

Parasite tolerates other pesticides

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Laboratory tests with field-collected foliage showed the selected strain of *Trioxys pallidus* was also resistant to Lorsban, Thiodan, Supracide, and Zolone, pesticides used in walnut IPM programs.

The Guthion-resistant strain and a susceptible wild strain of the walnut aphid parasite were evaluated for their ability to survive on foliage treated with field rates of Guthion, Supracide (methidathion), Lorsban (chlorpyrifos), Thiodan (endosulfan), and Zolone (phosalone). These pesticides are used in walnut IPM and could be encountered by the Guthion-resistant *Trioxys pallidus* strain, should it become established in California walnut orchards.

Colony development and testing

The Guthion-resistant (Selected) strain of *T. pallidus* was selected in the laboratory for resistance to Guthion as described in *California Agriculture* July-August 1988. The wild (Base) colony was a combination of field-collected colonies from commercial walnut orchards in California. Both colonies were maintained on walnut aphids reared on potted walnut trees grown in a greenhouse at the University of California at Berkeley. Parasites of known age were reared on potted walnut trees containing walnut aphids in cages at 80°F under continuous light.

We tested parasites by exposing them to pesticide residues in clip cages attached to walnut leaves collected from the field. The clip cages were clear acrylic tubing, 1 1/4 inches in diameter, cut into 5/16-inch rings, covered with cloth mesh, and attached to the underside of the walnut leaf with a hair clip. There were 10 parasites (both sexes) per cage. We tested 100 parasites per colony, except for the 15-day-old Hanford residues, which had 50 parasites per treatment.

Survival was scored after 4, 8, 18, 24, 48, and 72 hours of exposure to residues of various pesticides sampled at different intervals after application. Survival of the Selected and Base colonies on each residue age was compared statistically (using the Mantel and Haenszel's Chi-Square test).

We conducted two series of tests. In one, using an experimental walnut block near Davis, California, field rates were used of

Guthion 50WP (1 pound active ingredient [lb AI]), Lorsban 4E (2 lb AI), Supracide 2E (2 lb AI), Zolone 3E (2.25 lb AI), and Thiodan 50WP (1.5 lb AI), all rates per 400 gallons per acre. The insecticides were applied to drip with approximately 8 gallons by a single applicator to individual trees using a hand gun. This allowed simultaneous comparison of residues of the different pesticides. An untreated tree served as a buffer between treatments. Residues were tested by the clip cage method after 1, 14, and 28 days (in cases where the residues remained toxic after 14 days).

In the second series of tests, foliage was collected from three commercial walnut blocks, one near Hanford and two near Colusa (North and South blocks). In the Hanford block, the grower applied Guthion 50WP (1.5 lb AI), Supracide 2E (2 lb AI), and Zolone 3E (2.25 lb AI), all per 250 gallons per acre, using commercial spray equipment. In the Colusa blocks, Supracide 2E (1.5 lb AI/120 gal/acre) was applied with a windmill sprayer. Residue toxicity was tested after 5, 15, and 35 days by the clip cage method.

Results

Experimental block. The Selected and Base colonies of *T. pallidus* differed in their responses to all pesticides tested (fig. 1). The Selected colony survived significantly better than the Base colony on all except the 14-day-old Thiodan residues, on which there were no significant differences in survival of the two colonies. These results indicate that selection for Guthion resistance resulted in cross-resistances to Lorsban, Supracide, Thiodan, and Zolone.

On fresh (1-day-old) residues, the Selected colony exhibited 22%, 3%, 91%, 43%, and 76% survival after spending 72 hours on Guthion, Lorsban, Thiodan, Supracide, and Zolone residues, respectively. In contrast, the Base colony exhibited 1%, 0%, 34%, 4%, and 13% survival after the same interval on these residues.

Survival of the Selected and Base colonies was still significantly different after the residues were 14 days old, except for the Thiodan residues. The Selected colony's high rate of survival on Guthion, Lorsban, and Supracide residues indicates that these pesticides could favor retention of this col-

ony in walnut orchards even after 14 days. The survival of the Base colony on 14-day-old residues of Thiodan and Zolone suggests these products are relatively selective to the wild populations of *T. pallidus* because residues persist a shorter time.

The Selected colony survived significantly better than the Base colony on 28-day-old Guthion, Supracide, and Lorsban residues. After 72 hours on Guthion, survival of the Selected colony was 46% compared with 7% for the Base colony. Guthion clearly has a long residual action. After 72 hours on Supracide, survival of 97% and 56% for the Selected and Base colonies indicates that Supracide may continue to select for the Selected colony in walnut orchards even after 28 days. Lorsban appears to have a shorter residual life than Guthion or Supracide, as indicated by the 98% and 81% survival rates of Selected and Base parasites, respectively, after 72 hours on the residues.

Pesticide residues remained toxic to the Base colony of *T. pallidus* for different intervals, with Guthion the most toxic for the longest interval and Supracide, Lorsban, Zolone, and Thiodan less toxic, in that order. For the Selected colony, Guthion was also the most toxic for the longest time, but 22%, 49%, and 46% of the Selected parasites survived 72 hours on residues that were 1, 14, and 28 days old, respectively. Zolone and Thiodan were nearly nontoxic to the Selected strain; 91% and 95% survived 72 hours on 1- and 14-day-old Thiodan residues, and 76% and 100% on 1- and 14-day-old Zolone residues. Survival of the Selected strain on Supracide residues was nearly as good, with 43% and 94% surviving 72 hours on 1- and 14-day-old residues. Lorsban residues declined sharply in toxicity to the Selected strain between 1 and 14 days; survival increased from 3% on 1-day-old residues to 90% on 14-day-old residues.

Commercial blocks. The results of tests on foliage from three commercial walnut orchards treated with Guthion, Supracide, and Zolone generally confirm results from the experimental block, despite the differences in pesticide concentrations applied and application equipment. The Selected and Base colonies responded significantly differently to residues of Guthion, Supracide, and Zolone in these tests (data not shown). The Selected colony survived bet-

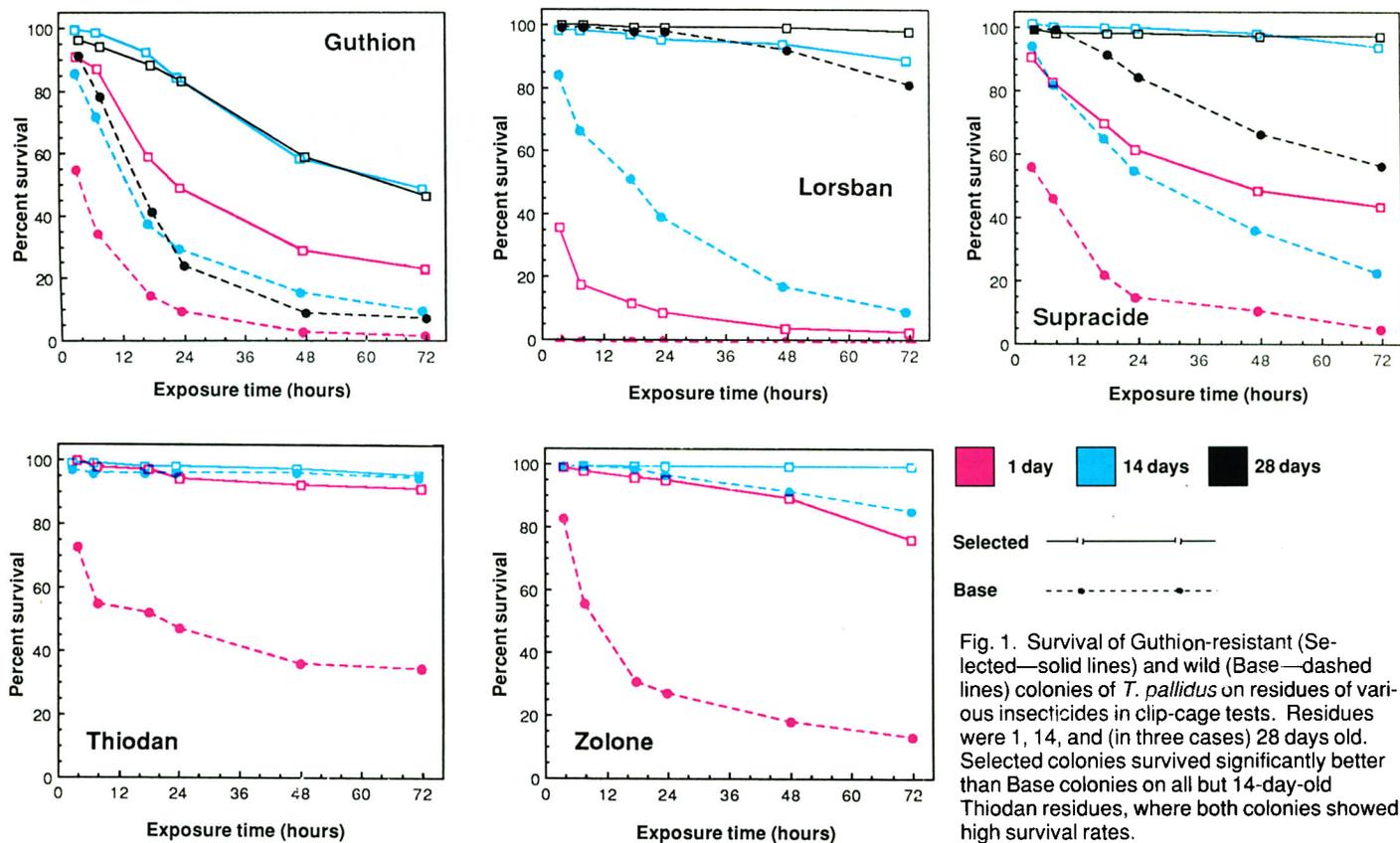


Fig. 1. Survival of Guthion-resistant (Selected—solid lines) and wild (Base—dashed lines) colonies of *T. pallidus* on residues of various insecticides in clip-cage tests. Residues were 1, 14, and (in three cases) 28 days old. Selected colonies survived significantly better than Base colonies on all but 14-day-old Thiodan residues, where both colonies showed high survival rates.

ter in all cases. Again, Guthion was the most toxic pesticide tested, with Supracide and Zolone less toxic to *T. pallidus*, in that order.

Guthion residues from the Hanford orchard remained highly toxic to the Base colony of *T. pallidus* 35 days after application. After 24 hours in the clip cages, none survived, but 41% of the Selected colony were alive. Survival of the Selected colony on the Guthion residues declined to 2% after 72 hours. However, the Selected colony consistently survived better than the Base strain on all Guthion residues (5, 15, or 35 days old). It is interesting that the 35-day-old Guthion residues were essentially as toxic as the 5-day-old residues.

None of the *T. pallidus* Base colony survived after 72 hours on 5-day-old Supracide residues on foliage from the three walnut blocks. Supracide residues 15 days old from the Hanford orchard allowed 88% survival of the Selected strain, but only 36% survival of the Base colony. These results are close to the 94% and 23% survival of the two colonies on 14-day-old residues from the experimental block.

Zolone residues from the Hanford orchard were more toxic to the Base than the Selected colony of *T. pallidus* (11% vs. 94% survival after 72 hours on 5-day-old residues and 12% vs. 85% survival after 72 hours on 15-day-old residues). Survival of the Base colony on foliage from the Hanford block was lower than that from the experi-

mental block, but the difference could be explained by the differences in Zolone application rates, spray equipment, and coverage, or in the foliage of different walnut varieties.

Conclusions

Selection for Guthion resistance in *Trioxys pallidus* apparently has yielded cross-resistances to Lorsban, Thiodan, Supracide, and Zolone, because the Selected strain consistently survived better on these pesticide residues than did the wild (Base) colony. The mode of inheritance and mechanism(s) of the Guthion resistance are unknown at this time.

These cross-resistances should facilitate implementation of the Guthion-resistant strain of *T. pallidus* in walnut orchards. Persistence of the genetically manipulated Guthion-resistant strain depends on a combination of factors, including the fitness of the resistant strain, the mode of inheritance and stability of the Guthion resistance, the degree of interbreeding with surrounding susceptible parasites, and the selection intensity in favor of the resistant strain. If Guthion is applied to control second-brood codling moth (usually in June), the long-lasting residues should favor retention of the Guthion-resistant strain and continue to cause mortality of the wild strain. If growers apply Supracide to control scale insects during the growing season,

this should also favor retention of the Guthion-resistant strain, since there was a substantial differential in survival of the Selected and wild strains for at least 2 weeks. Even applications of Zolone or Thiodan, which are considered to be less disruptive to wild *T. pallidus*, may favor the Selected strain, because these insecticides were also more toxic to the wild than the Selected strain for about 2 weeks. The data suggest the establishment and implementation of the Selected strain may not require an application of Guthion. Since all the pesticides tested are commonly applied in walnut IPM, application of one or more of them during the growing season could aid the establishment and persistence of the Guthion-resistant (Selected) strain of *T. pallidus* in California walnut orchards.

The results obtained with the wild strain have implications for walnut IPM. The lengthy negative effects of Guthion on the Base colony explain, at least in part, the often-observed secondary outbreaks of walnut aphids where Guthion is applied.

Zolone is recommended for use against codling moth in walnut orchards, because it is thought to be less disruptive to *T. pallidus* than Guthion. It is also considered useful in controlling aphids. In our tests, fresh residues of Zolone were more toxic to the Base colony than to the Guthion-resistant strain for about 2 weeks. Perhaps the relatively short residual activity of Zolone, in conjunc-

tion with its toxicity to aphids, is responsible for the perceived selectivity of Zolone to wild *T. pallidus* populations.

Supracide, periodically applied to control scale insects in walnut orchards, is considered to be disruptive to *T. pallidus*. Survival of the Base colony after 72 hours on 28-day-old residues was 56%, suggesting that Supracide should be applied in ways to enhance selectivity to *T. pallidus*. If Supracide were applied in strips or alternate rows in walnut orchards, wild parasites might be preserved in the untreated reservoirs. *Trioxys pallidus* might then recolonize the treated portion of the orchard within a month or so from these reservoirs.

Thiodan has a relatively short residual activity against the wild strain of *T. pallidus*. This material is applied to control aphids, and its use has rarely resulted in aphid re-surgences. Perhaps this observation is due, in part, to the fact that the residues are not highly toxic to *T. pallidus*, thereby allowing the parasite to control residual patches of aphids not controlled by Thiodan.

Lorsban is applied to control codling moth and navel orangeworm, and its residues are highly toxic to the wild strain of *T. pallidus*. After 72 hours, only 10% of the wild strain survived on 14-day-old residues. Based on these results, we would predict that Lorsban would stimulate aphid outbreaks in walnut orchards through destruction of the parasite populations.

The data from our tests describe the effects of different-aged pesticide residues on *T. pallidus* adults held in clip cages on field-treated walnut foliage. The relationship between this test method and mortality in the orchard is unknown, because field conditions can differ substantially from those in the laboratory. The test provides no information on the effect of the pesticides on aphids, or sublethal or indirect effects on *T. pallidus*. Such indirect effects can have significant impacts on host or parasite populations. However, the information may help growers and pest control advisers to make more informed decisions about using pesticides commonly used in walnut IPM.

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Computerized corral feed stations for dairy cows

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The mechanical feed stations monitored the feed intake of individual cows fed in large groups, making it easier to spot changes in each animal's condition.

The dairy cow of today has a greater genetic capacity to produce milk than capability to consume energy for that production. The intensive dairying practiced in California depends on adequate feed intake to maximize cow performance. Managers of the relatively large herds in central and southern California have evolved a group feeding system, in which several dozen cows are fed in a corral, based on average milk yield per cow. Attention to individual cow nutritional needs are therefore limited, and some over- and underfeeding of a particular cow may occur.

The use of computerized, mechanical feed stations has proved beneficial in meeting individual cow nutritional needs by reducing feeding errors and monitoring feed intake as an indicator of cow health. This system has been used successfully for several years with small groups of cows. Information is scarce concerning its use in the

larger production groups common in California. A 2-year study was therefore conducted on a dairy in Tulare County, in central California, to observe computerized corral feed system use in large group feeding circumstances.

Dairy study

The feeding system consisted of a bulk concentrate feed storage tank with a flex auger that automatically moved feed to a small hopper in a specially designed feed dispensing stall. Here the cow, with a coded transponder hanging from her neck, emitted an electronic identification specific for that cow. This signal was received by a transmitter-receiver connected to the feed delivery motor, which was connected by cable to a computer. The computerized feeding system used in these observations was "Surge Infarmation."

The computer had been programmed to feed each cow according to her previous milk yield. Feed delivery was set for six equal feedings during a 24-hour period, and any one visit was limited to 25% of the total.

Each corral, with an average of 86 cows, had one feed tank and four feed stations. Previous research has shown that one station is adequate for 22 cows, as a general recommendation. The cows were production-grouped by daily milk yield as high (70 to 90 pounds), medium (50 to 70 pounds), or low (30 to 50 pounds) to observe milk production effects on feed station use.

Cows received all of their daily concentrate allocation via the corral computerized feeder, except for 3 pounds during each milking twice daily. Feed stations were shaded, and each corral had shaded rest areas. Alfalfa hay and corn silage were fed to all cows on the opposite side of the corral from the concentrate feeder stations. Percent concentrate intake was averaged from computer printouts, and feed station occu-

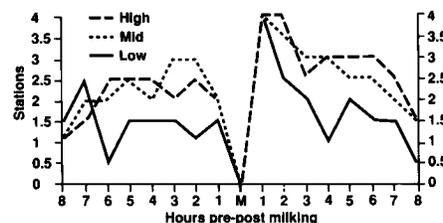


Fig. 1. Overall average feed station use shows similar patterns in high- and medium-production groups and lower use, before and after milking, by low-production cows.