Progress Report--Western Cotton Research Laboratory, Phoenix, AZ

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Development rates of Arizona and Texas tobacco budworm strains.--Biological studies of the effect of temperature on the development of *Heliothis virescens* were continued using 3 laboratory and wild strains. The larval and pupal stages of the laboratory and field strains developed at similar rates. Development of *H. subflexa*, a related species which is being crossed with *H. virescens* to produce sterile offspring, was also determined. Its egg and larval stage was about 4.4 and 2.3 days longer than *H. virescens* at 20° and 30°C, respectively. (G. D. Butler, Jr.)

Pink bollworm oviposition inhibitor and insect growth regulators.--Field plots of cotton were treated on a 3-, 5-, or 7-day schedule with 10,000 ppm of phenylacetaldehyde in water or with a microencapsulated formulation of phenylacetaldehyde on a 7-day schedule. The 3-day schedule of applications of phenylacetaldehyde in water resulted in significant reductions in pink bollworm infestations in treated plots on 4 of 8 sampling dates while the remaining treatments were ineffective. The 3-day schedule of applications also significantly reduced the numbers of larvae of the cotton leafperforator, *Bucculatrix thurberiella* Busck, but significantly increased the numbers of larvae of the saltmarsh caterpillar, *Estigmene acrea* (Drury). Treatments with the microencapsulated formulation reduced the numbers of eggs and damage of *Heliothis* sp. on plant terminals but had no measurable effect on the other Lepidoptera observed.

Five insect growth regulating chemicals were tested against the pink bollworm in laboratory tests. All of the compounds prevented development of adults when fed in larval diet at 1-10 ppm. Contact experiments with adult moths indicated little activity. A further test in field cages indicated that diflubenzuron was superior to EL-494 for control of the cotton leafperforator, but neither compound had any activity against the pink bollworm. (H. M. Flint)

Utilizing night vision equipment to study insect nocturnal behavior.--Pink bollworm, tobacco budworm, fall armyworm and bollworm traps were observed throughout the night using night vision goggles and their behavior was photographed using infrared techniques. The Delta trap for pink bollworm using 1000 µg of gossyplure was slightly more attractive to adult pink bollworm males than the Sharma trap or mating tables with pheromone or 50 clipped-wing females. The attracting power of 50 females was ca. equal to the Sharma trap. The Delta trap with pheromone captured 37% of those that were attracted as compared to 22% for the Sharma trap and 30% for 50 clipped-wing females on a mating table.

Tobacco budworms were highly attracted to live traps containing virelure (as many as 6500/trap in one night) but less than 1% were captured. On the other hand, live traps containing 5 virgin females attracted as many as 2800 males per trap per night but captured ca. 9% of those attracted. Trap efficiency studies using virgin female bollworms and fall armyworms showed the electric grid trap to be 43% efficient for bollworm capture as compared to a directional live trap (13%), cone trap (1%), or pie plate (3.5%). Similar trap efficiencies were recorded for the fall armyworm.

Studies using night vision goggles, infrared photography and radar showed that insect populations began a major downwind movement at ca. 8:30 p.m. (CDT) 10 m above canopy level and up to one mile high. This downwind movement decreased as the night progressed but continued throughout the night. Also at ca. 8:30 p.m. major upwind movement was observed at or near canopy level. This movement is associated with feeding and oviposition. Later in the night (ca. 11 p.m.) major crosswind movement was observed in tobacco budworm populations. This movement is related to male searching behavior. Males of the tobacco budworm, bollworm, fall armyworm, and pink bollworm were observed to move crosswind, contact the pheromone plume from virgin female and/or pheromone traps, turn toward the traps, and some were captured by the traps.

The pheromone plume in most cases was less than 40 feet from the trap and in late season the plume was no more than 10 feet from the trap in the case of the pink bollworm. Observations and photographs of pink bollworm males responding to traps in late season indicated that the pheromone was settling down into the canopy and it dispersed only a few feet from the trap because males would come into contact with the pheromone at or in the canopy and then follow the plume up to the trap which was placed ca. one foot above canopy level. (P. D. Lingren)

Onset and occurrence of diapause in field populations of pink bollworms.--The incidence of diapause in pink bollworm was determined by collecting infested bolls, holding the bolls for larval development and cut-out, and observing the larvae for diapause. Diapause (ca. 1%) was observed first in larvae that developed in green bolls collected Sept. 1. The incidence of diapause increased slowly during early September to ca. 27% on Sept. 20, then increased rapidly to 75% by Oct. 11. This pattern is similar to that observed in previous years with slight differences being due to seasonal temperature variations. There were no significant differences in the induction of diapause in larvae from terminated and nonterminated plots, and also no differences in larvae from nectariless and nectaried varieties.

During the summer (July and August), all larvae cut out of the bolls when mature to pupate. Beginning in September, an increasing portion of the larvae would remain in the bolls when mature. This percentage was similar to but slightly less than the percent of larvae that entered diapause. However, diapause larvae were found cutting out of the bolls as well as remaining in the bolls.

Diapause larvae, collected from terminated or nonterminated plots in the fall of 1976, were buried under pyramid emergence cages in the field or placed in containers under various temperature or humidity regimes in the laboratory. In the field emergence cages, there were no differences in the emergence pattern of larvae from terminated or nonterminated plots. Also, there were no apparent differences in survival or emergence patterns of the diapause larvae that were collected on different dates throughout the previous fall.

In laboratory tests, larvae that were held at $85^{o}+15^{o}F$ emerged faster than larvae held in the insectary under ambient conditions during February through June or held at $70^{o}+15^{o}F$. Chilling larvae at 35, 41, or $50^{o}F$ had no apparent effect. Length of the chilling period (1, 2, or 4 weeks) did affect emergence, except that emergence was delayed by the 4-week chilling period. Emergence began in early March (3 weeks after transfer) of those transferred to $85^{o}F$, whereas emergence in the insectary did not begin until mid- to late April. Addition of H_2O to diapause larvae resulted in nearly 100% mortality of larvae in petri dishes in temperature cabinets; in the insectary, mortality due to water was not as great, but was excessive (75-80%). These tests on termination of diapause are not conclusive due to wide variations in results and so few replicates. Thus these results are preliminary until more replicates can be run and data analyzed more thoroughly. (L. A. Bariola)

Effect of 1976 chemical termination of late-season cotton fruiting on overwintering moth populations.--At Yuma, AZ, in 1976, diapause pink bollworm larvae in soil and trash were reduced 80% and 64% in chemically terminated nectariless and nectaried cotton plots. In 1977, pink bollworm emergence cages were placed in the field in plots treated at Yuma and Tempe, AZ, in 1976. No pink bollworm moths emerged from chemically terminated, nectaried cotton plots, and 95% fewer moths emerged from terminated nectariless cotton plots.

At the Arizona State University Experimental Farm, diapause pink bollworm larvae in soil and trash were reduced 42% and 50% in nectariless and nectaried cotton plots, respectively. Spring emergence was extremely low and no differences were observed in terminated or nonterminated plots of either nectaried or nectariless cotton plots. (L. A. Bariola, T. J. Henneberry, and D. L. Kittock)

Potential of combining nectariless cotton for in-season population suppression and chemical termination of late-season fruiting for reducing the overwintering generation as an integrated system to control pink bollworms.--In 1977, nectariless and nectaried cotton plots were planted in replicated plots at two locations, Yuma and Tempe, AZ (ASU). Weekly samples of green bolls were taken from each plot at each location to estimate pink bollworm populations. In addition, D-vac samples were taken to provide information regarding numbers of beneficial and other insects. At Yuma, results were variable and little difference occurred in numbers of pink bollworms in nectariless and nectaried cultivars. However, at ASU fewer pink bollworms were found in the nectariless cotton plots. At both locations, *Lygus*, *Empoasca* leafhoppers, and cotton leafperforator populations were lower in nectariless plots as were total predator populations. (T. J. Henneberry, L. A. Bariola, and D. L. Kittock)

One-half of each of the replicated plots at each location was chemically terminated in September. Termination treatments reduced the number of green bolls at harvest 85-90% and yields were not reduced.

Inheritance of seed damage caused by pink bollworm to cotton.--At Tempe, AZ, in a 6 X 6 diallel grown in unsprayed plots, general combining ability for low seed damage was significant for AET-5 (an upland resistant breeding stock) and Texas 167 (T-167). Neither of these entries, however, or T-31 or T-55 had less seed damage than the cultivars 'Deltapine 61' and 'Stoneville 256'. Cumulative seed damage increased at a lower rate in T-31 than in the 5 others. In another unsprayed test at Tempe, T-31 and two T-31 X cultivar F_1 hybrids had less seed damage than the cultivars at fifth harvest, but not at earlier harvests. (F. D. Wilson and B. W. George)

Field testing mutant cottons for resistance to pink bollworm.--Eight field tests at Tempe, AZ, revealed several cottons that sustained less seed damage from pink bollworm than the check cultivars at fourth or fifth harvest (seasonal means not different because of late buildup of insect populations) as follows: Texas 31 (T-31), T-167, ORMAR-S-2-75 (Okra-leaf, frego, Smooth), AET Br 2-1, AET Br 2-7, AET Br 2-8, AET-5 (upland strains of complex parentage), W1404-6HG (high gossypol). Four nectariless cottons had less damage than the 'Stoneville' check but not less than the 'Deltapine' check as follows: DPL 7146N, 'Stoneville 731N', St 825N, La 17801. Pima glandless had less damage than the upland check but not less than the Pima check. AET-5 and 14 of 107 Texas race stocks screened at Isabela, Puerto Rico had less seed damage from pink bollworm than the cultivar check as follows: T-101, T-610, T-635, T-1053, T-1180, T-168, T-170, T-181, T-489, T-503, T-55, T-99, T-7, T-202. Six of 7 Okra-leaf and Super-Okra-leaf cottons had fewer cotton leafperforator larvae/g of leaf tissue than the check cultivar. Cotton leafperforator populations were no different on strains of frego-bract, nectariless, high-terpenoid, glabrous, glandless, and highly pubescent cotton than on the checks. (F. D. Wilson and B. W. George)

Studying insect flight and dispersal.--A 10-cm meteorological radar (NOAA, Norman, OK) was evaluated for potential use in detecting airborne insects. Three sizes of insects were released from an aircraft. Single tobacco hornworms were detected at a range of 26 kilometers from the radar with a signal to noise ratio of 20 decibels. A cluster of 100 *Heliothis virescens* was detected at a range of 27 kilometers with signal to noise ratio of 2 decibels. Individual *H. virescens* or pink bollworms were not detected because ground clutter prevented close range observations. The most pertinent findings were as follows: (1) Doppler radar provided increased sensitivity to moving targets, and indicated wind flow; (2) a color radar terminal could provide a contoured, color-coded display of target density gradients; (3) 10-cm radar is not adequate for small insects; (4) meteorological radars may be useful for certain insect studies. Assembly of a 3-cm entomological radar was started and the asimuth-elevation mount is operating.

A study of meteorological data indicated that air flow occurs from the Imperial Valley of California toward the San Joaquin Valley during certain meteorological events. This flow of air could transport pink bollworms to the San Joaquin Valley. (W. Wolf)

Isozyme analysis techniques for determination of polymorphic isozyme loci in the pink bollworm.--Four areas of research into pink bollworm isozyme analysis were carried out (1) to determine specific isozyme phenotypes which give readable zymograms and which showed genetic variability, (2) to determine which stage of development (larva, pupa, adult) produced the most consistent and readable results, (3) to begin a preliminary survey of isozyme variability in geographic strains of pink bollworms, and (4) to study the inheritance of isozyme phenotypes. Six isozyme analyses gave consistently good results on all stages of development. Six other analyses were variable over stages, while 12 other tests produced no readable zymograms. Six to 10 isozyme loci were polymorphic depending on the stage examined. Preliminary geographic surveys showed very slight differences between strains in the frequencies of 4-6 loci. Homozygous strains have been established for 4 loci so inheritance patterns can now be studied. Pink bollworm strains from El Centro, Indio, and San Joaquin Valley, CA, as well as APHIS, appear similar. (A. C. Bartlett)

Pink bollworm adult emergence patterns of irradiated diapause larvae in Maricopa County, AZ, and the San Joaquin Valley of California.--In cooperation with Dr. Robert Staten (APHIS) diapausing larvae were irradiated with 3 (field) or 4 (laboratory) doses of gamma radiation. In the field tests, the larvae were buried on the Phoenix farm and also near Bakersfield, CA, and adult emergence checked. In the laboratory tests, the diapausing larvae were placed in diet and allowed to emerge for reproductive checks. The field tests demonstrated that the pink bollworm could survive in the soil of the San Joaquin Valley and emerge in the spring. Laboratory tests showed that the irradiated larvae may be able to reproduce after emergence at the lowest dose used in the field tests. Further laboratory tests will be run to establish a range of radiation doses which can be safely used in tests of this type. (A. C. Bartlett)

Mating behavior of pink bollworm.--In laboratory experiments, the pink bollworm mated as frequently in gossyplure-permeated atmospheres as in untreated atmospheres. Male moths with antennae ablated at the basal segment did not mate. We concluded that males require olfactory stimulation to mate and that close range chemical communication takes place even in an atmosphere permeated with gossyplure. Flight activities recorded from field experiment and laboratory observations indicated that male moths fly at random in untreated and pheromone-permeated atmospheres. We estimate a large number of random male-female encounters which could result in many matings. Male random movement may be an effective mate acquisition strategy and this behavior may thwart attempts to control the pink bollworm by chemical confusion with gossyplure. (H. M. Flint)

Nocturnal behavior and interaction of native and released sterile pink bollworm adults.--Releases of both sexes in 4 separate tests showed the native and laboratory-reared males to be quite competitive for the laboratory-reared females but no laboratory-reared males were found mating with native females. Releases of females alone again showed the laboratory-reared female to be equally competitive with the native female for native males. Releases of males only at low native population densities resulted in some mating between laboratory-reared males and native females (20% as compared to 80% for native males). All data indicate that knowledge of the native population age structure is critical for determining the interaction between released and native pink bollworm populations. Rejection of laboratory-reared males by native females appears to be the primary reason for lack of male competitiveness at moderate temperatures. At high and low temperature thresholds (below 60°F and above 90°F), the native insects are much more functional than the released insects. This appears to be related to the male's response to temperature because the female secretes pheromone and mates with wild males, as well as her native counterpart at the temperature thresholds. No mating was found to occur when temperatures were above 95°F or below 52°F.

Temperature affects the time and location of mating. Temperatures above 95°F during the first 4 hours after sundown result in mating peaks at 3 a.m. Temperatures below 70°F during the first 4 hours after sundown result in mating peaks that occur before 10 p.m. Temperatures intermediate between those of 70°F and 95°F result in mating peaks that occur between 10 p.m. and 3 a.m., and mating can be observed just after sundown when temperatures are low and not before 1 a.m. when temperatures are high. At high temperatures, most matings occur on the top half of the cotton plant. At low temperatures, most mating occurs on the bottom half of the plant and a great deal of mating will occur on the ground. (P. D. Lingren)

Potential of ACNPV and the bait formulation for use in controlling *Heliothis* spp. in cotton.--Nuclear polhedrosis virus (NPV) from the alfalfa looper applied to cotton (2 applications) in August 1977, in a spray adjuvant, reduced the larval population of *Heliothis* spp. (91% *H. virescens*) in bolls or squares 73% within 12 days compared to untreated cotton. The cotton in this test was nearing maturity and the *Heliothis* numbers were low (<0.5 larvae/plant). The percentage boll damage in the treated field was 2.3% compared to 11.0% in the untreated cotton (79% reduction in boll damage). Thus, the treatment could increase yield only 44 lbs. lint/acre based on the number of green bolls present. Larvae (59%) collected from the treated area 3 days after the first application died of virus infection, and 75% of the larvae less than 20 mg in size were infected.

In a second test in October, the virus (ACNPV) was applied to late-planted cotton with and without the spray adjuvant developed by this laboratory. The adjuvant significantly increased the effectiveness of the virus. The average mortality due to virus infection (at 7 days) of larvae collected from plots treated with virus plus adjuvant was 71% compared to 47% of those from plots treated with the virus alone, and 1.8% of those from untreated cotton. At 14 days after first treatment, the average number of undamaged bolls per plant was 13.0, 9.8, and 6.7 in plots treated with virus plus adjuvant, virus alone, and untreated, respectively. Also, the average number of live larvae per plant was 1.4, 2.4, and 6.5, respectively. The number of larvae in fruiting forms was reduced 84.7% in the virus plus adjuvant plots compared to the untreated control. The results also demonstrated a faster reduction of the population when the adjuvant was used; thus, less damage to the plants after larval infection.

The spray adjuvant was also field tested at the University of Arkansas on cotton for *Heliothis* control. Results indicated this adjuvant to be equal or superior to the adjuvant currently produced by industry. The spray adjuvant also increased virus persistence. At 3 days after application, virus applied in adjuvant had 54% activity remaining, whereas virus applied in water had 20% activity. (M. R. Bell)

HOST-PLANT RESISTANCE

B. W. George and F. D. Wilson

Pink Bollworm:

At Isabela, Puerto Rico, only Texas 17 (T-17) and T-158 among 58 primitive race stocks had significantly lower seed damage caused by pink bollworm than the check Deltapine and Stoneville cultivars. Only 1 of 57 cultivar X race stock hybrids, Deltapine 61 X T-226, had less seed damage than its cultivar parent. Four of 14 race stocks, T-55, T-99, T-101, and T-214, had no more seed damage than AET-5..., a resistant upland breeding stock.

At Tempe, Ariz., 8 of 32 race stocks had less seed damage than the check cultivar, as follows: T-17, T-39, T-58, T-65, T-218, T-226, T-570, and T-703.

At Tempe and Phoenix, AET-5... had significantly less seed damage than the check cultivars in 4 separate tests. In a 6 X 6 complete diallel experiment, AET-5... and T-167, for the second year, showed significant general combining ability for low seed damage. Pupation percentages in pink bollworm were 23% lower in AET-5... and 26% lower in T-167 than in the Deltapine check in a greenhouse experiment where cotton bolls had been hand-infested with pink bollworm larvae.

Other cottons that had less seed damage than the check cultivars in the field at Phoenix were 1 X 6-56, 'SP-37' (early maturity), ORS-75-75, ORMAR-S-2-75, and ORS-13 (Okra-leaf, frego-bract, Smooth-leaf), ORH-77-75 (Okra-leaf, frego-bract, pubescent-leaf), and AET Br 2-1, a sister stock of AET-5....

In a comparison of seed damage in selections of Okra-leaf, frego-bract, Smooth-leaf in all combinations in a La 71-7 background, there was consistently but not significantly higher seed damage in combinations with frego-bract and Smooth-leaf, and lower damage in combinations with Okra-leaf.

None of 7 high-gossypol stocks or of 2 *Heliothis*-tolerant PD-breeding stocks had less seed damage than the check cultivar. Pima glandless had less seed damage than 'Pima S-5' but both Pima entries had more damage than the upland check cultivar, 'Deltapine 61'.

At one point in the season, pink bollworm survival was lower, and boll temperatures were higher, in Okra-leaf than in normal-leaf cotton, but this trend was not consistent.