelure (16:1 ratio of (Z)-11-hexadecenal and (Z)-9-tetradecenal), (3) gossyplure plus (Z)-9-TDF (Z)-9-tetradecen-1-ol formate), and (4) control plots treated with commercial insecticides as recommended by grower-employed pest control advisers. The 4 ha cotton field was not treated with insecticides or pheromones. The chemicals were formulated in plastic laminate systems (ca. 0.04 cm^2 flakes). The flake formulations were applied by air and suspended in acrylic adhesive carrier (Phero-Tac 5®).

From the time of the first application of gossyplure on May 16 and continuing to mid-July, male moth catches in all fields seldom exceeded an average of 1 moth per trap. However, significant reduction of pink bollworm male moth catches in gossyplure-baited traps occurred in the gossyplure-flake treated fields when populations of pink bollworm began to increase in mid-July. During the period July 14-September 11, trap catches in pheromone-treated fields were reduced by an average of 93% (range 78-99).

Higher numbers of pink bollworm larvae were found in bolls on each sampling date, except July 26, from the control plots than were found in boll samples from gossyplure-treated plots. The differences were statistically significant on 9 of 20 sampling dates. The total number of larvae found in bolls during the season was reduced 68% in plots treated with gossyplure. During the season, infestations ranged from 0-5.3 larvae per 100 bolls from gossyplure-treated fields, and 0-21 larvae per 100 bolls in control fields.

In the single untreated check plot, 14% of the bolls were infested on July 30. Beginning in late August, populations increased progressively to the end of the season and reached 58 larvae per 100 bolls with 38% of the bolls infested.

More pink bollworm moths were caught in flight traps and higher percentages of mated females, as well as spermatophores per female, were found in control plots than in the gossyplure-treated plots. The total number of insecticide applications per 4 plots in each case was 7, 7, 11, and 15 in gossyplure-TF, gossyplure-virelure, gossyplure-(Z)-9-TDF, and control plots, respectively.

Pink Bollworm Biology and Cotton Insect Parasite Studies

G. D. Butler, Jr., Research Entomologist

Male and female pink bollworm moths were held at 6 fluctuating temperatures with an average of 21.0° to 34.6°C (55-85° to 80-110° at 5° intervals). Survival of the postdiapause adults was similar to that of the summer generations. Results are being utilized with diapause termination equations to provide projections of pink bollworm male activity to use with pheromone trap catches and for female egg-laying potential.

Modified Malaise traps were placed in 40 fields of cotton and other crops to sample various parasitic insects. In addition to parasites, traps collected female pink bollworms which were useful for evaluating their mating status in pheromone-treated cotton.

Insect Growth Regulating Compounds

H. M. Flint, Research Entomologist

The effects of 7 insect growth-regulating compounds on the pink bollworm were determined. The work was in cooperation with Dr. Leonard Jurd (SEA, Albany, CA). Jurd compound (J2581) was the most active compound tested against the pink bollworm. This compound prevented larval development when fed in larval diet at 0.01%, and its mode of action appeared to be prevention of molting or pupation. The compound also sterilized adult moths when they were exposed to surfaces treated with 0.001 μ/cm^2 but the sterility was not permanent if the exposure was terminated. A field plot test using J2581 at a rate of 1 lb AI/a indicated no significant control of pink bollworm populations.

Pink Bollworm Diapause Studies

L. A. Bariola, Research Entomologist

Diapause pink bollworm larvae were collected during the fall, allowed to build hibernation cells in paper in petri dishes, and kept in the insectary until early March; then some were buried under 1" of soil in pyramid cages. Also, bolls containing diapause larvae were placed in emergence cages in early April; in some cages the bolls were buried, in some the bolls were kept above ground level, and some cages were irrigated at monthly intervals. The survival of the moths kept in petri dishes in the insectary was 65% compared to 30% survival of the larvae that were buried under the emergence cages. Also, moths emerged earlier when buried; ca. 53% of the larvae buried emerged suicidally (before fruiting cotton was available as host material) compared to ca. 22% suicidal emergence of those kept in the insectary. There were no differences in survival or emergence patterns due to date of collection in the fall, whether from chemically terminated plots or whether the larvae cut out of the bolls or remained in the bolls when mature. When bolls containing diapause larvae were buried and irrigated, survival was reduced. The emergence pattern of moths showed ca. 32% emerged suicidally.

Host Plant Resistance

F. D. Wilson, Plant Geneticist, and Boyd George, Research Entomologist

Plants from first and second backcross progenies were selected for desired resistance characters (nectariless, Smoothleaf, Okra-leaf, Super Okra-leaf, and early maturity) and backcrossed again to AET-5. Smoothleaf, nectariless plants were selected and backcrossed to 24-8ne. F_1, F_2, and backcross hybrids were produced to study the inheritance of pink bollworm resistance in Texas 167 and AET-5. Most agronomic and fiber properties of these 2 cottons compared favorably with those of commercial cultivar. Early-nectariless and early-Smoothleaf-nectariless stocks were crossed to AET-5 and to Stoneville Okra-leaf to combine resistance characters. Certain F_2, BC_1F_2 plants and F_3 progenies from (AET-5 X24-8ne) combined low seed damage with the nectariless character.

An F_2 population from normal X "undulate" leaf shape segregated 35 normal:60 intermediate:5 mutant. A backcross population of (normal X mutant) X normal had all normal leaf shape. Small and large-leaved plants were selected from backcross populations and backcrossed again to the Deltapine recurrent parent. Backcross plants from (long X short) X short boll beak had bolls with beaks of intermediate length. Progenies from a plant with 100% abnormal floral bract number (>3) were grown at 5 locations. Abnormal bract number varied from 20% of the flowers examined at College Station, TX to 67% at Phoenix, AZ. Plants with few and many teeth per bract were selected and backcrossed again to the Stoneville recurrent parent. Pink filament is hypostatic to petal spot and is apparently conditioned by one pair of incompletely dominant genes.

AET-5..., an Upland type cotton with complex genetic background has consistently shown reduced pink bollworm damage in the field. In greenhouse free-choice tests (see Objective 6 for details)under heavy insect pressure, AET-5... had significantly lower numbers of larval entrance holes and lower larval survival than a susceptible cultivar. This indicates antixenosis and antibiosis as mechanisms of resistance. No-choice tests in progress support these conclusions.

Eight cottons selected from previous field screening as possibly resistant to pink bollworms were planted in 4 row plots with 4 replicates. They included 7 Texas race stocks (T-39, T-40, T-53, T-62, T-167, and T-705), a breeding stock AET-5... and a commercial check 'Deltapine 61' (DPL-61). Flowers were tagged and 14-day-old bolls were infested with egg papers (see Objective 6). Green bolls were harvested after 10 days, entrance holes and larvae were counted. Several race stocks showed a probable antibiosis. T-39 had a significantly higher number of entrance holes and lower number of larvae per boll than the other selections, while T-167 and T-40 had low numbers of entrance holes and low numbers of larvae surviving.

Okra-leaf cottons consistently have slightly less seed damage from the pink bollworm than normal leaf cottons. To compare the canopy environment under normal and Okra-leaf cottons, soil temperatures were measured early in the season under the normal leaf canopy of ST7A, its Okra-leaf isoline (ST7A okra) and Arizona Super-Okra. Soil temperatures were higher and sometimes at lethal levels under Okra-leaf canopies very early in the season. Differences disappeared as canopies developed.

Evaluation of Cymbush, a Synthetic Pyrethroid, on Cotton Pests

D. G. Fullerton, T. F. Watson, A. L. Wuensche and Barry Engroff

Cymbush, a new experimental pyrethroid insecticide, was tested at the Yuma Experimental Farm in replicated plots to determine its level of activity against a spectrum of cotton insect pests.

Two rates of Cymbush, 0.06 and 0.12 Lbs./A., were compared with Ambush, the standard insecticide, and an untreated check for its effects on pink bollworms, lygus bugs, tobacco budworm and cotton leafperforator. Vydate was added to the test for evaluation of cotton leafperforator control.

The initial application was applied on Aug. 7, mainly for pink bollworm, and subsequent treatments were made on Aug. 13, 20, 27 and Sept. 4. Tobacco budworm populations remained too low to be assessed in this test and was not a factor in evaluation or yield data.

Table 1 shows the percent of boll infestations for pink bollworms. Cymbush, at both rates, effectively reduced the boll infestation rate. Although no significant difference occurred between Ambush and Cymbush, the Cymbush treatments consistently produced a lower boll infestation. All three treatments were significantly better than the untreated check.

Cotton leafperforator data, shown in Table 2, again shows both Cymbush rates were equally effective in controlling this insect. Vydate compared favorably with Cymbush and both were significantly better than Ambush when population pressure began to increase.

Yield data, indicated in Table 3, confirms the effectiveness of Cymbush in controlling cotton pests. No differences occurred between the pyrethroid treatments, however, they produced significantly more cotton than the untreated check. Vydate, effective on cotton leafperforators, is not a good pink bollworm insecticide and the yield loss can be attributed to pink bollworm damage.

A late August increase of lygus bugs was not sufficient to make a proper evaluation, however, preliminary data from this test tends to suggest that Cymbush may be highly effective on this insect. Other observations indicate that Cymbush appears to be detrimental to beneficial insects and moderately effective on whiteflies. Applications of Cymbush were followed by spider mite infestations, particularly at the higher rate.

The effectiveness of both rates of Cymbush appeared to be equal. Since the low rate showed as well or better than the standard, Ambush, further evaluation on reduced rates may be justified.

Table 1. Pink Bollworm - Percent Boll Infestation

Treatments**	Rate Lb./A.	Sample Date* 8/13	8/20	8/27	9/4	9/10
Check	--	35.6 a	52.0 a	38.0 a	56.0 a	80.0 a
Ambush	0.15	33.3 a	20.0 b	10.0 b	8.0 b	10.0 b
Cymbush	0.06	20.0 a	20.0 b	2.0 b	2.0 b	2.0 b
Cymbush	0.12	42.2 a	10.0 b	4.0 b	0.0 b	2.0 b

*Pre-treatment samples taken 8/7/80 averaged 55% boll infestation.
**Treated on Aug. 7, 13, 20, 27 and Sept. 4.
Means followed by the same letter are not significant at 5% level.

Table 2. Cotton Leafperforator - Larvae per 50 Leaves

Treatments*	Rate Lbs./A	8/13	8/20	8/27	9/3	9/10
		Sample Date				
Check	--	9 a	13 a	12 a	49 a	75 a
Ambush	0.15	3 a	3 b	6 b	18 b	40 b
Cymbush	0.06	0 a	0 b	3 b	1 c	6 c
Cymbush	0.12	0 a	1 b	1 b	0 c	6 c
Vydate	0.50	0 a	1 b	1 b	1 c	8 c

*Treated on Aug. 7, 13, 20, 27 and Sept. 4.
Means followed by the same letter are not significant at the 5% level.

Table 3. Yield - Lbs. Seed Cotton

Treatments	Rate Lbs./A.	Seed Cotton Per Acre
Check	--	3119 a
Ambush	0.15	4915 b
Cymbush	0.06	4866 b
Cymbush	0.12	4948 b
Vydate	0.50	3462 a

Means followed by the same letter are not significant at the 5% level.

Population Responses of Pink Bollworms to a Continuous Short Season Cotton Culture

Dale Fullerton

Efforts to evaluate the population responses of major cotton pests in a continuous short season cotton culture was initiated at the Mesa Experiment Farm. DPL 60 was planted in two locations about one mile apart. One location was established as a short season culture and the other as a long term culture. Normal farming practices were utilized in both treatments. Short season cotton was irrigated 6 times and was terminated on Aug. 21. Long term cotton received 8 irrigations and the final irrigation was applied on Oct. 2. No insecticides were used on either of the two treatments.

Since yield information was not considered necessary for the first year of this experiment, shredding of the treatments was used in place of defoliation to insure that all fruiting parts would be destroyed. Short season cotton was shredded on Sept. 27 and long term cotton on Oct. 23.

Intensive sampling through the season indicated that minimal population differences occurred between the two cotton treatments. Lygus numbers were moderate and reached an early season peak on July 10. *Heliothis* populations were extremely light and had no effect on either of the cotton cultures. Beet armyworm and cabbage looper populations were almost non-existent. In general, predator numbers were moderate to very high. Pink bollworm populations appeared after Aug. 1 and, in the absence of chemical control, increased rapidly during the ramainder of the season.

Table 1 shows the percent of pink bollworm infestations at various sampling dates. Economic thresholds were reached about Aug. 20 in both cultures and reached a peak of 96 percent in the long term cotton on Oct. 17. It was apparant that no population differences occurred between the two cotton treatments during the first year of production.

Table 1. Pink Bollworm - Percent Boll Infestation

Treatment	8/20	9/5	9/18	10/6	10/17
			Sample Date		
Short Season	14.5	32.3	84.7	--	--
Long Term	13.0	30.0	83.9	92.8	96.4

The percent of diapausing pink bollworm larvae is shown in Table 2. The first diapause sample, taken just prior to shredding of the short season cotton, indicates that diapause at that time was light and that only 12.9% of the existing population in the short season cotton has a chance to survive through the winter. On the other hand, long term cotton had a 93.8% diapause prior to shredding, indicating that a much higher number of larvae could survive until the next cotton season.

Both cotton cultures will be replanted in 1981 in the same locations in order to evaluate the effects of early termination on the population dynamics of the following season. Insect populations will continue to be assessed and overwintering survival of pest species determined.

Table 2. Irrigation Termination and Percent Diapause

Treatment	No. Irrigations	Irrigation Termination Date	% Diapause 9/23	10/7	10/22
Short Season	6	8/21	12.9	--	--
Long Term	8	10/2	11.3	88.7	93.8

Dosage-Mortality Studies of Synthetic Pyrethroids on the Tobacco Budworm in Central Arizona

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Summary

Tobacco budworm cultures have been established in the laboratory during the latter part of each growing season since 1976. Field collections were made at three locations in Arizona: Maricopa, Pinal, and Yuma Counties. Larvae were returned to the laboratory and placed on a modified lima bean-agar diet. Resulting adults were mated and progeny between F_1 and F_8 were tested.

Insecticide applications and mortality counts were by the standard test method for determining resistance in Heliothis. Larvae weighing about 20-25 mg (third instar) were topically treated and held at room temperature (24-26°C). Four replicates for a total of 100 larvae at each of 5-6 concentrations plus 100 control larvae treated with acetone were employed for each insecticide/location. Samples of these larvae (10-20% of each replicate) were weighed prior to treatment.

Mortality counts were made at 48, 72, and 96 hr. Larvae were considered dead if they did not respond to repeated prodding with a blunt probe. Dosage-mortality lines were computed for the 72 and 96 hr data using probit-analysis.

Problems with the tobacco budworm as a damaging mid- to late-season pest of cotton have increased in severity during recent years in Arizona. Levels of tolerance to methyl parathion have increased 13X between 1972 and 1978 and 21X when compared to a USDA strain which has been in culture without insecticide challenge since 1965. Synthetic pyrethroids were first used in Arizona in 1977 on an emergency basis for control of this pest. Therefore, dosage-mortality lines were needed to serve as a basis of comparison for future studies on the potential development of resistance of the tobacco budworm to the pyrethroids.

In 1977, LD_{50} values for permethrin (Pounce) were ~145X more toxic than methyl parathion in Maricopa County collections. During 1978, this difference decreased to ~50X for permethrin. Fenvalerate (Pydrin) was less toxic than permethrin in 1977, but the picture has reversed in 1978; however, these differences may not prove to be statistically significant. Cis-permethrin was 1.5X more toxic than the standard cis/trans formulation. An area of concern is the 2-3X change in susceptibility between 1977 and 1978 for the pyrethroids. This indicates a resistance potential for the pyrethroids in the tobacco budworm.

Since the insecticide usage patterns differ around the state, the susceptibilities of budworms from various locations in Arizona are being determined. Insects were more tolerant from Maricopa than Pinal County in 1978; they were slightly more tolerant to Pounce and Pydrin. Indications are that budworms from Yuma County are more susceptible than those from Pinal County for both Pounce and methyl parathion. These data correlate to the lower insecticide usage on an area-wide basis for Yuma than Pinal County.

Responses to Pounce and Pydrin were compared between methyl parathion-susceptible and methyl parathion-tolerant (field collected) cultures. The 1977 LD_{50} of 240 mg/g for the tolerant strain was 20X greater than the 11.8 mg/g for the susceptible strain. About a 5X difference was noted for these strains' response to the pyrethroids. Higher LD_{50}s and flatter slopes were observed for the pyrethroids with the tolerant strain.

The 1980 studies are only partially completed. The only data to date are from the Yuma strain. The LD_{50} of methyl parathion remained virtually unchanged. Although the LD_{50} of Pounce is somewhat higher than that obtained in 1979, all replications have not been completed. No data were obtained in 1979 with Pydrin for the Yuma strain; however, the 1980 data indicate an LD_{50} intermediate between those for the Maricopa and Pinal strains for 1979.

In an attempt to facilitate the topical studies, a developmental study with tobacco budworm larvae was conducted at constant temperatures of 25°, 27.5°, and 30°C. In general, the desired larval weight of 25 mg is obtained near the mid-point of the third larval instar regardless of the temperature under which it was reared; the major difference is the developmental time to reach the desired instar and weight.

CONCLUSIONS:

A. Changes in LD_{50}s over the years show that judicious use will be necessary in order to prolong the pyrethroids useful life.

B. There was decreased susceptibility to the pyrethroids where insects already possess high levels of tolerance to methyl parathion.

C. Preliminary indications are where budworms have experienced a past history of high insecticide usage, they are more tolerant to the pyrethroids.

D. Appropriate studies should be performed to examine the possible cross-resistance between the pyrethroids and organophosphates.

E. Insufficient data are available at present to compare the 1980 results with the trends shown in previous years.