to see if the material would be lost under these conditions. No significant difference was found between these plots and the plots to which Ordram was applied only one day before flooding. Observations made on these plots did indicate that incorporation of this material by light harrowing gave slightly better control. Previous research indicates that light rains moistening this material prior to incorporation might cause a loss of active material. However, in these tests, Ordram was always applied on dry soil, and no rain fell between the time of application and flooding.

Effects on yield due to different application rates and timing of chemical control can be indicated by a count of rice panicles. Correlation of total yield and number of panicles per 2 sq ft gave the highly significant positive correlation of 0.82, shown in table 5. In all cases, regardless of rate and timing of propanil application, both total yield and the number of panicles per 2 sq ft were higher in the sprayed plots than in control plots. The greatest reduction of panicle numbers occurred when the watergrass was allowed to compete with rice for 79 days. All the plots treated with 3 lbs of Ordram per acre produced much greater numbers of panicles than did the 2 lb-per-acre treatment and the check—indicating again that early elimination of watergrass competition allows more panicle development.

Whether a grower chooses to use propanil as a postemergence spray over shallow water in fields already infested with watergrass or to use Ordram as a granular preemergence material to control grass before it can become established, current recommendations on the manufacturer's label and those made by University of California should be followed.

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Recent field experiments indicate that commercial preparations of the nucleopolyhedrosis virus of Heliothis zea and the bacterium, Bacillus thuringiensis Berliner, offer much promise for effective and selective control of early instar bollworms on cotton.

**The bollworm, Heliothis zea (Boddie),** is a frequent pest of cotton in California. For nearly 20 years, it was effectively controlled with DDT and certain other chlorinated hydrocarbon insecticides. However, a build-up of resistance to DDT in recent years, has caused increasing control difficulties. Furthermore, severe use limitations have been placed on DDT and related materials, because they pose a contamination threat if they drift to crops adjoining cotton.

### Control Materials

The need for improved control methods has resulted in an intensive research program now in progress to investigate the possibility of developing highly effective and selective control procedures against this pest. In 1964, cooperative field studies were conducted to determine the effectiveness of field applications of the nucleopolyhedrosis virus of *H. zea* and the bacterium, *Bacillus thuringiensis* Berliner, at different concentrations and to compare these materials with candidate experimental chemical compounds and with a recommended chemical insecticide. Materials used in the test were: Biotrol VHZ, a preparation of the nucleopolyhedrosis virus of *H. zea*; Thuricide 90T, a concentrated spore preparation of *B. thuringiensis*; Azodrin (crotonamide, 3 hydroxy-N-methyl-cis-dimethylphosphate); Nia 10242 (2,2-dimethyl-2,3-dihydro benzo furanyl-7 N-methylcarbamate); and carbaryl, a carbamate insecticide currently recommended for bollworm control.

### Field experiments

Three field experiments were conducted in Kern County to test the value of the various materials when applied as sprays against populations of early instar (small) bollworms. The sprays were applied with a high-clearance, eight-row ground sprayer, utilizing five nozzles per row. The rate of application of dilute spray was 28 gallons per acre.

To thoroughly test the materials, severe bollworm infestations were created by augmenting the natural populations with
INSECT DISEASES tested for
Control of Cotton Bollworm

I. A. FALCON · T. F. LEIGH · R. VAN DEN BOSCH · J. H. BLACK · V. E. BURTON

laboratory-reared bollworms. These worms were first hatched in the laboratory and held on a semi-synthetic diet for one to three days. Field transfer was accomplished by placing a worm in the apical terminal of each test plant on the evening following spray treatment.

Plant examination

The effectiveness of the materials was determined by examining the entire plant for worms and for evidence of their feeding damage. Bollworm eggs and larvae, whether dead or alive, were recorded and the live larvae were classified to instar (growth stage). Assessment of damage included evidence of feeding in the terminals, squares and bolls. In the first experiment, applications were made on July 29, and each plot was hand-infested with 100 laboratory-reared worms following treatment. The plots were two 3 x 400-ft rows interspaced by three untreated rows, and sampling was done on the fourth and twelfth days following treatment. No differences in the infestations were evident until the twelfth day. Heliothis virus applied at the rate of 3 x 10^11, 6 x 10^12, and 6 x 10^13 polyhedra (equivalent to 50, 100 and 1,000 mature diseased larvae, respectively, according to the manufacturer), proved most effective and reduced the number of bollworms by 31 to 69% and the number of damaged bolls by 53 to 63%. B. thuringiensis used alone at the rate of two gallons per acre appeared ineffective. Two other treatments, one combining two gallons per acre of B. thuringiensis with 3 lbs per acre of carbaryl (80% WP) and the other a treatment of carbaryl alone at 3 lbs per acre both reduced boll damage by 44%.

Second experiment

In the second experiment, two spray applications were made, one each on August 12 and 26. Following the first application, 100 laboratory-reared worms were used and also in the second spray treatment, damaged bolls were counted in the areas where laboratory-reared worms were used and also in 100 row ft where only a natural infestation of bollworm had occurred. The total yield of seed cotton in each treatment was also evaluated.

Seven days after treatment, all the ma-

Graph 1. Average abundance of predators per 100 plant terminals 24 hours after application of insecticides in experiment 2.

Graph 2. Average number of damaged bolls 14 and 56 days after application of insecticides in experiment 2.
A third experiment was conducted following the second spray application in experiment 2. The procedures employed were identical to those used in the previous experiment; but different areas of the plots were infested, and laboratory-reared worms were placed only in the virus, carbaryl and check plots. By the 14th day, the virus demonstrated superior control, reducing the number of live worms by 61% and boll damage by 68%. The carbaryl treatment was less effective, having reduced live worms by 31% and boll damage by 44%.

Results

Based on results of the experiments conducted thus far, the *Heliothis* virus preparation as well as the *B. thuringiensis* preparation appear to offer the most promise of the materials tested for effective and selective control of early instar bollworms on cotton. Of the two insect pathogens, the virus preparation demonstrated more rapid immediate control, and more effective long-term control. *B. thuringiensis* did not appear to give immediate control but was effective over the longer period, apparently because it inhibited larval feeding activity and disrupted insect development. The addition of carbaryl to *B. thuringiensis* did not appear to enhance the effectiveness of either material 14 days after treatment. At harvest, the combination treatment was no more effective than *B. thuringiensis* alone. Of the chemical insecticides tested, only Nia 10242 and carbaryl appeared to give adequate bollworm control over a 14-day period at the concentrations used. The disadvantage of these compounds is their lack of selectivity and apparent short residual effectiveness which permits reinfection by bollworm unless repeated applications are made at frequent intervals. Research in 1965 will be largely directed towards determination of the proper timing and dosage of *Heliothis* virus and *B. thuringiensis* for effective, economical control of early instar bollworm larvae on cotton.

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Psylla and virus

The virus appears to be persistent in the psylla vector for at least three to four weeks. In the tests showing this persistence, the same groups of psylla were transferred serially to as many as seven different healthy pear trees after removal from the shoot severely infected with pear decline. The feeding time on each healthy tree varied from a few hours on the first trees to five to seven days on subsequent trees. Studies conducted at Riverside suggest that adult psylla transmit virus more effectively following long acquisition feeding periods on diseased plants than after relatively short periods of feeding.

It was further demonstrated in 1964 that pear psylla toxin, in the absence of virus, is not the primary cause of pear decline. In 1963, a series of 234 young pear trees, on *Prunus serotina* rootstock in the greenhouse at Berkeley, had been heavily infested for one to two months with psylla, most of which were apparently virus-free. The infested branches of many of them were killed by the feeding, and the trees showed other evidence of...