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# Evaluation of Fluvalinate, Methomyl and Kinoprene on the Greenhouse Whitefly, *Trialeurodes vaporariorum* West. (Homoptera: Aleyrodidae)[1]

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## ABSTRACT

The effectiveness of three insecticides, fluvalinate, kinoprene and methomyl (synthetic pyrethrin, juvenile hormone analog and organophosphate, respectively), against the greenhouse whitefly, *Trialeurodes vaporariorum* West. (Homoptera: Aleyrodidae), was evaluated in commercial greenhouses. The impact of chemicals was studied on isolated whitefly stages in a rearing room (24 ± 1°C, 65 ± 5% r.h. and L:D 16:8h). Fluvalinate was the most effective toxicant through its broad activity on whitefly life stages. Kinoprene controlled 2nd and 3rd larval instars but a moderate effectiveness was noticed on eggs, first instar larvae and pupae. Methomyl was effective against first instar larvae and adults but it had no substantial effect on the other stages. Of the three materials tested only fluvalinate approached the total control requirements for a successful whitefly suppression.

## Introduction

The greenhouse whitefly *Trialeurodes vaporariorum* West. (Homoptera : Aleyrodidae) was the most important pest of greenhouse crops during 1979-1982 in Crete. Its control is difficult because of asynchronous populations and rapid development of resistance to currently used insecticides (Wardlow et al. 1972, Webb et al. 1974, Onillon 1982). Moreover, some insecticides like the new synthetic pyrethroids and the broad spectrum organophosphates affect natural control agents and cause a burst of mites and whiteflies (Onillon 1982). The juvenoid kinoprene has a very selective activity on Homoptera. Its activity is combined with a direct toxic effect at high doses. This property allows kinoprene to affect all life stages of pests such as whiteflies (Staal 1982). On the other hand, in integrated control programmes a careful choice of insecticides should be designed to have the least adverse effects on useful parasites and predators. Consequently, knowledge on the acute effect of chemicals on each life stage of the greenhouse whitefly and their adverse effects on predation and parasitism is essential.

This paper reports results of experiments designed to evaluate the effectiveness of three insecticides, fluvalinate, kinoprene and methomyl, with different properties, on each life stage of the greenhouse whitefly in the laboratory as well as in the greenhouse.

## Materials and Methods

The experimental design was a complete randomized block with each of four blocks occupying a different greenhouse of ca 40m$^2$. In each block, three treatment plots were established. The distance between plots wa ca. 3.5 m. Six tomato plants (*Lycopersicum esculentum* Mill.) of the Earlipak variety were transplanted in each plot (March 20, 1982) and were artificially infested with 15-21 whiteflies/plant. A 2-week spray program was in-

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itiated 15 days after planting and continued for 12 weeks until the decline of the control plants. The insecticides tested were: fluvalinate (Maurick 2E, 24.9% a.i., Zoëcon) a synthetic pyrethrine, kinoprene (Enstar, 65.3% a.i., Zoëcon) a juvenile hormone analog and methomyl (Lannate, 90% a.i., Du Pont) an organophosphate, and the dosages used were 0.015%, 0.03%, 0.008%, respectively. Adults were counted on the three top apical leaflets per plant one day before application and 10 days after. Three leaflets were sampled using a 1.4 cm diameter cork borer beginning from the lower first infested leaves and proceeding gradually to the higher ones. Thirty six leafdiscs per plot (two leafdiscs/leaflet) were examined under a dissecting microscope and the number of eggs, larvae and last nymphal instar cast skins were recorded. The total production of each plot was recorded weekly and the honey dew and sooty mould affected tomatoes were separated. The mean temperature and relative humidity values (range in parenthesis) during the experiment were as follows: 18.8 °C (5.3-32.3) and 60% r.h. (35-82) in March, 23.2 °C (9.6-36.8) and 50.4% r.h. (22.2-78.8) in April, 24.6 °C (9.8-39.5) and 50.8% r.h. (22.6-78.9) in May, 26.3 °C (14-39.6) and 46.6% r.h. (21.5-71.8) in June and 27.1 °C (16.3-37.8) and 52.8% r.h. (28.8-76.8) in July.

Laboratory tests on potted cucumber plants at the two-leaf stage were conducted according to F.A.O. No. 23 method (dip-test) (1979). The young cucumber plants at the two-leaf stage were put inside a greenhouse with old tomato plants haevily infested with whiteflies. By slogging lightly the tomato plants the whiteflies flew to young cucumber leaves and an adequate infestation with a fresh deposit of eggs was obtained after six hours. The adult whiteflies were then blown off by a jet of air and the remaining ones were removed with an aspirator. The young plants were kept in a rearing room at 24±1 C°, 65±5% r.h. and 16 hours light daily. When the whiteflies developed to an appropriate stage (Table 2) (Hargreaves 1914), cucumber leaves were immersed in the insecticide solutions at the above mentioned dosages for 10 seconds, with gentle agitation. Each heavily infested leaf was considered one replicate and there were four replicates per treatment. Mortality was recorded one week after treatment and dead insects were counted under a dissecting microscope.

Adult mortality was tested by Agricultural Development and Advisory, Wye, Kent, United Kingdom method (French et al. 1973). Batches of about 50 newly emerged whiteflies of similar age, collected with an aspirator from foliage infested with pupae, were exposed at -5 °C for 20 minutes. Afterwards, chilled insects were transferred to room temperature where they remained immobile for about five minutes; during this period they were placed on black filter paper in the half of a 4cm petri dish and sprayed in a Potter tower. This was operated at 42 KPa (6psi). Two ml of the test insecticides were used. Then the insects were placed into one liter beaker, containing two bean leaves trimmed to 6.5 $cm^2$ in a tube of water; the tubes were sealed with a slotted cork and were attached to the upper half of the beaker. The escape of surviving white flies was prevented by a muslin. The mortality was assessed after 24-hours.

## Results and Discussion

At the beginning of the experiment a uniform infestation of plants by whiteflies was achieved but after five applications, each every two weeks, a significant difference in the number of adult whiteflies was observed among the various treatments (Table 1). Adults per apical leaflet increased 26.2 times in the control plants, 1.48, 5.35 and 5.60 in fluvalinate, methomyl and kinoprene-treated ones respectively. Fluvalinate allowed a lower adult density per leaflet than methomyl and kinoprene. The above results were verified by stage density (eggs, larvae, pupae) assessed on tomato leafdiscs (Fig. 1).

The sooty mould grown on honey dew excreted by the whiteflies, mainly 2nd and 3rd larval instars (Hargreaves 1914) interferes in plant photosynthesis causing reduced vigour and plant death after 120 days. The first signs of sooty mould occurred on the leaves and fruits 55 and 90 days after transplantation, respectively. A similar appearance on the fruits occurred 30 days later in the methomyl and kinoprene plots while the fruits in the fluvalinate plots were clean throughout the crop sea-

TABLE 1. Adult whiteflies per apical leaflet after five insecticidal applications. Four replicates of six plants each; mean number of insects on three apical leaflets per plant.

| Insecticidal treatment | Pre-spray[1] | Final[2] | Rate of increase | Total no. whiteflies[3] |
|---|---|---|---|---|
| Fluvalinate | 15.0 a[4] | 22.4 a | 1.48 | 287.5 a |
| Methomyl | 17.4 a | 110.5 b | 5.35 | 600.2 b |
| Kinoprene | 16.8 a | 94.4 b | 5.60 | 892.7 b |
| Control | 22.0 a | 578.0 c | 26.20 | 2586.5 c |

[1] One day before first application.
[2] Ten days after last application.
[3] Sum of direct counts on three top apical leaflets of 6 plants during five insecticidal applications.
[4] Means followed by same letter are not significantly different by Duncan's multiple range test (P=0.05).

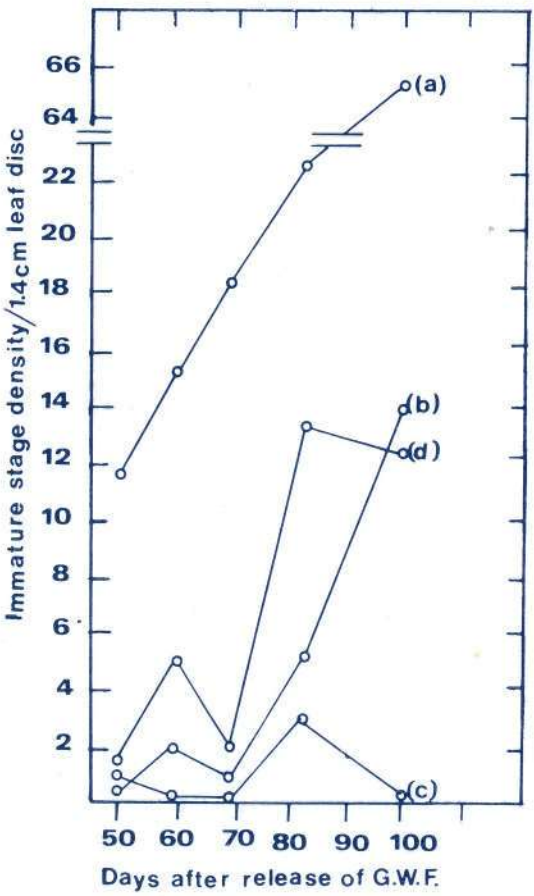


FIG. 1. Stage density (eggs, larvae, pupae) of the greenhouse whitefly (GWF) with time on 1.4 cm tomato leaf-discs in untreated (a) and in plants treated with methomyl (b), fluvalinate (c) and kinoprene (d).

son. The whitefly adults were greatly suppressed by fluvalinate and moderately by kinoprene and methomyl. Sooty mould growth was very rapid on control fruits but on kinoprene and methomyl ones varied at lower levels (Fig. 2).

The total counts of whitefly adults per leaflet during 120 days of experimentation were the lowest in the fluvalinate plots (287.5) and differed significantly from all the others (Table 1). Under such adult density, and a stage density ranging between 0-3/leafdisc the fruits produced were clean without any signs of sooty mould. Total fruit production did not differ in the various treatments (3.58 in the control and 3.90-4.16 kg/plant in the treated plants) but the fruits affected by honey dew and sooty mould per plant were significantly higher in the control than in the treated plants (3.42 and 0.0-0.96 kg/plant respectively).

In laboratory tests, assessment of the percentage mortality of each stage revealed large differences among the chemicals depending on the material applied and the stage treated (Table 2). The three compounds had different action. Fluvalinate had a significant impact on all whitefly stages. Treated white eggs darkened as normal but a high percentage of embryos died at hatching. Toxicity in the larvae was very high (99%). When pupae were treated, adults died after emergence probably because of residual toxicity. Methomyl had no significant toxicity on eggs and crawlers. First instar larvae and adults were very sensitive (99 and 100% respectively) but 2nd and 3rd instars were moderately sensitive (43.3 and 51.2% respectively). Kinoprene had a very different action as compared with that of fluvalinate and methomyl. Mortality increased as treated stages approached the third larval instar (95.9%) but the second one was slightly less sensitive (89.9%). First larval instar and the pupal stage showed moderate sensitivity (53.7 and 37.8% respectively) but adults remained unaffected. Some white eggs (11.5%) died after treatment but the rest of them completed their development. Black eggs were less sensitive (5.7%). Riddiford and Williams (1967) found eggs to be most sensitive to juvenile hormone analog applications immediately after oviposition. Our data indicate that the third larval instar of the whitefly was the most sensitive. Staal (1975) found that insects show a period of highest sensitivity to juvenile hormone analog applications depending on the species, the dose, the mode of action and the type of the compound. Willis and Lawrence (1970) suggested that juvenile hormone analogs pass through the molting fluid from the old to the new cuticle where they persist throughout the larval development. If this is the case, the increased mortality we observed it may be due to increased amounts of residues present at the critical period. However, Riddiford (1970) does not agree that these analogs persist throughout development. She found no detectable amounts of JH analogs in the early third larval instar of *Pyrrhocoris apterus* (L.) after egg treatment. Thus, the increased amounts could result from the treatment of larger larvae with a greater surface area than the smaller ones (two times greater in the third

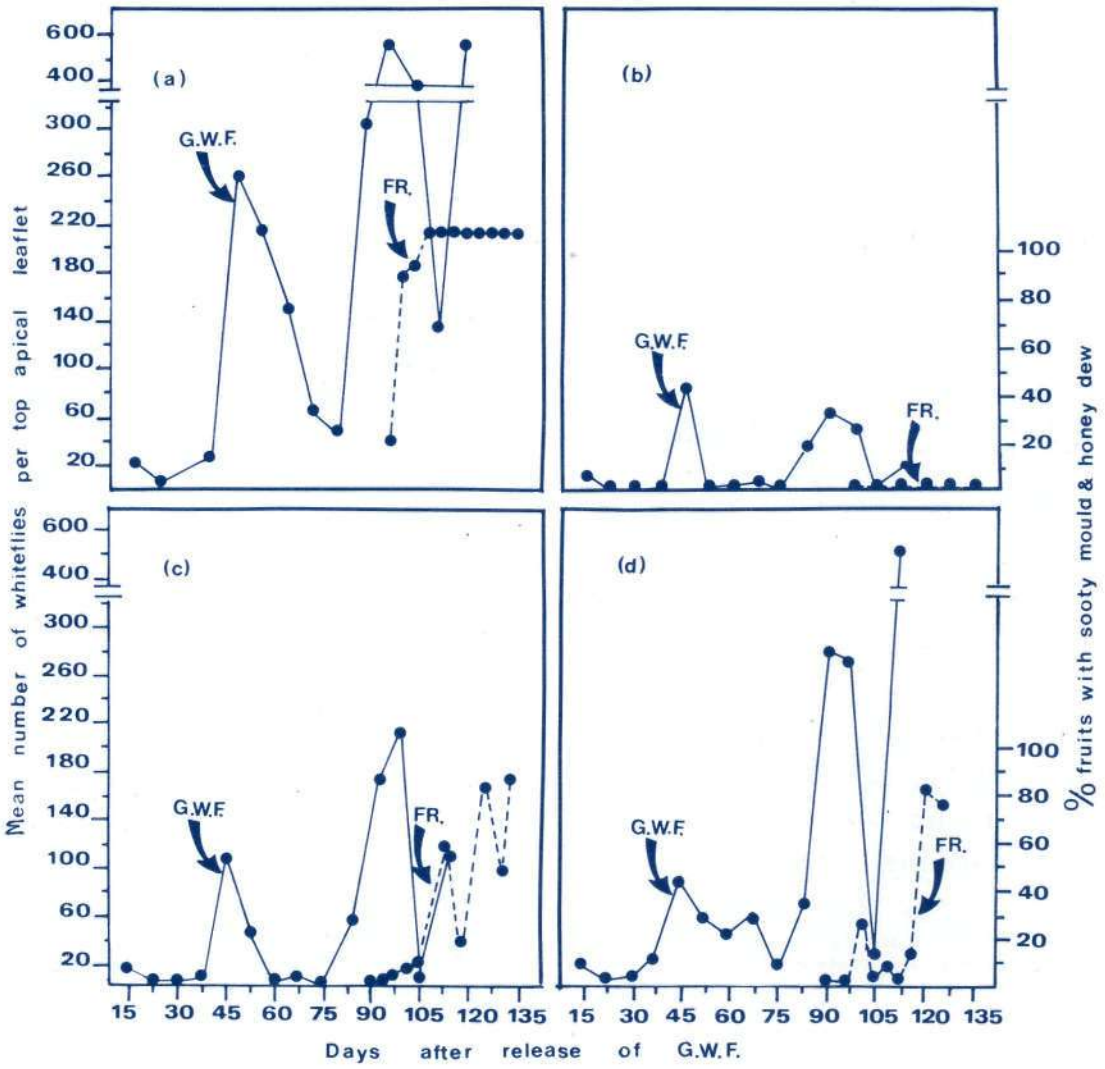


FIG. 2. Fluctuation of the adult greenhouse whitefly (GWF) density per top apical leaflet and % fruits affected by sooty mould and honeydew (FR) in untreated (a) and in plants treated with fluvalinate (b), kinoprene (c) and methomyl (d).

than in the first stage) to absorb the analog rather than an inceased physiological persistence of kinoprene.

The present experiments demonstrated differential sensitivity of whitefly stages to various types of commercial insecticides tested. These findings have implications to control programs, especially in horticulture and floriculture where asynchronous populations can readily develop. Frequent applications would be necessary with most toxicants to insure whitefly-free plants. Of the three materials tested on each whitefly stage, only fluvalinate approached the total control requirements for a successful whitefly suppression. Kinoprene was more toxic to the second and third larval instars than to the first larval instar and pupal stage. Therefore, more frequent applications are needed to control these stages. Methomyl was found to be very toxic to the adults and to the first larval instar but not to the second and third larval instars and the pupal stage. Similar results were obtained in greenhouse tests. Asynchronous populations

TABLE 2. Percent mortality[1] of the greenhouse whitefly after treatment[2] with various chemicals.

| Insecticidal treatment | Life stage | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Eggs | | | | Larval instars | | | | |
| | White | | Black | | | | | | |
| | egg stage | overall[3] | egg stage | overall | 1st | 2nd | 3rd | Pupae | Adults |
| Fluvalinate | 3,3 | 98.8 | 0.0 | 99.1 | 99.4 | 96.8 | 86.4 | 100.0* | 100 |
| Kinoprene | 11.5 | 0.0 | 5.7 | 0.0 | 53.6 | 89.9 | 95.9 | 37.8 | 0 |
| Methomyl | 6.9 | 5.0 | 0.0 | 6.3 | 99.0 | 43.3 | 51.2 | 21.7 | 100 |
| Control | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |

[1] Percent control corrected by Abbot's formula.
[2] Dipping test (FAO recommended method No. 23).
[3] Including residual effect to crawlers emerging from dipped eggs.
* Adults died at emergence.

can be controlled only through repeated applications or combination of materials. If compatible, a kinoprene-methomyl combination could be extremely lethal to whiteflies because of high toxicity to most instars.

During the experiments, two harmful insects, the greengarden looper (*Plusia chalcites* Esper.) and the leafminer (*Liriomyza* sp.), invaded the greenhouses causing certain damage depending on the chemicals used. Their control was successful by fluvalinate. Methomyl had a moderate effectiveness. In the kinoprene treated as well as in the control plot severe injuries were observed. The hymenopterous parasite of the greenhouse whitefly, *Encarsia formosa* Gahan, moved in from a neighboring greenhouse and the parasitism ranged from O to 18%. The average rate of parasitization by *E. formosa* was 18%, 3% and 1% in the kinoprene, control and methomyl plots. Of the three materials tested fluvalinate prevented parasitism completely (a light level of parasitism was observed only 20 days after the last application). The low level of parasitism in the control was presumably due to the extensive honeydew and sooty mould growth that prevented serious parasite activity and caused high mortality trapping most of the parasites.

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KEY WORDS: Greenhouse whitefly, Fluvalinate, Methomyl, Kinoprene *Trialeurodes vaporariorum*, Chemical control,

# Αξιολόγηση των Εντομοκτόνων Fluvalinate, Methomyl και Kinoprene στον Αλευρώδη των θερμοκηπίων *Trialeurodes vaporariorum* West. (Homoptera: Aleyrodidae)

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## ΠΕΡΙΛΗΨΗ

Σε πειράματα στο θερμοκήπιο και στο εργαστήριο (24 ± 1°C, 65 ± 5% σχετ. υγρ. και φωτοπερίοδο 16:8) μελετήθηκε η αποτελεσματικότητα των fluvalinate (συνθετική πυρεθρίνη), methomyl (οργανοφωσφορικό) και Kinoprene (ουσία με δράση ανάλογη της νεανικής ορμόνης) στον αλευρώδη των θερμοκηπίων *Trialeurodes vaporariorum* West. Από τα πειράματα αυτά προέκυψε ότι μόνο το fluvalinate (0,015% δ.ο.) πληρεί τις προϋποθέσεις για ικανοποιητικό έλγχο του αλευρώδη λόγω της αποτελεσματικότητάς του σε όλα τα στάδια (99-100%). Τα methomyl (0,03% δ.ο.) και kinoprene (0,008% δ.ο.) είχαν την ίδια αποτελεσματικότητα. Το methomyl ήταν αποτελεσματικό μόνο στα ακμαία και το πρώτο προνυμφικό στάδιο (100 και 99% αντίστοιχα) ενώ το kinoprene στο δεύτερο και τρίτο στάδιο (89,9 και 95,5% αντίστοιχα). Στα αυγά ηλικίας 24η και 76η ώρα μόνο το kinoprene προκάλεσε κάποια θνησιμότητα (11,5 και 5,7% αντίστοιχα) ενώ τα άλλα ασήμαντη (0-3%). Παρατηρήθηκε επίσης ικανοποιητικός έλεγχος των *Liriomyza* sp. και *Plusia chalcites* Esper. από το fluvalinate, μέτρια αποτελεσματικότητα είχε το methomyl, ενώ τα φυτά που ψεκάστηκαν με το kinoprene είχαν σοβαρή προσβολή και από τα δύο παραπάνω έντομα. Το kinoprene επίσης δεν παρεμπόδισε σοβαρά τη δράση του ωφέλιμου παρασίτου *Encarsia formosa* Gahan.