

## Effect of Repeated Applications of Fipronil on Arthropod Populations in Experimental Plot Studies

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### ABSTRAK

Kesan dua kali semburan fipronil ke atas populasi Arthropod telah dikaji di plot kajian menggunakan *Cuphea ignea* yang berusia 3 bulan. Lapan puluh satu famili daripada 12 order Arthropod telah diperangkap sebelum disembur. Empat order dominan telah dikenal pasti iaitu Hymenoptera (28.6%), Homoptera (19.1%), Collembola (17.8%) dan Diptera (16.2%). Beberapa order lain telah dikenal pasti wujud dalam bilangan yang rendah iaitu Hemiptera, Coleoptera, Orthoptera, Thysanoptera, Araneida, Acarina, Lepidoptera and Isopoda. Selepas semburan pertama dan kedua, jumlah famili dalam order Arthropod telah berkurang masing-masing kepada 44 dan 47 famili. Peratus populasi Collembola meningkat secara bererti selepas semburan pertama dan kedua berbanding bilangannya sebelum rawatan diberikan. Peratus populasi Homoptera (Aleyrodidae) pula meningkat selepas semburan pertama tetapi peratusannya menurun selepas semburan kedua. Famili Isotomidae (Collembola) meningkat secara signifikan selepas semburan pertama dan kedua. Beberapa order lain seperti Isopoda dan Lepidoptera telah tidak dapat dikesan selepas plot dirawat dengan fipronil.

### ABSTRACT

The effect of two applications of fipronil on arthropod populations were studied under experimental plot conditions using 3-month old *Cuphea ignea*. Eighty-one families belonging to 12 orders of Arthropoda were trapped before spraying. The four dominant orders were Hymenoptera (28.6%), Homoptera (19.1%), Collembola (17.8%) and Diptera (16.2%). Other orders were present in small numbers i.e. Hemiptera, Coleoptera, Orthoptera, Thysanoptera, Araneida, Acarina, Lepidoptera and Isopoda. The abundance of arthropods was reduced to 44 and 47 families after the first and second sprayings, respectively. The percentage population of Collembola increased significantly after the first and second sprayings as compared to the number before treatment. The percentage population of Homoptera (Aleyrodidae) increased after the first spray but declined after the second spray. The family Isotomidae (Collembola) increased significantly after the first and second sprays. Some orders such as Isopoda and Lepidoptera disappeared after the plot was treated with fipronil.

### INTRODUCTION

Arthropoda belongs to a large phylum of invertebrate organisms that include crustaceans, mites, millipedes, centipedes, and insects such as springtails, proturans, diplurans, beetles, flies, ants, and termites. Some arthropods are beneficial (soil aeration, nutrient release), but some are considered pests to crops. Although only approximately 1% of the arthropods are pests to crops and flowers in the nursery, they can cause yield reduction between 5-15% (Davidson and Lyon 1987).

Pesticide application may not only kill the target organisms but also non-target and beneficial organisms. Mullie *et al.* (1999) reported that 26 species of arthropods such as Carabidae and Tenebrionidae were killed after the applications of Cyanox and Fenthion. Chlorpyrifos, an organophosphate insecticide, was reported to be very toxic to the parasitoid Hymenoptera (Pussey *et al.* 1994; Cohen *et al.* 1996; Viggiani 2000).

Horticultural nurseries are an ecosystem having a variety of arthropods, each with a specific role. The population of soil arthropods

has a positive correlation with soil properties, for instance, the Isopoda, Diplopoda and Staphylinidae have positive correlations with the availability of K and P in the soil (Danxiao *et al.* 1999). Furthermore, the populations of the arthropods are not necessarily the same in different ecosystems due to variability in abiotic factors.

Fipronil ((±)-5-amino-(2,6-dichloro- $\alpha,\alpha,\alpha$ -trifluoro-p-tolyl)-trifluoromethyl-sulfinylpyrazole-3-carbonitrilephenylpyrazole) is a phenylpyrazole insecticide developed by Rhone-Poulenc (Bobe and Cooper 1998). It is a highly effective and broad-spectrum insecticide against piercing-sucking, contact and chewing, pests and is widely used to control many species of soil and foliar insects on various crops such as rice, vegetables and fruits (Colliot and Kukorowski 1992; Balanca and de Visscher 1997).

Recent experiments showed that fipronil provided efficient protection against vegetable pests such as *Pieris rapae* and *Plutella xylostela* (Zhou and Wu 1995; Stevens and Helliwell 1998; Zhou *et al.* 2004). Since organophosphorus pesticides are gradually limited in application due to their high toxicity threaten human health and long-term residue in vegetables, it seems that organophosphorous pesticides would be replaced by fipronil in future.

Many horticultural nurseries in Malaysia especially those propagating *Cuphea ignea* use fipronil for pest control. Usually, this compound is used repeatedly to control pests but no reports on the effect of this insecticide on arthropods' populations has been documented. To the best of our knowledge, there are no published reports on the effects of fipronil on arthropod populations in Malaysia. The result of this study would provide a clear picture on the impact of this insecticide, particularly on arthropod populations. Therefore, the aim of this study was to determine the effects of repeated applications of fipronil on arthropod populations under experimental plot conditions.

## MATERIALS AND METHODS

### Study Site

The study was carried out at the experimental plots of the Universiti Kebangsaan Malaysia at Bangi, Selangor, Malaysia. Three month old *Cuphea ignea* seedlings were planted in black polybags and arranged at 30-cm intervals. Light intensity and humidity were measured by using

a photometer (LI-COR Model LI-189) and Hygrometer (Hanna Instrument Model H18565), respectively. Soil and air temperatures, pH and organic contents of the soil used were also recorded.

### Sampling of the Arthropods

Samplings of the arthropods were carried out for 4 months at 2-weekly intervals starting from 7 January 1999 prior to treatment. Arthropods were trapped using the pitfall trap and the yellow pan trap. The pitfall trap was used to trap invertebrates crawling on the soil surface. In our initial trials, it was found that very few specimens were collected from the soil samples, thus the pitfall trap and yellow pan traps were deemed sufficient and suitable for the purpose of this study. Ten holes were dug between the plastic bags in the plot and the trap comprising a glass bottle (4.5 x 4 cm) was placed in each hole. The yellow pan traps (petri dishes painted in yellow) were used for trapping flying arthropods and those crawling on leaves. The traps were placed randomly in the plots. Teepol (10%) was placed in each trap and left for 24 hours. The trap catches were brought back to the laboratory, sorted and identified to the family level using Borror *et al.* (1981) and Goulet and Huber (1993).

Fipronil (Regent 3G®, manufactured by Rhone Pholenc) was sprayed on 22 April 1999, at the rate of 0.03-kg a.i./ha. The spraying volume was 1 L per 10 m<sup>2</sup> using a knapsack sprayer at 12 kPa. Sampling recommended 1 WAT and continued at 2-weekly intervals. The second treatment was applied on 17 June 1999, and sampling was continued for another two months.

## RESULTS AND DISCUSSION

*Fig. 1* shows the percentage of arthropods in the plot before and after treatment with fipronil. The four most dominant orders found before spraying were Hymenoptera (28.7%), Homoptera (19.1%), Collembola (17.8%) and Diptera (16.3%); the prespraying abundance of the orders Thysanoptera, Acarina, Coleoptera and Araneida were 7.7, 4.7, 2.3 and 2.1% of total arthropods, respectively. Four orders, namely Orthoptera, Hemiptera, Lepidoptera and Isopoda, were present at less than 1%. The percentage population of Collembola significantly increased after the first and second sprays, whilst the population of Hymenoptera significantly



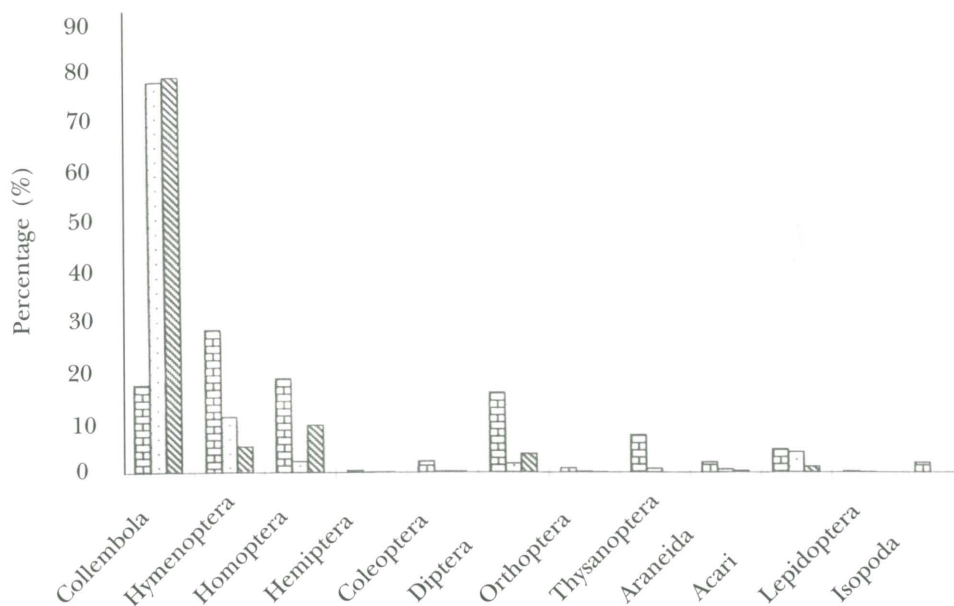


Fig. 1: Arthropod community in *Cuphea ignea* before and after spraying with fipronil

decreased after each treatment with fipronil. For Homoptera and Diptera, the population significantly decreased after the first spray but recovered slightly after the second spray. Generally, the percentage of the remaining arthropod populations decreased after the first and second treatments.

Fig. 2 shows the total number of arthropod families before and after treatment. The number of arthropod families was 81 before treatment, decreasing to 44 and 47 after the first and second sprays, respectively. The number of families belonging to Diptera and Hymenoptera recorded before treatments were 24 and 20, respectively, whilst Homoptera and Coleoptera had 9 families each.

Only 4 families of Collembola were found in the plot, but the number of individuals sampled was large. Hemiptera and Acarina were represented by 3 families each before treatment: Araneida, 6 families; and Lepidoptera, Thysanoptera and Isopoda, 1 each.

This paper reports in detail changes in the families representing only the four dominant orders (> 10% of the total populations), namely Hymenoptera, Homoptera, Collembola and Diptera. Some families of these orders were present only in small numbers during the sampling period.

Fig. 3 shows the population of Collembola families before treatment with fipronil and after the first and second treatments. After the first treatment, a larger number of Collembola were observed than of other orders (Fig. 1). Only four families of Collembola were trapped: Entomobyiidae, Isotomidae, Poduridae and Sminthuridae. Before treatment, the total number of Isotomidae was 60, but it increased to 785 after the first spraying and to 938 after the second spraying. The total number of Entomobyiidae before spraying with fipronil was 296, but numbers decreased to 190 and 87 after the first and second sprayings, respectively. The total numbers of Poduridae and Sminthuridae were low prior to spraying but increased drastically after both sprayings. The total number of Poduridae was 20 before spraying. However, the number increased to 639 after the first spray, and then decreased to 121 after the second spray. For Sminthuridae, the total number before spraying was 73, increasing to 394 after the first spraying, before decreasing to 140 after the second spray. The fluctuations in population abundance of Poduridae and Sminthuridae indicate the short term effects of fipronil on population increase of the two families of Collembola.

Fig. 4 shows the effect of the two applications of fipronil on the population of Hymenoptera.

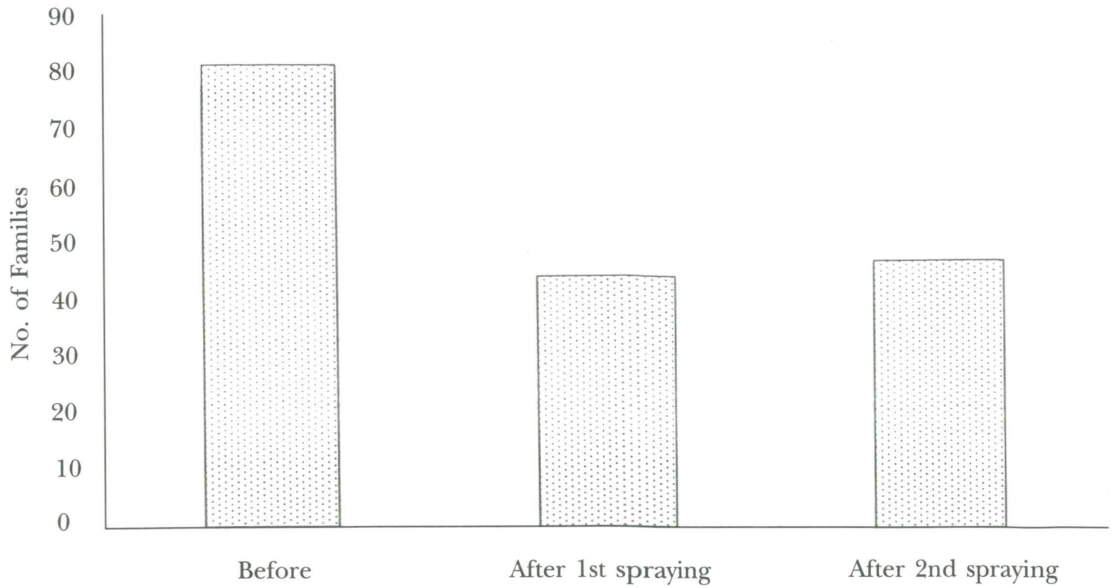


Fig. 2: Total number of families before and after spraying

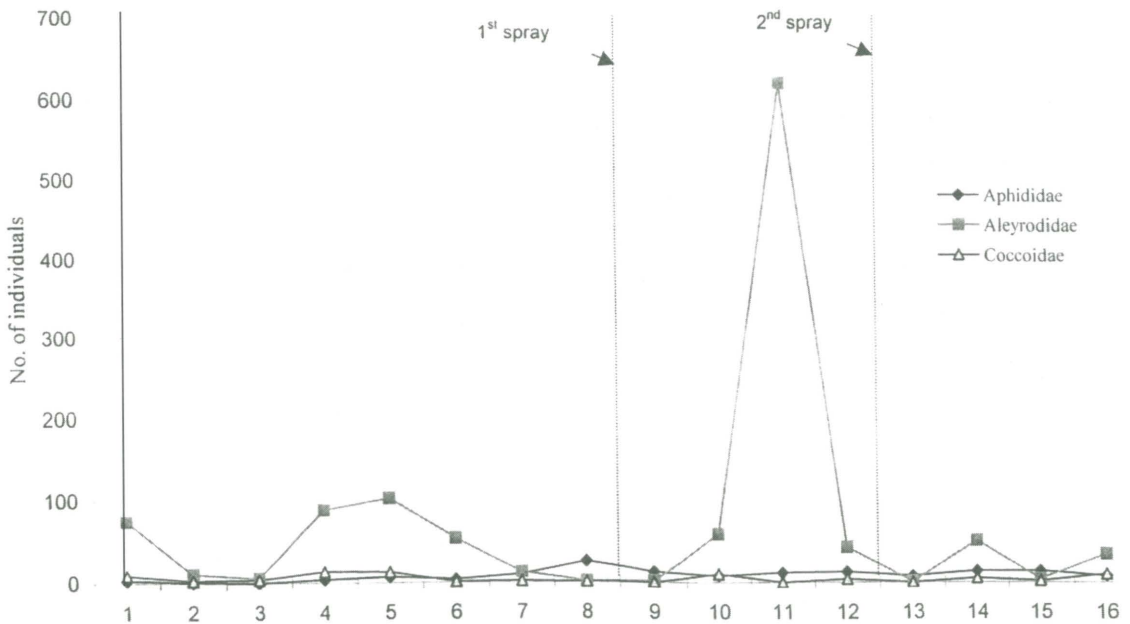


Fig. 3: Effect of repeated applications of fipronil on Collembola population

Twenty families of Hymenoptera were identified prior to the treatment, but this number decreased to 14 after the first spraying. The population of Formicidae was higher than that of other families of Hymenoptera. The highest number of Formicidae was observed at 8 weeks before treatment. The total number of Formicidae before treatment was 400, but it decreased to 254 and 34 after the first and second treatments

respectively. Other families of Hymenoptera were present in small numbers before treatment, and their populations similarly decreased after the first and second treatments. Before spraying with fipronil, the total numbers of Scelionidae, Mymaridae and Ceraphronidae were 72, 38 and 33, respectively. The numbers of Mymaridae were reduced to 10 and 74, and of Scelionidae, to 8 and 7 after the first and second sprayings,

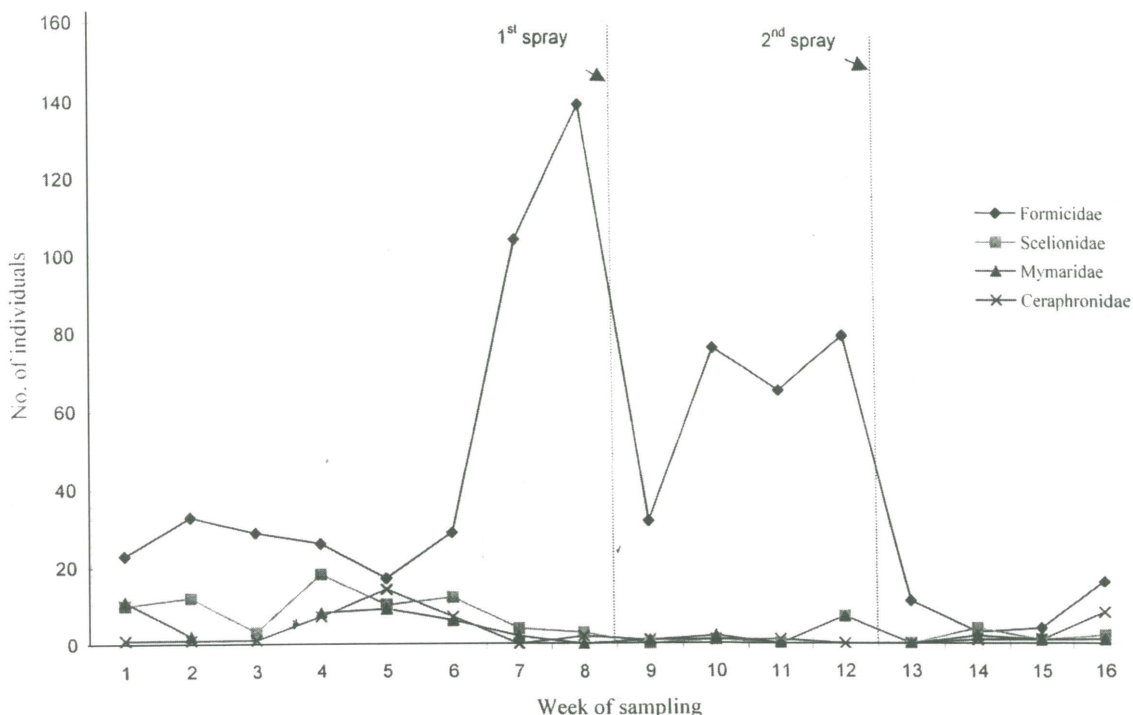


Fig. 4: Effect of repeated applications of fipronil on Hymenoptera population

respectively, whilst the Ceraphronidae were reduced from 33 prespraying to 3 after the first spraying, but this number increased after the second spraying.

Fig. 5 shows the effect of two applications of fipronil on Homoptera populations. The seven families of Homoptera found before the first spraying decreased to 3 after the first spray. The population of Aleyrodidae was comparatively higher than those of the other families after spraying with fipronil. The total number of Homopterans trapped before spraying was 353, but this number increased to 704 after the first spraying and subsequently decreased to 91 after the second spraying. Before treatment, the total numbers of Aphididae and Coccoidae were 55 and 47, respectively. After the first and second sprayings, the numbers were reduced to 46 and 44 for Aphididae and 14 and 17 for Coccoidae, respectively.

Fig. 6 shows the population of Diptera before and after treatment with fipronil. Diptera was represented by 24 families before treatment, but this number was reduced to 7 and 9 families after the first and second sprayings, respectively. However, many of the families existed in small numbers. The dominant family of Diptera was

Phoridae, with a total of 157 individuals trapped before spraying. This was followed by Cecidomyiidae, Agromyzidae and Chironomidae (58, 52 and 49 individuals, respectively). After the first and second sprayings, many of the dominant Phoridae were only 20 and 10 after the first and second sprayings, respectively.

Twelve orders and 81 families were represented in the 2,521 arthropods observed in the plot before spraying with fipronil. Most arthropod families belonged to the order of Hymenoptera, but many from other orders were also present in the plot. These results indicate that fipronil applications caused a shift in the population of arthropods in the experimental plot. The numbers of families decreased after applications of fipronil, and some families disappeared.

This work also shows that the number of individuals from the three families of Acarina (namely Tetranychidae, Ixodidae and Oribatei) declined significantly after the second spraying. The total numbers of Tetranychidae, Ixodidae and Oribatei were 97, 11 and 13, respectively, after the first spraying, but decreased significantly to 7, 6 and 5 after the second spraying.

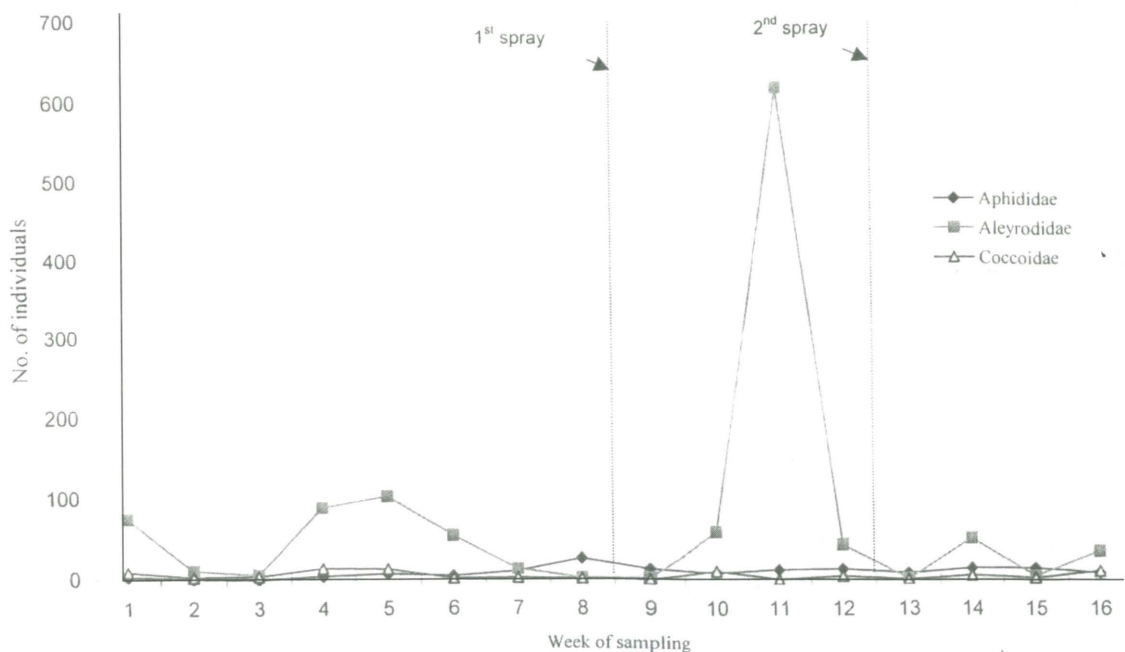


Fig. 5: Effect of repeated applications of fipronil on Homoptera population

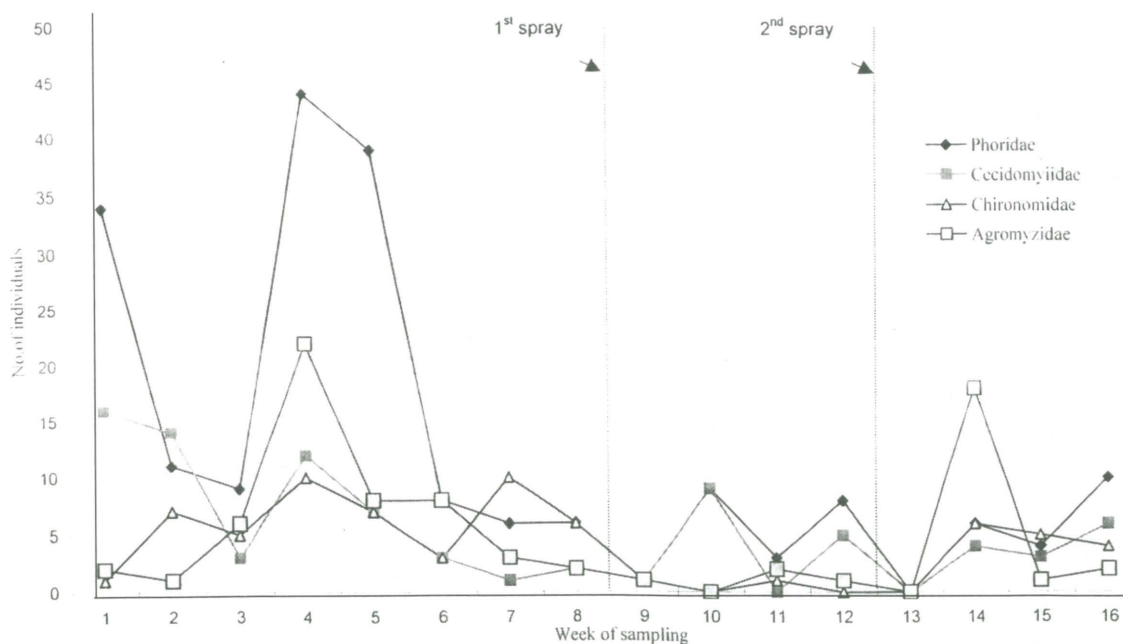


Fig. 6: Effect of repeated applications of fipronil on Diptera population

Application of fipronil may reduce some predators and parasitoid populations due to the reduction in host populations. For instance, a decrease in pest populations such as Homoptera, Hemiptera, Acarina and Orthoptera would cause a reduction in certain predators, such as Staphylinidae (Coleoptera), and in such

parasitoids as Scelionidae and Pteromalidae (Hymenoptera).

Our results show that no Staphylinidae was detected after the second spraying, while for the Pteromalidae and Scelionidae, the total numbers obtained after the second spraying was 1 and 7, respectively. Populations of these predators or



parasitoids declined, probably due to limited food sources and hosts. Certain parasitoids such as Ichneumonidae and Braconidae have very specific hosts, so the disappearance of their hosts due to pesticides such as fipronil would affect their population (Idris and Grafius 1993).

In contrast, some families such as Isotomidae, Poduridae and Sminthuridae belonging to the Collembola and Aleyrodidae (Homoptera) increased in numbers after the application of fipronil. This may be due to reduction in predator (Coleoptera) and parasite (Hymenoptera) populations and reduction in interspecies competition. The life cycles of these families were shorter (approximately 3 weeks) at 24-30°C (Yee and Toscano 1996) as compared to their predators. Therefore, we suggest that these families were able to recover faster than their predators, resulting in their number increasing tremendously.

It is noteworthy that the population of Aleyrodidae increased during the first sampling but decreased 2 weeks later. A marked reduction of Aleyrodidae population could well be due to different numbers being in the larval stage during the two samplings. The two methods of sampling used were only able to trap adults, not larvae. A rise in the Aphelinidae population (Hymenoptera), which is a parasitoid for Aleyrodidae, may also have contributed to the reduction in the Aleyrodidae population.

The experimental results have shown that there is no correlation between abiotic factors (such as temperature and pH) and the abundance of arthropod populations (data not shown). This observation is different from results reported in similar research in temperate regions (Goulet and Huber 1993; Davey *et al.* 1998; Danxiao *et al.* 1999). These researchers report a positive correlation between soil arthropods (such as Isopoda and Formicidae) with salt content, available K and P and organic matter content of the soil. Abiotic factors, such as temperature during winter, may cause the life cycle of soil arthropods in temperate regions to be prolonged (Fujiyama 1996) when compared to the length of life cycles of soil arthropods in tropical regions. The temperature in the study plot ranged from 23° to 35°C, a temperature range suitable for their development. Therefore, the results concerning arthropod abundance cannot be compared directly between temperate and tropical regions due to variability in temperature effects.

In conclusion, in this study we found that, while a great diversity of arthropod populations existed before the treatment, application of fipronil caused a decline in the population of some families, which may be directly due to its toxicity. However, we also found that the number of Collembola populations (such as Isotomidae) increased after the fipronil treatment, perhaps due to a reduction in predator populations or family tolerance to fipronil. However, further study needs to be carried out to confirm this speculation. Also, we note that findings on arthropod abundance cannot be compared directly between temperate and tropical regions due to variability in the effects of temperature and other environmental factors. Therefore, we suggest further investigation of the environmental effects, and the mechanisms responsible for those effects, on arthropod populations. Such information would provide a clear picture on their distributions in different soil conditions.

#### ACKNOWLEDGEMENTS

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