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Attendance at the XIX International Congress of Entomology, Beijing, China June–July 1992

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Summary

The International Congress of Entomology was held in Beijing in June/July 1992. The Congress is held every four years and is the major international forum for entomologists.

I was invited to present a paper on spraying thresholds for apple dimpling bug in a workshop on the use of zoo-phytophagous bugs in IPM. I also presented a paper on results of trials with the new acaricide, tebufenpyrad.

I attended two plenary lectures, six symposia, one workshop and one contributed paper session. Sessions were selected on the basis of their relevance to my own work, or because they dealt with future directions in integrated crop protection. Sessions were attended on management of non-crop habitats of pests and predators, use of pheromones in pest management, use of zoo-phytophagous bugs in IPM, behavioural ecology and IPM, insect migration, new classes of insecticides and acaricides, alternative food of phytoseiid predators in relation to biological control, dynamics of insects in diverse landscapes and toxicology.

Six recommendations are made for future directions in pest management research in pome fruit and/or horticulture in general.

Recommendations

It is recommended:

1. **That reduction of pesticide usage continue to have a high priority for research and development funding.**

   High input production systems are ultimately unsustainable. Governments in the EC and SE Asia are legislating in increasing numbers for pesticide reduction. This trend is likely to continue.

2. **That research be conducted to evaluate the value of cover crops and windbreaks as harbours for beneficial insects in horticulture, and to investigate their manipulation to minimise refuges for pests.**

   As horticultural production systems move to lower pesticide use and more environmentally friendly pesticides, management of cover crops, windbreaks and surrounding vegetation will become increasingly important.

3. **That the concept of Integrated Fruit Production (IFP) be adopted for horticultural research and extension in Australia.**

   This concept, widely adopted in the EC, sees the farming enterprise and its surrounding community as a system whose activities need to be harmonised to maximise economic returns while minimising adverse impacts. The approach would encourage multidisciplinary cooperation to produce unified systems with minimal internal inconsistencies or conflicting practices.

4. **That future research on apple dimpling bug focusses on its movements into orchards from local or distant sources to enable forecasting systems to be established.**

   Apple dimpling bug is the major pest of orchards which does not originate within the orchard itself. The key to understanding outbreaks of this pest is to understand its movements.

5. **That resistance management strategies be implemented for all major pests and diseases of horticultural crops.**

   The number of new pesticides coming onto the market has slowed to a trickle. It is therefore important that susceptibility to existing products be maintained in pests and diseases for as long as possible.

6. **That the provision of alternative food be investigated for appropriate key predatory and parasitic species in order to greater stabilise pest fluctuations.**

The importance of alternative food sources is only just becoming apparent. It offers an important means of improving the stability of pest control.

Report on Attendance at the XIX International Congress of Entomology, Beijing, China 28 June to 4 July 1992

INTRODUCTION

The International Congress of Entomology is held every four years and is the major international forum for entomologists in all branches of the discipline. Since most entomologists work in the area of crop protection, major emphases of the congress are on pest control, toxicology, biological control, pesticide development, ecology, behaviour and integrated pest management. The International Congress is therefore the best means of obtaining an up to date perspective of the latest developments in the many fields relevant to agricultural entomology.

The Beijing Congress hosted some 2,500 delegates from all parts of the globe, the largest international meeting so far in China. The Congress was held at the Beijing International Conference Centre, a complex of hotels, lecture theatres and meeting rooms, which was originally constructed for the Asian Games in 1990. The facilities were excellent and organisation was generally very good. There were several thousand presentations, both oral and by poster; the proceedings is a set of abstracts comprising 730 pages. It is therefore not practicable to reproduce the proceedings and they are not appended to this report. The program booklet comprises 359 pages and the program itself ran in 30+ concurrent sessions each day. It was therefore difficult to attend all presentations of interest. I attempted to attend sessions most relevant to my own work and which seemed to deal with future directions in integrated crop protection.

A major disappointment of the congress was the virtual collapse of the contributed papers program. Many speakers listed in the program did not turn up and this threw the program into chaos as chairmen compressed sessions, or stuck to the program at random. In some sessions two thirds of the speakers did not appear. It seems that the program was prepared from the initial abstracts which were not always followed up with registrations. The Chinese had no plan to deal with the impact of gaps in the program and did not appear to be aware of the problem.

In this report I highlight the most important developments and trends presented at the sessions I attended. The implications of the findings for future directions in crop protection in Australian horticulture are briefly discussed and six recommendations are made.

Objectives of Attendance at Congress

- To accept an invitation to deliver a paper entitled "Components of a variable spraying threshold for apple dimpling bug, *Campylomma liebknechti* Girault on apple," at a workshop on the "Use of Facultative (Zoo–Phytophagous) Bugs in IPM."

- To deliver a submitted paper entitled "Tebufenpyrad: a new acaricide compatible with integrated mite control on apple" in the Agricultural Entomology section.

- To attend Congress sessions relevant to pome fruit horticulture in NSW and assess latest developments in the field.

- To meet with colleagues from overseas to ascertain current and future directions in pome fruit entomology.

Program

The lectures, symposia and workshops I attended are listed in Appendix 1.

Summaries and Highlights

- ***Plenary Lecture. Living with Insects. Max Whitten (CSIRO, Australia)***

  Dr Whitten pointed out that pest control technologies should be:

  - cost effective
  - environmentally friendly
  - sustainable
  - empower user

  Ultimately, high input/high production systems, as in Dutch horticulture, are not sustainable. Governments of various EC countries have legislated targets for reduction of pesticide use with the aim of reducing both dependency on pesticides and accessions to the environment. These trends create opportunities for entomologists. Some SE Asian countries are going down the high input path, but others, eg Indonesia, China, are reducing pesticide use and adopting integrated pest management (IPM). Chemicals will remain important in the foreseeable future, but IPM has the best chance of success where the farmer controls the production system.

- ***Symposium – Influence of understorey cover and surrounding habitat on interactions between beneficial arthropods and pests in orchards.***

Papers in this symposium were around the theme that cropping systems need to be viewed and managed in the context of their surrounds. Adjoining vegetation, or cover crops in orchards, can be potentially managed to reduce harbour for pests and/or increase the potential for migration of beneficials into the crop. It may be possible to manage surrounding vegetation selectively, eg eliminate wild apple trees that host codling moth, but retain pin cherry and black cherry which harbour parasites. However, the balance may not always be easy to strike, especially since neighbours, public authorities etc may be involved. Actions taken to reduce the potential for one pest may adversely affect the natural enemies of another, thereby worsening the second problem inadvertently. In China manipulation of cover crops in apple orchards in Beijing resulted in a doubling of predators on trees and reduction of sprays by 50–70 percent. In Utah mite problems were worse in cultivated orchards, and least where a grass sod is maintained. In Finland high predator numbers in surrounding vegetation were correlated with elevated populations in orchards.

Potential for utilising these approaches exists in Australia. Codling moth in apples is an obvious example. Apple dimpling bug has many alternate hosts and management of these on a cooperative district-wide basis may reduce the problem permanently. As yet there appears to be little or no work in this area in Australia. It will need to be undertaken if the concept of Integrated Fruit Production is pursued here.

- ***Symposium – Application of insect sex pheromones in pest management: strategy and perspectives***

Only one segment of this day long symposium was attended, mainly to hear the paper by J Franklin Howell on mating disruption by pheromones in codling moth.

In China, mass trapping with pheromone traps to remove males of four major fruit and nut pests including Oriental fruit moth gave control equivalent to spraying. A 15 year study on Oriental fruit moth showed pheromone trap monitoring could improve chemical control and reduce pesticide applications by 1 to 3 sprays per season. Pheromone mating disruption also gave satisfactory results with fruit damage 40–75% less than standard sprayed controls.

In Washington State mating disruption of codling moth had been adopted on 1000 ha by 1992. Howell found that with the dispensers available in 1991, 2 applications of 1000 ties per ha were needed for satisfactory control. The major problem was occurrence of minor pests normally controlled by codling moth sprays. Spray use was reduced from 8 to 2. New long life ties were used in 1992 at lower rates, but were not as successful as in 1991.

Howell found the problem in 1992 was lowered pheromone release rates when temperatures fall and as dispensers age. He found that release rates of 6–8 mg/ha/hour were needed to effect disruption. To achieve this, temperatures needed to be over 14°C. Since moths become active above 10°C this left a window for mating. Solutions proposed were either more dispensers or dispensers that emit at lower temperatures.

Howell's studies have particular relevance to similar studies being undertaken in Australia and funded by HRDC. Biocontrol Ltd is involved in both the USA and Australian studies, but disputes Howell's interpretations of the data. Having seen Howell's data I tend to believe him!

- ***Workshop – Use of facultative (zoo-phytophagous) bugs in IPM***

This workshop was particularly relevant to the HRDC funded project (AP003), "Management of Apple Dimpling Bug." The theme of the workshop was the biology and management of mirid bugs that are mixed feeders (zoo phytophagous), consuming both plant and animal food. A few species, eg apple dimpling bug, are both key pests and key predators in certain crops. I presented an invited paper on apple dimpling bug to this workshop.

Al Wheeler presented a review of the biology of the family Miridae. Robert Weidenman showed that *Podisus maculiventris* in Texas can survive on plant food alone but requires prey in order to reproduce. Guy Boivin discussed the potential of 5 mirid species in Quebec for use in IPM programs. My paper (Appendix 2) showed that the severe damage caused by even quite low apple dimpling bug populations will not permit its predatory characteristics to be utilised for integrated mite control. Studies by Jacques Malausa on predatory mirids in the south of France showed one species, *Macrolophus caliginosus* is an effective predator of whiteflies and does not damage tomato crops. It is being mass reared for biological control of whitefly. *M. caliginosus* is also being used against whitefly on tomatoes in Spain along with *Dicyphus tamaninii*. However, *D. tamaninii* will attack the crop when prey is scarce. Oscar Alomar presented an elegant decision-chart to allow pest managers to advise on successful biocontrol, spraying for whitefly, spraying for *D. tamaninii* or spraying for both.

- ***Plenary Lecture – From behavioural ecology to integrated pest management***

Ron Prokopy used tephritid fruit flies, especially apple maggot, *Rhagoletis pomonella* to demonstrate the importance of an understanding of insect behaviour in designing improved management practices.

- ***Symposium – Insect migration: physical factors and physiological mechanisms***

  This symposium was of interest for HRDC project AP003, "Management of Apple Dimpling Bug" because the current view of this pest is that it may at times migrate to orchards from a distance. An understanding of the movements or migration of apple dimpling bug may lead to improved forecasting of bug outbreaks and management. Papers in the session highlighted ecological and environmental factors governing migration patterns of insects. While no papers dealt with analogous species, the symposium provided a good background to current knowledge on insect migration and indicated the kind of studies needed to elucidate movement patterns in apple dimpling bug.

- ***Symposium – Newer classes of insecticides/acaricides: progress, prospects and mechanisms***

  This session was attended to obtain information on new products in the pipeline and their likely application to IPM in apples in Australia. Currently there is a critical shortage of acaricides and codling moth control is threatened by increasing resistance to azinphos–methyl:

  > Fenazaquin – this promising new product is an effective acaricide with some selectivity to predatory mites and other predators.
  >
  > Diafenthiuron – this product has been trialed in Australia for mites without showing great promise. It is being developed for European red mite, citrus mites, whitefly and aphids. Most potential seems to be for aphids.
  >
  > AC 303, 630 – a pyrrole from Cyanamid with activity against a wide range of insects and mites, including multi–resistant strains.
  >
  > Sulfluramid – a slow acting product, most useful in baits. May have an application in stone fruit orchards against earwigs.

- ***Symposium – Alternative food of phytoseiid predators and its importance in biological control of phytophagous arthropods***

  Alternative food sources for predatory mites are often quoted as a means of stabilising pest mite/predator mite prey/predator systems. The presence of a second food source has several advantages:

  > predator populations persist in the system rather than declining after overexploiting a singe prey species;

pest mites are less likely to outbreak when predators are maintained on alternate food.

Alternative food sources therefore have important implications for integrated mite control. Sabelis reviewed the types of alternative prey, how they affect predators, theoretical models and plant strategies to maintain high predatory mite populations. Paul van Rijn found that the addition of pollen as an alternative food source to a Western Flower Thrips/*Amblyseius cucumeris* system resulted in better control of the pest. Work by Frank Bakker on control of cassava mite by *Typhlodromus limonicus* on cassava showed that the production of exudates by the plant improves predator survival, but animal food is required for reproduction. When exudates are present the classical predator/prey cycle is dampened; predators remain at high levels and prey are suppressed consistently.

These ideas may have relevance in Australian horticulture where mite predator/prey interactions are often unstable. Consideration could be given to encouraging apple rust mite, *Aculus schlechtendali* on apple, or providing artificial alternate food by spraying.

- ***Symposium - Spatial and temporal dynamics of insects in diverse landscapes***

This symposium examined the distribution and movement of insects in heterogeneous environments. Important points were:

the same insect may behave quite differently in different environments

parasites and predators may disperse faster than pests not more slowly as previously thought

understanding spatial relationships of pests and beneficials in a cropping system will guide IPM choices

- ***Contributed Paper - Toxicology***

Many speakers did not turn up for this session. My own paper (Appendix 3) outlined trial work on tebufenpyrad (Pyranica (R)) for integrated control of European red mite and proposed a resistance management strategy. The paper by Silvia Dorn on fenoxycarb (Insegar (R)) demonstrated that its selective action allows survival of many natural enemies thereby stabilising many agroecosystems. Insegar (R) is being widely used on apples in Australia where stabilising effects on San Jose scale and woolly aphid have been observed.

Program of Presentations Attended

28 June, 1730 hrs – Opening Lecture

Principles and Implementation of integrated pest management in China. Da–rong Zhou (China).

29 June, 0800–0900 – Plenary Session

Living with Insects. M J Whitten (Australia).

0900–1200 and 1600–1800 – Symposium

Influence of understorey cover and surrounding habitat on interactions between beneficial arthropods and pests in orchards.

- Habitat manipulation within an orchard IPM framework. R J Prokopy (USA).
- Managing cover crops to manage pests. R Bugg (USA).
- Vegetation diversity and its relation to pest management in apple orchards in the Beijing region of China. Yu–hua Yan (China).
- Apple and cherry arthropod management in relation to orchard floor vegetation in Utah. D Alston (USA).
- Effects of umbelliferous understorey plants on parasitoids of leafrollers in a New Zealand apple orchard. E Scott (New Zealand).
- Apple orchard characteristics affecting abundance of pest mites and mite predators in Arkansas, USA. T D Johnson (USA).
- Influence of orchard ground cover on the arthropod community in citrus orchards in China. Weiguang Liang (China).
- Understorey effects on predatory mites in Massachusetts apple orchards. W M Coli (USA).
- Impact of orchard ground cover on dynamics of <u>Amblyseius fallacis</u> in New York. J P Nyrop (USA).

1400–1520 – Symposium

Application of insect sex pheromones in pest management: strategy and perspective

- Monitoring and control of fruit tree pests by sex pheromones in North China. Meng–ying Liu (China).
- The studies on the application of the sex pheromone of oriental fruit moth, <u>Grapholitha molesta</u> Busck. Xian–zuo Meng (China).
- Development of the formulation of the sex attractant and trap system for corambola fruit borer, <u>Eucosoma notanthes</u> Meyrick. Jenn–Sen Hwang.
- Control of codling moth (Cydia pomonella) – via pheromone treatments to disrupt mating (Lepidoptera: Tortricidae). J F Howell (USA).

30 June, 0800–1200 – Workshop
Use of facultative (zoo-phytophagous) bugs in IPM

- Feeding habits of the Miridae: Pests, predators and opportunities. A G Wheeler (USA).
- Impact of facultative plant feeding on the life-history of a heteropteran predator. R N Wiedenmann (USA).
- Predatory mirids in apple orchards in Quebec. G Boivin (Canada).
- Components of a variable spraying threshold for apple dimpling bug, *Campylomma liebknechti* Girault on apple. C Bower (Australia).
- Strategy of use of the predaceous bug, *Macrolophus caliginosus* in glasshouse crops. J C Malousa (France).
- Management of the facultative predator *Dicyphus tamaninii* in field tomatoes. O Alomar (Spain).

1300–1400 – Plenary Lecture
From behavioural ecology to Integrated Pest Management. R J Prokopy (USA).

1400–1750 – Symposium
Insect migration: physical factors and physiological mechanisms

- The physiological and reproductive status of natural migratory populations. Xiao-xi Zhang (China).
- Physiological mechanisms controlling migratory potential. J N McNeil (Canada).
- Aeodynamics, energetics, and reproductive constraints of migratory flight in insects. R Dudley (USA).
- Recent advances in research on migration and prediction of the rice pest, *Nilaparvata lugens* in China. Xia-nian Cheng (China).
- Forecasting locust outbreaks and migration. M Lecoq (France).
- Migration of *Mythimna separata* to Japan: weather factors leading to sudden outbreaks. K Hirai (Japan).
- Migration, weather and climate: overview and synthesis. V A Drake (Australia).
- Forecasting migrant pests. J Magor (UK).
- Insect migration: physical factors and physiological mechanisms. R A Farrow (Australia).

1 July – Conference Tour

2 July – 0800–1125 – Symposium
Newer classes of insecticides/acaricides: progress, prospects and mechanisms

- Fenazaquin: A new acaricide/insecticide. C J Hatton (USA).
- Diafenthiuron: a novel insecticide/acaricide. F J Ruder (Switzerland).
- Mechanism of action and pesticidal properties of the pyrrole AC 303, 630.

M F Treacy (USA).
- Properties and toxic actions of the perfluorinated sulfonamide insecticide, sulfluramid. G Gadelhak (USA).
- Heterocyclic insecticides acting at the GABA–gated chloride channel. J E Casida (USA).
- Nitromethylene insecticides: actions on insect nicotinic acetylcholine receptors. D B Sattelle (UK).

1400–1600 – Symposium
Alternative food of phytoseiid predators and its importance in biological control of phytophagous arthropods

- Introduction: Theoretical background of the use of alternative food in biological control. M W Sabelis (Netherlands).
- Pollen as an alternative food source for predators: Its effect on a thrips–predatory mite system. P C J van Rijn (Netherlands).
- Transtrophic interactions in cassava. F M Bakker (Netherlands).

1610–1745 – Symposium
Spatial and temporal dynamics of insects in diverse landscapes

- Ecological strategies of three _Athalia_ sawflies (Hymenoptera: Tenthredinidae) feeding on cruciferous plants in the same area. K Nagasaka (Japan).
- Role of adjacent habitats in the dynamics and management of onion maggot. D L Haynes (USA).
- Spatial movements of hosts and parasitoids within a field interaction. T H Jones (UK)
- Concluding remarks. S H Gage (USA).

3 July – Contributed Papers – Toxicology
0800–1140

- Introduction. L O Ruzo (USA).
- Glutamate receptors as sites for the development of insect specific toxicants. P N R Usherwood (UK).
- Electrophysiological effects of spilanthol on single neurons in the sixth abdominal ganglion of _Periplaneta americana_ L. A A Kechil (Malaysia).
- Tebufenpyrad: a new acaricide compatible with integrated mite control on apple. C C Bower (Australia).
- Stabilising important agroecosystems: The contribution of juvenoids. S Dorn (Switzerland).

APPENDIX 2

COMPONENTS OF A VARIABLE SPRAYING THRESHOLD FOR APPLE DIMPLING BUG, *CAMPYLOMMA LIEBKNECHTI* GIRAULT, ON APPLE

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ABSTRACT

Apple dimpling bug, *Campylomma liebknechti* Girault invades orchards in bloom from surrounding vegetation and feeds on the ovaries of flowers causing dimple-like depressions and russet to develop on the fruit of susceptible varieties. However, *C. liebknechti* is also an effective predator of mites post-bloom. Data from a five year study on Granny Smith apples showed a linear relationship between cumulative bug activity (bugdays) during flowering and downgrading of fruit at harvest. Economic thresholds for sprays of fluvalinate and endosulfan were determined from a spreadsheet model of the costs and returns for a typical NSW apple orchard. For fluvalinate the economic threshold was 22 bugdays per 50 inflorescences, which causes one percent downgrading of the crop. The corresponding figures for endosulfan were 7.3 bugdays or 0.3 percent downgrading. A caging experiment showed that most damage occurs over about a 30 day period between the spurburst and one week post petal fall stages of development. A variable spraying threshold, based on the concept that damage is a product of both bug numbers and the length of time bugs are in the flowers, is proposed. The variable threshold tolerates larger bug populations towards the end of bloom when there is less time for damage to occur. The high potential for low populations of *C. liebknechti* to cause significant economic damage means there is little likelihood of utilising its predatory behaviour for mite control on apple varieties susceptible to its damage.

INTRODUCTION

Apple dimpling bug, *Campylomma liebknechti* Girault is a serious pest of apples on mainland Australia. It is a native Australian species which can be found on a very wide range of native and introduced host plants. Apple dimpling bug (ADB) invades apple orchards during flowering in spring. It feeds by puncturing the ovaries of flowers which results in dimple like depressions and russet on the fruit. The more severe forms of damage result in downgrading of the fruit; up to 35 percent of Granny Smith and Delicious varieties may be downgraded in some years. Due to this high potential risk, and also because ADB is difficult for many growers to identify, routine prophylactic sprays are usually used to control it.

Although ADB is a serious pest at blossom time, it is a beneficial species post bloom since it is an effective predator of pest mites (Readshaw 1975). The predatory characteristics of ADB may have significant value for apple varieties such as Jonathon which are not susceptible to ADB damage (Thwaite 1982). Whether or not ADB can be utilised as a mite predator on susceptible varieties will depend on the levels of ADB that can be tolerated without causing economic damage.

In this paper we determine the economic threshold for ADB on Granny Smith apples for sprays of endosulfan and fluvalinate. A spraying threshold which varies according to time after commencement of bloom is developed for both chemicals. The prospects for utilising the predatory qualities of ADB on susceptible apple varieties are discussed.

METHODS

i Damage relationship

The relationship between bug numbers at flowering and damage at harvest was determined in a block of 99 Granny Smith variety trees at Bathurst Agricultural Research Station between 1984 and 1989. The block was divided into sub-blocks of ca. 20 trees each, which were treated each spring with one or two sprays of endosulfan, DDT, fluvalinate or no spray, to manipulate ADB populations. Five study trees were selected in the centre of each sub-block for population sampling and damage assessment. Fifty inflorescences per tree were sampled 2 or 3 times weekly from the late pink stage of flower bud development to two weeks after complete petal fall. Inflorescences were tapped sharply by hand over a suitable container to catch the dislodged bugs, which were counted.

At harvest up to 500 fruit, if available, were randomly selected from each study tree for assessment of damage and downgrading due to ADB. Fruit was classified according to whether or not it was damaged by ADB and whether the damage was sufficient to warrant downgrading from No. 1 Grade. Fruit was accepted as no. 1 Grade under NSW regulations if total insect blemishes on the surface did not exceed the area of a 5 mm diameter circle.

In 1986–87 and 1987–88 an additional 120 sets of similar data were obtained from individual Granny Smith trees in three chemical spray trials for control of ADB, giving a total of 244 data sets for analysis.

Regression analysis was used to relate the percentage of fruit downgraded at harvest to ADB populations present during blossoming. ADB populations were first converted to bugdays, a cumulative measure of bug activity over the bloom period. It was considered that damage at harvest would relate better to bugdays than to measures such as peak bug numbers, or total bug numbers in a series of samples. Bugdays are defined as follows:

$$\text{Bugdays} = \sum_{n=1}^{t} \frac{(X_n + X_{n+1})}{2} (d_{n+1} - d_n)$$

where x = number of bugs in a sample
d = number of days after the first sample
n = sample number
t = number of the last sample.

ii Economic model

The economic losses due to ADB, and the cost of sprays to control it, were calculated from a computer spreadsheet model of the costs and returns of a typical Orange district apple orchard (Mullen and Valentine 1982). The model takes account of all the costs involved in fruit growing including chemicals, machinery, fuel and labour for spraying. It was also used to examine the effects on profits of reducing the yield of No. 1 grade fruit.

iii Susceptibility of flower stages

Caging experiments were conducted at Bathurst Agricultural Research in 1991/92 to determine whether different stages of flower development differed in their susceptibility to ADB damage. Cylindrical cages (20 cm long x 15 cm diam), consisting of a light wire frame covered in white insect-proof cotton lawn, were placed over groups of 4 inflorescences at spurburst to exclude bugs. There were 22 cages per tree on 20 replicate trees . Bugs were introduced to 3 cages per tree for sequential periods of one week over 7 weeks from spurburst to 4 weeks after petal fall. Three densities of bugs were used, 4, 8 and 16 bugs per cage, one density in each of the 3 cages per tree. ADB for caging were captured on alternate hosts, principally lucerne tree (*Chamaecytisus prolifer*), wattles (*Acacia* spp) and hawthorn (*Crataegus monogyna*).

The bugs were removed at the end of the week and the flowers recaged. The number and developmental stage of flowers was recorded at the beginning and end of the week, and the number of live and dead bugs at the end. Flowers were hand pollinated by brushing the pollen laden anthers of cv. Jonathon flowers against the stigma of the caged flowers. The cages were removed from the developing fruitlets after the first spray of azinphos-methyl was applied for codling moth. Yield of fruit and ADB damage were assessed after the cages were removed and at harvest. The harvest fruit were graded according to NSW regulations.

The susceptibility of different flower stages to bug attack was compared using an index since the number of flowers or fruitlets available for bugs varied considerably over time, and between replicates, due to abortion of buds in the cages, shedding of unpollinated flowers and shedding of weak fruitlets. The index of susceptibility is defined as the mean number of ADB stings per fruit per bugday x 100, measured after cage removal.

RESULTS

i Damage relationships

The relationships between bugdays and the percentage of fruit downgraded at harvest was linear (Fig.1), highly significant ($P<0.001$), and accounted for 80.3 percent of the variance. The relationship shows that low bugdays can result in significant downgrading. For example, ten percent downgrading is caused by only 220 bugdays per 50 inflorescences; an average of 7.3 bugs per day over 30 days.

ii Economic threshold (ET)

The orchard spreadsheet model showed that for every one percent of fruit downgraded from No 1 grade, profit declined by 2.3 percent. It also showed that single sprays of endosulfan and fluvalinate reduced profit by 0.8 and 2.3 percent respectively (Table 1). Therefore, sprays of endosulfan and fluvalinate will recover their costs if they prevent downgrading of 0.3 and 1.0 percent, their respective ETs in terms of fruit damage. The damage relationship (Fig 1) allows the ET for damage to be converted to bugdays; 22 bugdays per 50 inflorescences for fluvalinate and 7 for endosulfan.

iii Susceptibility of flower stages

The changes in populations of ADB on inflorescences are shown in Figure 2 for spring 1991, which is typical of most years. Bugs are generally present only at low levels prior to the pink bud stage of development and increase as bloom commences. Numbers may peak at full bloom or shortly after and decline gradually as fruit development progresses. Bugs may be present over a 7 week period.

The susceptibility to flowers and fruitlets to ADB damage over this period varies considerably (Fig 3). Damage is greatest in the two weeks of flowering from late pink to petal fall. However, significant damage can also occur in the spurburst to late pink and one week after petal fall periods. Although quite high numbers of bugs may be present, the period from 2 to 4 weeks after petal fall is one of low susceptibility to damage. Data from 1984 to 1988 at Bathurst (Bower, unpubl.) indicates the susceptible period is usually about 30 days long.

iv Spraying Threshold (ST)

The ETs of 22 and 7 bugdays per 50 inflorescences for fluvalinate and endosulfan, respectively, can be converted to static STs of 0.73 and 0.23 bugs/day/50 inflorescences by dividing by 30. However, the bugdays concept suggests the possibility of a new time-based variable ST. Bugdays recognise that damage is a product not only of the number of bugs, but also of the time they are present. As bloom proceeds there is less time for damage to occur, and higher bug populations are required if the ET level of bugdays is to be exceeded (Fig 4). For example, on day 29 of the susceptible period there is only one day left to protect the flowers. Therefore, the number of bugs needed to justify a spray of fluvalinate is 22, the full ET in bugdays. On day 1, the ST is 0.73, the ET divided by 30, because bugs are assumed to remain at or above this level for the whole 30 day period. The variable spraying threshold is given by

ST = ET/t-n

where ST = spraying threshold

ET = economic threshold in bugdays

t = the length of bloom, 30 days

n = the number of days since spurburst

DISCUSSION

The results of this study show the economic threshold for ADB on apples is very low. Spraying with endosulfan is justified for bug population as low as 0.23 per 50 inflorescences. ADB is therefore a particularly damaging pest, which cannot be allowed to build up in numbers when the crop is susceptible to attack in the period from spurburst to one week after petal fall.

ADB populations vary considerably from year to year (Bower et al 1993) which suggests there is potential for population monitoring and the use of an ST. However, the ET for ADB is exceeded in most years and at least one spray would generally be needed per season, justifying the routine prophylactic treatments applied for this pest. This agrees with the conclusion of Mumford and Norton (1984) that pests which cause cosmetic injury, like ADB, may have impractically low ETs. Prophylactic spraying for such pests may not be avoidable (Poston et al 1983).

The variable spraying threshold developed in this study introduces time as a variable into the ST and shows that monitoring and thresholds may still be useful for pests affecting product quality. The variable ST shows that higher bug populations can be tolerated towards the end of bloom. Even though sprays will nearly always be required at the beginning of bloom, monitoring later in the bloom period can determine the need for second and subsequent sprays.

The low tolerance for ADB on apple trees suggests it may not be possible to utilise it for mite control. Even so, late invading bugs, which arrive beyond one week after petal fall, may still be useful. However, at this time there is a naturally declining trend in ADB numbers, suggesting the trees become less attractive after flowering has finished. Therefore, there is not likely to be a net gain in bugs, unless another food source, such as mites or thrips is available.

ACKNOWLEDGMENTS

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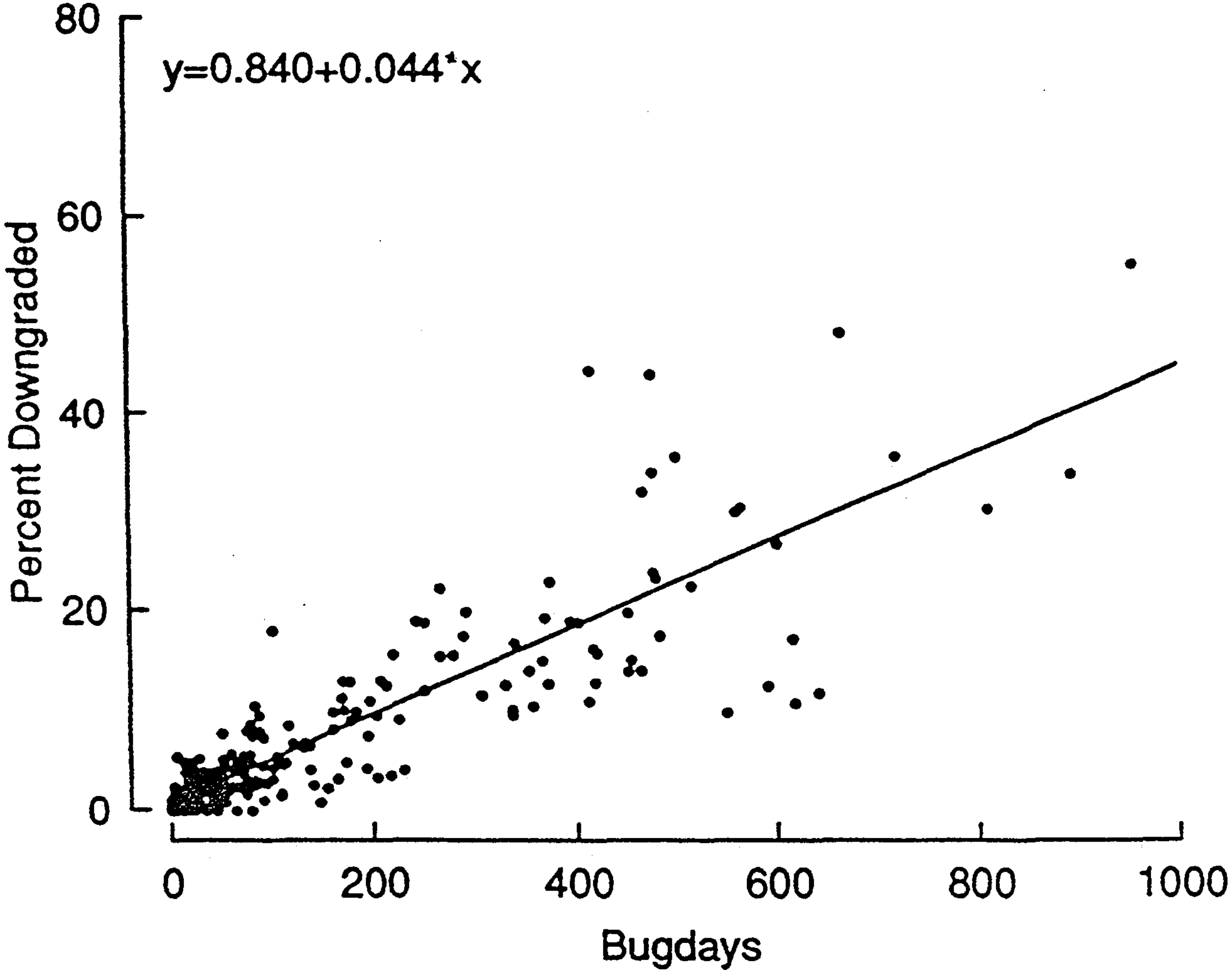


Figure 1. The relationship between the percentage of fruit downgraded by apple dimpling bug and cumulative bugdays per 50 inflorescences at flowering.

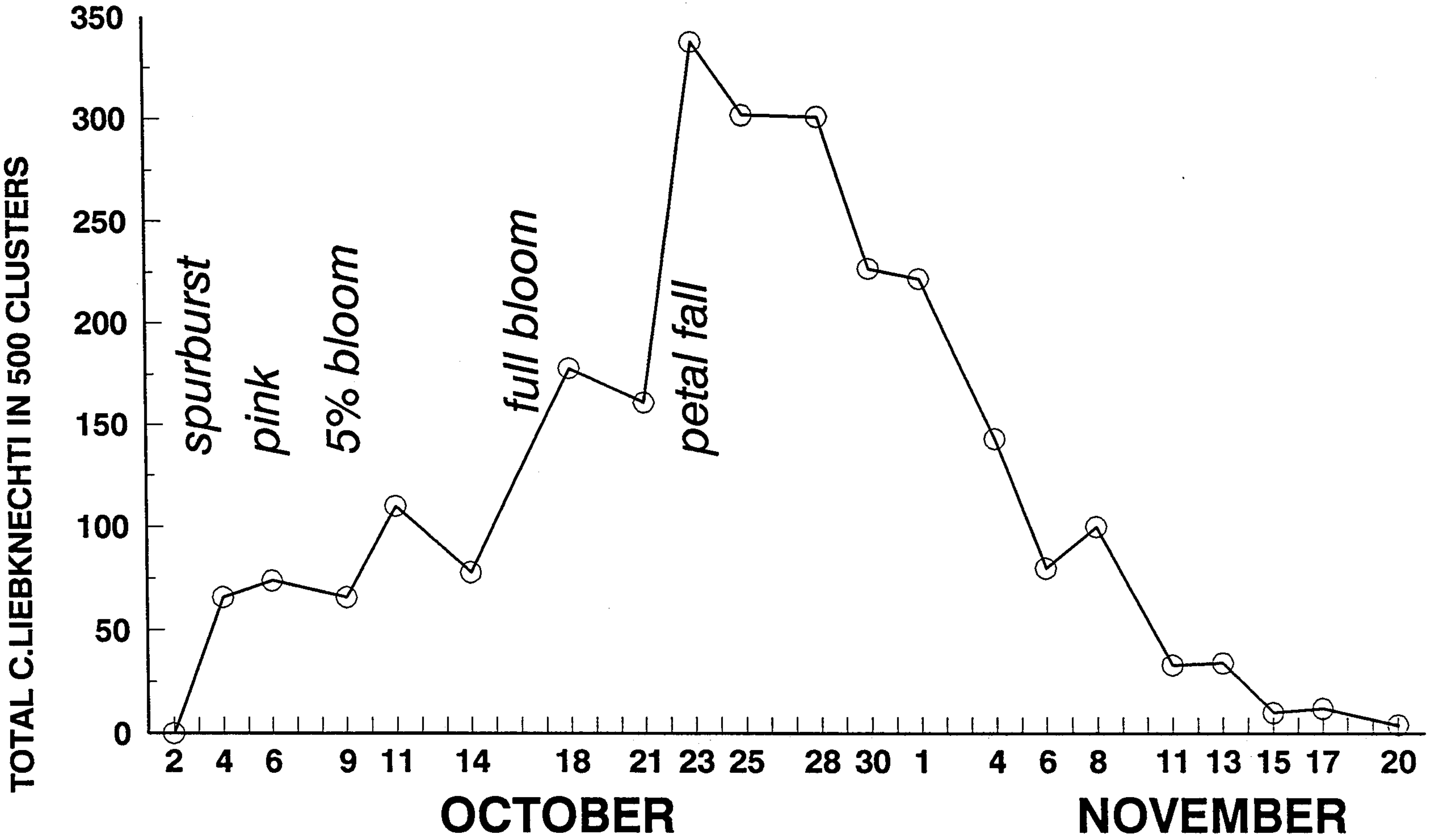
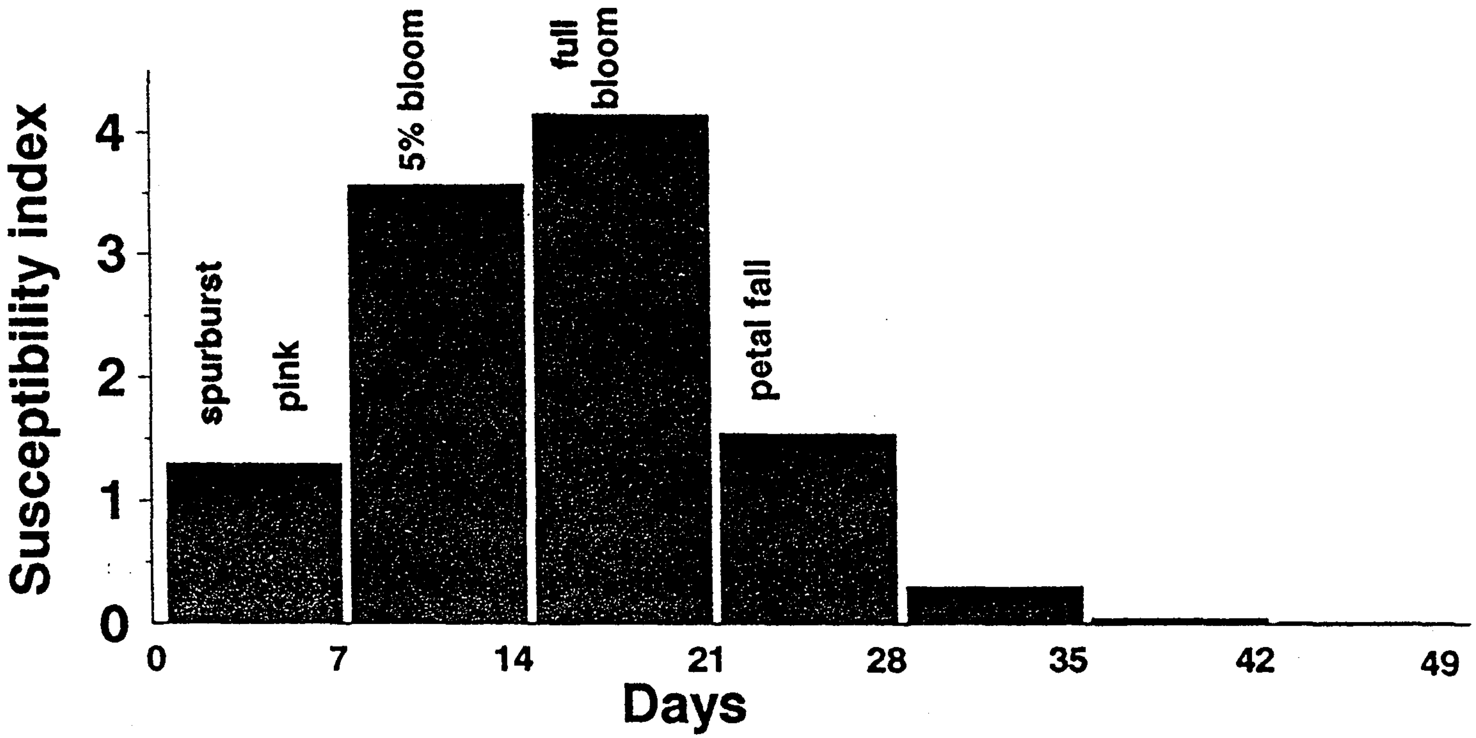


Fig. 2. Changes in C. liebknechti numbers in apple inflorescences, H Block, Bathurst Agricultural Research Station, 1991.

SUSCEPTIBILITY OF FLOWER GROWTH STAGES TO DAMAGE BY C.LIEBKNECHTI



Index is mean number of stings per fruit per bugday x100

Figure 3.

TIME-BASED VARIABLE SPRAYING THRESHOLD

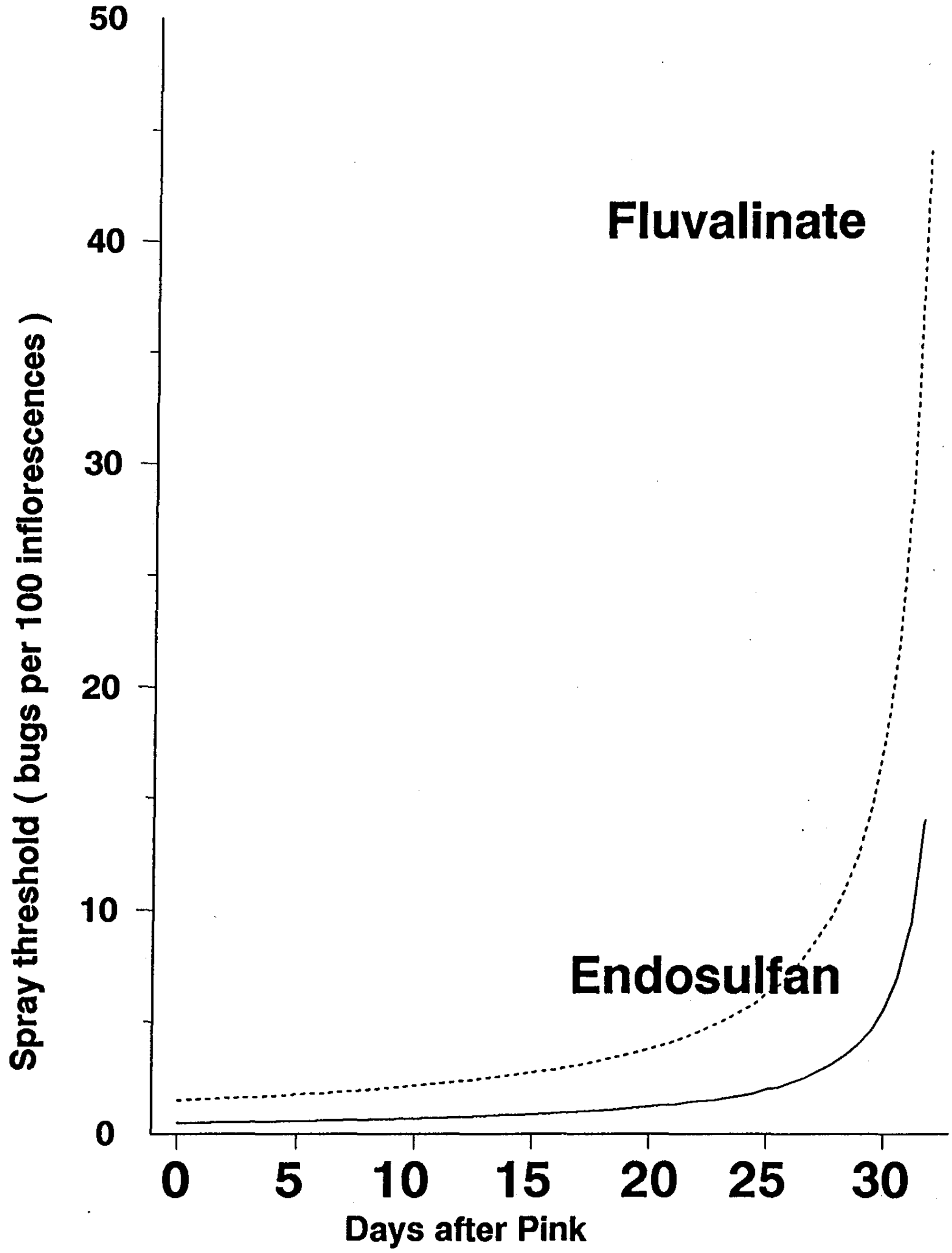


FIGURE 4. Variable spraying threshold for endosulfan and fluvalinate in numbers of C. liebknechti per 100 inflorescences

APPENDIX 3

TEBUFENPYRAD:

A NEW ACARICIDE COMPATIBLE WITH INTEGRATED MITE CONTROL

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INTRODUCTION:

Mite control on apples in Australia, as elsewhere, currently faces a number of problems. There is a complex of mite pests and predators of which European red mite, *Panonychus ulmi* (Koch) and twospotted mite, *Tetranychus urticae* (Koch) are the major pests (Bower and Thwaite, 1986). The two pests have different life histories, require different control strategies, and respond differently to some acaricides and to various predatory mites. However, the main difficulty faced in Australia is a lack of effective acaricides. This is a result of several factors including the withdrawal of the organotin acaricides, cyhexatin and azocyclotin, from Australia in 1987 and widespread resistance in both pests to the organotins, all older products and the newer ovicides, clofentezine and hexythiazox (Thwaite, 1991).

The only effective acaricide currently available in Australia is propargite, but its performance against *P. ulmi* is often unsatisfactory and there is low level resistance in some populations of *T. urticae* (Edge & James, 1983). There is concern that resistance to propargite will increase, but options for managing resistance are limited by the lack of alternative acaricides.

Resistance management strategies have been in place in New South Wales for acaricides in pome fruit since 1987 when resistance to the ovicides clofentezine and hexythiazox was first detected (Thwaite *et al*, 1987). Tactics in resistance management strategies have included integrated mite control, alternation of acaricides with different modes of action, and restrictions on the use of some products (Bower & Thwaite, 1989). Integrated mite control is based on the pesticide–resistant predatory mites, *Typhlodromus occidentalis* Nesbitt and *T. pyri* Scheuten, which have been introduced from Washington State and New Zealand, respectively (Seymour, 1982). These predators are now fully naturalised in the major apple growing districts of New South Wales and about 70 percent of growers practise integrated mite control. Currently, integrated mite control is not working with optimum efficiency due to the low efficacy of propargite against *P. ulmi*.

There is therefore an urgent need in Australia for new selective acaricides (Croft *et al*,

1987) to allow more efficient operation of integrated mite control. We have been investigating one potential new acaricide, tebufenpyrad, in the laboratory and field since 1989. This paper reports the comparative toxicology of tebufenpyrad against *P. ulmi* and its predator *T. pyri*, and the results of field trials which examined its effects on the *P. ulmi/T. pyri* and *T. urticae/T. occidentalis* prey/predator interactions in commercial apple orchards in New South Wales.

METHODS:

Tebufenpyrad is a discovery of the Mitsubishi Kasei Corporation of Japan. It is a member of a new group of acaricides, the pyridenes, and has the chemical formula:

N – (4–t–butylbenzyl) –4–chloro–3–ethyl–1–methyl–5–pyrazolecarboxamide

Tebufenpyrad used in this work was formulated as a white 20% wt/wt WP which will be marketed under the name Pyranica [(R)] in Australia by Sandoz Australia Pty Ltd.

Laboratory bioassay

Mites for laboratory bioassays were collected on foliage from commercial apple orchards in the Orange (n=7) and Batlow (n=2) districts of New South Wales. Foliage was transported to the laboratory in plastic bags in foam insulated boxes. Transport from Batlow was by overnight freight. Mites were tested as soon as possible after arrival, usually on the same day, or after a maximum of one night in a refrigerator at 4°C. Young adult female *P. ulmi* were transferred from apple leaves to 20 mm diameter peach (*Prunus persica* (L) Batsch) leaf discs placed upper surface down on cotton wool pads saturated with water in a petri dish. There were 20 to 30 mites per disc and 4 discs per treatment. Treatments consisted of 4 or 5 serial dilutions of an aqueous suspension of tebufenpyrad. The four discs of each treatment were sprayed together on a metal spatula in a Potter spray tower calibrated to give a deposit of 1.6 mg of liquid/cm^2 at 23° using 2 mL of suspension. After spraying, the discs were returned to the petri dishes and dead or injured mites were removed. The discs were then held at 26°C and 95% RH under constant illumination until mortality was assessed after 48 hrs. Mites were classified as dead if they failed to walk when gently prodded with a bristle. Mortality on the treated discs was corrected for the mortality on 4 control discs using Abbott's formula (Abbott 1925). Control discs were sprayed with water only and were handled in the same way as the treated discs. Data from tests where control mortality exceeded 20% were discarded.

The method for testing eggs of *P. ulmi* was similar to that developed by Thwaite (1991). Eggs were obtained by transferring 10 mature adult females from apple leaves to 15 mm diam. peach leaf discs on wet filter paper over saturated cotton wool. The discs with females were held at 28°C, 50% RH and constant light for 24 hours after which the females were removed. There were four discs per treatment with an average of ca 3.5 eggs laid per female. Eggs were treated by immersing the discs for 5 seconds into one of 4 or 5 aqueous suspensions of tebufenpyrad obtained by serial dilution. Immediately prior to immersion a wetting agent (Agral (R) 60) was added to the suspension at a concentration of 0.03%. After removing damaged eggs and counting the remainder on each disc, the discs were held for 7 days at 28°C, 50% RH and constant light. The number of unhatched eggs, including partly hatched eggs with dead larvae, was counted and the percent mortality calculated. Abbott's formula was used to correct for control mortality determined from four identically handled discs dipped in water with wetting agent only.

Mature adult female *T. pyri* for bioassay were collected from field populations in commercial apple orchards and treated in the same way as for adult *P. ulmi.*

Field Trials

Four field trials were conducted in the 1990-91 season in commercial apple orchards in the Bathurst and Orange districts of NSW (Tables 1 and 2). Two trials (Reedy, Gartrell, Table 2) examined the effects of tebufenpyrad on the *T. urticae/T. occidentalis* prey/predator relationship and the other two (Pearce, Pierce) were in orchards where *P.*

ulmi/T.pyri were dominant. Identical treatments and methods were used in the four trials (Table 1). Tebufenpyrad was applied at four concentrations from 2.5 to 10.0 g a.i. per 100L water. Methidathion, (Supracide ®, 40% wt/vol. EC, Ciba-Geigy Australia Ltd) which is known to be highly toxic to both *T. occidentalis* and *T. pyri* (Bower & Thwaite, 1986), was included as a toxic standard.

Control trees were sprayed with water only. Treatment were single sprays replicated four times, each replicate being fully randomised on unbuffered single tree plots. A row of handsprayed buffer trees separated the trial area from the rest of the orchard to minimise drift from airblast applied by the grower. Application of sprays was by a hand wand, with two adjustable fan nozzles, aiming for complete wetting of the foliage.

Apple varieties, treatment dates and the mean volume of spray per tree in each trial are shown in Table 2. To prevent excessive damage to foliage, propargite was applied to treatments F and/or E (Table 2), between 31 and 47 days after the treatments were applied (Table 2). In one trial (Pierce) the grower accidentally applied a cover spray of propargite over all replicates 56 days after the treatments were applied and a few hours before a routine sample was taken. Propargite had been applied to the trial block 7 days and ca. 2 weeks before the treatments in the Pierce and Gartrell orchards, respectively. No prior acaricides were used in the other two orchards in 1990/91. All trial blocks received sprays regarded as safe to predatory mites (Penrose *et al* 1990) for control of diseases and other pests.

Mite numbers were monitored fortnightly commencing with a sample immediately pre-spraying. Twenty five mature leaves were taken from the lower part of the tree (0.5 to 2 m) distributed evenly between the inner and outer canopy around the circumference. Samples were stored in a domestic refrigerator or coolroom at 4°C for up to one week before counting. The number of active stages of each mite species were recorded for each leaf using a binocular microscope.

RESULTS:

Laboratory bioassays

The dose-response statistics for the four strains of adult female *P. ulmi* were very consistent, both for LC50 and slope (Table 3). The strain LC50's were not significantly different (P>0.05), which allowed a combined LC50 based on 2259 mites to be calculated. The combined LC50 of only 1.6 ppm shows that tebufenpyrad is active at very low concentrations against adult *P. ulmi.* Tests on two strains of *P. ulmi* eggs (Table 4) gave less consistent LC50's, 7.40 and 5.25 ppm respectively, which were significantly different (p>0.05). These data show tebufenpyrad also has significant ovicidal activity, although the mean LC50 for eggs was 3.3 times more than for adults.

The LC50's for adult female *T. pyri* were much greater than for eggs or adult females of *P. ulmi* (Table 5). Three of the 4 strains tested had similar LC50's, (mean 220.7 ppm), but that far the Gartrell strain (119 ppm) was significantly lower (P>0.05), indicating it was ca. 1.9 times more susceptible to tebufenpyrad than the other strains. The data show adult females of *T. pyri* are more tolerant of tebufenpyrad by 73 (Gartrell strain) to 135 times.

Field trials

P. ulmi/T. pyri

The results obtained in two field trials on the *P. ulmi/T. pyri* prey/predator interaction were similar (Tables 6 and 7). Initial populations of both *P. ulmi* and *T. pyri* were much higher in the Pearce orchard than in the Pierce orchard. In both trials there was a small decline in *P. ulmi* populations following sprays of water on the controls (Table 6 and 7), but numbers increased again from two weeks after spraying. There was also a marked decline in *T. pyri* numbers after the water treatment on the controls in the Pearce orchard (Table 6) and a smaller decline in the Pierce orchard (Table 7). In the latter case the decline continued slowly for 4 weeks before numbers increased again in response to a rising *P. ulmi* population. Methidathion also caused initial declines in *P. ulmi* and *T. pyri* (Tables 6 and 7). As in the controls, *P. ulmi* populations rebounded beyond two weeks after spraying. To prevent excessive damage to foliage, propargite was applied to the methidathion and control treatments ca. 6 weeks after both trials commenced.

All concentrations of tebufenpyrad reduced *P. ulmi* and *T. pyri* populations to very low levels in both trials (Tables 6 and 7). At all concentrations, control of *P. ulmi* was maintained until the end of the season. Some concentration dependant effects are apparent in the Pearce trial (Table 6). The length of control given by tebufenpyrad was positively correlated with concentration. The time was taken for *P. ulmi* to exceed 0.2 mites/leaf after spraying at each concentration was 10 weeks at 10 g a.i./100L, 8 weeks at 7.5 g, 8 weeks at 5 g, and 6 weeks at 2.5 g. The largest increase in *P. ulmi* occurred at the lowest concentration of tebufenpyrad. However, sufficient *T. pyri* were present to maintain *P. ulmi* below the economic threshold (10 mites/leaf) (Bower, unpubl.) at all concentrations of tebufenpyrad. A substantial numerical response to the rising *P. ulmi* population occurred in *T. pyri* at the lowers tebufenpyrad concentration (Table 6).

Graded resurgences in response to the concentration of tebufenpyrad did not occur in *P. ulmi* in the Pierce orchard before it was oversprayed with propargite. However, significantly higher ($P > 0.05$) populations of *T. pyri* developed at the lowest concentrations of tebufenpyrad (2.5 g a.i./100L) during February compared with the highest concentration (10 g a.i./100L).

T. urticae/T. occidentalis

Both field trials on the *T. urticae/T. occidentalis* interaction took place in apple blocks in which successful biological control of the pest occurred on the control trees (Table 8 and 9). In the Reedy orchard (Table 8) *T. urticae* and *T. occidentalis* peaked two weeks after the trial commenced. Over the next 4 weeks *T. urticae* was reduced to very low numbers by *T. occidentalis*, which declined more gradually. The Gartrell trial commenced with low *T. urticae* and relatively high *T. occidentalis* populations orchard following an application of propargite ca. 2 weeks earlier. The rapid decline in *T. occidentalis* numbers in the first two weeks on the controls was probably due mainly to a shortage of prey induced by the earlier propargite spray. However, *T. occidentalis* increased again in February in response to a small resurgence by *T. urticae* and maintained control of the pest until the end of the season.

Methidathion disrupted biological control in both trials by reducing *T. occidentalis* to very low levels (Tables 8 and 9). This allowed *T. urticae* to increase rapidly above the spraying threshold (20 mites/leaf) and propargite was applied.

Tebufenpyrad at all concentrations effectively controlled *T. urticae* in the Reedy trial (Table 9) but also reduced *T. occidentalis* to very low levels. The pest showed a minor resurgence at the 3 highest concentrations by 6 weeks post-spraying, but was maintained well below the spraying threshold by *T. occidentalis* on all treatments.

In the Gartrell trial, all concentrations of tebufenpyrad further reduced the initially low *T. urticae* populations and severely reduced the relatively high *T. occidentalis* numbers. In this trial there was a greater resurgence of *T. urticae* than in the Reedy trial, but rapid numerical responses by *T. occidentalis* at all concentrations of tebufenpyrad kept pest numbers below the spraying threshold.

Discussion

The bioassay data show that tebufenpyrad is highly active against both the eggs and adults of *P. ulmi*. The 20 WP is about 67 times more active than the 30 WP formulation of propargite (Thwaite, unpubl.) which is the main acaricide currently used in Australian orchards. The combined LC50 for the four strains of adult females tested in this study (1.63 ppm) provides a baseline measure of the toxicity of tebufenpyrad prior to its commercial release. Future monitoring for resistance can therefore look for shifts in the susceptibility of *P. ulmi* from this reference point.

Adult female *T. pyri* are 73–135 times more tolerant of tebufenpyrad than adult female *P. ulmi*. The LC50s for *T. pyri* ranged from 120 to 220 ppm for the strains tested, which is higher than the concentrations of tebufenpyrad used in the field trials (25–100 ppm). These data indicate that tebufenpyrad should select in favour of *T. pyri* in the field if all other life stages have similar tolerances. These results suggest tebufenpyrad would be compatible with integrated control of *P. ulmi* based on *T. pyri*, although some mortality of *T. pyri* could be expected.

The field trials confirmed the high efficacy of tebufenpyrad against *P. ulmi* and showed it was also effective against *T. urticae*. However, *T. urticae* populations recovered more quickly than *P. ulmi* after spraying, which suggests *T. urticae* may be less susceptible.

The suppression of *T. pyri* in the field by tebufenpyrad was greater than expected from the bioassay results. However, in both field trials predator/prey ratios after spraying favoured the predator and control of *P. ulmi* was maintained for the remainder of the growing season. In contrast, methidathion was highly disruptive. It removed *T. pyri* populations, had less effect on *P. ulmi*, and resulted in severe outbreaks of the pest. These data confirm that tebufenpyrad is selective and compatible with integrated mite control. The relative toxicity of tebufenpyrad to *T. urticae* and *T. occidentalis* was not determined in laboratory bioassays, but the field data indicates tebufenpyrad is also selective in this interaction.

The new group of acaricides of which tebufenpyrad is a member, the pyridenes, is arriving at a crucial time for Australian horticulture. Resistance to all acaricides except propargite is widespread in *P. ulmi* and *T. urticae* (Thwaite 1990). Tebufenpyrad is effective against all life cycle stages of mites and can be used at any time during the growing season. This flexibility and its great effectiveness mean growers may become overdependent on it, with consequent overuse. We consider it is essential that a resistance management strategy for the pyridenes should be in place when these products are first released commercially.

A resistance management strategy should include the following elements. Growers should practise integrated mite control (Bower & Thwaite 1986, 1989). Use of pyridenes should be restricted to one application per season and this spray should be timed for mid to late summer (January and February in Australia) when mite control is most difficult and *T. pyri* is least effective (Bower, 1984). In practice, the effectiveness of tebufenpyrad should mean that only one spray is needed for *P. ulmi*, particularly where IMC is being practised. The lower effectiveness of tebufenpyrad against *T. urticae* may require further acaricide applications where IMC is not established. If additional treatments are needed before or after the single pyridene spray, alternative products such as propargite, or fenbutation oxide should be used.

Acknowledgments

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Table 1. Chemical treatments and concentrations in four integrated mite control trials at Orange and Bathurst, 1990-91.

Treatment code	Chemical name	Product name	Formulation	Concentration (g a.i./100L water)
A	tebufenpyrad	Pyranica [R]	20 WP	10.0
B	"	"	20 WP	7.5
C	"	"	20 WP	5.0
D	"	"	20 WP	2.5
E	methidathion	Supracide [R]	400 EC	50.0
F	water	-	-	-

Table 2. Treatment dates, spray volumes and apple varieties in four integrated mite control trials, 1990-91.

Grower name	District	Apple variety	Treatment date	Date of propargite on treatments E and F	Mean spray vol. per tree (L)
J & K Reedy	Bathurst	GS	15 Jan 91	15 Feb 91 (E)	11.2
D Gartrell	Orange	GS	9 Jan 91	25 Feb 91 (E)	15.5
R Pearce	Orange	Delicious	6 Jan 90	17 Feb 91 (E&F)	15.0
WS Pierce & Sons	Orange	Delicious/GS	7 Jan 90	18 Feb 91 (E&F)[1]	17.4

[1] Grower accidentally applied propargite to the whole trial block on 1 Feb 91 (56 DAT).

Table 3. Dose response data for four strains of adult female *Panonychus ulmi* to a wettable powder formulation of tebufenpyrad.

Strain	LC50 (ppm)	95% CL	Slope ± S.E.	n[1]
Bagnall, Batlow	1.37	0.93-2.00	1.44 ± 0.25	412
Gale, Shadforth	1.69	1.41-2.02	2.63 ± 0.44	419
Pearce, Orange	1.61	1.26-2.04	1.89 ± 0.13	535
Pierce, Nashdale	1.64	1.40-1.92	2.33 ± 0.34	893
Combined	1.63	1.48-1.82	2.14 ± 0.13	2259

[1] n = number of mites tested, including controls.

Table 4. Dose response for data for the eggs of four strains of *Panonychus ulmi* to a wettable powder formulation of tebufenpyrad.

Strain	LC50 (ppm)	95% CL	Slope ± S.E.	n[1]
ARS, Bathurst	7.40	6.47–8.45	2.65 ± 0.66	716
Signor, Batlow	5.25	4.52–6.11	2.28 ± 0.32	489
Mean LC50	6.30	–		1205

[1] number of mites tested including controls.

Table 5. Dose response data for four strains of adult female *Typhlodromus pyri* to a wettable powder formulation of tebufenpyrad.

Strain	LC50 (ppm)	95% CL	Slope ± S.E.	n[1]
Cantrill	207	166–258	2.28 ± 0.34	249
Pierce	236	206–271	3.09 ± 0.25	373
Dally	219	170–247	2.33 ± 0.15	184
Gartrell	119	94–151	2.42 ± 0.31	275

[1] number of mites tested including controls.

Table 6. Effect of tebufenpyrad on *P. ulmi* and *T. pyri* on Delicious apples, R Pearce, Orange, 1990–91. Retransformed mean numbers of mites per leaf.

Chemical	Concentration (g a.i. per 100L)	Days after treatment (DAT) -1[1]	14	29	42	56	70	81	97	111
P. ulmi										
tebufenpyrad	10.0	30.5 ab[2]	0.0 a	0.0 a	0.04 a	0.0 a	0.01 a	0.44 a	0.20 a	0.0 a
tebufenpyrad	7.5	14.6 ab	0.0 a	0.0 a	0.01 a	0.19 a	1.04 a	1.40 a	0.14 a	0.0 a
tebufenpyrad	5.0	38.1 b	0.0 a	0.01 a	0.02 a	0.0 a	0.21 a	0.52 a	0.06 a	0.0 a
tebufenpyrad	2.5	16.2 ab	0.0 a	0.02 a	0.18 a	1.57 b	4.92 b	2.76 b	0.08 a	0.0 a
methidathion	50.0	12.8 ab	0.3 a	2.58 a	10.2 b	0.14 a[3]	0.75 a	0.75 a	1.52 b	0.01 a
water	–	7.4 a	3.46 a	10.8 b	34.6 c	0.24 a[3]	0.91 a	1.08 a	1.79 b	0.20 a
T. pyri										
tebufenpyrad	10.0	2.57 ab	0.0	0.0	0.0	0.0	0.03 a	0.06 a	0.48 ac	0.23 a
tebufenpyrad	7.5	2.43 ab	0.01	0.0	0.0	0.01	0.04 a	0.06 a	0.12 a	0.33 a
tebufenpyrad	5.0	3.13 b	0.0	0.0	0.0	0.03	0.09 a	0.21 a	0.82 bc	0.46 ab
tebufenpyrad	2.5	1.22 a	0.02	0.0	0.09	0.24	0.44 b	1.13 b	1.19 c	1.00 b
methidathion	50.0	1.15 a	0.0	0.0	0.0	0.0	0.0 a	0.01 a	0.04 a	0.15 a
water	–	1.18 a	0.08	0.14	0.15	0.01	0.05 a	0.07 a	0.34 ab	0.18 a

[1] Pre-treatment count, 5 Dec 1990

[2] Means followed by the same letter are not significantly different ($P < 0.05$)

[3] Propargite applied to these treatments 42 DAT

Table 7. Effect of tebufenpyrad on *P. ulmi* and *T. pyri* on Delicious apples, W Pierce, Orange, 1990–91. Retransformed mean numbers of mites per leaf.

Chemical	Concentration (g a.i. per 100L)	−4[1]	12	27	41	56[3]	69	84	102
P. ulmi									
tebufenpyrad	10.0	1.76 a[2]	0.0 a	0.0 a	0.19 a	0.02 a	0.0 a	0.0 a	0.07 a
tebufenpyrad	7.5	1.21 a	0.0 a	0.0 a	0.04 a	0.05 a	0.0 a	0.0 a	0.02 a
tebufenpyrad	5.0	1.47 a	0.0 a	0.0 a	0.18 a	0.08 ab	0.0 a	0.0 a	0.01 a
tebufenpyrad	2.5	1.11 a	0.0 a	0.01 ab	0.23 a	0.17 ab	0.0 a	0.0 a	0.0 a
methidathion	50.0	1.26 a	0.61 b	2.65 ab	15.3 b	1.34 b[4]	0.03 a	0.0 a	0.0 a
water	–	1.30 a	0.64 b	4.10 b	10.1 b	0.17 ab[4]	0.0 a	0.0 a	0.02 a
T. pyri									
tebufenpyrad	10.0	0.59 a	0.0 a	0.02 a	0.04 a	0.02 a	0.01 a	0.02 ab	0.0 a
tebufenpyrad	7.5	0.68 a	0.0 a	0.0 a	0.05 a	0.06 ab	0.04 ab	0.07 c	0.03 b
tebufenpyrad	5.0	0.21 a	0.0 a	0.0 a	0.04 a	0.08 ab	0.05 ab	0.03 bc	0.02 ab
tebufenpyrad	2.5	0.66 a	0.03 a	0.01 a	0.08 a	0.18 b	0.10 b	0.05 bc	0.02 ab
methidathion	50.0	0.44 a	0.0 a	0.01 a	0.03 a	0.13 ab	0.05 ab	0.02 ab	0.01 ab
water	–	0.58 a	0.43 a	0.23 b	0.35 b	0.14 ab	0.02 ab	0.0 a	0.01 ab

[1] Pre-treatment count, 3 Dec 1990

[2] Means followed by the same letter are not significantly different ($P < 0.05$)

[3] Trial area accidently oversprayed with propargite 56 DAT

[4] Propargite applied to these treatments 42 DAT

Table 8. Effect of tebufenpyrad on *T. urticae* and *T. occidentalis* on Granny Smith apples, J and K Reedy, Bathurst, 1991. Retransformed mean numbers of mites per leaf.

Chemical	Concentration (g a.i. per 100L)	-1[1]	14	28	42	56	69	84
		Days after treatment (DAT)						
T. urticae								
tebufenpyrad	10.0	10.8 a[2]	0.14 a	0.74 a	0.48 a	0.01 a	0.0 a	0.02 a
tebufenpyrad	7.5	8.5 a	0.0 a	0.17 a	0.34 a	0.17 a	0.01 a	0.01 a
tebufenpyrad	5.0	5.9 a	0.02 a	0.46 a	0.14 a	0.0 a	0.0 a	0.06 a
tebufenpyrad	2.5	13.3 a	0.04 a	0.04 a	0.11 a	0.04 a	0.01 a	0.01 a
methidathion	50.0	5.8 a	24.5 b	64.0 b	2.12 b[3]	2.35 b	1.25 b	1.67 a
water	–	7.7 a	10.7 b	3.10 a	0.05 a	0.0 a	0.01 a	0.01 a
T. occidentalis								
tebufenpyrad	10.0	1.28 a	0.03 a	0.24 a	0.66 b	0.20 ab	0.02 a	0.04 a
tebufenpyrad	7.5	0.73 a	0.0 a	0.0 a	0.15 ab	0.29 b	0.03 a	0.09 a
tebufenpyrad	5.0	1.39 a	0.02 a	0.05 a	0.20 ab	0.11 ab	0.01 a	0.04 a
tebufenpyrad	2.5	0.80 a	0.0 a	0.01 a	0.06 a	0.06 ab	0.02 a	0.04 a
methidathion	50.0	0.62 a	0.01 a	0.0 a	0.0 a	0.01 a	0.05 a	0.05 a
water	–	0.34 a	1.00 b	0.86 b	0.61 b	0.23 ab	0.03 a	0.07 a

[1] Pre-treatment count, 14 Jan 1991

[2] Means followed by the same letter are not significantly different ($P < 0.05$)

[3] Propargite applied to this treatment 30 DAT

Table 9. Effect of tebufenpyrad on *T. urticae* and *T. occidentalis* on Delicious apples, D Gartrell, Orange, 1991. Retransformed mean numbers of mites per leaf.

Chemical	Concentration (g a.i. per 100L)	-1[1]	14	28	42	56	70	83	96
		Days after treatment (DAT)							
T. urticae									
tebufenpyrad	10.0	0.49 a[2]	0.0 a	0.04 a	0.76 a	4.65 a	10.5 a	7.5 b	5.5 b
tebufenpyrad	7.5	1.07 a	0.0 a	0.0 a	0.28 a	1.60 a	3.1 a	4.4 ab	2.9 ab
tebufenpyrad	5.0	0.53 a	0.0 a	0.02 a	1.28 a	3.8 a	3.0 a	2.9 ab	0.63 ab
tebufenpyrad	2.5	0.52 a	0.0 a	0.0 a	0.44 a	1.48 a	3.2 a	3.8 ab	5.1 ab
methidathion	50.0	0.81 a	0.97 a	6.7 b	40.5 b	0.55 a[3]	0.59 a	0.18 a	0.36 a
water	–	1.18 a	0.03 a	0.03 a	0.57 a	0.99 a	0.55 a	0.76 ab	0.69 ab
T. occidentalis									
tebufenpyrad	10.0	0.90 a	0.0 a	0.01 ab	0.03 a	0.24 a	1.72 a	2.55 b	1.74 b
tebufenpyrad	7.5	0.81 a	0.01 a	0.03 ab	0.01 a	0.09 a	0.52 a	0.96 ab	1.18 ab
tebufenpyrad	5.0	0.90 a	0.0 a	0.01 ab	0.03 a	0.11 a	1.23 a	2.18 b	1.22 ab
tebufenpyrad	2.5	1.08 a	0.0 a	0.0 a	0.0 a	0.04 a	0.36 a	0.71 ab	0.87 ab
methidathion	50.0	0.75 a	0.0 a	0.0 a	0.01 a	0.06 a	0.21 a	0.11 a	0.16 a
water	–	1.23 a	0.03 a	0.06 b	0.20 b	0.32 a	1.18 a	1.26 ab	0.54 ab

[1] Pre-treatment count, 9 Jan 1991

[2] Means followed by the same letter are not significantly different ($P < 0.05$)

[3] Propargite applied to this treatment 47 DAT