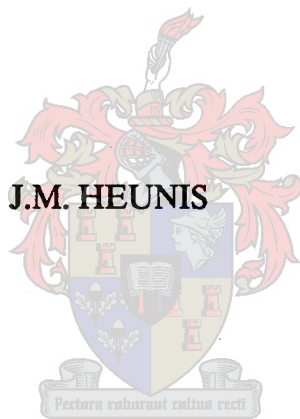


**THE INFLUENCE OF SYNTHETIC PYRETHROIDS ON PHYTOPHAGOUS
MITES AND THEIR NATURAL ENEMIES IN APPLE ORCHARDS.**

by



**Thesis presented in partial fulfilment of the requirements for the degree of
Master of Science at the university of Stellenbosch.**

Study leader: Dr. K.L Pringle

March 1992

Declaration

I the undersigned hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

Signature

Date:

Abstract

The effects of synthetic pyrethroids on the spider mite, *Tetranychus urticae* Koch, and its natural enemies was investigated. The pyrethroid cyfluthrin, sprayed for the control of fruit weevil *Phlyctinus callosus*, did not cause mite outbreaks and was not harmful to the predators when sprayed before they appeared on the apple trees. This spray also gave good control of thrips, bollworm (*Heliothis armigera*) and fruit weevil (*P. callosus*). A late season spray of deltamethrin against codling moth, caused an increase in the phytophagous mite population. This was associated with a temporary reduction in the population level of the predatory beetle, *Oligota fageli*.

The plants found on the orchard floor were examined. The plant diversity was low and plants that acted as hosts of phytophagous mites during the winter were scarce. However, *Solanum nigrum* carried high mite populations and infected the adjacent apple trees. The plants were too few to have an effect on the whole orchard.

Eight synthetic pyrethroids were tested for repellency in a leafdisk dip and spray bioassay using *T. urticae*. Deltamethrin and fenvalerate caused no walk-off. Cyfluthrin and fluvalinate caused moderate walk-off and bifenthrin, cyhalothrin and lambda-cyhalothrin caused high walk-off.

UITTREKSEL

Die invloed van sintetiese piretroïedes op die rooispinmyt, *Tetranychus urticae* Koch en hul natuurlike vyande is ondersoek. Die piretroïed, cyfluthrin, gespuit vir die beheer van snuitkewer, *Phlyctinus callosus*, het nie mytuitbrake veroorsaak nie en was ook nie skadelik vir predatore nadat dit vroeg in die seisoen, voordat myte in die appelbome verskyn het, gespuit is nie. Die bespuiting het ook goeie beheer van blaaspootjies, bolwurm (*Heliothis armigera*) en *P. callosus* gegee. Deltametrien wat later in die seisoen toegedien is vir die beheer van kodlingmot, *Cydia pomonella*, het 'n mytuitbraak veroorsaak. Dit word geassosieer met die tydelike onderdrukking van die populasievlak van die predatoriese kewer, *Oligota fageli*.

Die plante in die dekgewas is ondersoek. Die plant-verskeidenheid was laag en plante wat kon dien as oorwinterings gashere vir fitofage myte kon dien was skaars. *Solanum nigrum* het egter groot bevolkings myte gedra wat die appelbome naaste aan hulle eerste besmet het. Daar was egter te min van hierdie plante om 'n invloed op die hele boord te hê.

Agt piretroïedes is vir afwering van *T. urticae* in 'n blaarskyf doop en spuit bioessaï getoets. Deltamethrin en fenvalerate het geen afwering getoon nie. Cyfluthrin en fluvalinate het 'n redelike afwering, terwyl bifenthrin, cyhalothrin en lamda-cyhalothrin het 'n hoë mate van afwering getoon

CONTENTS

CHAPTER 1 INTRODUCTION	1
CHAPTER 2 THE EFFECTS OF SYNTHETIC PYRETHROIDS ON PHYTOPAGOUS MITES AND THEIR PREDATORS IN APPLE ORCHARDS	
2.1 Introduction.....	5
2.2 Materials and Methods.....	6
2.2.1 Pyrethroid for fruit weevil control	6
2.2.1.1 Experimental Design.....	6
2.2.1.2 Sampling.....	7
2.2.1.3 Data Analysis.....	8
2.2.2 Pyrethroid for codling moth control.....	8
2.2.2.1 Experimental Design.....	8
2.2.2.2 Sampling.....	9
2.2.2.3 Data Analysis.....	9
2.3 Results and Discussion	9
2.3.1 Pyrethroid for fruit weevil control	9
2.3.1.1. Phytophagous mites and their natural enemies	9
2.3.1.2 Fruit damage.....	19
2.3.2 Pyrethroid for codling moth control	23
2.4 Conclusion	28
CHAPTER 3 THE STUDY OF THE COVER CROP IN APPLE ORCHARDS.	
3.1 Introduction.....	32
3.2 Material and Methods.....	32
3.2 Results and Discussion	33
CHAPTER 4 REPELLENCY OF PYRETHROIDS TO <i>T.URTICAE</i> KOCH.	
4.1 Introduction.....	44
4.2 Material and Methods.....	45
4.2.1 Mites	45

4.2.2 Chemicals.....	46
4.2.3 Bioassays	46
4.2.3.1 Leaf-disk dip technique.....	46
4.2.3.2 Spray-technique.....	47
4.4 Results	48
4.4.1 Dip-technique.....	48
4.4.2 Spray-technique.....	48
4.4 Discussion	53
CHAPTER 5 GENERAL DISCUSSION AND CONCLUSIONS.....	54
Acknowledgements.....	56
Summary.....	57
References	59

LIST OF TEXT FIGURES

Figure

1.1	10
1.2	12
1.3	13
1.4	14
1.5	16
1.6	17
1.7	18
1.8	20
1.9	21
1.10	22
1.11	24
1.12	25
1.13	27
1.14	29
1.15	30

3.1	36
3.2	38
3.3	40
4.1	49
4.2	50
4.3	51
4.4	52

LIST OF TABLES

3.1	35
3.2	43
4.1	46

CHAPTER 1

INTRODUCTION

During the past quarter of a century more emphasis has been placed on integrated pest management (IPM) to obtain optimum pest control with the minimum use of pesticides. Since the mid-1960's the strategy of insect pest control on apples has shifted slowly from one based solely on pesticides to one incorporating alternate means of control, and improved selectivity of pesticides and application techniques. Implicit in this kind of pest management is the maximum use of natural enemies of arthropod pests.

Several non-chemical and modified chemical approaches to pest control have been utilized in apple orchards, but most growers still depend heavily upon synthetic organic pesticide treatments to achieve commercial control of the key pests. The present emphasis on integration of chemical and biological methods reflects the consensus that insecticides will continue to be part of most pest management programs until satisfactory alternative methods are found (Croft and Brown, 1975).

Probably the greatest success with alternative methods has been achieved with the IPM programs for phytophagous mites which have been researched and implemented in several countries, and which take advantage of predatory arthropods (Croft and Brown, 1975). Not only has there been a reduction in pesticide usage since the adoption of IPM tactics, but the incidence of insect and mite resistance has been stabilized in many apple pests (Croft and Hoyt, 1978).

The successful establishment of natural enemies in apple orchards depends, in part, on their ability to survive applications of pesticides for the control of other pests. For the past three to four decades organophosphate insecticides have been used to control the major apple pests (e.g. codling moth, *Cydia pomonella* (L.)) in most of the fruit growing areas. Subsequently the synthetic pyrethroids have been introduced. They have a high level of efficiency against a broad range of insect pests and low mammalian toxicity (Elliott, 1977). Pyrethroids gave good commercial control of codling moth in the U.S.A. (Hoyt, *et al.*, 1978). In South Africa pyrethroids are mainly used for the control of the banded fruit weevil, *Phlyctinus callosus* Boh., on apples. The pyrethroids are broad spectrum pesticides and are harmful to beneficial insects, including bees and predators. For example, pyrethroids have caused outbreaks of woolly apple aphid, *Eriosoma lanigerum* (Hausman.), on apples in Washington (Croft and Hoyt, 1978).

In addition, major disadvantages of the use of pyrethroids are the numerous instances of phytophagous mite outbreaks (Hall, 1979; Hoyt *et al.*, 1978; Zwick and Fields, 1978). Several explanations have been given for these outbreaks. The usual explanation suggests the elimination of predaceous mites and insects by pyrethroids, allowing phytophagous mite populations to increase unchecked. Wong and Chapman (1979) showed that three predaceous mite species, *Thyphlodromus pyri* Scheuten, *T. occidentalis* Nesbitt, *Amblyseius fallacis* Garman, are sensitive to the pyrethroids cypermethrin and fenvalerate. Roush and Hoy (1978) reported that several strains of two-spotted spider mite, *Tetranychus urticae* Koch, were 20-40 times more resistant to permethrin than the predator, *T. occidentalis* Nesbitt.

Another explanation involves the changes pyrethroids may bring about on apple leaf biochemistry which may increase fecundity of the phytophagous mites (Breese and Searle, 1977).

In addition, pyrethroids exhibit a repellent effect on phytophagous mites (Ruscoe, 1977; Penmann *et al.*, 1981) which further complicates the situation. Hall (1979) found that *T. urticae* females moved out of areas with high pyrethroid residues to areas with lower residues or areas completely free of these residues. Many laboratory studies (e.g. Iftner & Hall, 1983(a); Penman *et al.*, 1986) showed that when pyrethroids were applied to leaf surfaces bearing mite colonies, the mites became active and began dispersing to areas free of residues by walking off the leaves or by dropping down on threads of webbing. This can be of importance, because studies have shown that if mite population density increases, the reproductive potential declines, even if there is enough food available (Iftner & Hall, 1983(a)). Iftner and Hall (1983 a) hypothesised that where pyrethroids are sprayed the larger colonies of mites found under field conditions could be broken into smaller, more scattered colonies. An increased reproductive potential in these smaller colonies could be expected, which would result in an earlier mite build-up.

Furthermore, even with the most efficient spraying techniques, apple trees are seldom sprayed uniformly. Coverage, in terms of chemical deposits, is affected by many factors (height of trees, thickness of foliage, wind, droplet size, etc.). As a result, there are many small, unsprayed areas within the canopy (Hall *et al.*, 1975(a)). Pielou (1960) found that the repellent effect of DDT caused greater concentration of mites in the upper parts of the tree and that this stratification was directly correlated to the lesser insecticide deposits in the upper region. It is likely that a similar phenomenon is being exhibited in the field with the use of pyrethroids. Since most new pyrethroids have a half-life on foliage of several days to several weeks (Ruscoe, 1977), mites could be expected to move back into sprayed areas as residues decline. As a result, this dispersion into smaller colonies in which there is reduced competition, resulting in higher reproductive potential, could be an important factor in mite outbreaks, and would remain so

until crowding and leaf quality begin to affect the population adversely (Iftner and Hall, 1983(a)).

The dispersal of phytophagous mites as a result of pyrethroid application, could also affect the few mite predators which survive the spray. The smaller and more scattered colonies would result in more time and energy being spent searching for prey, reducing the energy available for reproduction (Iftner and Hall, 1983(a)).

The objective of this study was to determine the effect of two pyrethroids on phytophagous mite populations and their predators in apple orchards. The study was extended to include the cover crop as the phytophagous mite concerned, *T. urticae*, is polyphagous and known to feed on a number of plants in the cover crop. In addition, laboratory studies were carried out with different pyrethroids to determine which of these were repellent to phytophagous mites.

CHAPTER 2

THE EFFECTS OF SYNTHETIC PYRETHROIDS ON PHYTOPHAGOUS MITES AND THEIR PREDATORS IN APPLE ORCHARDS

2.1 Introduction

Population outbreaks of phytophagous mites after the use of synthetic pyrethroids in orchards are well documented (Hall, 1979; Hoyt *et al.*, 1978; Zwick and Fields, 1978; Kapetanakis *et al.*, 1985).

The usual explanation for this phenomenon is the elimination of predaceous mites and insects by pyrethroids which allow mite populations to increase unchecked (Roush and Hoy, 1978; Zwick and Fields, 1978; Chapman and Penman, 1979). However, Hoyt *et al.* (1978), Hall (1979), and Iftner (1983) (in Iftner and Hall 1983 b) have shown that increasing pyrethroid rates in the absence of predators also result in an increase in the numbers of phytophagous mites.

In South African apple orchards synthetic pyrethroids are registered for the control of fruit weevil, *Phlyctinus callosus* Boh. and codling moth, *Cydia pomonella* (L.). The present study was designed to investigate the effect of the synthetic pyrethroids commonly used against these pests on the natural enemies of the red spider mite, *Tetranychus urticae* Koch. Two early season sprays of

cyfluthrin for weevil control, and a late season spray of deltamethrin for codling moth control were investigated. In deciding whether pyrethroids can be used for insect pest management on apples the advantages and disadvantages have to be compared. Therefore, the degree of commercial control of various pests achieved by cyfluthrin was also investigated.

2.2 Materials and methods

2.2.1 Pyrethroid for fruit weevil control

The work was conducted in an apple orchard near Grabouw. The basic spray program consisted of mancozeb (2 applications) and a mixture of mancozeb and bitertanol (5 applications) for scab control, and triadimefan (6 applications) for powdery mildew control. Codling moth was controlled using one application of azinphos-methyl in mid summer, following on the banded fruit weevil sprays (described later) which controlled this pest during the early part of the season.

2.2.1.1. Experimental design

The experiment was laid out in a randomized block design with four replicates. Plots were blocks of Granny Smith apple trees consisting of five rows of thirty trees per row. In addition to the program described above, one plot was sprayed with cyfluthrin and the other with acephate, which was thought to have little effect on phytophagous mites and their natural enemies. These chemicals were applied twice, once during the first week of November and once during the last week of November. The centre row of each treatment was used for sampling to monitor the activity of phytophagous mites and their predators as well as to determine damage caused by insects to the fruit. This experiment was carried out over two seasons (1988/89 and 1989/90).

cyfluthrin for weevil control, and a late season spray of deltamethrin for codling moth control were investigated. In deciding whether pyrethroids can be used for insect pest management on apples the advantages and disadvantages have to be compared. Therefore, the degree of commercial control of various pests achieved by cyfluthrin was also investigated.

2.2 Materials and methods

2.2.1 Pyrethroid for fruit weevil control

The work was conducted in an apple orchard near Grabouw. The basic spray program consisted of mancozeb (2 applications) and a mixture of mancozeb and bitertanol (5 applications) for scab control, and triadimefan (6 applications) for powdery mildew control. Codling moth was controlled using one application of azinphos-methyl in mid summer, following on the banded fruit weevil sprays (described later) which controlled this pest during the early part of the season.

2.2.1.1. Experimental design

The experiment was laid out in a randomized block design with four replicates. Plots were blocks of Granny Smith apple trees consisting of five rows of thirty trees per row. In addition to the program described above, one plot was sprayed with cyfluthrin and the other with acephate, which was thought to have little effect on phytophagous mites and their natural enemies. These chemicals were applied twice, once during the first week of November and once during the last week of November. The centre row of each treatment was used for sampling to monitor the activity of phytophagous mites and their predators as well as to determine damage caused by insects to the fruit. This experiment was carried out over two seasons (1988/89 and 1989/90).

For the pre-harvest evaluation five trees in the centre row were randomly selected as sampling units. All the fruit on each tree were counted during both seasons. Pre-harvest damage was assessed only during the first season, as the pre-thinning sample during the second season revealed extremely low levels of damage.

2.2.1.3. Data analysis

The data for mite days, insect days, C and P were analysed using a 2 x 2 factorial model with season and treatment as main effects. The C and P values give an indication of the dispersion patterns of organisms (Tanigoshi *et al.*, 1975). Differences between treatments in these two parameters would indicate differences in dispersion patterns between treatments. Prior to analysis all the above data were transformed using natural logs to stabilize the variance. The results of the damage assessment were analysed using the factorial analysis for binary data described by Cox (1970).

2.2.2. Pyrethroid for codling moth control

The effect of one late-season pyrethroid treatment as registered for the control of codling moth, *C. pomonella*, was investigated in a second orchard experiment in which a pyrethroid was compared with an organophosphate. The timing of these sprays was determined by moth counts in pheromone traps (Madsen *et al.*, 1972, Myburgh *et al.*, 1972).

2.2.2.1. Experimental design

This experiment was also laid out in a randomized block design with four replicates. Plots were blocks of five rows of apple trees, with ten trees per row. Three of the plots were Granny Smith trees and one was Starking. The pyrethroid used was deltamethrin, and the organophosphate azinphos-methyl, which was thought to have little effect on phytophagous mites and their

predators. The pyrethroid was sprayed in the second week of February. This was carried out over one season only.

2.2.2.2. Sampling

Sampling of leaves for phytophagous mites and predators was carried out by taking two leaves from the outside and two leaves from the inside of each of ten trees in the centre row of each treatment. The leaves were treated the same way as in the experiment described above. Mites (both the red and green form of *T. urticae*), eggs and predaceous mites and insects on the leaves were counted using a microscope. Sampling of *O. fageli* was as described in 2.2.1.2. above.

2.2.2.3. Data analysis

The average number of phytophagous mites per leaf was analysed using a factorial model with date and treatment as main effects. The mean colony size (C) and the P-value (Tanigoshi *et al.*, 1975) were also determined. These data were analysed as described above to determine if there were any changes in the dispersion statistics. Prior to analysis all the above data were transformed using natural logs to stabilize the variance.

2.3 Results and discussion

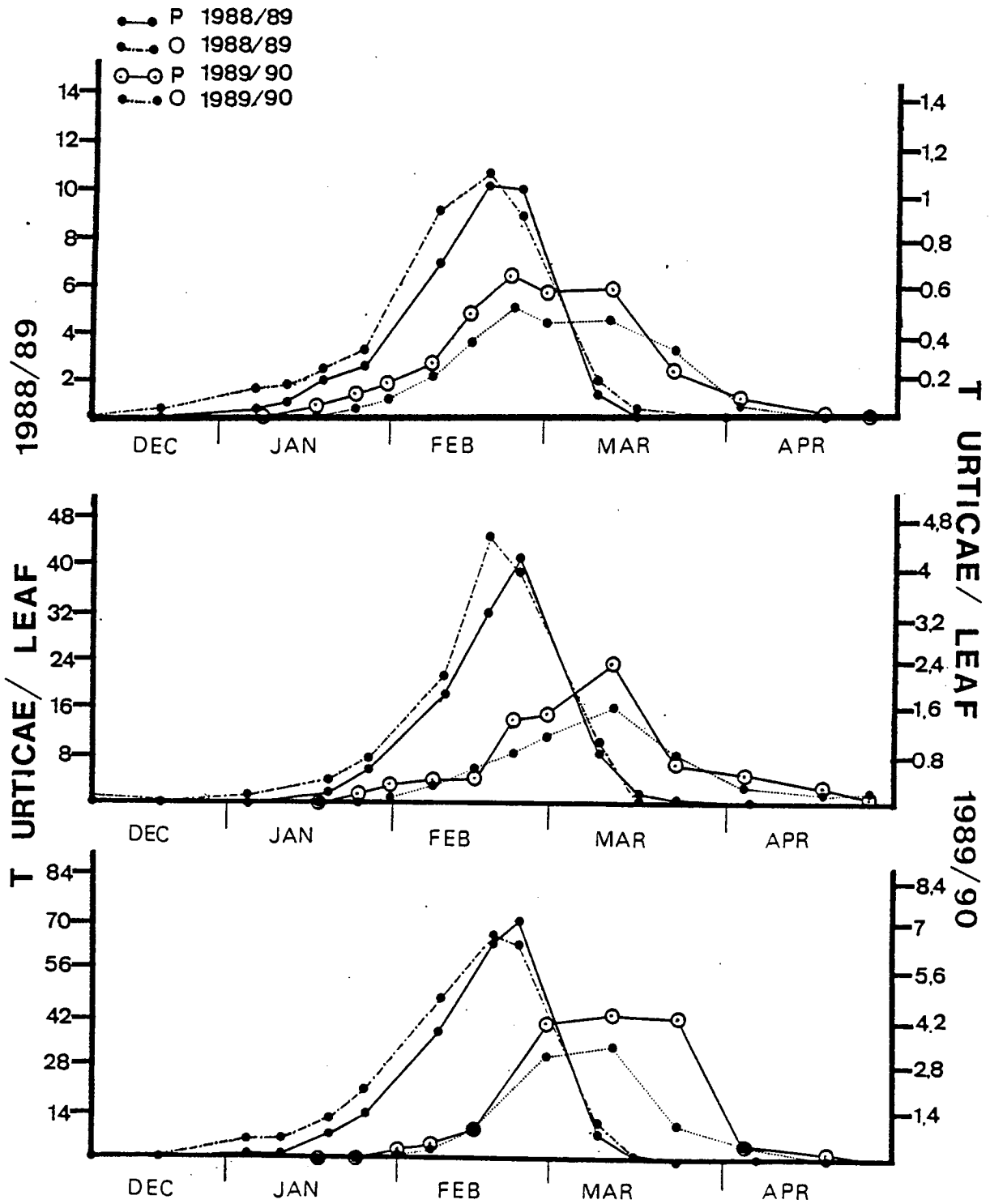
2.3.1 Pyrethroid for fruit weevil control

2.3.1.1. Phytophagous mites and their natural enemies

The population fluctuations of the adult females, the immature stages and males, and the eggs of *T. urticae* for both seasons are illustrated in Fig. 1.1. Phytophagous mites appeared late in the season in this orchard. In the 1988/89 season mite activity started in the first week of January and reached a peak in February. This was earlier than in the 1989/90 season when mites became active from the middle of January and reached a peak between late February to the middle of March (Fig. 1.1A). The number of mites per leaf differed greatly for



Fig. 1.1: Population fluctuations of mature female *T. urticae* (A), immature and male *T. urticae* (B), and *T. urticae* eggs (C) for the pyrethroid (P) and organophosphate (O) treatment for both seasons.



the two seasons. In the 1988/89 season a maximum of 10,19 mites per leaf was recorded compared to 0,59 for 1989/90. This was supported by the factorial analysis of variance using mite days for *T. urticae* which indicated no interactions between season and treatments ($F_{1;9} = 0.12$; $P = 0.74$) or differences between treatments ($F_{1;9} = 0.02$; $P = 0.90$), but differences between seasons ($F_{1;9} = 127,76$; $P < 0.001$). The main effects are shown graphically in Fig. 1.2.

The factorial analysis of variance for the mean colony size, C, and percent leaves bearing the mean colony size, P, (Fig. 1.3A and B respectively) for the first season indicated no interactions between treatment and date ($F_{9;57} = 0.45$, $P = 0.90$ for C and $F_{9;57} = 0.51$, $P = 0.86$ for P) or difference between treatments ($F_{9;57} = 0.72$, $P = 0.41$ for C and $F_{1;57} = 0.92$ for P). However, in the second season, there were interactions between treatments and date for the C values ($F_{9;57} = 2.13$; $P = 0.04$) (Fig. 1.3D). The interactions was due to higher C values early in the season in the pyrethroid than in the organophosphate treatment. In addition, there were no interactions for the P-value ($F_{9;57} = 0.86$; $P = 0.56$) but there was a slightly higher P-value ($F_{1;57} = 3.34$; $P = 0.07$) in the pyrethroid treatment (Fig. 1.3C). The higher P-values throughout the season and C-value early in the season suggest that there were more and larger colonies in the pyrethroid treatment.

The graphs for the population fluctuations of adult and immature *O. fageli* recorded on the sticky traps are given in Fig. 1.4A and B respectively. When phytophagous mite activity reached a peak in the 1988/89 season (Fig 1.1) *O.fageli* started to increase rapidly. The high predator activity could be one of the reasons why mite numbers dropped so rapidly (Fig. 1.1). In the first season much higher numbers of *O. fageli* were found on leaves and traps than in the second season, but there were no difference between the two treatments (Fig. 1.4). The lower phytophagous mite numbers in the second season could have been the

Fig. 1.2: The mean number of mite days and the corresponding 95% confidence interval for all active stages of *T. urticae* during the two seasons in the two treatments.

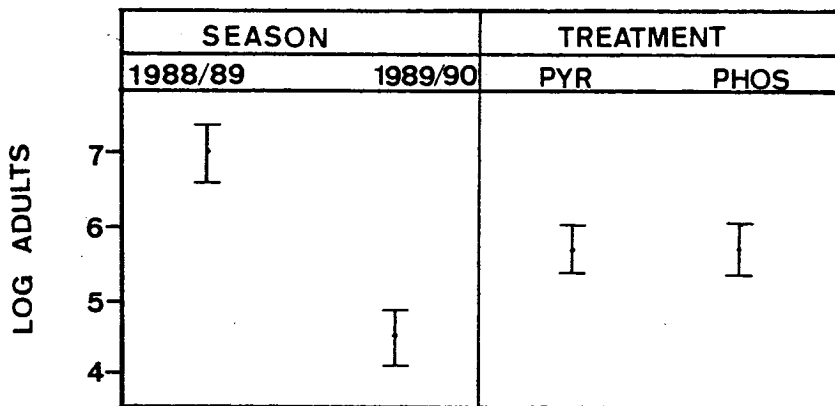


Fig. 1.3: The mean colony size (A) and P-value (B) for *T. urticae* for the 1988/89 season and the P-value (C) for the 1989/90 season for the two treatments and dates and the interaction between date and treatment for the colony size (D) for the 1989/90 season. Bars indicate 95% confidence intervals.

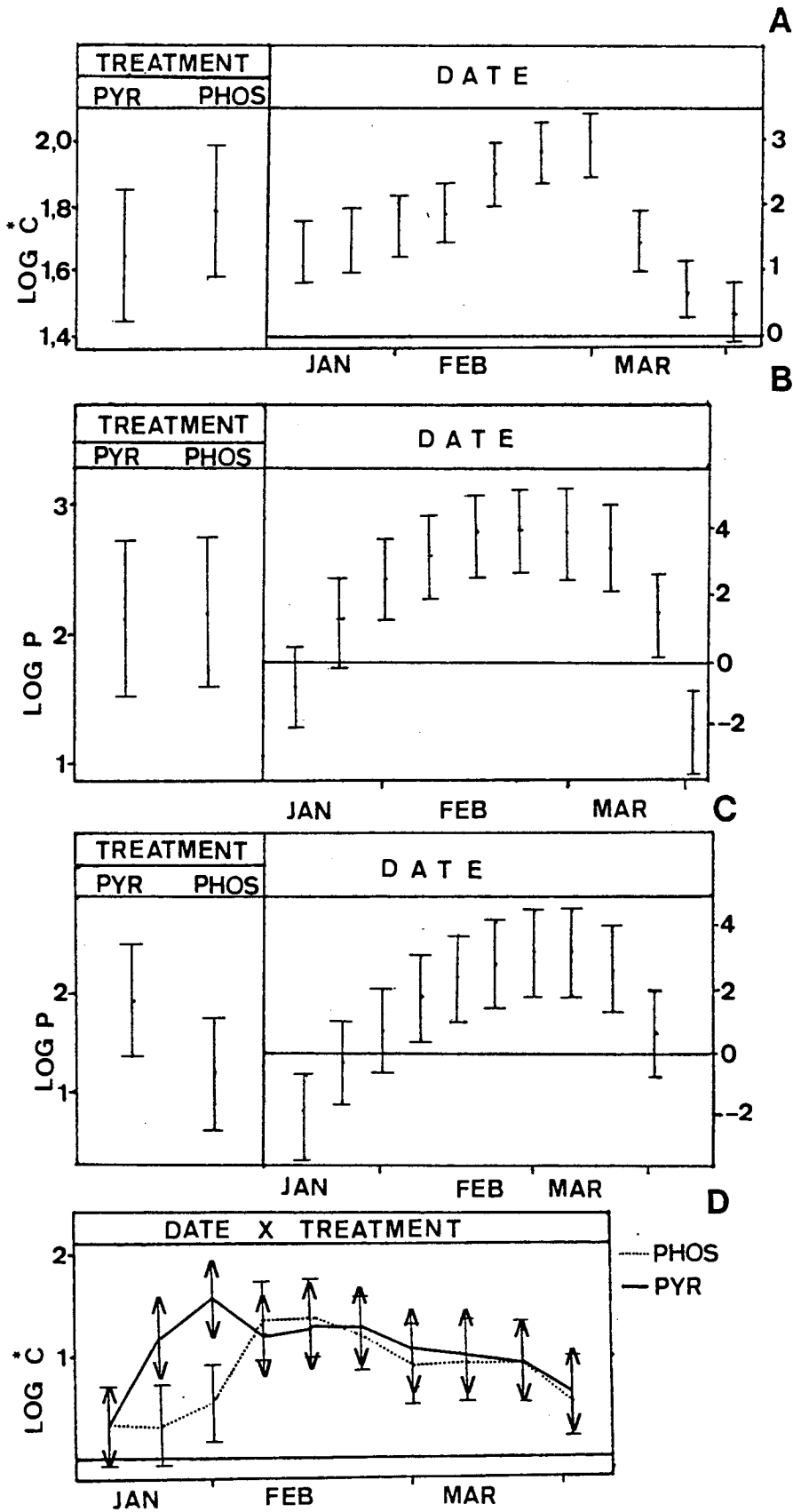
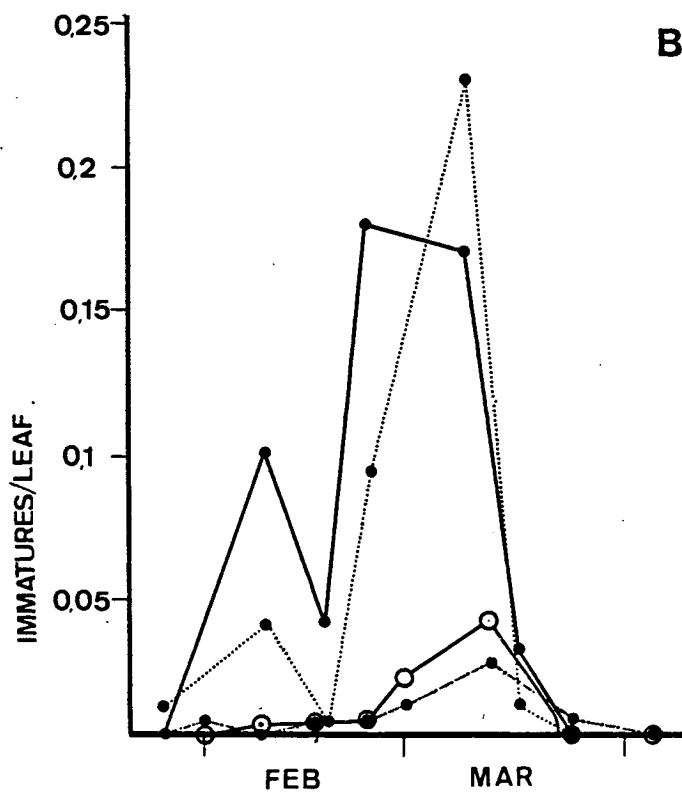
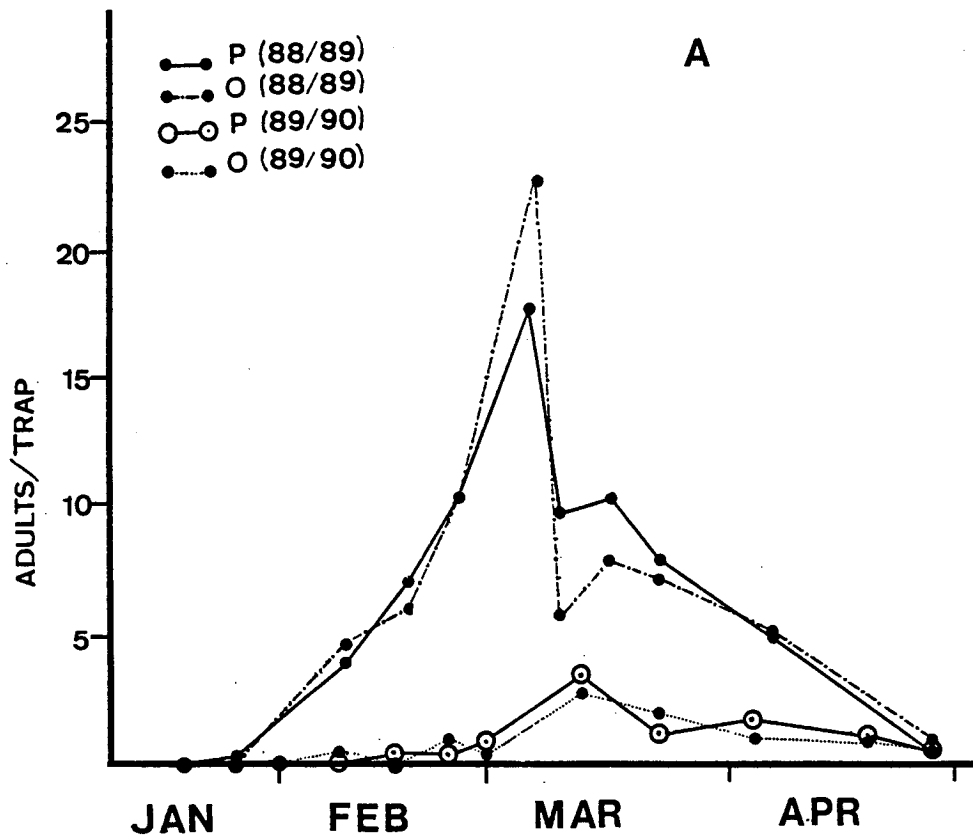


Fig. 1.4: Population fluctuations of adult (A) and immature (B) *O. fageli* for the pyrethroid (P) and organophosphate (O) treatment for both seasons.



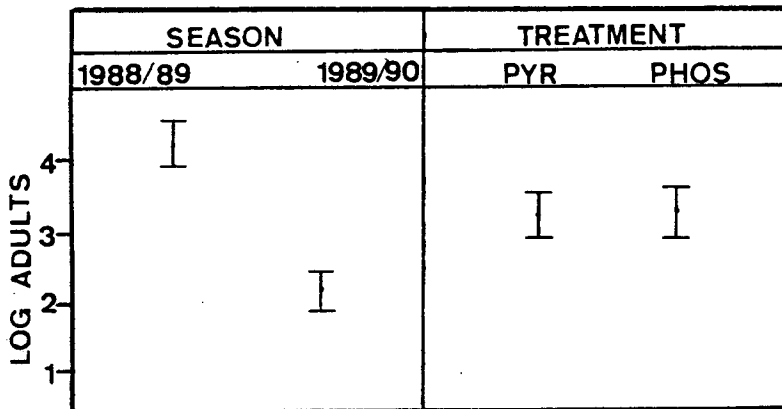
major cause for the lower *O. fageli* numbers found in comparison with the second season. Predator numbers decreased when their food source was exhausted.

The difference between seasons was supported by the factorial analysis of variance for the immature *O. fageli* (Fig. 1.5A) which indicated no interactions between seasons and treatments ($F_{1;9} = 0.07$, $P = 0.80$) or difference between treatments ($F_{1;9} = 0.34$, $P = 0.59$). However, there was a highly significant difference between the seasons ($F_{1;9} = 49.56$, $P < 0.001$). Similar results were obtained for adult *O. fageli* (interaction $F_{1;9} = 0.37$, $P = 0.56$; treatment $F_{1;9} = 0.00$, $P = 0.98$; season $F_{1;9} = 110.94$, $P < 0.001$). This is shown graphically in Fig. 1.5B.

The population fluctuations of adult and immature *S. aethiops* are shown in Fig. 1.6. The mean number of adult *S. aethiops* per trap and immatures per leaf with the corresponding 95% confidence intervals are given in Fig. 1.7. The *S. aethiops* numbers showed a similar increase and decrease of numbers to those of *O. fageli* (Fig. 1.6). In the case of adults (Fig. 1.7) there were no interactions between seasons and treatments ($F_{1;9} = 4.08$, $P = 0.07$) but both these main effects were significant (season $F_{1;9} = 187.9$, $P < 0.001$; treatment $F_{1;9} = 17.64$, $P < 0.001$). More *S. aethiops* were caught on traps in trees treated with acephate than in those treated with cyfluthrin (Fig. 1.6A). In the second season *S. aethiops* numbers were much lower and no larvae were found on the leaves. Pyrethroids could not have been the only cause for this decrease in numbers during the 1989/90 season, because counts of *S. aethiops* were low at all sites examined. Perhaps the reason is that mite numbers were so low in the second season (Fig 1.1). However, from the results of the 1988/89 season it appeared as if the use of the pyrethroid cyfluthrin suppressed *S. aethiops* numbers.

Fig. 1.5: The mean number of adult *O. fageli* per trap (A) and the mean number of insect days for immature *O. fageli* with their corresponding 95% confidence interval for the 1988/89 and 1989/90 seasons for both the treatments.

A



B

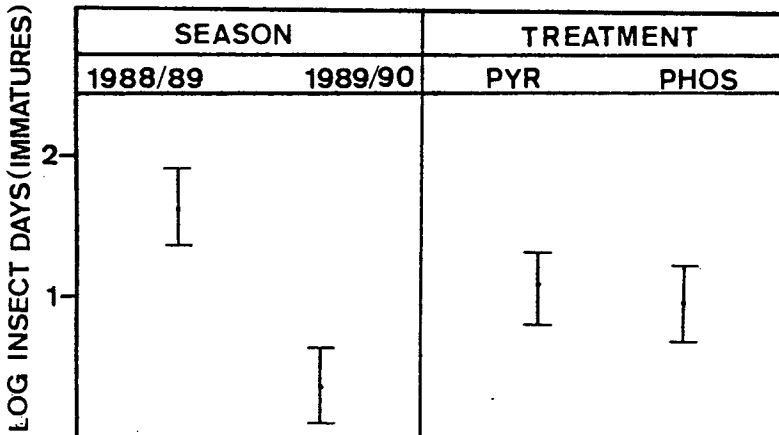


Fig. 1.6: Population fluctuations for adult (A) and immature (B) *S.aethiops* for the pyrethroid (P) and organophosphate (O) treatment for both seasons.

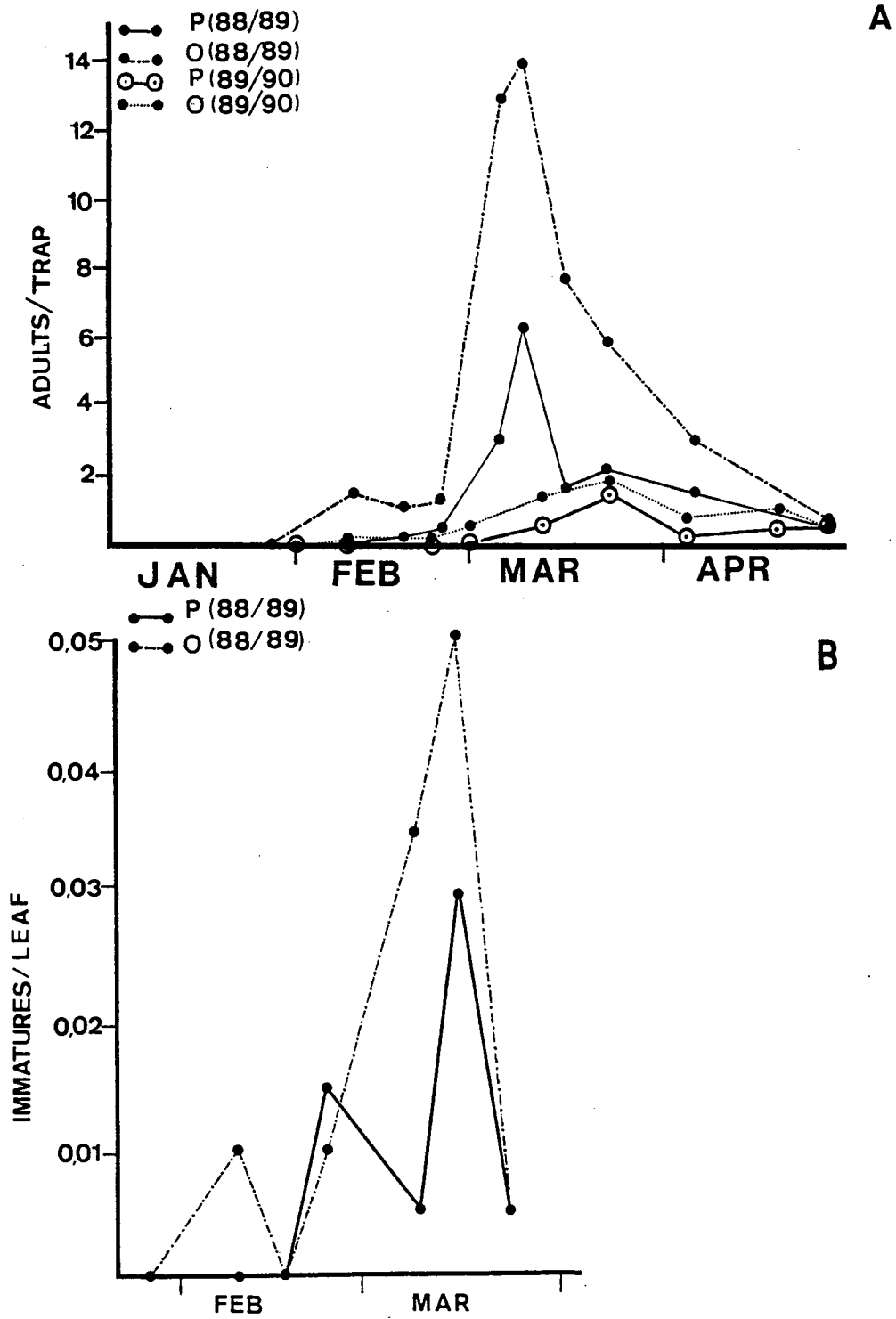
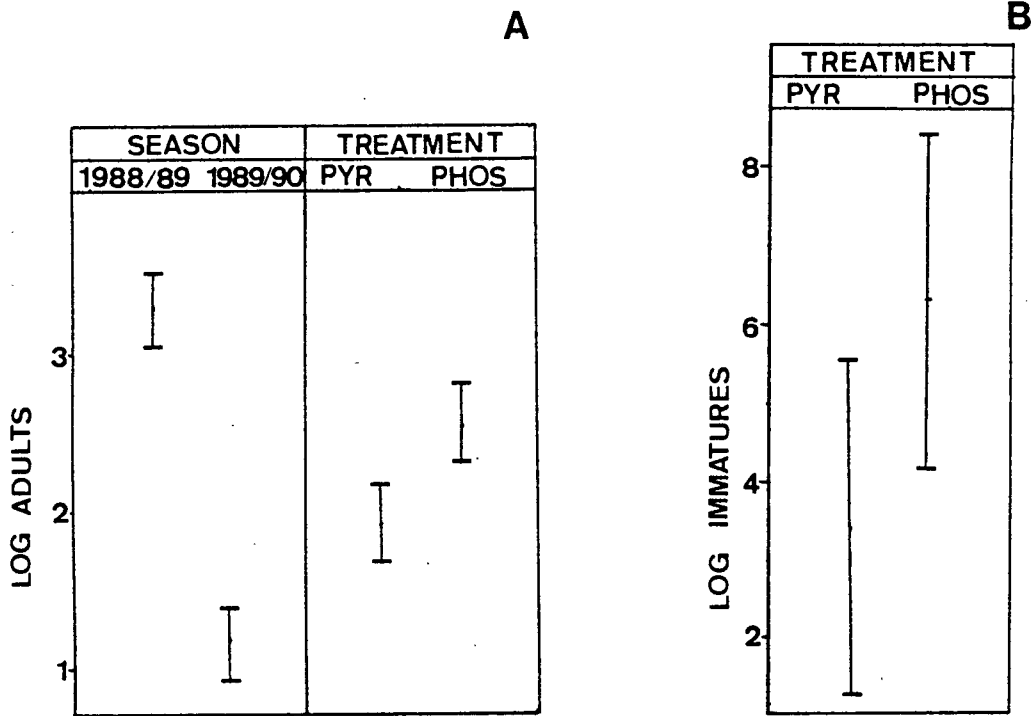


Fig. 1.7: The mean number of insect days and the corresponding 95% confidence intervals for adult *S. aethiops* for the 1988/89 and 1989/90 seasons and the two insecticide treatments (A), and for the immature *S.aethiops* (B) for the two insecticide treatments during the 1988/89 season.



The population fluctuations of the predatory mites, *Phytoseiulus persimilis* Anthias-Herriot, *Agistemus africanus* (Meyer & Ryke) and *Tydeus grabouwi* (Meyer & Ryke), are shown in Fig. 1.8. The numbers of the predatory mite *P. persimilis* reached a peak early in March of the first season but this predator was absent from the second season (Fig 1.8A). The numbers of *A. africanus* started to increase at the end of April of the first season. During the second season *A. africanus* reached higher population numbers than in the first season (Fig 1.8B). *T. grabouwi* first appeared in the second season and the population numbers reached a peak from March for the pyrethroid treatment and from early in April for the organophosphate treatment (Fig 1.8C).

The mean number of mite days per leaf and 95% confidence intervals of the three predators for the two seasons are given in Fig. 1.9. Numbers of the predatory mite *P. persimilis* showed no difference between the treatments ($F_{1;7} = 1.94$, $P = 0.26$) for the 1988/89 season (Fig.1.9A). In the 1989/90 season the predatory mite *T. grabouwi* was found on apple leaves. There were no differences between treatments ($F_{1;7} = 0.16$, $P = 0.72$), suggesting that the pyrethroid did not affect *T. grabouwi* more than the organophosphate (see also Fig. 1.9B).

In the case of *A. africanus* (Fig. 1.9C) there were no interactions between treatments and seasons ($F_{1;9} = 0.13$, $P = 0.73$) or differences between treatments ($F_{1;9} = 0.61$; $P = 0.61$). However, there was a difference between seasons ($F_{1;9} = 10.61$; $P = 0.01$), probably due to the availability of mites as food.

2.3.1.2. Fruit damage

The amount of damaged apples out of a thousand fruit is shown in Fig. 1.10. Damage was mainly caused by bollworm, *Heliothis armigera* (Hübner), fruit

Fig. 1.8: Population fluctuations of the predatory mites, *P. persimilis* (A), *A. africanus* (B) and *T. grabouwi* (C) over two seasons and for the two insecticide treatments..

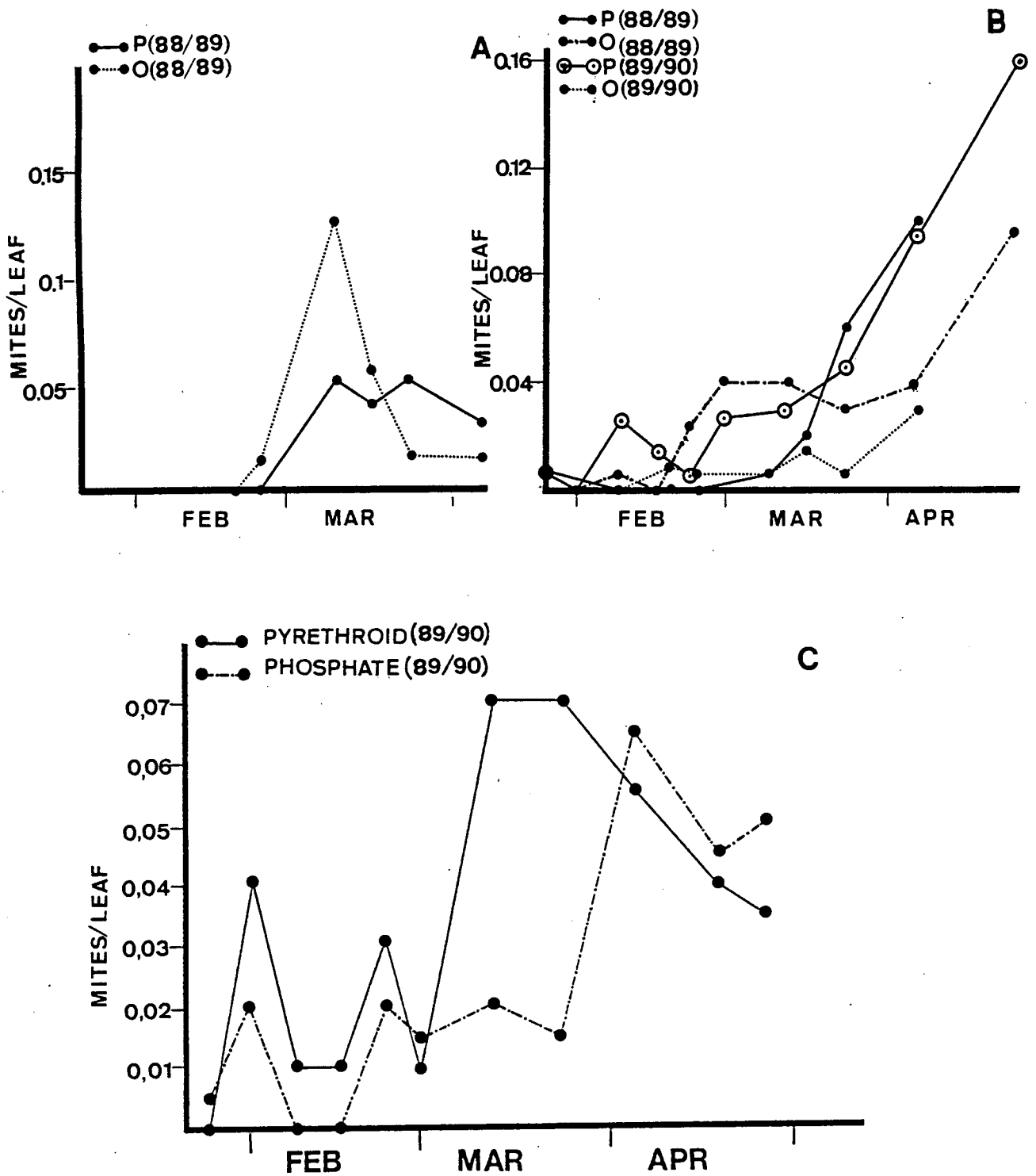


Fig 1.9: The mean number of mite days and the corresponding 95% confidence intervals for the two insecticide treatments for *P.persimilis* (A), *T. grabouwi* (B) and *A. africanus* (C) for the 1988/89 and 1989/90 seasons.

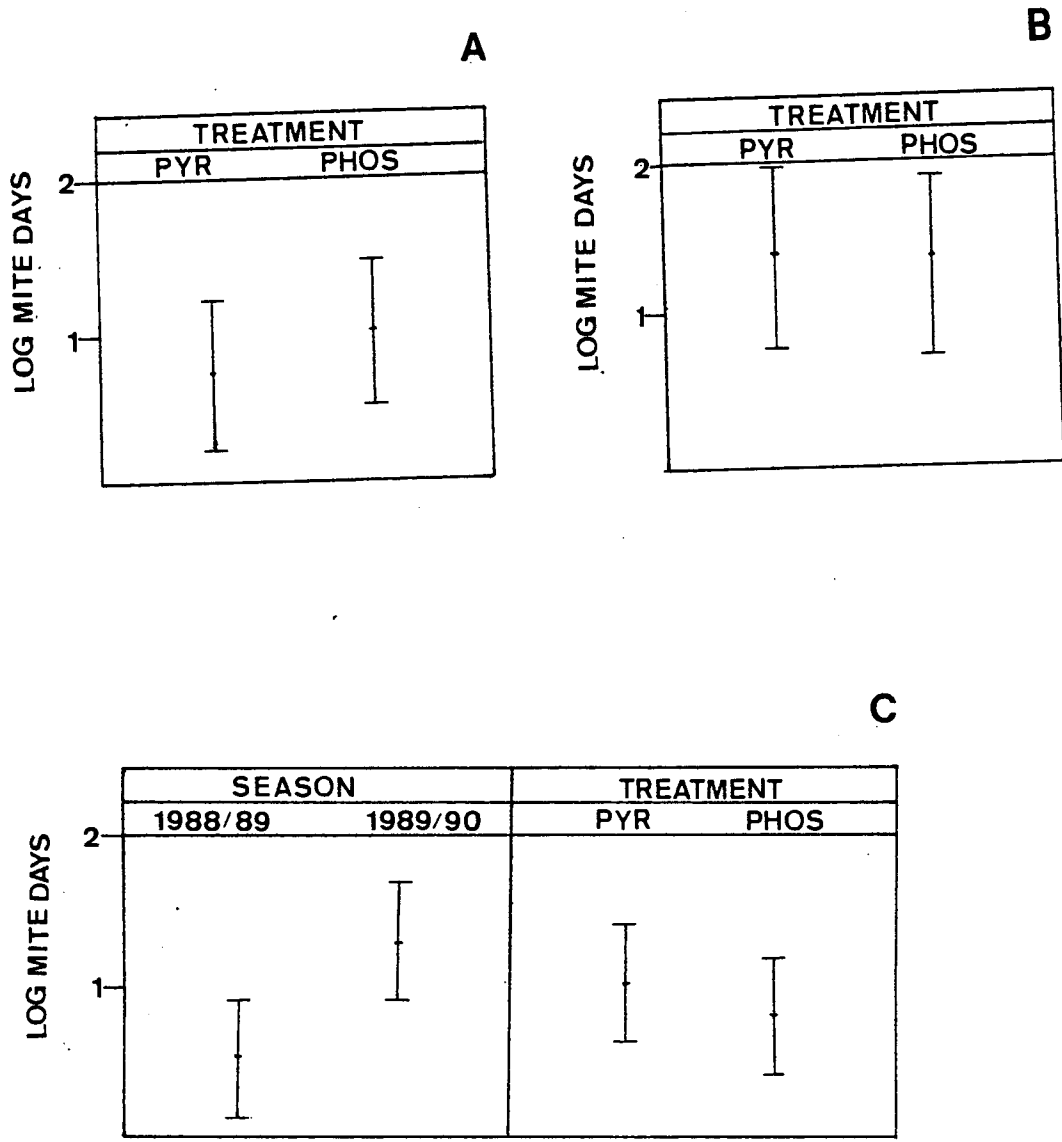
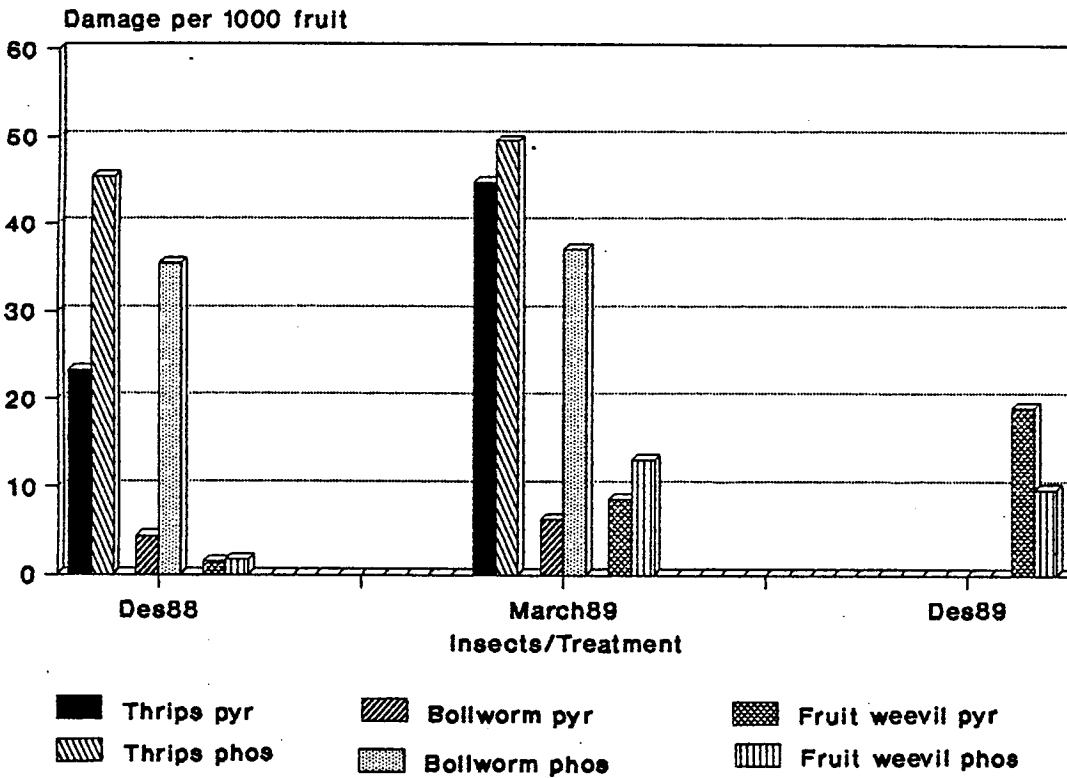


Fig. 1.10: Insect damage to apples recorded at three times of evaluation for each treatment.



weevil, *P. callosus* and unidentified thrips. Very few apples were damaged by codling moth, *C. pomonella*, (0.15%) and the results were ignored.

Thrips caused fairly heavy damage in the first season. There were no interactions between time of year and treatment ($Z = 1.59$; $P = 0.11$). The pyrethroid gave better control than the organophosphate ($Z = 2.17$; $P = 0.03$) in the first season and there were more thrips later in the season ($Z = 2.01$; $P = 0.04$). In the case of the bollworm the pyrethroid also gave better control ($Z = 6.21$; $P = 0.00$) and the percentage damage did not differ between the two times of the year ($Z = 0.5$; $P = 0.62$). In the second season no thrips or bollworm was found on the apples. The control of fruit weevil was very similar for the two treatments during both seasons. More fruit damage by fruit weevil was found in the March damage assessment than in the December assessment ($Z = 0.60$; $P = 0.00$). In the following year no difference was found between the two treatments for fruit weevil ($Z = 1.10$; $P = 0.27$).

2.3.2. Pyrethroid for codling moth control

The population fluctuations of the adult females, immature stages and males, and the eggs of *T. urticae* for the 1989/90 season are shown in Fig. 1.11. After the spray in February the numbers declined in the pyrethroid treatments, suggesting a mild miticidal effect, but thereafter the numbers increased rapidly to peak at the end of March. From April the number of mites per leaf declined rapidly.

The mean number and the 95% confidence interval for mites per leaf for both treatments and the mean number and the 95% confidence interval for the phytophagous mites per leaf are given in Fig. 1.12A. The factorial analysis of the numbers of motile mites per leaf indicated no interactions between date and treatment ($F_{7,45} = 1.18$; $P = 0.11$) but a significant difference between treatments ($F_{1,45} = 19.69$; $P < 0.01$), with higher population levels in the

Fig. 1.11: Population fluctuations of mature females (A), immatures and males (B) and eggs (C) of *T. urticae* where the pyrethroid deltamethrin and the organophosphate azinphos-methyl were applied as a late codling moth spray.

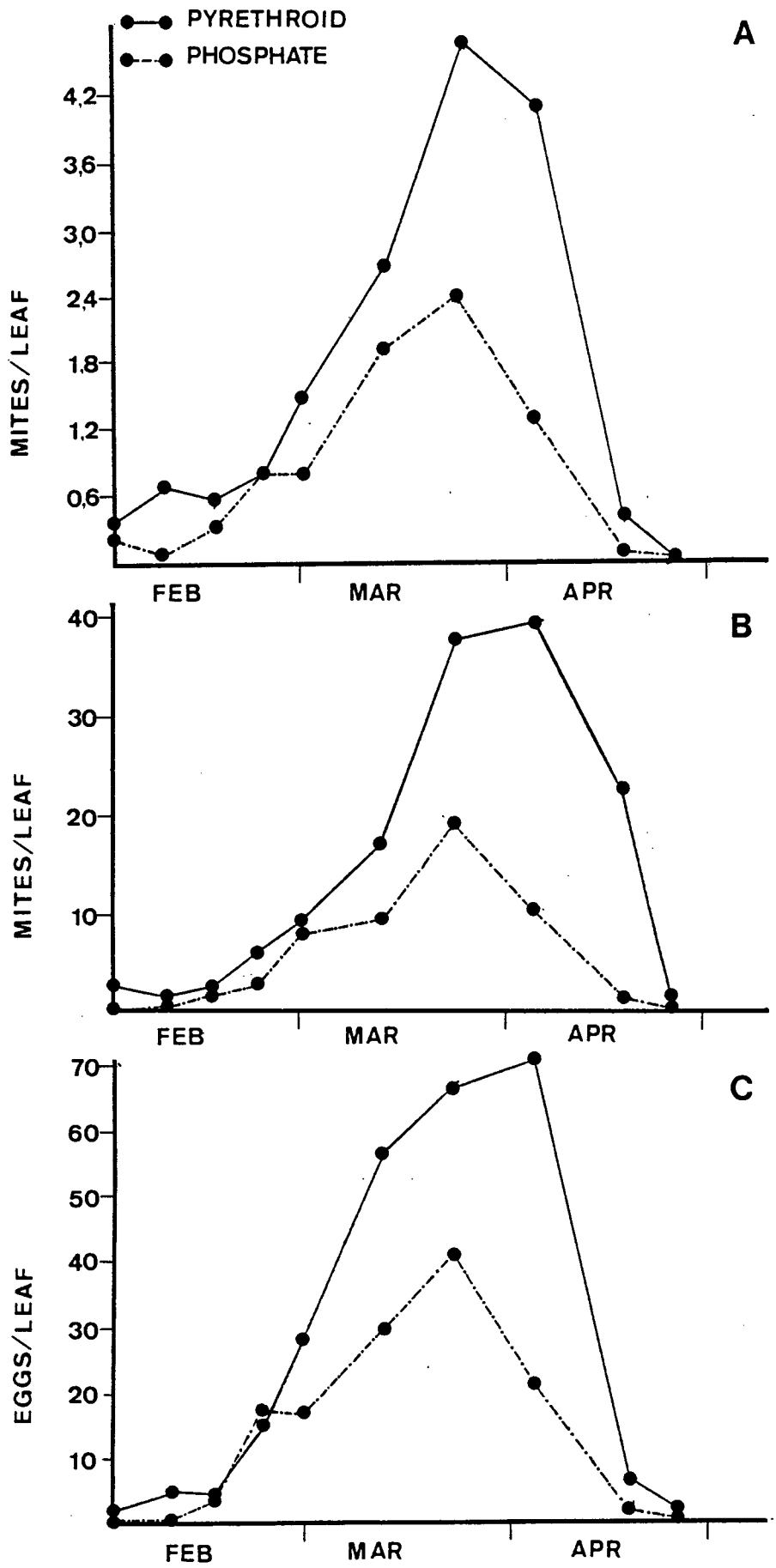
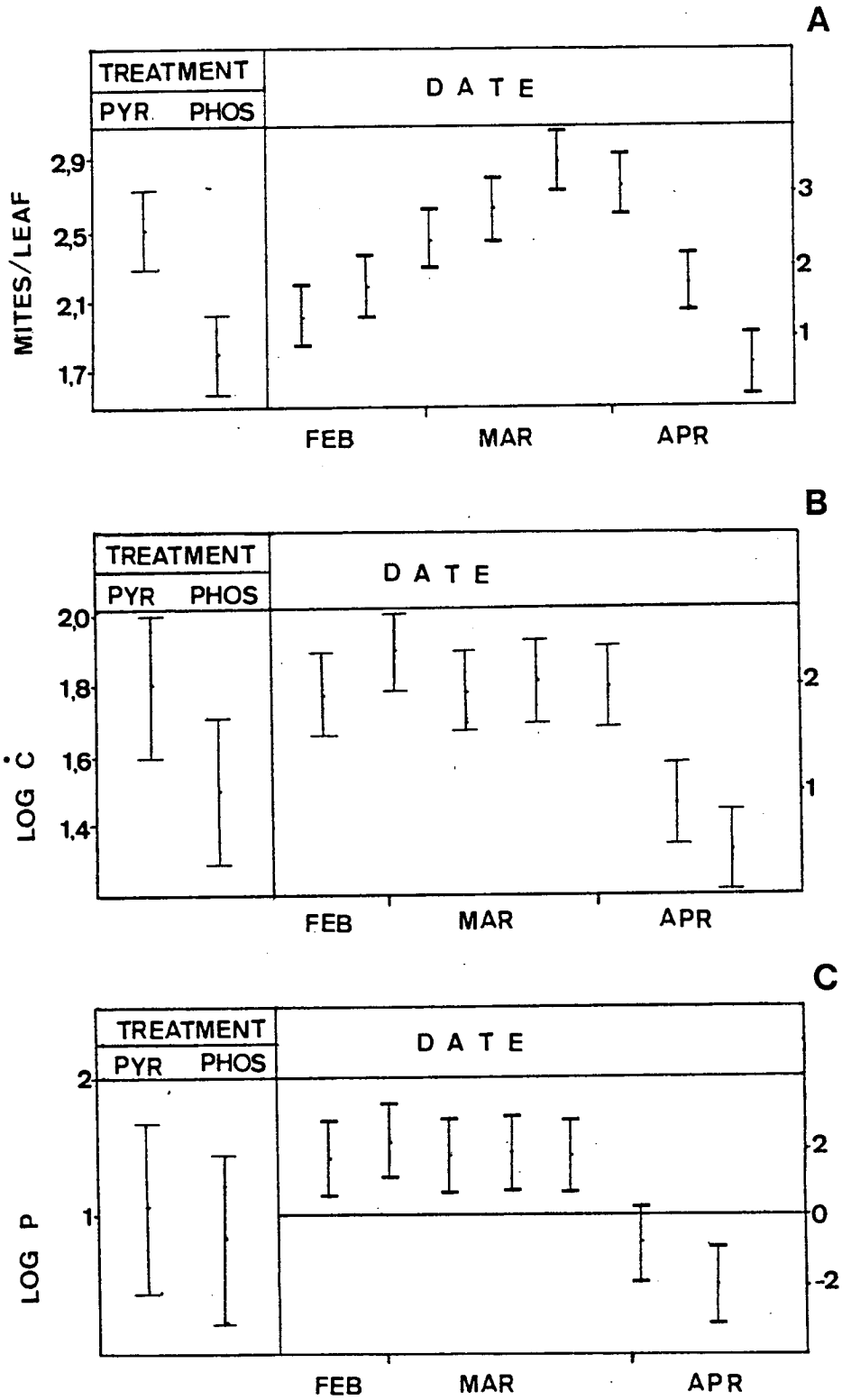


Fig. 1.12: The mean number of *T. urticae* per leaf for the two insecticide treatments and dates (A) and the mean colony size (B) and the P-value (C) for the two insecticide treatments.

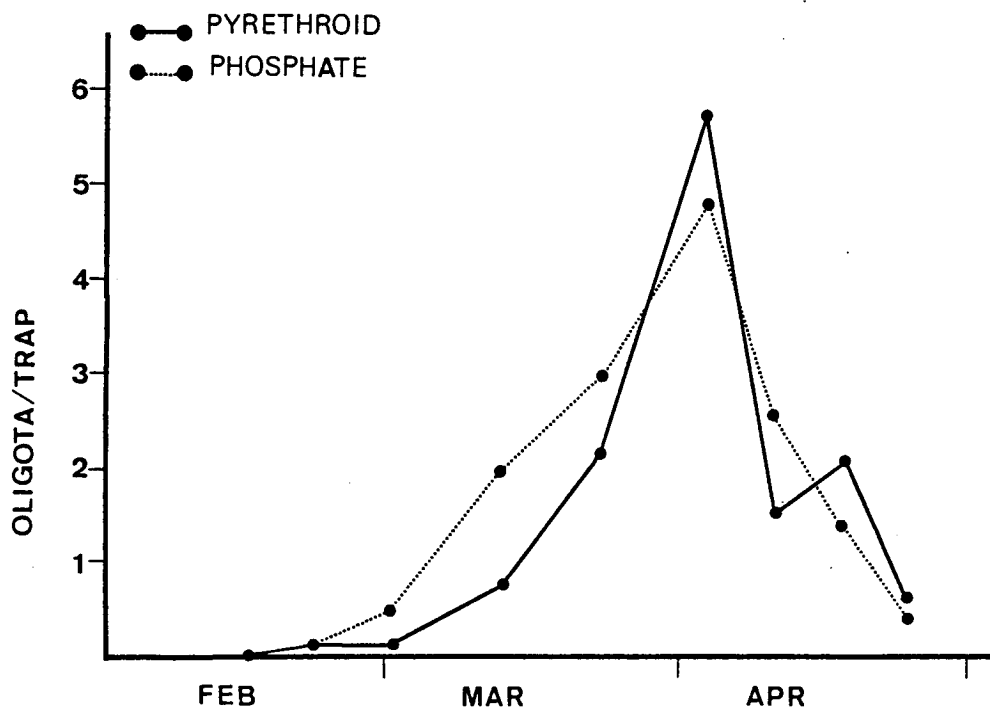


deltamethrin than in the azinphos-methyl treatment. Therefore, the pyrethroid deltamethrin, when used as a late season spray, could be a reason for mite outbreaks.

The mean colony size (C) of *T. urticae* and the P-value, with the corresponding 95% confidence intervals, are given in Fig. 1.12B and 1.12C respectively. The factorial analysis of variance indicated no interactions between treatment and date for either C and P ($F_{6;39} = 1.27$; $P = 0.29$ and $F_{6;39} = 0.58$; $P = 0.74$ respectively). There were differences between treatments for C ($F_{1;39} = 4.38$; $P = 0.04$), with the colony size higher in the pyrethroid treatment. However, for the P-value there was no interactions or difference between treatments ($F_{1;39} = 0.28$; $P = 0.61$). This suggests that the pyrethroid did not cause dispersal of the phytophagous mites into smaller colonies, but resulted in the gradual increase in the size of the colonies.

The population fluctuations of the adult stages of the predator *O. fageli* are given in Fig. 1.13. After the pyrethroid spray *O. fageli* numbers stayed the same but in the organophosphate treatment their numbers increased. This may indicate that *O. fageli* was negatively affected by the pyrethroid treatment. However, after two weeks their numbers started to increase rapidly. In both treatments the numbers of *O. fageli* peaked early in March, just after the peak of *T. urticae* (Fig. 1.11). High predator activity could have been one of the main reasons for the rapid decline in mite numbers. In the first replicate of the pyrethroid treatment very high mite counts were recorded. The number of *O. fageli* was also highest in this plot. However, it appeared as if *O. fageli* caused a rapid decrease in mite numbers, and when the food source was exhausted, the predator numbers also declined rapidly. There were more larvae in the pyrethroid treatment, probably due to the higher number of mites in this treatment. Therefore it appears that the pyrethroid residues did not affect *O. fageli* more than the organophosphate.

Fig. 1.13: The population fluctuations of adult *O.fageli* after a late season codling moth spray using a pyrethroid and organophosphate.



The factorial analysis of variance using mature *O. fageli* per trap indicated no interactions between treatment and date ($F_{7;45} = 1.01$; $P = 0.44$) or differences between treatments ($F_{1;45} = 1.17$; $P = 0.28$). However, there were interactions between date and treatment for immature *O. fageli* ($F_{6;39} = 8.11$, $P < 0.01$). It appeared as if these interactions were due to one date on which there were many more *O. fageli* immatures in the pyrethroid than in the organophosphate treatment. Besides this one date the numbers in the two treatments were very similar (Fig.1.14A).

In the case of *T. grabouwi* counts varied through the season (Fig. 1.15). There were interactions between date and treatment ($F_{1;45} = 2.23$; $P = 0.05$). The numbers tended to be higher in the organophosphate than in the pyrethroid treatment in all data except one, which could indicate that the pyrethroid had a negative effect on *T. grabouwi*.

2.4 Conclusion

According to Ruscoe (1977) most synthetic pyrethroids have a half-life on foliage of several days to several weeks. Since the last pyrethroid treatment was sprayed late in November in the first experiment the residues may have decreased to such a degree (see Chapter 4) that mites and some of the natural enemies were not influenced.

Another possible reason why no phytophagous mite population outbreak was recorded after the use of the pyrethroid cyfluthrin, may be found in the characteristics of the specific insecticide and its formulation. According to Penman *et al.* (1986) the relative contributions of direct toxicity and repellancy to overall pyrethroid activity vary depending on the chemical and its formulations. Bioassays using cyfluthrin indicated that the irritant effect of this material was relatively low (Chapter 4). Therefore, the dispersal into smaller, more scattered

Fig. 1.14: The mean number of immature *O. fageli* for the interaction between date and treatment (A) and the mean number of adult *O. fageli* for the two insecticide treatments and different dates (B).

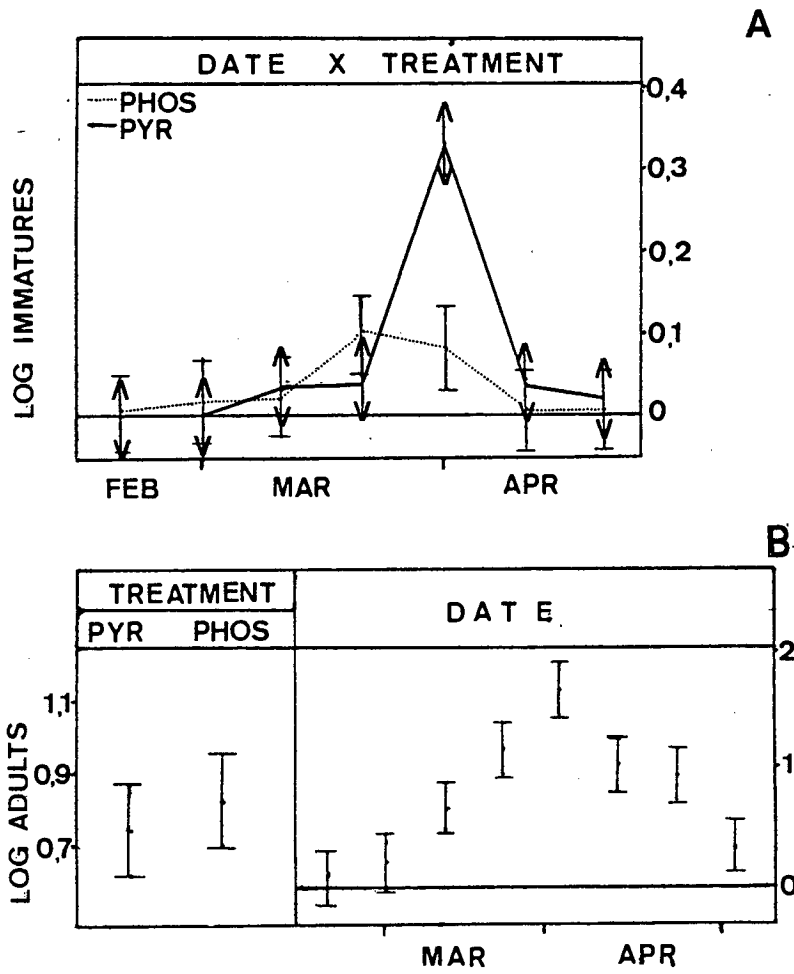
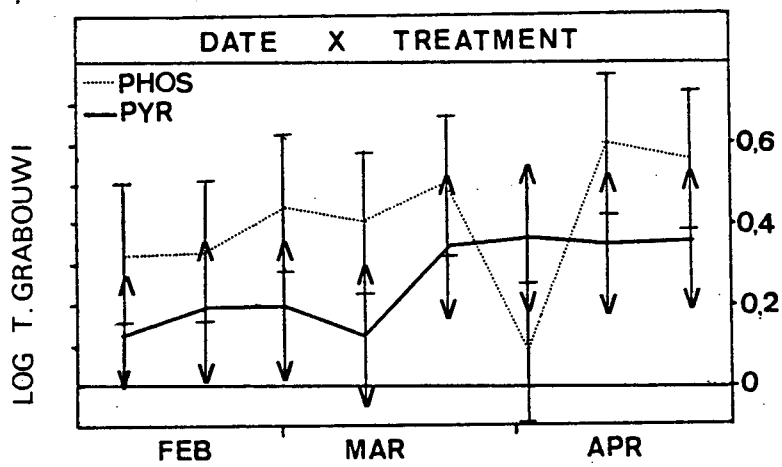


Fig. 1.15: The mean number of *T. grabouwi* for the interaction between dates and treatments for the two insecticide treatments.



colonies, which could lead to a higher reproductive potential (Iftner and Hall, 1983 (b)), was not so apparent.

Cyfluthrin gave better control of bollworm and thrips than the organophosphate azinphos-methyl and satisfactory control of the fruit weevil for which it was applied.

The pyrethroid deltamethrin caused a mite outbreak after being used as a late season spray for codling moth. This could be explained by the negative effect this pyrethroid had at the time it was sprayed on the *O. fageli* population. However, after two weeks the residue effect decreased and *O. fageli* numbers increased rapidly and initially lead to the decrease of mite numbers in the pyrethroid treatment.

Therefore, before a synthetic pyrethroid is used for commercial control in apple orchards the repellent effect of the spray and its residues on the phytophagous mites must be tested. The susceptibility of the natural enemies of phytophagous mites to the chemical must also be known.

CHAPTER 3

A STUDY OF MITES IN THE COVER CROP OF APPLE ORCHARDS.

3.1 Introduction

The mite, *Tetranychus urticae* Koch, is polyphagous and known to feed on a number of plants in the cover crop of apple orchards. In milder areas there is often no diapause during the winter and the mites live on these weeds, which, when present through the winter, could act as overwintering sites for the mites and their natural enemies.

In a study over a two year period it was determined what plants are to be found in an apple orchard and what their effect on the mite population could be.

3.2 Material and methods

The apple orchard near Grabouw that was used for comparing the effects of a pyrethroid spray with an organophosphate on banded fruit weevil (Chapter 2, 2.2.1) was used for this study. During the summer, weekly assessments of the plants on the orchard floor were made and every alternate week during the winter, when mite activity was low.

The bases of apple trees were used as the origin in a co-ordinate sampling system. The length of the first axis was the distance between trees within the row and the length of the second axis, at a right angle to the first, was half the

distance between rows. The latter distance was twice that of the former. Therefore, the length of the axes of the co-ordinate sampling system was also in that ratio. A stick with evenly spaced holes numbered from 1 to 10 was used to determine the positions of co-ordinates. A randomly generated number between 1 and 5 was selected. To find the co-ordinate on the first axis the stick was placed against the tree along the axis and a piece of wire was dropped through the hole corresponding to the random number. A random number between 1 and 10 was selected, and with the end of the stick on the point where the wire fell, the stick was orientated in a direction at right angles to the first axis. The piece of wire was dropped through the hole corresponding to the second random number. The plant or habitat first touched by the wire was noted. Other than plants, three habitats were identified, namely bare ground, dead weeds and litter. Litter was defined as plant material originating from apple trees.

Sampling was conducted in this way at the 25 trees in the centre row of the 8 plots described in 2.2.1.1. In this way the plants or habitats occurring at a total of 200 points were recorded on each sample date. From these data the percentage of the orchard covered by each plant could be estimated.

The orchard floor was divided into three areas, namely the drip, marginal and interrow areas. The drip area was the weed-free area directly under the canopy of the apple trees. The interrow area was the strip between the rows which did not receive herbicides, while the marginal area was at the interface of the above two and which could not be easily identified as either one.

Four periods or times of the year were defined: January to March (A), April to June (B), July to September (C) and October to December (D).

The data were arranged in a two-way table of periods (columns) by weeds (rows) and analyzed using correspondance analysis (Greenacre, 1985). The positions (drip, marginal and interrow) were entered as supplementary columns. Because the number of samples was not the same for each period, percentages were used in the analysis. Only plants that covered 0,3% of the apple orchard floor was included in the analysis except for *S. asper* and *S. nigrum*. They were included because of their importance as mite hosts.

Samples from the cover crop were taken by picking leaves from the plants in the cover crop. These samples were taken to the laboratory in paper bags in a cool bag. They were held in a cool room until they were examined with a microscope. All stages of mites and their predators were recorded on each plant species. Only plants that had all developmental stages of *T. urticae* were regarded as possible host plants.

3.3 Results and discussion

The plants identified in this orchard, those which were detected using the coordinate sampling system and those which were included in the correspondance analysis are listed in Table 3.1.

The correspondance analysis is given graphically in Fig 3.1. This indicates that each period during the year is in a separate quadrant, suggesting that the plants in each quadrant dominate during the different times of year. Litter, bare ground, *S. nigrum* and *F. scabra* are close to the origin indicating that they are present all the year round. *C. dactylon* dominates the late summer period (Period A, January to March). *P. dilatatum*, *E. crus-galli* and *D.*

Table 3.1: The plants identified in the apple orchard, the plants that were found with the sampling system and the plants that were included in the correspondance analysis.

PLANTS	Found with monitor system	Included in analysis
<i>Chenopodium album</i> L.	*	
<i>Conyza bonariensis</i> (L.) Cronq.	*	
<i>Cynodon dactylon</i> (L.) Pers.	*	*
<i>Dactylis glomerata</i> L.	*	
<i>Digitaria</i>		
<i>ciliaris</i> (Retz) =		
<i>D.adscendens</i> (H.B.H.Henraad)	*	*
<i>Echinochloa crus-galli</i> (L.) Beauv.	*	*
<i>Elytropappus</i>		
<i>rhinocerotis</i> (l.f) Less	*	*
<i>Epilobium</i>		
<i>tetragonum</i> L. subsp. tetragouum	*	*
<i>Erodium moschatum</i> (L.) L' HERIT EX AIT	*	
<i>Festuca scabra</i> Vahl	*	*
<i>Geranium molle</i> L.		
<i>Helichrysum patulum</i> (L.) D.Don.	*	*
<i>Hypochoeris radicata</i> L.	*	*
<i>Ischyrolepis sieberi</i> (Kunth) Linder	*	
<i>Medicago polymorpha</i> L.	*	
<i>Oxalis pes-caprae</i> L.	*	
<i>Panicum gluberscens</i> Steud.	*	
<i>Paspalum dilatatum</i> Pior.	*	*
<i>Picris echioides</i> L.	*	*
<i>Plantago lanceolata</i> L.	*	*
<i>Pseudognaphalium</i>		
<i>luteo-album</i> (L.) Hilliard & Burt	*	
<i>Solanum nigrum</i> L.	*	*
<i>Sonchus asper</i> (L.) Hill	*	*
<i>Stoebe</i> sp.	*	*
<i>Veronica persica</i> Desf.		
<i>Vulpia myuros</i> (L.) C.C. Gmel.	*	

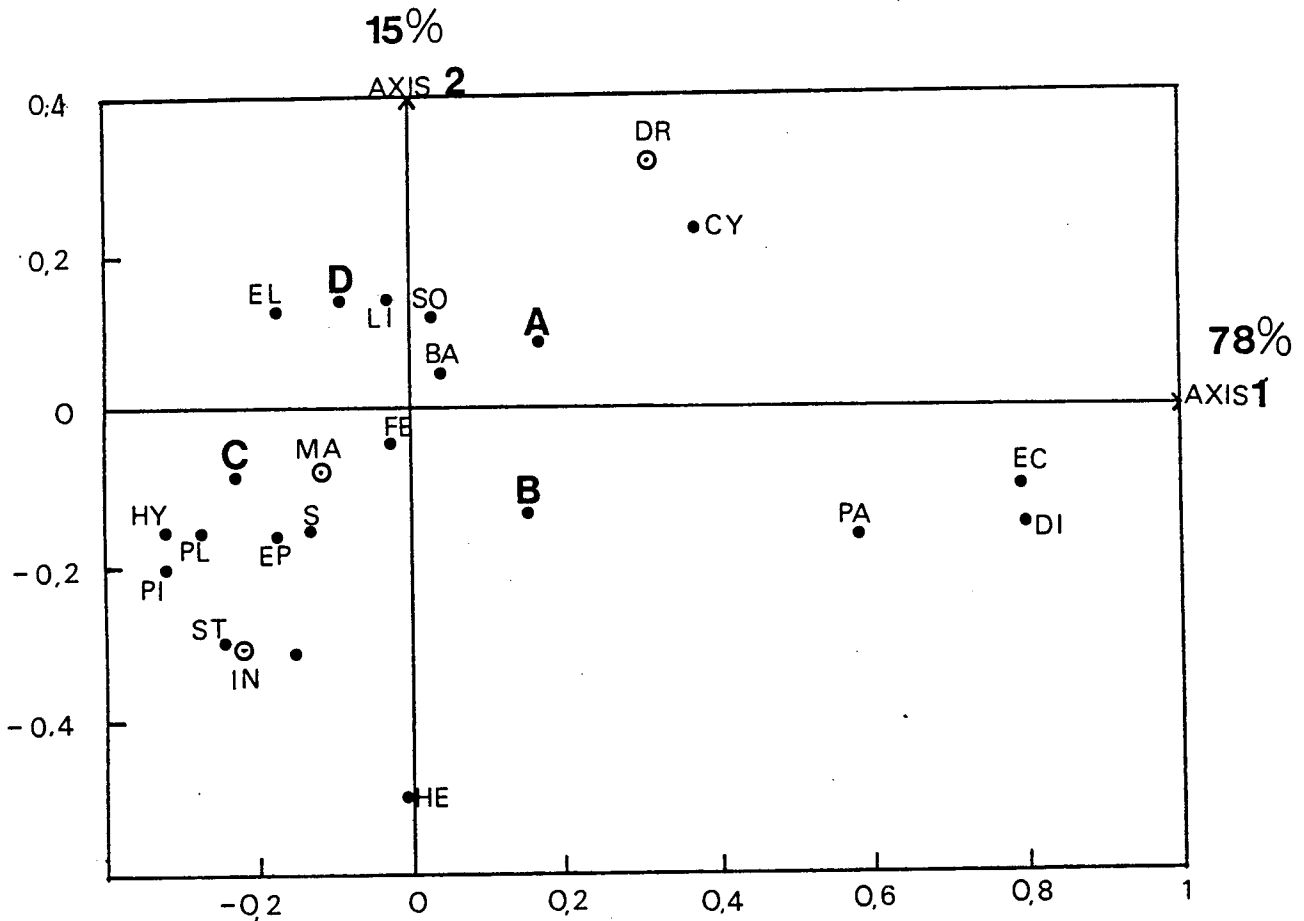


Fig. 3.1 Correspondence analysis of the four times of the year and the twenty-two most frequently occurring habitats with the positions as supplementary variables. Abbreviations: Time: A = January to March; B = April to June; C = July to September; D = October to December. Position: DR = Drip; MA = marginal; IN = inter-row. Habitat: bare ground; CY = *C. dactylon*; DI = *D. ciliaris*; EC = *E. crus-galli*; EL = *E. rhinocerotis*; HY = *H. radicata*; EP = *E. tetragonum*; FE = *F. scabra*; HE = *H. patulum*; LI = litter; PA = *P. dilatatum*; PI = *P. echioides*; PL = *P. lanceolata*; S = *S. asper*; SO = *S. nigrum*; ST = *Stoebe* sp.

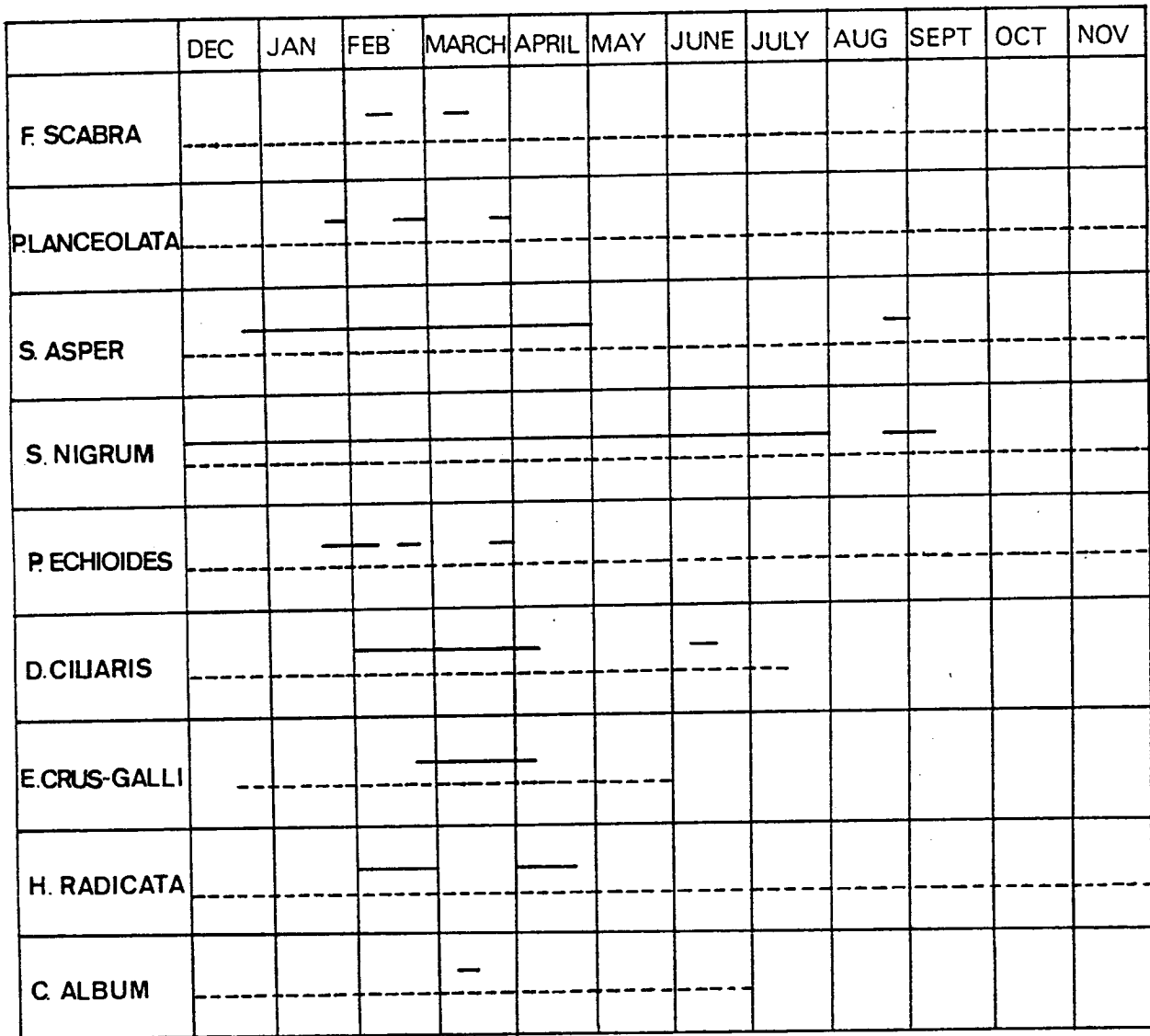
ciliaris appear in the lower right quadrant corresponding to period B (April to June) indicating that these three plants dominate during the early winter. *S. asper*, *E. tetragonum*, *P. lanceolata*, *H. radicata* and *P. echioides* correspond with time C (July to September). These plants were also dominant in the marginal area suggesting that they are pioneers which start invading after herbicide application. The grass *F. scabra* was planted as a cover crop and was mostly found in the interrow area, but was also common in the marginal area. This grass was present throughout the whole year and is near the origin in the correspondance analysis.

The fynbos plant *Stoebe* sp., and the grass *D. glomerata* (Cocksfoot grass) were found mainly in the interrow and during the winter (Period C, July to September). During period B (April to June) the grasses *D. ciliaris*, *E. crus-galli* and *P. dilatatum* were prominent but did not compete with *F. scabra* because they were found mainly in the marginal and drip-area. *S. nigrum* was more prominent during the summer and was found mainly in the drip area directly under the apple trees.

There is a linear gradient from the drip area (DR) in the top right quadrant through to the marginal (MA) and the interrow area (IN) in the bottom left quadrant. This suggests a gradual change in the plant composition of the plant community on the orchard floor from the drip area into the interrow. The drip area is widely separated from the other two areas, which is to be expected as herbicides are applied to the drip area, drastically altering the composition of the plant community.

The weeds that were present during the study period and the time mites were found on them are given in Fig. 3.2. During the first season *T. urticae* was found in high numbers on *S. nigrum* from early December. Mite days accumulated from

Fig 3.2: Weeds found in an apple orchard near Grabouw hosting the phytophagous mite *T. urticae*.

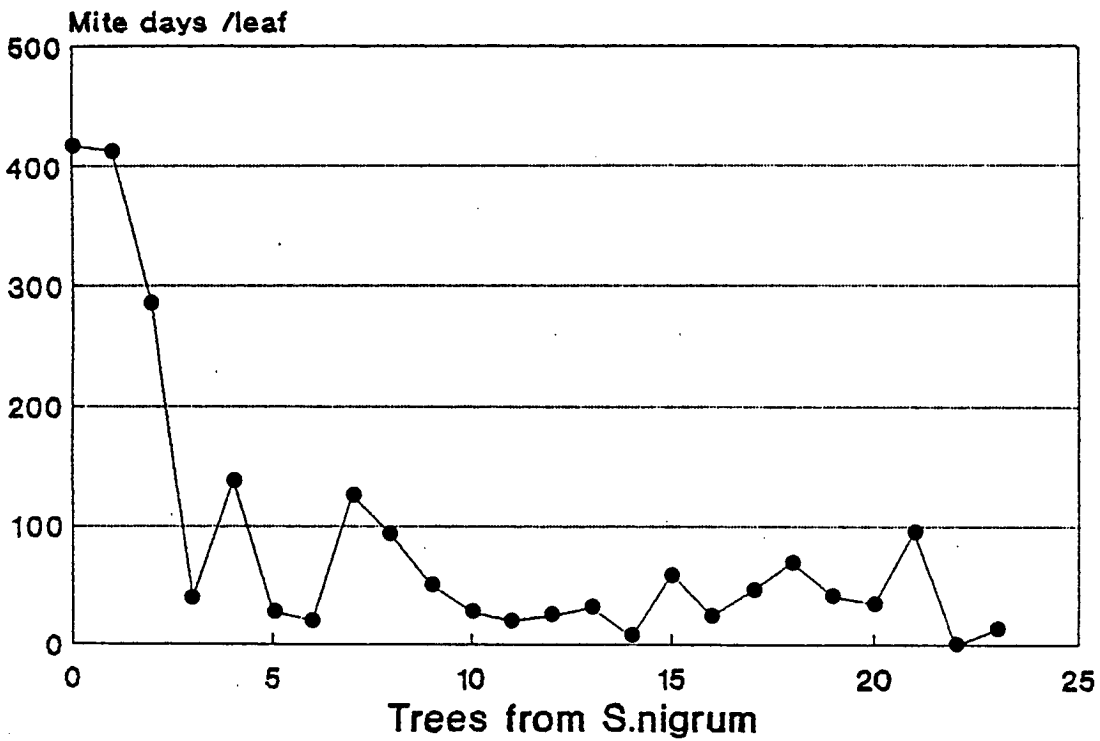


MITES PRESENT ———
 WEEDS PRESENT - - - - -

the beginning of December to mid-January are plotted against distance of the trees from *S. nigrum* in Fig. 3.3. As can be seen trees near this plant showed much higher cumulative mite days per leaf than those trees further away. It was clear that apple trees near these infested plants were the first to show signs of mite infestation on the apple leaves. *S. nigrum* was mainly found in the organophosphate treatment and this could be one of the explanations why mite counts were initially higher in this treatment (Chapter 2). Later in the season many of the *S. nigrum* plants died back, probably due to the heavy mite infestations. From the middle of March mite numbers on these plants were low. The plants were much smaller and the leaves were also thicker and smaller in size than earlier in the season. During the first winter, mite populations were low and the following season the mites appeared much later in this orchard than in some of the surrounding apple orchards. They were found on *S. nigrum* only from mid February, but not on the small plants with the thicker leaves. Mite counts on the apple trees were much lower than during the previous season (Chapter 2, fig. 1.1). Although *S. nigrum* was less abundant than during the 1988/89 season mites were found on them throughout the winter until the first week in September when the experiment was terminated. This data for *S. nigrum* corresponds with the findings of Flexner et al. (1991) who found that *Solanum nodiflorum* was a suitable host for two spotted spider mite. These authors also found that plants in the cover crop which are suitable hosts for phytophagous mites can influence infestation patterns in orchards.

During the 1988/89 season mites were found on *S. asper* from December, but the numbers were not as high as on *S. nigrum*. From the end of March the numbers declined, but one mature female was found in April and one immature mite early in June. During the 1989/90 season mites were present on this plant from late February until the middle of April.

Fig 3.3: Mite days from 8 December 1988 to 19 January 1989 plotted against distance (in number of trees) from trees under which *S. nigrum* grew. Zero on the x-axis represents the trees under which *S. nigrum* grew.



S. nigrum and *S. asper* were the only two plants that were present throughout the year and on which mites were found throughout the winter. Therefore it is assumed that these were the only plants on which mites could overwinter in this specific orchard.

Mites were also found on the grass *F. scabra*. However, it is assumed that this was only accidental, because they were only found on the few plants directly under apple trees and only when mite counts were high on the apple leaves during the 1988/89 season.

P. lanceolata, *P. echioides* and *H. radicata* had a few mites on them but also only during the 1988/89 season when mites were present in high numbers on the apple trees. The grass *D. ciliaris*, appearing from December, was present until July. Mites were found on this grass from February until the end of March during the 1988/89 season. However, another colony was found on a *D. ciliaris* leaf in the first week of June. During the 1989/90 season mites were present on this grass from the last week in February until the beginning of April after which they were not found again for the rest of this season. However, it is possible that mites could use *D. ciliaris* as a host during the first half of the winter because mites were found on this plant in June during the first season, after which it started to die back. The grass *E. crus-galli* that was also only present from December to May, also had mites for a short period (mid February to mid April).

A large mite colony was found on *C. album*, during the first week of March but during the second week only dead female, male and immature mites were found on the leaves.

From this study it was apparent that there were no suitable plants in consistently high numbers on which *T. urticae* could overwinter to assure that mites and their

predators would be present in large numbers early in the summer. The plant diversity in this cover crop might have been low but the presence of some species, like *S. nigrum*, appeared to effect mite numbers.

In Table 3.2 the percentage cover of the different habitats is given. Areas without any plants were mainly found in the drip area all through the season. The area covered by plants which hosted mites was very small. These plants were mainly found in the drip area under the apple tree from where infestation of mites could take place. During period C and D (July to December) very few of these plants were found (only 0,01%) indicating that there were few plants on which mites could overwinter. Most of the orchard was covered by plants that did not host mites, especially in the interrow area.

Plant species present in the cover crop can have an influence on mite activity in apple trees. When plants suitable as mite hosts cover a large percentage of the orchard floor it is likely that mites will be active in the apple trees from early in summer. However, when these plants are only present at low densities, phytophagous mite population levels will be low, resulting in a later appearance on the trees during the summer.

Table 3.2: Per cent cover of habitats in different areas of the orchard floor in which there are no plants (bare ground, dead weeds, litter), plants which host mites (*S. nigrum*, *S. asper*, *D.ciliaris*, *E.crus-galli*) and plants which do not host mites during the four periods of the year (A=January to March; B=April to June; C=July to September; D=October to December).

Habitat	Period	Interrow %	Marginal %	Drip %
No plants	A	4,50	16,19	29,85
	B	2,29	9,92	28,88
	C	3,89	7,10	32,88
	D	3,50	9,77	37,82
Plants hosting mites	A	0,08	0,69	5,35
	B	0,04	1,46	4,88
	C	0,00	0,00	0,01
	D	0,00	0,00	0,01
Plants not hosting mites	A	24,04	15,31	4,00
	B	33,00	13,54	6,00
	C	33,39	14,94	7,72
	D	2,64	13,10	4,14

CHAPTER 4

REPELLENCY OF PYRETHROIDS TO *T. URTICAE* KOCH.

4.1 Introduction

Experiments to determine the effects of pyrethroid insecticides on the natural enemies of phytophagous mites as a possible cause of mite outbreaks (Chapter 2) have indicated that there are probably other factors which may contribute to these outbreaks.

Synthetic pyrethroids are used for the control of major apple pests (e.g. codling moth, *Cydia pomonella* (L.) and banded fruit weevil, *Phlyctinus callosus* Boh.) Repellency is a major component of spider mite responses to exposure to pyrethroid residues (Ruscoe, 1977, Hall 1979, Iftner & Hall 1983 b, Penman & Chapman 1983, Penman *et al.* 1981, Margolies and Kennedy 1988). Iftner and Hall (1983 b) described the role repellency might play in explaining phytophagous mite outbreaks after pyrethroid sprays. Pyrethroids induce dispersal of phytophagous mites with the result that colonies break up into smaller, more scattered groups. These smaller colonies have a lower population density resulting in reduced competition and an increased reproductive potential.

According to Penman *et al.* (1986) the relative contributions of direct toxicity and repellency to overall pyrethroid activity vary depending on the chemical and its formulation.

In this chapter the results of repellency tests using eight synthetic pyrethroids on the red spider mite, *Tetranychus urticae* Koch, are given.

4.2 Materials and methods

4.2.1 Mites

Adult female red spider mites were obtained from a population maintained in the laboratory on bean plants and exposed to the insecticides through a leaf disk dip and a spray technique.

4.2.2. Chemicals

The chemicals bifenthrin (Brigade), cyfluthrin (Baythroid), deltamethrin (Bitam), fenvalerate (Agrithrin), lamda-cyhalothrin (Karate) and cyhalothrin (Cypha) were investigated for their repellency to *T. urticae* in a leaf disk dip bioassay. The same chemicals and fluvalinate (Klartan) were also used to determine their repellent effect on *T. urticae* in a spray technique. Chemicals were used at the recommended field rates as given in Vermeulen *et al.*, 1990. The chemicals, formulations and concentrations are given in Table 4.1.

Table 4.1: Pyrethroids used in a bioassay to determine repellancy of *T. urticae* with their formulations and concentrations.

CHEMICAL	*FORMULATIONS	CONCENTRATION
Bifenthrin	sc	37,5 ml/100 l
Cyfluthrin	ec	20 ml/100 l
Deltamethrin	sc	30 ml/100 l
Fenvalerate	ec	15 ml/100 l
Lamda-cyhalothrin	ec	70 ml/100 l
Cyhalothrin	ec	20 ml/100 l
Fluvalinate	sc	30 ml/100 l

* sc = suspension concentrate

ec = emulsifiable concentrate

4.2.3 Bioassays

4.2.3.1 Leaf-disk dip technique

Fifty leaf disks (10 mm diam) were cut from bean leaves and dipped into the chemical solutions for five seconds. They were then placed upside down on filter paper disks (20 mm diam) on a foam rubber block (20 x 20 x 20 mm) in a plastic container filled with water. The water was deep enough to keep the leaf disks damp on the filter paper. The leaf disks in the control group were dipped in a detergent wetting agent, Teepol, in distilled water (2 ml/100 l).

The disks were held at $25 \pm 1^\circ\text{C}$ until dry, after which one adult female was placed on each disk using a fine brush. They were then placed into a cooled incubator in which the temperature was $25 \pm 1^\circ\text{C}$, the humidity 60 to 95 % RH and the photoperiod 16:8 (L:D) for 24 hours. Repellency was assessed after the

24 hour period by counting the mites in the water barrier around each disk. Mites not responding to prodding with a fine brush were considered dead. Three replicates were conducted over time.

Correspondence analysis was performed with the number of mites dead, alive, or walk-off as rows and the three replicates as columns in the data matrix.

4.2.3.2 Spray technique

Tests for repellency were done by exposing adult females to pyrethroid residues at three different times after spraying on disks (10 mm diam) cut from bean leaves. Seventy-five leaf disks were cut for each pyrethroid. The leaf disks were placed upside down in petri dishes and sprayed in a Potter spray tower with 400 l of the pesticide solution at a pressure of 124 kPa (18 lb/in²). This deposited approximately 0.18 mg/cm² of the solution. The disks were placed upside down on filter paper disks (20 mm diameter) on foam rubber blocks (20 x 20 x 25 mm) as described in 4.1.2.3. Leaf disks in the control group were sprayed with distilled water.

To examine the immediate effect of the eight pyrethroids the disks were left to dry and a single adult female mite was placed on each of 25 leaf disks for each pyrethroid using a fine brush. The disks were placed in a cooled incubator set as described in 4.3.1.3. for 24 hours. Repellency was assessed by counting the mites trapped in the water barrier around each disk. Individuals were counted as being dead on the leaf disk when there was an absence of voluntary movement after being gently prodded with a fine brush. After 48 hours and one week after spraying adult females were again placed on each of 25 leaf disks to test the residual repellency of the pyrethroids. Repellency was assessed 24 hours after mites were placed on these leaf disks. Two replicates were conducted over time.

Correspondence analysis was carried out with the number of mites that were dead, alive and that walk-off as rows, and the three periods and the two replicates as columns in the data matrix.

4.4 Results

4.4.1. Dip technique

A histogram showing the number of dead, walk-off and live mites in each treatment is given in Fig. 4.1. In no case was the mortality particularly high in relation to the control, while the walk-off in the fenvalerate and deltamethrin treatments was similar to that of the control. The walk-off in the remaining four treatments (bifenthrin, cyhalothrin, cyfluthrin and lamda-cyhalothrin) was considerably higher than in the control.

This was supported by the correspondence analysis (Fig. 4.2) with deltamethrin and fenvalerate on the left of the centroid together with live mites while the other four treatments are on the right of the centroid together with walk-off and dead mites.

4.4.2 Spray-technique

A histogram showing the percentage of mites that walked off the leaf disks at the three different times is given in Fig. 4.3. Walk-off for bifenthrin, lamda-cyhalothrin and cyhalothrin was much higher than for the control, for cyfluthrin, deltamethrin and fluvalinate higher than in the control, and for fenvalerate similar to the control. This is supported by the correspondence analysis (Fig. 4.4) which places lamda-cyhalothrin, bifenthrin and cyhalothrin on the left of the centroid together with walk-off for the three periods. The remaining treatments (two formulations of cyfluthrin, fenvalerate and deltamethrin) are on the right of the centroid together with the live mites at the three different times, with fenvalerate the furthest to the right.

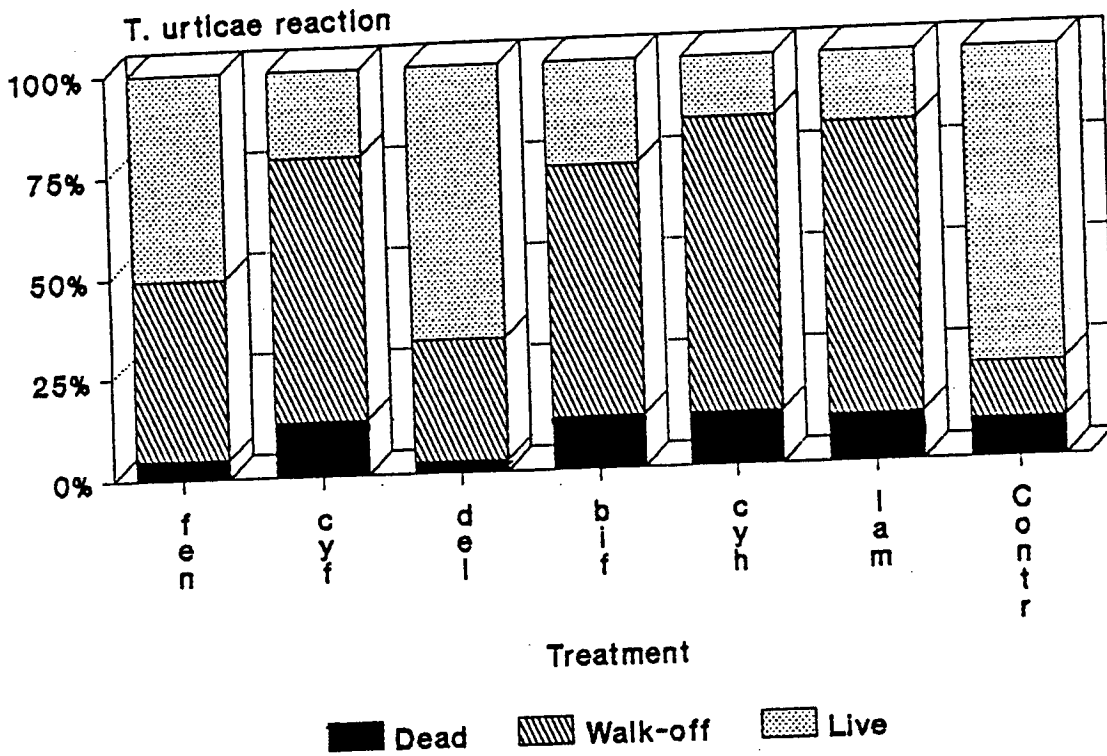
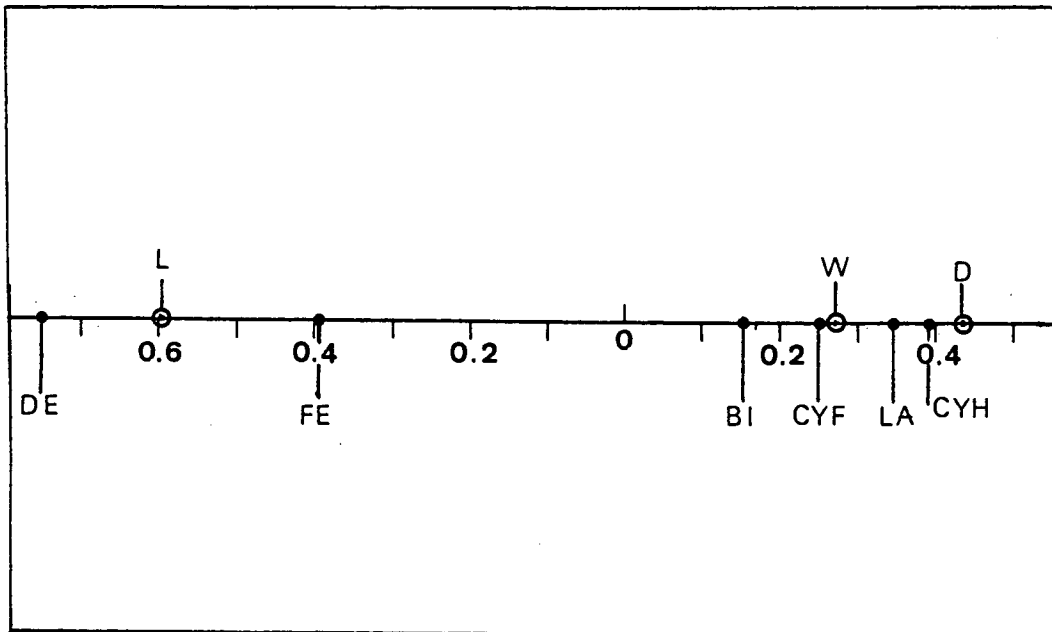


Fig. 4.1: The reaction of the phytophagous mite, *T. urticae* in a leaf dip bioassay with six pyrethroids. Abbreviations: fen = fenvalerate; cyf = cyfluthrin; del = deltamethrin; bif = bifenthrin; cyh = cyhalothrin; lam = lamda-cyhalothrin; Contr = control.

Fig. 4.2: Correspondance analysis of six pyrethroids tested in a bioassay to determine its repellency to *T. urticae*. Abbreviations: Reaction: D = mites dead; L = mites alive; W = mites walk-off. Chemicals: BI = bifenthrin; CYF = cyfluthrin; CYH = cyhalothrin; DE = deltamethrin; FE = fenvalerate; LA = lamda-cyhalothrin.



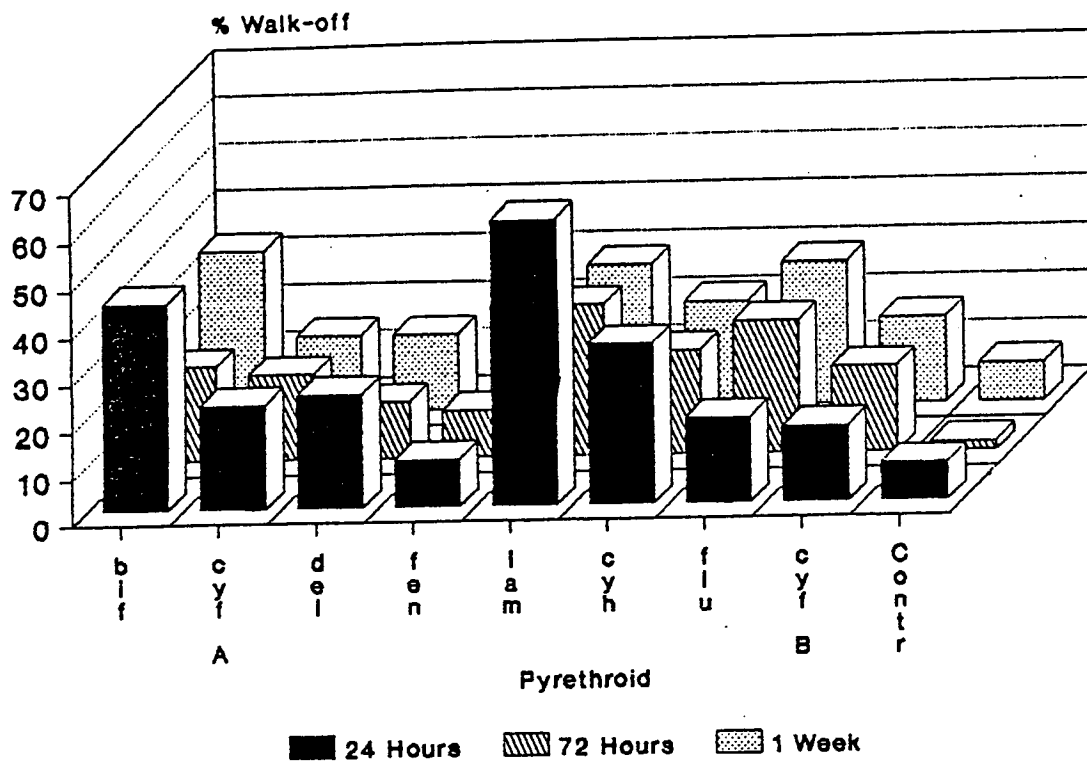
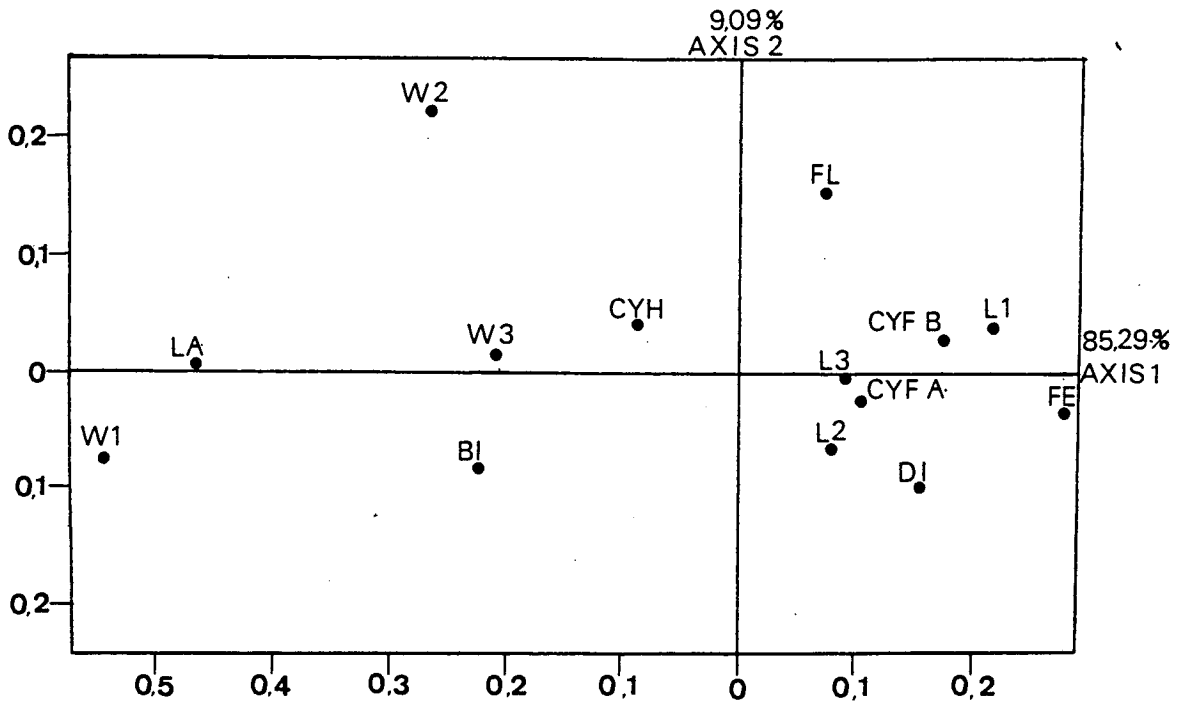


Fig. 4.3: Repellency (% walk-off) of the phytophagous mite *T. urticae*, at the three times after spraying to eight pyrethroids. Abbreviations: bif = bifenthin; cyf A = cyfluthrin (Baythroid); cyf B = cyfluthrin (Bulldock); del = deltamethrin; fen = fenvalerate; lam = lamda-cyhalothrin; flu = fluvalinate; Contr = control.

Fig. 4.4: Correspondance analysis of eight pyrethroids tested in a bioassay to determine their repellency to the phytophagous mite *T.urticae*. Abbreviations: Reaction: L1 = live after 24 hours; L2 = live after 72 hours; L3 = live after 1 week; W1 = walk-off after 24 hours; W2 = walk-off after 72 hours; W3 = walk-off after 1 week. Chemicals: BI = bifenthrin; CYF A = cyfluthrin (Baythroid); CYF B = cyfluthrin (Bulldock); CYH = cyhalothrin; DE = deltamethrin; FE = fenvalerate; FL = fluvalinate; LA = lamda-cyhalothrin.



4.4 Discussion

Bioassays in which leaf disks were dipped gave a higher percentage of walk-off than those that were sprayed, probably because the percentage of chemical coverage was higher. However the spray bioassay possibly gave a more realistic picture of the reaction of mites relative to what could be expected in the field where coverage in terms of chemical deposits is not 100 %.

The data pertaining to walk-off responses may assist in the interpretation of field responses of phytophagous mites to pyrethroid insecticides. Our data suggests that the relative contributions of direct toxicity and repellency to overall pyrethroid activity depends on the specific chemical, as can be seen in the difference in reaction to, for example, fenvalerate and lambda-cyhalothrin. This supports the findings of Penman *et al.* (1986).

Pyrethroids with high walk-off counts could probably cause mite outbreaks in field situations for the reasons given by Iftner and Hall (1983 b). Therefore preference should be given to pyrethroids that cause minimum walk-off unless they are very harmful to the natural enemies of phytophagous mites. However it appears that even a relatively low repellency could still lead to a mite outbreak. In both bioassays deltamethrin walk-off was one of the lowest of all the pyrethroids tested, but it still caused a mite outbreak when used in a late season spray despite the presence of predators (see Chapter 2, 2.2.2.).

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

One of the considerations before using synthetic pyrethroids for the control of major apple pests (i.e. codling moth and fruit weevil) is the effect it may have on the phytophagous mites and their natural enemies.

The pyrethroid cyfluthrin used as a early season spray against fruit weevil had no effect on the phytophagous mites and their predators. The reason for this may be that the residues declined to a level that did not affect mites and their predators when they appeared on apple trees. A late season spray of deltamethrin for codling moth control applied when the phytophagous mites and their natural enemies were already active in the apple trees, suppressed *O.fageli* temporarily and the phytophagous mites increased to very high levels. The subsequent rapid increase of *O. fageli* quickly caused a decline in mite numbers. This specific pyrethroid was not repellent to phytophagous mites and therefore the mite outbreak was probably the result of the negative effect the pyrethroid had on the predators.

The presence of phytophagous mites on certain plants in the cover crop during the winter or early summer influence mite numbers the following season. In the experimental orchard only a few plants could act as winter hosts and they covered only a small portion of the orchard floor.

The plant, *Solanum nigrum*, carried high populations of mites early in the first season and the apple trees nearest to these plants were the first to show signs of

mite infestation. However, these plants were too few to have any major effect on mite numbers through the season.

The repellent effect of pyrethroids on phytophagous mites was tested by counting the number of mites walking off treated leaf disks. Deltamethrin and fenvalerate caused very limited walk-off suggesting that they are not repellent to phytophagous mites. Therefore, it may be safer to spray these pyrethroids when phytophagous mites are present in the orchard than pyrethroids which are more repellent as they will not cause dispersion of mites leading to a higher reproductive potential (Iftner and Hall, 1983(a)). However, the effects on the natural enemies are also very important as was shown using a late season spray against codling moth. Fluvalinate and cyfluthrin caused a relatively low percentage of mites to walk off the leaf disks while bifenthrin, cyhalothrin and lambda-cyhalothrin caused a high percentage of the mites to walk off. These chemicals could be dangerous if sprayed when phytophagous mites are present in the orchard as they may cause dispersal of mites into smaller, more scattered colonies causing a higher reproduction potential. (Iftner and Hall, 1983 (a)). Natural enemies also have to spend more energy finding their prey and therefore less energy is available for their own reproduction (Iftner and Hall (a)).

Although the synthetic pyrethroids gave good control of important apple pests they should be used with great care. The effect on the phytophagous mites and their predators has to be evaluated. The time of spraying could also be important because some pyrethroid residues do not affect phytophagous mites and predators as was found with cyfluthrin.

ACKNOWLEDGEMENT

The author would like to thank Dr. K.L. Pringle from Department of Entomology and Nematology, Stellenbosch University, Stellenbosch for his advice and help on this project and the invaluable assistance with data analysis.

I would like to thank Dr. P.F. du V. Cluver for an experimental site on his farm, Jakkalsrivier. Thanks also goes to Mr. F.J.G. van Schalkwyk for organizing of the experimental site and the spraying on Jakkalsrivier and Mr. P.J. Nel for organising the experimental site and spraying on the farm, Helderfontein.

SUMMARY

In South Africa pyrethroids are used for the control of codling moth, *Cydia pomonella* and fruit weevil, *Phlyctinus callosus*. However, after some pyrethroid sprays phytophagous mite populations often started to increase dramatically. The usual explanation for this is the elimination of the natural enemies but some pyrethroids also may have a repellent effect on the mites which cause dispersion, leading to a higher reproductive potential (Iftner and Hall 1983 a).

The pyrethroid, cyfluthrin, and the organophosphate, acephate, were used as early season sprays for the control of *P. callosus*. It was supposed that the acephate would not affect phytophagous mites and their natural enemies. The population levels of the spider mite, *Tetranychus urticae*, and its predators were monitored over two seasons by determining their numbers on apple leaves. The activity of the predatory beetles, *Oligota fagei* and *Stethorus aethiops* were monitored using yellow sticky traps in the apple trees. There were no mite outbreaks and there were no difference in predator populations between the pyrethroid and organophosphate treatment. The possible explanation could be that the residues of the pyrethroid applied early in the season declined to such a level that when phytophagous mites and their natural enemies appeared they were not influenced.

The degree of control of the apple pests was determined by monitoring damage prior to thinning and just before harvesting. The pyrethroid gave better control of thrips and bollworm (*Heliothis armigera*) than acephate. The control of *P. callosus* was similar for the two treatments.

In a second field experiment the pyrethroid, deltamethrin, and the organophosphate, azinphos-methyl, were applied as a late season sprays for the

control of *C. pomonella*. The phytophagous mites and their predators were monitored in the same way as described above. Deltamethrin caused a mite outbreak as a result of the negative effect on *O. fageli*. However, the beetles quickly recovered and caused a rapid decline in mite numbers.

Plants in the cover crop between apple trees were identified and examined for the presence of phytophagous mites and predators. Plant diversity in the orchard cover crop was relatively low and only a few plants served as winter hosts for the phytophagous mites. However, it was found that *Solanum nigrum* carried high populations of mites which infested adjacent apple trees.

Eight synthetic pyrethroids were tested in two laboratory bioassays to determine repellency of phytophagous mites as measured by the number of mites that walked off leaf disks treated with the pyrethroids. Deltamethrin and fenvalerate caused minimum walk-off, cyfluthrin and fluvalinate caused moderate walk-off and bifenthrin, cyhalothrin and lamda-cyhalothrin caused high walk-off. It is postulated that pyrethroids which are highly repellent (causing high walk-off) may lead to mite outbreaks when sprayed in apple orchards (Iftner and Hall, 1983 a).

REFERENCES

- BREESE, M.N. & SEARLE, R.J.G., 1977. Why the newer synthetic pyrethroids show promise. *Span* 20(1) : 18-21.
- CHAPMAN, R.B. & PENMAN, D.R., 1979. Toxicity of synthetic pyrethroid insecticides to phytophagous orchard mites. In. *Proceedings of 32nd New Zealand Weed Pest Control conference*, 240-244.
- COX, F.R.S., 1970. *Analysis of binary data*. Chapman and Hall, New York.
- CROFT, B.A. & BROWN, A.W.A., 1975. Responses of arthropod natural enemies to insecticides. *Annual Review of Entomology* 20: 285-335.
- CROFT, B.A. & HOYT, S.C., 1978. Considerations for the use of pyrethroid insecticides for deciduous fruit pest control in the U.S.A. *Environmental Entomology* 7 : 627-630.
- ELLIOTT, M., 1977. ed. *Synthetic pyrethroids*. Proc. ACS. Symp. Washington D.C.
- FLEXNER, J.L., WESTIGARD, P.H., GONZALVES, P. and HILTON, R., 1991. The effect of groundcover and herbicide treatment on twospotted spider mite density and dispersal in Southern Oregon pear orchards. *Entomologia experimentalis et applicata* 60: 111-123.
- GREENACRE, M.J., 1986. SIMCA: a program to perform simple correspondance analysis. *American Statistician* 51: 230-231.
- HALL, F.R., 1979. Effects of synthetic pyrethroids on major insect and mite pests of apple. *Journal of Economic Entomology* 72 : 441-446.
- HALL, F.R., REICHARD, D.L. & KRUEGER, H.R., 1975 (a). Dislogeable azinphosmethyl residues from air blast spraying of apple foliage in Ohio. *Archives of Environmental Contamination and Toxicology* 3 : 352-363.
- HOYT, S.C., WESTIGARD, P.H. and BURTS, E.C., 1978. Effects of two synthetic pyrethroids on the codling moth, pear psylla, and various mite species in north west apple and pear orchards. *Journal of Economic Entomology* 71(3) : 431-434.

- IFTNER, D.C. and HALL, F.R., 1983(a). Toxicities of selected synthetic pyrethroids to two species of phytophagous mites. *Journal of Economic Entomology* 76 : 687-689.
- IFTNER, D.C. and HALL, F.R., 1983(b). Effects of fenvalerate and permethrin on *Tetranychus urticae* Koch (Acari : Tetranychidae) dispersal behavior. *Environmental Entomology* 12 : 1782-1786.
- KAPETANAKIS, E.C., WARMAN, T.M. and CRANHAM, J.E., 1985. Effects of permethrin sprays on the mite fauna of apple orchards. *Annals of Applied Biology* 108 : 21-32.
- MADSEN, H.F. & VAKENTI, J.M., 1973. Codling moth : Use of codlemore-baited detection of entries to determine need of sprays. *Environmental Entomology* 2 : 677-679.
- MARGOLIES, D.C. & KENNEDY, G.G., 1988. Fenvalerate-induced aerial dispersal by the two-spotted spider mite. *Entomologia experimentalis et applicata* 46 : 233-240.
- MYBURG, A.C. & MADSEN, H.F., 1976. Monitoring range of codling moth sex attractant traps. *The Deciduous Fruit Grower* 26 : 137-143.
- PENMAN, D.R. & CHAPMAN, R.B., 1983. Fenvalerate- induced distributional imbalances of two-spotted spider mite on bean plants. *Entomologia experimentalis et applicata* 33 : 71-78.
- PENMAN, D.R., CHAPMAN, R.B. and BOWIE, M.H., 1986. Direct toxicity and repellent activity of pyrethroids against *Tetranychus urticae* (Acari : Tetranychidae). *Journal of Economic Entomology* 79 : 1183-1187.
- PENMAN, D.R., CHAPMAN, R.B. & JESSON, K.E., 1981. Effects of fenvalerate and azinphosmethyl on twospotted spider mite and phytoseiid mites. *Entomologia experimentalis et applicata* 30 : 91-97. Ned. Emtomol Ver. Amsterdam.
- PRINGLE, K.L., 1987. Development of a sampling system for monitoring population levels of tetranychid mites (Acarina : Tetranychidae) on

- apples in the Elgin area. Ph.D. (Agric) Dissertation. University of Stellenbosch.
- PIELOU, P.P., 1960. The effect of DDT on oviposition and behaviour in the European red mite, *Panonychus ulmi* (Koch). *Canadian Journal of Zoology* 38 : 1147-1151.
- ROUSH, R.T., & HOY, M.A., 1978. Relative toxicity of permethrin to a predator, *Metaseiulus occidentalis* and its prey, *Tetranychus urticae*. *Environmental Entomology* 7 : 287-288.
- RUPPEL, F.R., 1983. Cumulative insect-days as an index of crop protection. *Journal of Economic Entomology* 76 : 375-377.
- RUSCOE, C.N.E., 1977. The new NRDC pyrethroids as agricultural insecticides. *Pesticide Science* 8 : 236-242.
- TANIGOSHI, L.K., BROWN, R.W. & HOYT, S.C., 1975. A study of the dispersion pattern and foliage injury by *Tetranychus mcdanieli* (Acarina : Tetranychidae) in simple apple ecosystems. *The Canadian Entomologist* 107 : 439-446.
- VERMEULEN, J.B., SWEET, S., KRAUSE, M., HOLLINGS, N. and NEL, A., 1990. *A guide to the use of pesticides and fungicides in the republic of South Africa*. Department of Agricultural Development, Pretoria.
- WONG, S.W. and CHAPMAN, R.B., 1979. Toxicity of synthetic pyrethroid insecticides to predaceous phytoseiid mites and their prey. *Australian Journal of Agricultural Research* 30 : 497-501.
- ZWICK, R.W. & FIELDS, G.J., 1978. Field and laboratory evaluations of fenvalerate against several insect and mite pests of apple and pear in Oregon. *Journal of Economic Entomology* 71 : 793-796.