Residual Toxicity of Four Citrus Insecticides in South Africa to the Scale Predator *Chilocorus nigritus* (Coleoptera: Coccinellidae)

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ABSTRACT The effects of residues of various concentrations of triazophos, tartar emetic, chlorpyriphos, and mineral oil on last instars and adults of *Chilocorus nigritus* (F.) were determined. Only triazophos had a residual effect on the beetles. When triazophos is included in an integrated pest management program on citrus, it should be used at the dosage of 60 ml triazophos per 100 liters water applied twice, rather than as a single application of 125 ml triazophos per 100 liters water. Under field conditions, triazophos lost its toxicity to adult *C. nigritus* in only 5 d but was toxic for 16 d against last instars. Under glasshouse conditions, triazophos lost its toxicity against adults in 30 d.

KEY WORDS Insecta, *Chilocorus nigritus*, citrus, residual toxicity

THE COCCINELLID *Chilocorus nigritus* (F.), a voracious predator of many soft and armored scales, has been an extremely useful addition to the existing natural enemy complex of citrus pests in southern Africa (Samways 1984). The beetles have been successfully used in various integrated control projects (DeBach 1964, Laing & Hamai 1976). In the Seychelles (Vesey-Fitzgerald 1953) and Mauritius (Moutia & Mamet 1946), *C. nigritus* has been used to control coconut scale, *Aspidiotus destructor* Signoret, and in India it has been used for 30 yr to control California red scale, *Aonidiella aurantii* (Maskell) (Tirumala Rai et al. 1954). The beetle appeared in southern Africa in the early 1970s. *C. nigritus* is easy to colonize; it is now being mass-reared, released, and transferred from one citrus orchard to another at many localities in southern Africa (Samways & Mapp 1983).

Since the discovery of organophosphate (OP) resistance in California red scale (Georgala 1979, Nel et al. 1979), fewer OP insecticides have been used on citrus. At the same time, more narrow-fraction oils for scale control have been used (Georgala & Stephen 1981).

In integrated pest management (IPM) programs in citrus, California red scale is controlled by corrective treatment with mineral oil (narrow range) plus an organophosphate insecticide, whereas the citrus thrips, *Scirtothrips aurantii* Faure, is controlled with safer insecticides such as tartar emetic or triazophos (Georgala 1979, 1984; Bedford & Deacon 1984).

The advantages of triazophos are simultaneous control of citrus thrips, citrus psylla, *Trioza erytreae* (Del Guercio), and aphids, as well as suppression of American bollworm, *Heliothis armigera* (Hübner), and California red scale (Bedford 1979). One way to prevent pest resurgence is to eliminate harmful insecticides and to use safer insecticides. This study was done to evaluate insecticides nontoxic to *C. nigritus* for use in IPM on citrus.

Materials and Methods

Chilocorus nigritus was mass-reared in an insectary at 25 ± 1°C and 70 ± 5% RH. Oleander scale, *Aspidiotus nerii* Bouché, reared on potatoes and butternuts, were used as food for the beetles. Adults of the same age (10 d) were used in the experiments but the sexes were not separated.

Field Experiments. Three-year-old 'Olinda Valencia' seedling trees from an orchard of the Citrus and Subtropical Fruit Research Institute (CSFRI) (Nelspruit) were sprayed with different insecticides. The insecticides were applied with a knapsack sprayer until runoff to ensure proper wetting of the leaves. Control trees were sprayed with 0.2% Teepol (Agritek, Nelspruit, Transvaal) as a wetting agent. The insecticides used were: (a) triazophos (Hostathion emulsifiable concentrate (EC Hoechst South Africa, Johannesburg, Transvaal) (428 g [AI]/liter at 60 ml/100 liters water plus 2 ml Teepol); (b) tartar emetic (Tartox water soluble powder [WSP] Agricura, Pretoria, Transvaal) (995 g [AI]/liter at 200 g/100 liters water plus 200 g sugar); (c) chlorpyriphos (Durban EC FBC Holdings, Chloorkop, Transvaal) (480 g [AI]/liter at 60 ml/100 liters water plus 2 ml Teepol); (d) chlorpyriphos at 60 ml/100 liters water plus 1 liter mineral oil (Orchex N-695 EC Agritek, Nelspruit, Transvaal) (835 g [AI]/liter plus 2 ml Teepol); and (e) mineral oil at 1 liter/100 liters water and 1.4 liters/

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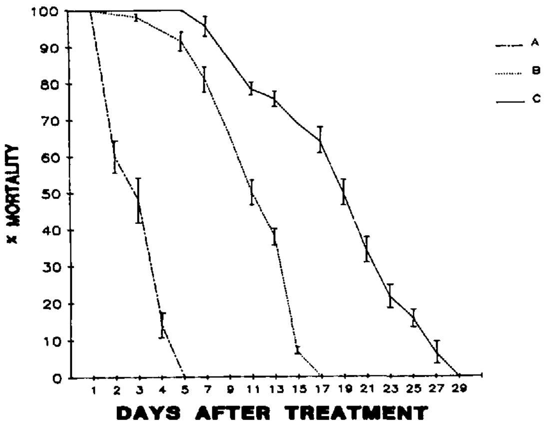

Fig. 1. Residual toxicity of triazophos to *C. nigritus*. A, adults (field conditions); B, final-instar larvae (field conditions); C, adults (glasshouse conditions).

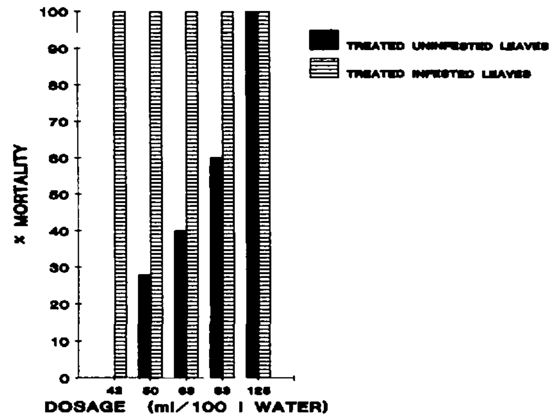

Fig. 2. Residual and stomach effect of triazophos doses on *C. nigritus* adults.

100 liters water, both plus 2 ml Teepol. Six beetles per Munger cell (Munger 1942) and six Munger cells per treatment were used. The experiment was replicated 10 times.

Glasshouse Experiment. Three-year-old 'Valencia' seedling trees in a glasshouse at CSFRI were sprayed with 60 ml triazophos per 100 liters water and check trees with 0.2% Teepol. Beetles were exposed to the insecticides on the upper surfaces of the leaves in modified Munger cells. Every day for the duration of the experiment, 20 Munger cells, each containing six beetles or larvae, were used. Leaves treated only with 0.2% Teepol were used as controls. Last-instar *C. nigritus* were also exposed to leaves treated with 60 ml triazophos per 100 liters water. The Munger cells were kept at 24 ± 1°C and 75 ± 5% RH. Circulation of fresh air was achieved by negative pressure through a diaphragm vacuum pump with an air displacement capacity of 12 liter/min. A drop of honey (3 mm) was supplied as food for the duration of the toxicity trials.

Mortalities in the Munger cells were determined 24 h after treatment. Beetles showing no leg or antennae movement were considered dead.

Laboratory Experiments. Three methods to determine the residual and stomach poison effect of triazophos on *C. nigritus* were used.

In the first experiment, two triazophos dosages (60 ml and 12 ml/100 liter water plus 2 ml Teepol) were tested. Leaves infested with long mussel scale, *Insulaspis gloverii* (Packard), were dipped in the triazophos solutions for 10 s. Thereafter, the poisoned scales were removed with a dissecting needle and placed on untreated leaves in the Munger cells. The number of scales per Munger cell varied between one and five for each treatment, with a corresponding untreated control for each treatment. Only one beetle was placed in each Munger cell, and for each dosage, 30 Munger cells were used; the experiment was replicated six times. Mortality was determined after 12 h.

In the second experiment, different dosages of triazophos were tested. The dosages used in the trials were 125, 83, 63, 50, and 42 ml triazophos per 100 liter water plus 2 ml Teepol. The higher dose of 125 ml triazophos per 100 liter water is also registered for citrus thrips control in the Republic of South Africa (Bot et al. 1986).

Leaves infested with long mussel scale were dipped for 10 s in the respective triazophos concentrations. They were then placed in drying racks and thereafter in Munger cells. An average of five scales per Munger cell was used, with a maximum of five beetles per Munger cell. For each triazophos dosage, five Munger cells were used, and the experiment was replicated six times. Untreated leaves, dipped in 0.2% Teepol solution for 10 s and infested with scales, were used as controls. Mortalities were determined after 12 h.

In the third experiment, uninfested leaves were dipped in the different triazophos solutions plus 0.2% Teepol for 10 s and left to dry. Thereafter the beetles were placed on these leaves in Munger cells, and mortalities were determined as above. Clean citrus leaves, dipped only in 0.2% Teepol for 10 s, were used as controls.

All data were statistically analyzed by a computer program (P/TTEST) using a one-tailed *t* test (Van Ark 1986).

Results and Discussion

The following insecticides and combinations thereof showed no residual effect on *C. nigritus*: chlorpyriphos, chlorpyriphos plus mineral oil, the different mineral oil concentrations, and tartar emetic. The residual effect of triazophos on *C. nigritus* is shown in Fig. 1. The residual and stomach poison effect of triazophos on *C. nigritus* is presented in Fig. 2.

Two of the insecticides registered for thrips control on citrus, tartar emetic and triazophos (Bot et al. 1986), differ markedly regarding their toxicity for *C. nigritus*. Tartar emetic showed no adverse effect on *C. nigritus*, whereas triazophos caused mortality up to 4 d after treatment. Tartar emetic may be used safely in IPM because of its low relative toxicity against parasitoids. Under conditions of severe thrips pressure, however, it may be necessary to spray five or more times, which could possibly affect the parasitoids.

Under field conditions, triazophos lost its toxicity in 5 d against adult *C. nigritus* but only in 16 d against last instars.

Under glasshouse conditions, triazophos lost its toxicity in 30 d against adults. However, the trees in the glasshouse were not subjected to rain, and the sunlight was lowered by about 30% through shade netting. Total mortality of *C. nigritus* was obtained when they fed on two scales treated with 60 ml triazophos per 100 liter water. With scale treated with 12 ml triazophos per 100 liter water, four scales were needed to achieve the same effect.

Total mortality occurred when *C. nigritus* fed on the scale-infested triazophos-treated leaves, whereas only 40% mortality occurred when the beetles were in contact with leaves without scale to feed upon (Fig. 2).

Although some of the insecticides evaluated do not have an influence on *C. nigritus*, they may affect parasitoids adversely (Schoonees & Giliomee 1984). A single oil spray could have a negative effect on *Aphytis* parasitoids for 3–5 yr (DeBach & Bartlett 1951).

The high initial mortality caused by triazophos and its effect on parasitoids are in contrast to the general belief that triazophos is a safe insecticide. This detrimental effect on *C. nigritus* is enhanced when the trees are heavily infested with California red scale. As mentioned above, the combined effect of triazophos as a contact and stomach poison is much greater than the contact effect alone. However, triazophos suppresses California red scale populations. This is not the case with tartar emetic. The beetles are forced into continuous contact with the insecticide in the Munger cells, whereas under field conditions they may move around freely and may at times not be in contact with insecticides. If triazophos is included in an IPM program, it should be applied at the lower dosage of 60 ml triazophos per 100 liters water early in the season (at 100% petal drop), and the application should be repeated 5 wk later rather than applying a single dosage of 125 ml triazophos per 100 liters water at 100% petal drop. Because *C. nigritus* larvae are more susceptible than the adults, application of triazophos at peaks of larval numbers should be avoided. Triazophos will also suppress a number of other pests on citrus at the same time.

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