Effects of Commonly Used Insecticides on the Potato Tuberworm[1] and Its Associated Parasites and Predators in Potatoes[2]

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ABSTRACT

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Larvae and adults of *Phthorimaea operculella* (Zeller) in potato foliage were effectively controlled by commercial applications of azinphosmethyl and a combination of methomyl and methamidophos, but eggs and pupae were not significantly affected. Azinphosmethyl, methomyl, and methamidophos provided adequate control of foliar larval populations, but larval parasitism was markedly reduced in treated plots. Predator populations and predation of potato tuberworm eggs and pupae were high in untreated potato plantings and were greatly reduced by scheduled applications of azinphosmethyl. After azinphosmethyl applications, adult populations of potato tuberworm resurged rapidly, but more time was necessary for larval resurgence.

In commercial potato plantings in California, control of the potato tuberworm, *Phthorimaea operculella* (Zeller), is based largely on the frequent use of insecticides. In southern California, treatments are typically applied at 10- to 14-day intervals beginning shortly after the vines close in the rows (Kennedy 1975). Several insecticides effectively reduce populations of potato tuberworm larvae mining in the foliage (Shorey et al. 1967, Bacon et al. 1972, Hofmaster and Waterfield 1972), but tuber infestation is largely determined by cultural practices affecting tuber accessibility (Shelton and Wyman 1979a,c), and insecticides may fail to prevent economic levels of tuber damage (Bacon 1960, Foot 1974). Immigration of potato tuberworm moths may also contribute to the inefficiency of insecticidal control (Bacon 1960).

In the absence of insecticidal control, the potato tuberworm is attacked by numerous natural enemies (Graf 1917). In southern California, Oatman and Platner (1974) recovered 13 species of primary parasites from potato tuberworm larvae, with parasitism being higher in late summer plantings than in spring plantings. Predation also may be an important mortality factor in helping to suppress potato tuberworm populations, as in South Africa where Findlay (1975) recommended limited use of insecticides to preserve the abundance of predators and parasites.

This study was conducted to determine the efficacy of standard commercial insecticide treatments for controlling various developmental stages of the potato tuberworm and to quantify the effects of such control practices on parasite and predator populations occurring in potato plantings in southern California.

Materials and Methods

Insecticide Effects on Potato Tuberworm Developmental Stages

Potato tuberworm eggs, larvae, pupae, and adults were removed from an insectary culture (Platner and Oatman 1968) and exposed to insecticide applications in commercial potato plantings in Riverside County, Calif. during 1978. Exposure and recovery were accomplished as follows. Ten swatches of muslin cloth, each containing 10 freshly laid eggs, were pinned to the soil surface near the base of potato plants where eggs are typically laid (Traynier 1975). After exposure, eggs were returned to the laboratory, counted to ascertain predation, and attached to potato tubers to complete development until adult emergence. Six potted potato plants (ca. 60 days old), each infested with 40 late larval instars were placed in the potato plantings. After exposure, plants were cut off at soil level and individualy placed in sealed emergence cartons with five potato tubers. Surviving larvae infested the tubers when the foliage desiccated and were allowed to complete development before emerged adults were counted to assess larval survival. Five pupae, which were washed to remove silk, were buried 0.5 cm under field soil in each of 10 plastic petri dishes (8.5 cm diameter). Petri dishes were placed on top of plant beds underneath the plant canopy and, after exposure, dishes were removed and placed in plastic bags until adult emergence. Groups of five unsexed adult moths (2 days old) were caged in each of 10 square lumite screen cages (50-mesh, 1,000 cm^3) and placed at the base of potato plants where adult potato tuberworm were frequently observed during daylight hours. After exposure, cages were returned to the laboratory where adult mortality was assessed after 24 h.

All potato tuberworm developmental stages were placed in the field, as described above, 1 h before insecticide application and retrieved 2 h after application. Four tests, utilizing the most commonly used insecticide treatments for control of potato tuberworm in this area, were conducted in spring potato plantings. In tests 1 and 2, a combination of methamidophos (0.83 kg of AI/ha) and methomyl (0.50 kg of AI/ha) was applied by air at 90 liters/ha. In tests 3 and 4, azinphosmethyl (0.83 kg of AI/ha) was applied by ground rig (420 liters/ha) and by air (90 liters/ha), respectively. No larvae were exposed in tests 3 and 4. Each test was duplicated at the same time in an adjacent untreated field and survival was transformed to account for natural mortality by Abbott's Formula. Percent mortality due to insecticide ap-

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plication was compared statistically with survival in untreated fields by using a t test.

Effects of Insecticide Application on Potato Tuberworm Larval Populations and Associated Parasites

A 0.31-ha late-summer planting (16 August) of Norgold potatoes was established on the University of California's Moreno Field Station in Riverside County in 1977. The experimental area (38 rows, 101 m long) was subdivided into a randomized complete block design with five treatments, including the untreated control, replicated five times. Plots (four rows, 15.2 m long) were buffered by three untreated rows on each side and by 3 m of untreated row on each end. Insecticide treatments were azinphosmethyl (0.83 kg of AI/ha), methamidophos (1.1 kg of AI/ha), methomyl (1.0 kg of AI/ha). Treatments were applied 71 days into the growing season with a tractor-mounted boom sprayer with three nozzles per row delivering 420 liters/ha.

Potato tuberworm larval populations were assessed at 70 days (preapplication) and 89 days (18 days posttreatment) after planting by random removal of five plants per plot. The lower six lateral branches and the main stem were dissected to determine potato tuberworm larval infestation. To assess parasitism, excised larvae were reared individually in 35-ml plastic cups containing a section of potato tuber. Emerged insects were counted after 4 weeks.

Effect of Foliar and Systemic Insecticides on Predation and Predator Numbers

A 0.74-ha late-summer planting (9 August) of White Rose potatoes was established on the Moreno Field Station in 1977. The experimental area (105 rows, 87 m long) was subdivided lengthwise into three 35-row plots. Plots were treated as follows: a single application of aldicarb (15G, 3.35 kg of AI/ha) applied at planting as a band in the seed furrow; four weekly applications (16, 23, and 30 October and 6 November) of azinphosmethyl (0.83 kg of AI/ha) applied with a tractor-mounted boom sprayer delivering 420 liters/ha; and untreated control. These insecticides were used because aldicarb has no significant effect on potato tuberworm larvae in potato foliage (Bacon et al. 1972) but is used for leafhopper control in this area, whereas azinphosmethyl is used extensively for foliar potato tuberworm control.

Predator populations were estimated with 36 pitfall traps per plot arranged in four groups of 9. Traps (200-ml plastic cups) were buried to the rim on the surface of potato beds and filled with a water-detergent mixture. The effects of predation on potato tuberworm immature stages were estimated by placing laboratory-reared eggs and puape in each plot. Egg predation was measured by pinning 40 swatches of muslin cloth, each containing 10 fresh potato tuberworm eggs, to the soil surface at the base of plants. Pupal predation was measured by burying 40 groups of five pupae 0.5 cm deep in the bed surface beneath potato plants. Predation was estimated in the center five beds of each plot, ensuring adequate buffering (15 rows) between treatments. The pitfall traps and immature stages were placed in the field weekly (14, 21, and 28 October and 4 and 11 November) and retrieved after 48 h. Predaceous arthropods captured in pitfall traps were counted and identified. Predation of eggs and pupae was calculated by subtracting the number of normal eggs and pupae recovered from the total placed in each plot.

Effect of Azinphosmethyl on Potato Tuberworm Adults and Larvae and on Parasitism and Predation of Their Immature Stages

Six 0.35-ha spring plantings (28 April) of Kennebec potatoes, separated by 13 m of unplanted buffer area, were established on the Moreno Field Station in 1978 for several research activities. For the tests reported here, three applications on azinphosmethyl (0.83 kg of AI/ha) were applied to three plantings on 6 and 25 July and 13 August, with the other three plantings left untreated. Treatments coincided with the period of highest potato tuberworm activity in the area (Shelton and Wyman 1979b,c). Treatments 1 and 3 were made with a tractor-mounted boom sprayer with three nozzles per row delivering 420 liters/ha, and treatment 2 was applied by air at 90 liters/ha. Soil type, cultural practices, and irrigation were similar in the treated and untreated plantings.

Adult populations were monitored with 2 UC/Davis water pan traps (Bacon et al. 1976) placed at ground level in each planting. Traps were baited with a rubber septum, impregnated with potato tuberworm sex attractant (*trans*-4, *cis*-7-tridecadienyl acetate, Zoecon Corp., Palo Alto, Calif.). Trapping was initiated on 3 July, and trap catches were monitored twice weekly until harvest.

To assess larval populations and parasitism, 20 plants were removed at random from each of two plantings on 6, 15, and 24 July and 3, 13, and 22 August. Each planting had similar cultural practices, but one was treated with azinphosmethyl, as described above, whereas the other was left untreated. Potato tuberworm larvae were excised from the plants, and 30 larvae per planting were placed individually on potato tuber sections in plastic cups. After 4 weeks, emerged potato tuberworm adults and parasites were counted. Predation was assessed by placing potato tuberworm eggs and pupae in th field as described previously. Eggs and pupae were placed in the field 48 h before the dates that plants were removed to assess parasitization.

Results

Insecticide Effects on Potato Tuberworm Developmental Stages

Air applications of methomyl in combination with methamidophos are frequently utilized in potato tuberworm control programs in California. In tests 1 and 2 (Table 1), this treatment caused significant mortality of adult and larval stages, with mean mortalities for both tests on 77.0 and 96.5% for adults and larvae, respectively. Egg and pupal stages did not suffer significant insecticide-induced mortality (average 20.1 vs. 6.6%, respectively). In tests 3 and 4, both ground and air applications of azinphosmethyl caused significant adult mortality (81.6 and 98.0%, respectively). Egg and pupal stages were not significantly affected.

Table 1.—Effect of various insecticides on potato tuberworm developmental stages, Riverside County, Calif., 1978.

Test	Insecticide	Rate (kg of AI/ha)	Application method	% Kill[a] Eggs	Larvae	Pupae	Adults
1	Methomyl + methamidophos	0.56 + 0.83	Air	15.7	95.8*	0.0	68.0*
2	Methomyl + methamidophos	0.56 + 0.83	Air	24.5	97.2*	13.2	86.0*
3	Azinphosmethyl	0.83	Ground	2.0	—[b]	8.3	81.6*
4	Azinphosmethyl	0.83	Air	16.9	—	2.6	98.0*

[a] Corrected for natural mortality. Asterisk indicates significant insecticide-induced mortality (0.05% level); 100 eggs, 240 larvae, 50 pupae, and 50 adults per treatment.
[b] —, Stage was not tested.

Effects of Insecticide Application on Potato Tuberworm Larval Populations and Associated Parasites

A single ground application of azinphosmethyl, methamidophos, methomyl, or a methamidodphos-methomyl combination significantly reduced populations of potato tuberworm larvae in potato foliage (Table 2). All materials reduced larval populations by more than 84% compared to the control and there was no significant difference between treatments. Larval parasitism over all plots averaged 53.1% before treatment (Table 2). After insecticide treatments in the plots, parasitism in the untreated control declined from 50 to 41.2%. Parasitism declined more sharply in the azinphosmethyl plots (57 to 30%) and was entirely eliminated by treatments of methamidophos, methomyl, or a combination of these materials. Although distinct differences in posttreatment parasitism were evident, this could have resulted partly from the significant reduction in host larval densities, and no conclusions could be drawn concerning the toxicity of the treatments to parasites. The braconids, *Agathus gibbosa* (Say) (40.0%), *Chelonus phthorimaea* Gahan (34.2%), and *Apanteles scutellaris* Muesebeck (19.2%), were the most frequently encountered parasites in this study. Oatman and Platner (1974) also reported these as the most common parasites of the potato tuberworm in this area.

Effect of Foliar and Systemic Insecticides on Predation and Predator Numbers

Predator populations were similar in all plots on 16 October, averaging ca. 30 total predators per nine pitfall traps (Fig. 1). Subsequent populations in the untreated control and aldicarb-treated plots remained high, with means of 38.6 and 36.2 predators per nine traps, respectively, over the last four sampling dates. The initial application of azinphosmethyl reduced the predator population by nearly half, and subsequent applications caused a decline throughout the study so that predator populations averaged 11.4 per nine pitfall traps from 23 October through 13 November.

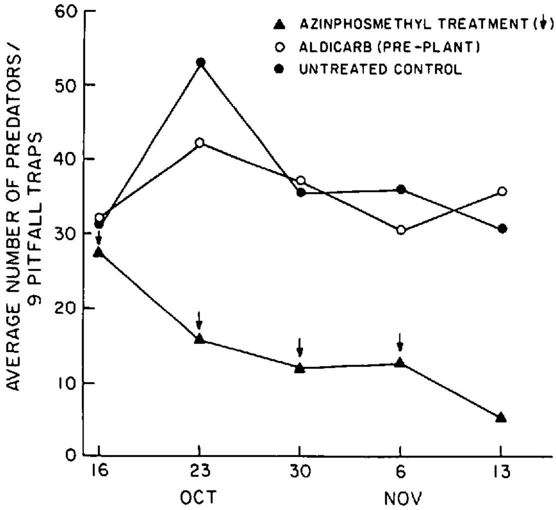

FIG. 1.—Effect of azinphosmethyl and aldicarb treatments on predator populations trapped in pitfall traps in potato plantings, Moreno, Calif., 1977.

Fourteen groups of predaceous arthropods were trapped in pitfall traps during the study. The relative abundance of the most commonly encountered predator groups, as percentages of the total, were: Anthicidae, 47.7; Araneida, 26.6; Staphylinidae, 13.7; Carabidae, 3.3; Miridae, 2.5; Syrphidae, 1.8; and Anthocoridae, 1.5. Coccinellidae, Dermaptera, Dolichopodidae, For-

Table 2.—Effect of various insecticides on potato tuberworm larval populations and larval parasitism in potato foliage, Moreno, Calif. 1977

Treatment	Rate (kg of AI/ha)	Total larvae/25 plants[a] Prespray	Total larvae/25 plants[a] Postspray	% Parasitization[b] Prespray	% Parasitization[b] Postspray
Untreated	—	40a	65a	50.0	41.2
Azinphosmethyl	0.8	29a	10b	57.0	30.0
Methamidophos	1.1	31a	6b	50.0	0.0
Methomyl	1.0	38a	3b	45.8	0.0
Methamidophos + methomyl	1.1 + 1.0	29a	5b	62.5	0.0

[a] Mean separation vertical. Means separated by the same letter are not significantly different, Duncan's multiple range test (0.05 level).
[b] Percent parasitization not statistically analyzed.

micidae, Lygaeidae (Geocorinae), Malachiidae, and Neuroptera were found in small numbers (less than 1% of total) throughout the survey period. No attempt was made to determine the relative efficiency of the various predators in destruction of potato tuberworm immature stages, and pitfall trap catches were utilized solely as an indication of predaceous arthropod populations in the plantings.

Predator activity, as measured by egg and pupal predation, was similar in all plots before azinphosmethyl application, with ca. 40 to 50% recovery of eggs and ca. 80 to 90% recovery of pupae (Fig. 2). After the first application of azinphosmethyl (16 October), recovery of eggs increased sharply, indicating a marked decrease in predator activity in the azinphosmethyl treated plots. Subsequent recovery rates in the azinphosmethyl treated plot averaged 87.9% for eggs and 81.0% for pupae. Over the last four survey dates recovery of eggs and pupae in the aldicarb and unsprayed plots was lower than in the azinphosmethyl plots, averaging 40% for eggs and 30% for pupae in these plots, thus indicating high levels of predator activity.

Effect of Azinphosmethyl on Potato Tuberworm Adults and Larvae and on Parasitism and Predation of Potato Tuberworm Immature Stages

Application of azinphosmethyl temporarily decreased adult populations in treated plantings, but trap catches subsequently increased rapidly to levels present in untreated plantings (Fig. 3). Thus, the seasonal average potato tuberworm catch (moths per trap per night) in treated plantings (140.3) was similar to that in untreated ones (154.5). Azinphosmethyl was more effective in suppressing the foliar larval population (Fig. 4). Although larval populations in the treated planting increased after insecticide applications, a time lag was necessary for resurgence so that the seasonal larval population per five plants in insecticide-treated planting (12.5) was considerably lower than in untreated planting (35.4).

Before the initiation of azinphosmethyl control applications, parasitism of potato tuberworm larvae in the two fields was similar (Fig. 5). Parasitism over the next 5 weeks averaged 52.5% in the untreated control. In the field treated with azinphosmethyl, the first application (6 July) reduced parasitism of potato tuberworm larvae by 56% and, for the remainder of the survey (15 July through 22 August), parasitism averaged only 21.4%. Again, the most commonly recovered parasites were the braconids, *A. gibbosa* (42.1%), *A. scutellaris*, (37.3%), and *C. phthorimaea* (19.2%).

Predator activity, as indicated by egg and pupal recovery rates, was similar (33 to 40%) in both fields before the initiation of the azinphosmethyl control program on 6 July (Fig. 5). After 6 July, recovery of eggs and pupae in the untreated field declined slightly and averaged 29.5% for eggs and 23.5% for pupae from 15 July through 22 August. Recovery of both eggs and pupae in the azinphosmethyl treated field increased during the week following the first application but declined before to the second application on 4 July. Subsequent recoveries in the last 3 weeks of the survey period increased rapidly, averaging 62.7% for eggs and 68% for pupae.

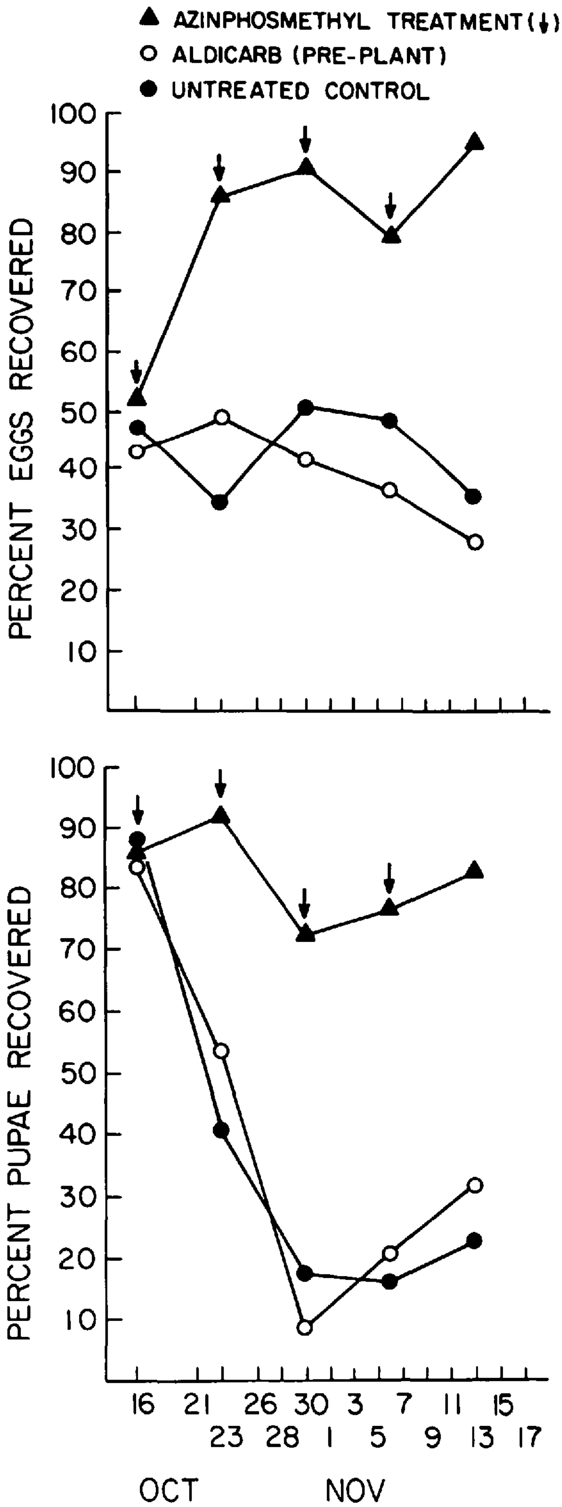

FIG. 2.—Effect of azinphosmethyl and aldicarb treatments on egg and pupal predation of the potato tuberworm in potato fields, Moreno, Calif., 1977.

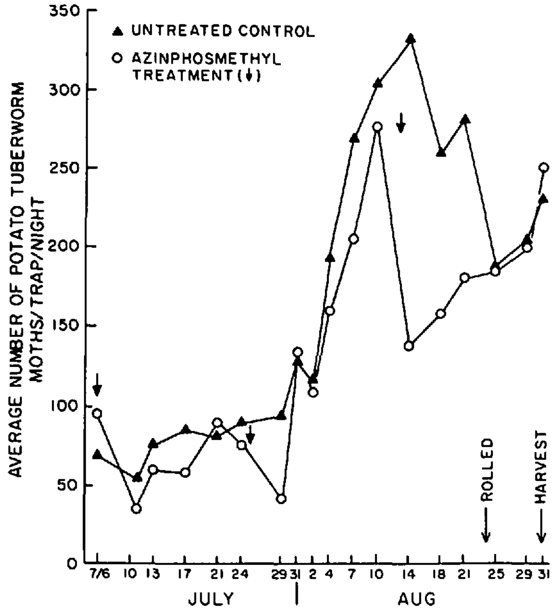

FIG. 3.—Effects of azinphosmethyl applications on potato tuberworm adult populations in potatoes as measured by pheromone traps, Moreno, Calif., 1978.

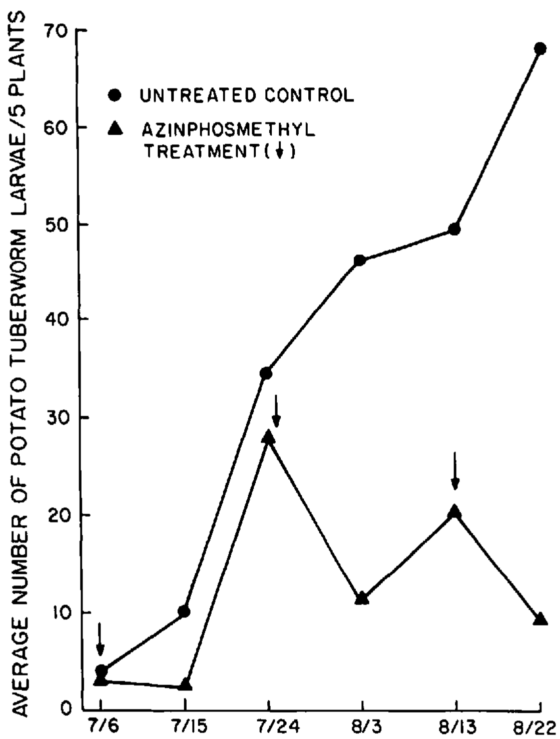

FIG. 4.—Effects of azinphosmethyl applications on potato tuberworm larval populations in potato foliage, Moreno, Calif., 1978.

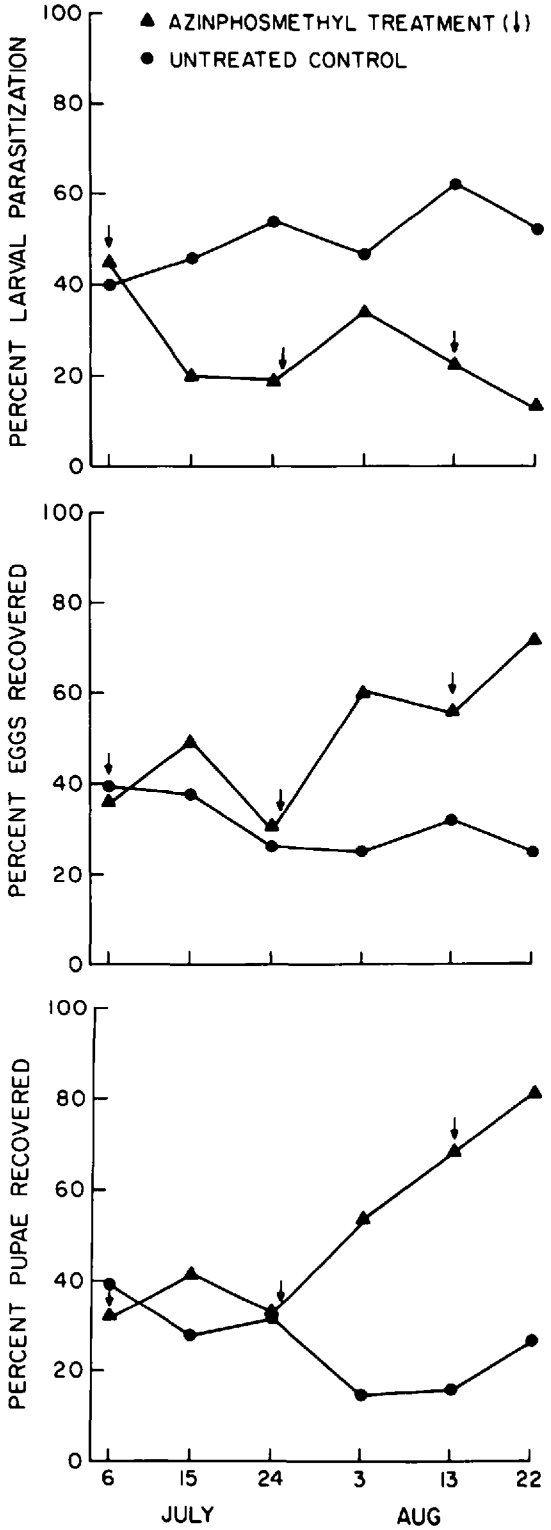

FIG. 5.—Effect of azinphosmethyl treatments on parasitism and egg and pupal predation of the potato tuberworm in potatoes, Moreno, Calif., 1978.

Discussion

These data suggest that potato tuberworm population resurgence following insecticide applications may result not only from adult immigration from untreated sources but also from residual in-field developmental stages which, in their natural habitats, are not susceptible to insecticidal control. Under the conditions of these experiments, adult migration into treated plantings from untreated adjacent plantings might be expected, but rapid adult resurgence after control applications is also known to occur commonly in commercial acreages under azinphosmethyl control (Bacon and Wyman 1976). A typical insecticide control program for potato tuberworm would achieve adequate control of adult and larval stages; however, egg and pupal stages would not be affected by contact action of the insecticide. Long-term, effective residual action would not be expected under the common commercial practice of frequent overhead sprinkler irrigation. Thus, the egg and pupal stages, together with immigrating gravid females and the surviving in-field larval population, may give rise to a potato tuberworm population largely free from many of their parasites and predators. Consequently, potato tuberworm resurgence would be more likely to occur and multiple insecticide applications would be required to avoid tuber damage by potato tuberworm larvae. Thus, chemical control of the potato tuberworm should be approached with concern for the naturally occurring biological control agents and utilized only when populations are high enough to result in economic damage. The effective pheromone monitoring system for this insect (Bacon et al. 1976, Shelton and Wyman 1979b,c) should be valuable in quantifying such damaging levels.

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