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 soil 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.

TABLE 3. YIELD OF RICE, WEED SEEDS AND DEBRIS FROM PLOTS SPRAYED WITH PROPANIL AT TWO RATES TO CONTROL WATERGRASS

Year	Application after flooding (days)	Yields (lbs/A) from plots sprayed with propanil at: 4 lb/A		6 lb/A	
		Paddy* rice	Weed seeds* and debris	Paddy rice	Weed seeds and debris
1962	36	3,000**	......	3,430**	......
	Control	300	......	800	......
1963	22	3,070	190	......	......
	35	......	......	3,820**	70
	Control	2,540	260	2,540	260
1964	29	3,100**	250	......	......
	37	3,500**	280	4,220**	300
	51	2,960**	300	3,520**	210
	59	......	......	2,920**	180
	79	......	......	2,400	160
	Control	1,830	330	1,830	330

* lbs per acre
** Significantly higher than untreated control at 1%.

TABLE 4. YIELD OF RICE, WEED SEEDS, AND DEBRIS FROM PLOTS TREATED WITH ORDRAM TO CONTROL WATERGRASS

Year	Ordram (lb/A)	Application before flooding (days)	Paddy rice (lb/A)	Weed seeds and debris
1962*	3	1	4,600	...
	6	1	4,670	...
	Control		4,120	...
1963†	1	½	3,160*	190
	3	½	3,470**	140
	5	½	3,350**	140
	Control		2,540	260
1964†	2	1	3,940**	270
	3	8	4,600**	160
	3	8‡	4,820**	140
	3	1	4,540**	140
	12	1	4,780**	170
	Control		1,830	330

* Liquid EC 6 lb/gal.
† 5% granular; applied with a ground-operated Gandy.
‡ Not incorporated into soil; rest in 1963 and 1964 incorporated with harrow.
* Significantly higher than control at 5%.
** Significantly higher than control at 1%.

Tables 3 and 4 show the amount of weed seed, mostly watergrass, and debris (straw, chaff, etc.) compared with the yields of paddy rice. In some years the differences found between yield of such material from treated and nontreated plots may be nearly 200 lbs per acre. If we assume that it costs 50 cents per cwt for harvesting, 25 cents per cwt for drying, and 15 cents per cwt for storage, each cwt per acre of extraneous material harvested with the rice will cost the rice grower about 90 cents. Reducing these costs is an additional advantage along with the increased rice yield.

TABLE 5. CORRELATION BETWEEN NUMBER OF PANICLES AND YIELD OF RICE FOLLOWING TREATMENT IN 1964 WITH PROPANIL AND ORDRAM FOR WATERGRASS CONTROL

Chemical	Application time* (days)	Application rate lb/A	Panicles per (2 sq ft†)	Yield (lb/A)
Control	..	.	24	1,830
Propanil	+29	4	38	3,100
	+37	4	47	3,500
	+37	6	42	4,220
	+51	4	52	2,960
	+51	6	46	3,520
	+59	6	40	2,920
	+79	6	28	2,400
Ordram	−8‡	3	51	4,600
	−8	3	54	4,820
	−1	3	66	4,540
	−1	2	24	3,940

* Correlation coefficient, .82—significant at 1%; + means days after flooding; − means days before flooding.
† Four replications.
‡ Not incorporated, remaining Ordram treatments incorporated by harrowing.

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 preflood 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-dimethyl phosphate); 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*

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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 3×200-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 3×10^{11}, 6×10^{11} and 6×10^{12} 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 68%. *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 placed in each plot. The plots consisted of eight 3×400 ft rows replicated three times. The virus preparation was applied at the rate of 6×10^{12} polyhedra per acre. The *B. thuringiensis* preparation was used alone at the rate of four gallons per acre, and in combination with 1½ lbs of carbaryl per acre. Carbaryl was applied alone at the rate of 3 lbs per acre and Nia 10242 and Azodrin, each at the rate of 0.5 lbs per acre.

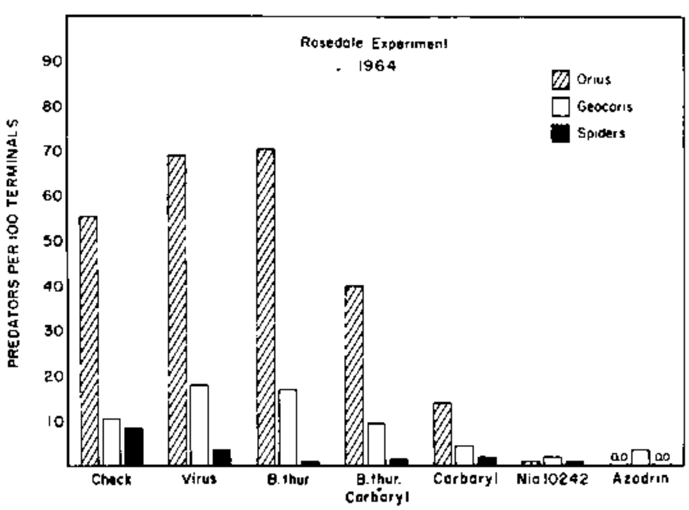
D-Vac (vacuum insect sampler) samples were taken from the treated plots 24 hours following spray treatment to determine the influence of the treatments on the minute pirate bug, *Orius tristicolor* (White), the big-eyed bug, *Geocorus pallens* Stål, and spiders. These are beneficial species known to prey on bollworm eggs and larvae. The experimental results are summarized in graph 1. Of the materials used, the virus had no influence on predator abundance, but *B. thuringiensis* possibly influenced spider abundance. The chemical insecticides were generally toxic to all the species sampled, with Azodrin and Nia 10242 appearing the most toxic.

Hand-infested plots

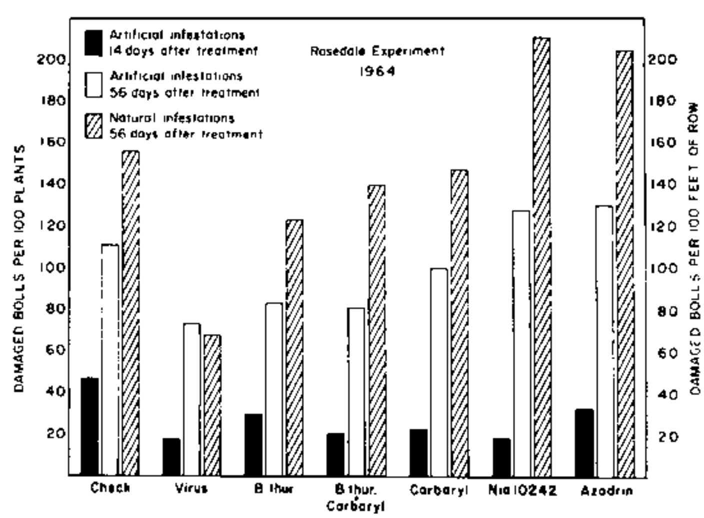
The hand-infested plots were sampled for bollworm abundance and boll damage seven and 14 days after the initial spray treatment. At harvest, 56 days after the second spray treatment, damaged bolls were counted in the areas where laboratory-reared worms were used and also in 100 row ft where only a natural 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.



terials had reduced the number of bollworms and the surviving larvae at that time were predominantly second and third larval instars (see table). Fourteen days after treatment, further reductions in bollworm numbers were recorded only in the virus, the two *B. thuringiensis* and the check plots. The larvae in these treatments were predominantly of the fourth and fifth instars. There was no change in bollworm abundance in the carbaryl treatment, and in the Nia 10242 and Azodrin treatments the number of worms had increased. In the latter three plots, the smaller instars predominated indicating survival of recently hatched worms of the natural population. This survival was attributed to the short residual nature of the compounds and to a lack of sufficient natural controls, as these compounds were demonstrated to be generally toxic to beneficial species which aid in controlling bollworms.

AVERAGE NUMBER OF BOLLWORM LARVAE AND THEIR PREDOMINANT LARVAL INSTAR PER 100 PLANTS 7 AND 14 DAYS AFTER TREATMENT WITH INSECTICIDES IN EXPERIMENT 2

Treatment and dosage per acre		Number surviving		Larval instar	
		7 days	14 days	7 days	14 days
Virus	6×10^{12} polyhedra	18	13	3	5
B. thuringiensis	4 gal	25	22	3	4
B. thuringiensis	4 gal				
and carbaryl 80 WP	1½ lb	20	19	2	4
Carbaryl 80 WP	3 lb	14	14	2	1
Nia 10242	0.5 lb	20	23	3	1
Azodrin	0.5 lb	24	27	3	3
Check	untreated	33	27	3	5

Boll damage

Seven days after the initial spray application, all materials had reduced boll damage by about 60% compared with the check. Fourteen days after treatment, as shown in graph 2, substantial reductions in boll damage were still evident in the Nia 10242, virus, carbaryl alone and the *B. thuringiensis*-carbaryl plots, respectively. At harvest, the virus and the two *B. thuringiensis* treatments resulted in fewer damaged bolls, whereas Nia 10242 and Azodrin recorded more damaged bolls than the check, both in the areas where laboratory-reared worms were used and where only a natural infestation of boll-worm had occurred. The values were significantly different at the 1% level as determined by Duncan's Multiple Range Test. These differences were also reflected in the yield data as Nia 10242 and Azodrin produced substantially less seed cotton per acre than did the other treatments, including the check.

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 their apparent short residual effectiveness which permits reinfestation 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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Progress report on

RESULTS OBTAINED during 1963, demonstrating that pear decline is caused by a pear psylla-transmitted virus, were confirmed during 1964. Most of the tests were conducted at a new three-acre experimental plot established at Vacaville where 2,230 young trees were planted in 1964. Most of the 1964 virus tests were conducted with Bartlett tops on *Pyrus ussuriensis* rootstocks. Some of the tree symptoms developed approximately two months after the pear psylla had fed on them, and consisted of quick decline collapse or of chlorosis in the youngest foliage. Also, many of the infected trees developed a reddish color in the leaves that was absent in healthy trees.

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 slow decline virus source tree. 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 *Pyrus 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