Biological control of grapevine mites

FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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Grape and Wine Research & Development Corporation

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SUMMARY

This report provides detailed data on grapevine mite and predatory mite population biology from four major viticultural regions of south-eastern Australia (Riverlands, Sunraysia, Murrumbidgee Irrigation Area (MIA), Canberra). In addition, data are presented on aspects of the biology, pesticide susceptibility and rearing of major predators involved in biological control of grapevine mites. It is concluded that considerable potential exists for the development of mite management strategies based on biological control in inland viticulture of south-eastern Australia.

Population monitoring of the major mite pests of grapevine (bunch mite, blister mite, rust mite) and associated natural enemies (principally predatory mites of the Family Phytoseiidae) over a three years period in commercial and Research Station vineyards, revealed considerable differences in levels of apparent natural control of mite pests. In the Riverlands of South Australia low numbers of pest mites and high numbers of predatory mites (principally *Typhlodromus doreenae)* were characteristic of most vineyards. Mites were not an economic problem in any sprayed or unsprayed vineyard studied. *T. doreenae* inhabited most Riverlands vineyards throughout the year and was considered responsible for the very low populations of bunch mite recorded. Another predatory mite, *Amblyseius victoriensis,* also occurred in Riverlands vineyards during summer and autumn and fed mostly on blister and rust mite.

In Sunraysia, natural control of mites was less satisfactory and some high levels of pest mites were recorded. *T. doreenae* was not recorded from this region although *A. victoriensis* and another predator *Amblyseius loxtoni* were often common late in the season. In the MIA, biological control of grapevine mites was absent or at too Iowa level to provide benefits.

T doreenae was not recorded in studied blocks, although *A. victoriensis* was often common during autumn when sprays had ceased. Greater use of synthetic fungicides and insecticides was made in MIA vineyards than in Sunraysia or Riverlands vineyards. In the Riverlands disease control was generally based on the use of sulphur and copper.

High numbers of predatory mites and low pest mite populations were also found in vineyards in the Canberra district. *T. doreenae* was the dominant predator, although two other species, *Phytoseius fotheringhamiae* and *Typhlodromus dossei* also occurred in significant numbers. A similar situation was recorded in vineyards in the Swan Hill district with the dominant phytoseiids being *T. doreenae* and *A. loxtoni. T. doreenae* was also recorded from vineyards in the southern Vales, Barossa Valley, Eden Valley (South Australia), King Valley (Victoria), Cowra, Mudgee and the MIA (NSW). Presence of *T. doreenae* in the MIA was restricted to two vineyards (Leeton, Griffith).

Laboratory biological studies on *A. victoriensis* established that this predator has a great tolerance of high temperatures with development occurring at temperatures between IO-40°C. An estimate of 10.3°C was obtained for the developmental zero (temperature below which no development can occur) and 93.1 degree days above this temperature is the estimated requirement for egg to adult development.

A successful laboratory rearing method for *A. victoriensis* and *T. doreenae* was developed using pollen of cumbungi *(Typha orientalis).* This has enabled year-round production of predators and has potential to be the basis for commercial mass rearing programs.

The effect of copper and sulphur sprays on survival of *T. doreenae* was examined in laboratory bioassays. Field rates of copper and wettable sulphur were not toxic.
Wettable sulphur at 200 x the field rate produced less than 50% mortality. The field rate of lime sulphur was very toxic to *T. doreenae* killing 98% of predators tested.

In a limited study an attempt was made to introduce *T. doreenae* to an MIA vineyard. Release of an estimated 1280 individuals on vine leaves collected from Riverlands vineyards, resulted in establishment.

This three- year study was initiated to investigate the potential and practicality of using predatory mites as biological control agents for bunch, blister and rust mites on inland grapevines in south-eastern Australia. These objectives were clearly met. Furthermore, there is considerable optimism that the longer term goal of developing sustainable vineyard mite management based on biological control, can be achieved. Biological control of grapevines mites is already a reality in at least two viticultural areas with quite different climatic and environmental factors. Biological control in both areas is provided by indigenous predators. This is the safest and most reliable type of biological control, least likely to unbalance the ecosystem or to suffer major variation in efficacy. As well as being native, the major predators involved in biological control of grapevine mites *(T. doreenae, A. victoriensis)* have the benefit of not being restricted to a single food source. They require minimal monitoring once established. Another major attribute of *T. doreenae* is its tolerance to wettable sulphur and copper.

This research is an excellent example of the cost-effectiveness and practical benefits which can be obtained from study of a natural system. The knowledge presented here was gained quickly with relatively little cost, but will revolutionise mite control in Australian vineyards. This research provides the basis for widespread implementation of biological mite management in inland viticulture. There is little reason to doubt that miticides can be entirely removed from inland viticulture.

BACKGROUND

Three species of mite commonly attack grapevines in Australia, bunch mite, *Brevipalpus* spp., grapeleaf blister mite, *Colomerus vitis* (Pagenstecher) and grapeleaf rust mite, *Calepitrimerus vias* Nalepa. They occur in all viticultural regions and are routinely treated with miticides.

Bunch mite

Adult bunch mites are 0.3 mm long, flat and shield shaped. They are generally reddish brown but range from pale white to bright red. They are usually difficult to see because they lie flush to the leaf surface and move slowly. The adults over winter under outer bud scales and under rough bark at the bases of canes. In spring they move out and feed on the developing canes and the under surfaces of leaves. By mid-summer they can be found on bunch stalks, berry pedicels and berries. The eggs are oval, bright red and hatch into six legged larvae, which moult twice before reaching adulthood.

Early signs of bunch mite activity are usually seen in November at the bases of canes. Injury at this time consists of slightly raised black spots, which merge into dark brown scar tissue. Mites then spread along the canes concentrating on the bunch stalks and berry pedicels. They can cause shrivelling of berries and thinning of bunches. As mite activity increases, the symptoms become more pronounced and the stalks and pedicels become covered with dark brown raised scar tissue. The damage partially starves the berries, preventing high sugar content and reducing size and weight. Berries can dry out while still on the vine. Bunch mites continue to feed during packing and transport, so bunches of table grapes will be flabby, some berries will fall and fruit that was attractive shows up poorly. Bunch mite appears to attack most grapevine varieties. However, damage can be worse on late harvested varieties, particularly when hot and dry conditions during late summer provide a favourable environment for rapid population increase.

Grapeleaf blister mite

The grapeleaf blister mite also known as erinose mite, occurs in two forms, the blister mite strain and the bud mite strain. Although morphologically identical, the two strains differ considerably in behaviour and the damage they cause. Greater damage is cased by the bud mite strain, but symptoms are not obvious and may be confused with those caused by boron deficiency or toxicity. Bailey (1985) states that bud mite is the most damaging grapevine mite in South Australia. However in New South Wales, Victoria and Western Australia it is not considered to be a major problem.

Mites are 0.2 mm long, white or creamy and worm-like. They have two pairs of legs at the head end and cannot be seen with the naked eye. They over winter inside the buds or under bud scales. The blister mite form moves onto the leaves during spring but the bud mite form penetrates the buds of new shoots where they feed and breed.

Blister mites cause damage by feeding on the undersides of leaves. The leaf responds

by producing a blister-like gall with the concave surface bulging from the upper surface of the leaf. Initially, the damage shows as small circular yellow areas on the leaf under surface becoming brown and felt-like. The entire leaf surface can become covered with blisters .The actual damage resulting from blister mite feeding is probably not significant but If the Infestation is very heavy, leaves may be reduced in size and distorted so that grape bunches are exposed to the sun.

The most notable symptom of bud mite damage is death of basal buds in new shoots resulting in yield loss. Other symptoms include abscission of bunches, death of the shoot tip in spring, stunted cane growth, short basal internodes, flattened canes, dead terminal buds on the new canes, witches broom growth of new shoots and zigzagged shoots.

Grapeleaf rust mite

Grapeleaf rust mite belongs to the same family as grapeleaf blister mite, consequently they are very similar in size and shape. However, grape leaf rust mites are most commonly found on uppers ides of grape leaves and are more active than blister mites.
Rust mites occur in all regions but are more of a problem in coastal or cool climate districts.

Damage is caused by mites rupturing the epidermal cells and causing the upper surface of leaves to become reddish-brown or purple. The area along the main veins and midrib where mites are most numerous tends to show the deepest discolouration. In bad infestations leaves can be blackened and leaf drop can occur causing bunches to suffer from sunburn.

Grapevine mites are generally controlled by budswell sprays of lime sulphur or promecarb and sprays of wettable sulphur and/or dicofol during the growing season. Wettable sulphur is routinely included with downy mildew fungicide sprays. It also provides protection against powdery mildew. Where bunch mite is a problem, a spray of dicofol is applied after flowering. The use of wettable sulphur has a number of problems. Application of sulphur sprays in hot weather can lead to burning of the young foliage. There is some evidence to suggest that sulphur sprays, while providing some protection against leaf blister mite, can lead to a heavy infestation of bunch mite, in the absence of a post-flowering spray of dicofol. Residual sulphur, especially if applied close to harvest can carry over into the wine, exacerbating problems of reduced sulphur in the wine. Sulphur is no longer essential for powdery mildew control. There are a number of alternative chemicals, dinocap, fenarimol, propiconazole and triademifon, registered in NSW for this purpose. The Australian Dried Fruits Association (AD FA) has recently advised its farmers/suppliers not to apply dicofol to grapevines if the grapes are intended for drying. This is because of the normal contamination of the technical grade active constituent with DDT during manufacture. Concern has also been expressed by wineries over possible contamination of their product and potential effects on exports. In Victoria, the use of dicofol in the production of all edible crops has been restricted and this situation could soon be repeated in other states. Contamination of produce from vineyards using dicofol is considered to be minute, however, there is

pressure to develop control strategies for vine mites, which do not involve the use of dicofol.

During the past few years chemical control of mites in horticultural crops has developed into a crisis situation, because of the lack of available and effective miticides. This is largely due to the withdrawal of cyhexatin (Plictran from the market, and the rapid development of mite resistance to a new generation of miticides (clofentezine and , hexythiazox). No new miticides are likely to become available in the foreseeable future. Thus, there are few chemical alternatives to dicofol, which are as effective or cheap. The current lack of miticides has increased the importance of researching alternative mite control strategies, particularly integrated and biological control.

Since 1986 research on mite management at Yanco has concentrated on evaluating and improving the performance of natural enemies in integrated and biological control. This work has established the importance of a powerful, native predatory mite in the MIA as a regulator of pest mite populations (James 1987,1988,1989,1990). This predator, *Amblyseius victoriensis,* has been studied primarily in peach orchards but has been found in diverse habitats and on a wide range of vegetation, including grapevines. Its major attribute is an ability to survive and reproduce even in the absence of mite prey (James 1988). This allows persistence of large predator populations on crops throughout the summer, which prevent mite infestation. Feeding and reproductive studies (James 1988) have shown that the most suitable prey for *A. victoriensis* are mites of the families Eriophyidae and Tenuipalpidae, which contain *Colomerus vitis* and *Brevipalpus* sp., the species, which cause most concern in inland vineyards. An obstacle to further use of this powerful predator in horticultural crops is its susceptibility to many commonly used pesticides.

However, recent field trials at Yanco have identified a number of insecticides, miticides and fungicides, which are less harmful to *A. victoriensis* and could be used in an integrated control approach. Other approaches to resolution of predator intolerance to pesticides include releases of predators after spraying, and development of genetically improved strains of predators with tolerances to pesticides. The demonstrated value of *A. victoriensis* as a biological control agent of phytophagous mites is such that I consideration should be given to any approach which would facilitate its greater use in horticultural crops.

Populations of *A. victoriensis* have been found on grapevines in the MIA not subjected to miticide sprays. In most instances such populations were associated with very small or absent bunch and blister mite populations. Our current level of knowledge of *A. victoriensis* suggests that providing predators are on the vines soon after bud burst and chemicals harmful to the predator are not used, a high level of biological control could be expected. Sensitivity to the issue of chemical residues in agricultural produce, particularly foodstuffs, has recently become a powerful factor in influencing crop management practices. The suggestion of DDT residues in dried fruit or wine products is potentially extremely damaging to the viticultural industry, particularly for exports. The possibility of access being denied to export markets because of possible DDT contamination is a real one. Thus, a mite management strategy in grapevines which

avoids the use *of* dicofol would have substantial commercial benefits to the industry. Further, the successful implementation *of* biological control *of* vine mites would remove the miticide costs *of* grape production, as well as encouraging a "pesticide-free" image for the industry.

Grape and Wine Research & Development Corporation

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OBJECTIVES

To investigate the potential and practicality of using predatory mites (Family: Phytoseiidae) as biological control agents for blister, rust and bunch mites on inland grapevines in south-eastern Australia.

Introduction and General Methodology

Biological and ecological studies on *A. victoriensis* at Yanco are well advanced.

However, greater attention to interactions between this predator and the three pest mite species of grapevines is required. Information on other predatory mite species such as *Typhlodromus occidentalis,* which could playa role in grapevine mite suppression is also desirable. This predator possesses resistance to certain insecticides and may provide a useful adjunct to the use of the more susceptible *A. victoriensis.* Studies on predator feeding behaviour, reproduction, longevity and development, will be performed in the laboratory. The effect of environmental factors such as temperature, humidity and photoperiod on these parameters will also be assessed to provide information on suitability of the predator to the inland grapevine ecosystem. Such an understanding might facilitate modification of the ecosystem to make it more favourable for the predator. A survey of vineyards in the MIA and Sunraysia will also be undertaken to determine the species of predatory mites already present in grape growing areas. Samples of leaves from grapevines and other vegetation in vineyards will be collected and examined under the microscope.

The field performance of predatory mites in controlling bunch and blister mites will be evaluated in field trials conducted in the MIA and Sunraysia. Evaluation will largely consist of regular population monitoring of pest and predatory mites, and assessment of damage. Leaf and berry samples will be collected at weekly or fortnightly intervals and examined under the microscope. Initial investigations will aim to establish the level 8 of biological control provided by predators in unsprayed vineyards. Subsequently, the effects on predator efficacy of spraying practices used in commercial vineyard management will be assessed. This will be done in conjunction with laboratory studies and specific field trials to determine the toxicity to predators of fungicides and insecticides used in vineyards. Armed with knowledge on the adverse effects of vineyard pesticides on predators, attention will then be directed to ameliorating these effects. This may be possible through substitution of a harmful chemical with one that is less harmful, or by better timing to reduce its impact on predator populations. For example, of the six compounds recommended in the MIA for treatment of Botrytis, two are known to be relatively harmless to *A. victoriensis* while the others are toxic. The rate of predator colonisation of vineyards during spring will also be examined in the field trials. Early predator establishment is likely to be a key factor in successful mite management and attention will be given to ways in which over wintering survival and early colonisation of grapevines could be improved. The practicality and effectiveness of early season releases of predators in vineyards will also be examined. Recent work at Yanco has indicated that *A. victoriensis* disperses very rapidly through orchards in spring even when prey mites are absent. Establishment of large predator populations in vineyards during spring, through early season releases may be an effective technique

to ensure effective biological control of vine mites during the season. In situations of unavoidable chemical disruption to predator populations, predator releases may provide an effective means of rapid restoration of biological control.

The possibility of using predator releases to augment natural populations will ultimately require a technique of predator mass production. Some efforts have already been made to mass rear A. *victoriensis* and this work will be continued. Commercial production of A. *victoriensis* is being considered by at least two Australian insectaries, because of its value in crops other than grapevines. However, a suitable propagation technique remains to be discovered. If A. *victoriensis* proves to be an effective biological control agent in inland vineyards, commercial availability of the predator would undoubtedly aid in its utilisation in vineyard mite management. The current stumbling block to laboratory production of A. *victoriensis* is selection of the most appropriate food *source* for the predators. Feeding studies on A. *victoriensis* are well advanced, and identification of a suitable diet for mass production of predators should be possible.

DETAILED RESULTS:

POPULATION ECOLOGY

Population dynamics of grapevine mites and mite natural enemies in MIA, Sunraysia and Riverland viticulture.

Introduction the vineyards of inland Southern Australia have relatively few insect and mite pests and none, which could be considered a key pest seriously affecting grape production. Most pests of grapevine are of minor-moderate Importance and are often irregular in incidence and abundance. Amongst the minor-moderate pests of Australian grapevines are mites of the families Tenuipalpidae (false spider mites) and Eriophyidae (rust mites). One or two species of the false spider mite genus *Brevipalpus (B. lewisi* McGregor, *B. californicus* Banks) cause most concern by damaging canes and bunches (Jones, 1967; Buchanan *et al.,* 1980). *B. lewisi* has also been recorded damaging grapevines in Europe (Sarospataki, 1972; Arias-Giralda *et al.* 1985). The eriophyids *Colomerus vitis* (Pagenstecher) and *Calepitrimerus vitis* (Nalepa) cause leaf blistering and discolouration which are usually of cosmetic concern only (Jones, 1967), although recent European experience suggests *Ca. vitis* is capable of causing economic damage (Baillod and Guignard, 1986). Calendar-based prophylactic sprays are applied routinely for mite control in most commercial vineyards of southern Australia.

Until recently, dicofol was the most commonly used miticide in Australian vineyards. However, in 1987, dicofol was implicated as the source of organochlorine residues in dried fruit from vines in the Sunraysia district of northern Victoria and south-western New South Wales (Buchanan, 1988). This chemical has subsequently lost favour as a viticultural miticide, stimulating a reappraisal of grapevine mite management. The results of a study on the population dynamics of pest and predatory mites on grapevines in three major viticultural regions of south-eastern Australia are presented. Implications of these results for development of biological control strategies for grapevine mites are discussed.

Material and Methods

Leaf and Shoot Samples

Pest and predatory mite populations were monitored from August 1989 to March 1992 in sprayed (fungicides) and unsprayed research station grapevine blocks in the three major irrigated horticultural areas of inland south-eastern Australia: Sunraysia (= 350 km ENE of Adelaide), the Riverlands (= 250 km ENE of Adelaide and the Murrumbidgee Irrigation Area (MIA) (= 500 km N of Melbourne). In 1989/90 (August-August), single sprayed and unsprayed blocks were monitored at Loxton Research Station (Riverlands), Dareton Agricultural Research and Advisory Station (Sunraysia) and Griffith Horticultural Research and Advisory Station (MIA). In 1990/91 and 1991/92 the same blocks were sampled at Loxton, but the sprayed blocks at Griffith and Dareton were omitted and a different unsprayed block used at Dareton. Blocks consisted of 10 rows

of 35-45 vines and were of the following grapevine varieties: Semillon (Griffith), Gordo (Dareton 1990/91, Loxton unsprayed) Sultana (Dareton 1989/90) and mixed Barbera, Merlot and Ruby Cabernet (Loxton sprayed).

Sprayed blocks received fungicide applications typical of commercial viticulture in the three regions. No insecticides were used. Fungicides used were wettable sulphur, copper oxychloride, triadimefon (Loxton), wettable sulphur, ziram, mancozeb, metalaxyl, propiconazole, fenarimol (Dareton) and mancozeb, wettable sulphur, copper oxychloride (Griffith). Wettable sulphur was used as a miticide as well as a fungicide.

Sampling was conducted using Ovine panels in each block from which either 8 leaves and 2 shoots (10 cm) (monthly, October-April) or a 200g sample of dormant spur or basal cane wood (single sample August) was collected. The same vine panels were used throughout the sampling period. Leaves and shoots were placed in plastic bags, stored in insulated cool boxes and transported to the laboratory. Leaves and shoots were examined under a stereomicroscope and numbers of pest and predatory mites and insects recorded. Phytoseiids were identified using the key of Schicha (1987). Confirmation of the identity of difficult or unusual species was provided by E. Schicha (NSW Agriculture). Voucher specimens of all species were retained. Numbers of eggs and motiles were recorded for *Brevipalpus* spp. and predatory mites. Due to difficulties encountered in counting C. *vitis* (hidden in leaf blisters) and *Ca. vitis* (very large numbers), only presence or absence of motiles was recorded for these species.

Dormant Wood Samples

Dormant wood samples comprising cane material (before pruning) or wood (spurs) were collected from vineyards during winter. The material was cut into ten 20 cm lengths, weighed into 10200 g samples and placed into plastic bags (26 x 44 cm). The bags were folded open at the mouth and placed upright in the plate stand of a domestic microwave oven (Panasonic model NN-5258 (600 W), open cavity 29.3 x 51.0 x 37.3 cm). The oven was operated at just below the "low" (120 W) setting for six minutes. This setting and duration were arrived at after a series of "trial and error" experiments. The aim is to provide sufficient stimulation to mobilise mites and cause their emigration from the wood. A setting above 120 W 'cooks' mites in their refugia. The ideal setting was one, which resulted in mites dropping to the bottom of the plastic bag in a moribund condition. After cooking, bags were removed from the oven, shaken and the wood discarded. The plastic bags were slit down both sides to expose the inside surface and examined under a stereomicroscope for mites.

Leaves and shoots were also sampled monthly at commercial vineyards in the Riverlands district (5 in 1989/90, 3 in 1990/91, 4 in 1991/92, varieties: Gordo, Ribier, Shiraz, Sultana, Sauvignon blanc), 5 in Sunraysia (1989/90 only, varieties: Gordo, Sultana, Ruby seedless, Flame seedless) and in the MIA (1989/90 only, varieties: Chardonnay, Traminer Riesling, Cabernet Sauvignon, Trebbiano, Rhine Riesling, Tokay). A greater variety of fungicides was used in commercial vineyards than in the research station I blocks (Riverlands: wettable sulphur, copper oxychloride, triadimefon, propiconazole, mancozeb, iprodione, fenarimolj Sunraysia: wettable sulphur, copper oxychloride, ziram,

iprodione, fenarimol, metalaxyl, dithianonj MIA: wettable sulphur, lime sulphur, copper, oxychloride, zineb, mancozeb, benomyl, dithianon, chlorothalonil, procymidone, metiram, ziram, carbendazim). Insecticides *(Bacillus thuringiensis,* carbaryl, methomyl, chlorpyrifos) were used in some blocks to control caterpillar pests such as *Epiphyas postvittana* (Walker). Lime sulphur and wettable sulphur were generally used to control mites in the three regions, although more emphasis was placed on mite control in the MIA where carbamult and dicofol were also used. Thirty leaves and 10 shoots were collected randomly from commercial vineyards and dealt with in the same way as samples from the research station sites.

Results were analysed where appropriate using ANOV A and LSD procedures.

Results

Brevipalpus spp., C. *vitis* and *Ca. vitis* were the only mite pests recorded on grapevines in each region. Predatory mite populations were dominated by Phytoseiidae with nine species recorded *(Amblyseius victoriensis* (Womersley), *Amblyseius loxtoni* Schicha, *Amblyseius masiaka* Blommers and Chazeau, *Amblyseius helmi* Schicha, *Amblyseius dieteri* Schicha, *Amblyseius lentiginosus* Denmark and Schicha, *Typhlodromus doreenae* Schicha, *Typhlodromus occidentalis* Nesbitt and *Typhlodromus applegum* Schicha. The predatory mite families Bdellidae, Anystidae, Cheyletidae, Tydeidae, Parasitidae and Ascidae were also represented but generally comprised less than 1 % of predatory mites found. Similarly, only small numbers of predatory insects (Cecidomyiidae, Chrysopidae, Thripidae) observed or suspected of feeding on grapevine mites, were recorded.

Pest and predatory mite populations on dormant grapevines

Brevipalpus spp. were recorded from all research station blocks but were in significantly lower numbers (P<O.05) in the Riverlands and Sunraysia than in the MIA (Table 1).
Numbers of *Brevipalpus* spp. at each site did not vary significantly between seasons except for the MIA where the value for 1989 was greater than 1991 (P-<0.05).

Phytoseiids were found at all sites and comprised four species *(T. doreenae, A. masiaka,* I *A. loxtoni* and *A. helm/. T. doreenae* was the only species found at the Riverlands sites and did not occur in the other regions. *A. masiaka* was recorded at the MIA and Sunraysia sites but was most common in the MIA. *A. loxtoni* dominated over wintering phytoseiid populations at the Sunraysia site and small numbers of *A. helmi* occurred in the MIA only. In Sunraysia and the Riverlands, numbers of

TABLE 1. Mean number (:tSE) of *Brevipapus* spp. and phytoseiids extracted from 200g samples of dormant grapevine wood from research station vineyards (sprayed and unsprayed) 1989-91.

Site	August 1989 *Brevipalpus*	August 1989 Phytoseiids	August 1990 *Brevipalpus*	August 1990 Phytoseiids	August 1991 *Brevipalpus*	August 1991 Phytoseiids
Loxton (Riverlands)	0.2 ±0.1	2.3[a] ±0.5	0.05 ±0.05	5.5[a] ±0.8	0.3 ±0.1	3.3[a] ±0.5
Dareton (Sunraysia)	0.5 ±0.1	2.1[a] ±0.5	0.2 ±0.1	22.4[a] ±3.8	0.3 ±0.1	1.5[a] ±0.4
Griffith (MIA)	15.0[a] ±2.7	1.6 ±0.4	9.9[a] ±1.6	0.6 ±0.2	6.6[a] ±1.9	0.5 ±0.2

[a] value significantly greater than value for alternative mite group at same sampling date ($P<0.05$).

phytoseiids were significantly greater than numbers of *Brevipalpus* spp. in all years (p'<0.05) (Table 1). In the MIA numbers of *Brevipalpus* spp. were always greater than numbers of phytoseiids (P'<0.05). Samples occasionally yielded small numbers of predatory mites from other families (Bdellidae, Tydeidae, Anystidae, Parasitidae, Ascidae).

Pest and predatory mite populations on grapevine leaves and shoots

Substantial differences in pest and predator population dynamics were observed between regions (Figs 1-25).

The Riverlands

In the sprayed and unsprayed research station vineyards infestation levels of pest mites on leaves generally remained below 50% and were usually less than 20%. *Brevipalpus* spp., potentially the most injurious species, infested less than 10% of leaves for most of each season (Figs 1-3). Phytoseiid populations were small during spring (October- November), increased rapidly in summer and infested 50-90% of leaves in January- February and declined during autumn. The same trend (low pest mite, high predatory mite numbers) occurred in both vineyards during all seasons. However, an accidental application of the fungicide dithianon to the unsprayed block in January 1991 was followed by a reduction in phytoseiid numbers and an increase in *Brevipalpus* spp. Similarly, triademefon was used in the sprayed block in January-February 1991 also appeared to depress phytoseiid populations (Fig. 1).

Identical trends in abundance of pest mites and phytoseiids were recorded on vine shoots.

In the commercial vineyards *Brevipalpus* spp. was often absent and only small 8 infestations of C. *vias* and *Ca. vitis* occurred (Figs 3-10). Large numbers of phytoseiids occurred in all vineyards except one (not shown), which was subjected to an intensive synthetic fungicide and insecticide spray schedule (mancozeb, iprodione, fenarimol, benomyl, Carbaryl). Two phytoseiid species were recorded from Riverland vineyards during the growing season, T. *doreenae* and *A. victoriensis,.* T. *doreenae* occurred throughout the sampling period whilst *A. victoriensis* was present during January-April only. T. *doreenae* was the dominant species (Figure 11 and Table 2).

Sunraysia

In 1989/90, infestation levels of mite pests were generally low in the unsprayed and sprayed research station vineyards (Fig. 12). However, in the unsprayed block in 1990/91, populations of *Brevipalpus* spp. and C. *vitis* developed earlier and were larger, with *Brevipalpus* spp. infesting 90% of leaves and shoots during February-April, 1991. A similar situation occurred in 1991/92 with *Brevipalpus* spp. but

TABLE 2. Species ratio (%) of phytoseiid fauna on grapevine leaves and shoots from research station vineyards in the Riverlands, Sunraysia and MIA during 1989-91. Sample size ranged from 1-463 with those containing less than 15 individuals excluded from the analysis.

TABLE 2. **Species ratio (%) of phytoseiid fauna on grapevine leaves and shoots from research station vineyards in the Riverlands, Sunraysia and MIA during 1989-91. Sample size ranged from 1-463 with those containing less than 15 individuals excluded from the analysis.**

1989/90

Site	Phytoseiid species	Month						
		O	N	D	J	F	M	A
Loxton (Riverlands)	*T. doreenae*	-	100	-	78	92	91	72
	A. victoriensis	-	0	-	22	8	9	28
Dareton (Sunraysia)	*A. loxtoni*	-	-	-	84	56	12	2
	A. victoriensis	-	-	-	16	44	88	98
Griffith (MIA)	*A. victoriensis*	-	-	-	14	69	94	99
	other	-	-	-	86	31	6	1

1990/91

Loxton (Riverlands)	*T. doreenae*	100	100	100	95	70	68	55
	A. victoriensis	0	0	0	5	30	32	45
Dareton (Sunraysia)	*A. loxtoni*	-	-	100	100	100	97	60
	A. victoriensis	-	-	0	0	0	3	40
Griffith (MIA)	*A. victoriensis*	-	-	-	97	91	99	100
	other	-	-	-	3	9	1	0

C. *vitis* remained at a low level throughout the season (Fig. 13). In 1989/90, phytoseiids entered the vineyards in December-January and increased rapidly to infest 40-60% of leaves during late February-April. Establishment of phytoseiids in the sprayed vineyard was associated with a concurrent decrease in numbers of C. *vitis* (Fig. 12). In 1990/91 and 1991/92, a large population of *Brevipalpus* spp. established prior to phytoseiids, which failed to occupy more than 40% of leaves in each season. Phytoseiids had little impact on *Brevipalpus* spp. but did appear to stabilise (1990/91) or control (1991/92) populations of C. *vitis* (Figs. 12-13).

Four of the commercial vineyards examined in Sunraysia developed large *Brevipalpus* spp. populations during the season (40-80% leaf infestation) and had low phytoseiid populations «20%). C. *vitis* populations were also relatively small «20%).

Phytoseiid populations were dominated by two species, *A. victoriensis* and *A. loxtoni* (Fig 14 and Table 2). Small numbers of *A. helmi* and *A. dieteri* were also recorded from some commercial vineyards. Early populations were dominated by *A. loxtoni,* which was progressively displaced by *A. victoriensis* as the season progressed.

MIA

Brevipalpus spp. infested 70-100% of leaves and shoots in the sprayed and unsprayed research station vineyards (Fig. 15). In contrast, C. *vitis* and *Ca. vitis* populations remained low «20%). This situation was repeated in the unsprayed vineyard in 1990/91 and 1991/92 although *Brevipalpus* spp numbers were slightly lower in the latter season (Fig 16). In each season, phytoseiids did not appear in numbers until January or February and generally did not infest more than 30-40% of leaves or shoots except in 1991/92 when occupation of leaves reached 70% in March (Fig. 16). They did not have any impact of *Brevipalpus* spp. populations but did appear to suppress numbers of C. *vitis* and *Ca. vitis* (Fig. 15-16.).

Seven of the commercial vineyards examined in the MIA had low mite and predator populations in 1989/90. The other three had large infestations of *Brevipalpus* spp. (>70%) for most of the season with small numbers of phytoseiids «20% infestation). All vineyards used miticides regularly (sulphur, carbamult, dicofol).

Phytoseiid populations in the MI.A were generally dominated by *A. victorienis,* particularly from February to April (Fig 17 and Table 2). A number of other species were recorded in January-February *(A. loxtoni, A. helmi, A. lentiginosus, A. dieteri,* T. *applegum,* T. *occidentalis),* with *A. dieteri* generally being the most abundant of these.

Summaries of mite and predator population data collected at the Research Station sites I during 1989-92, are presented in Figs 18-25.

Note that T. *doreenae* was introduced into the MIA unsprayed block during 1991/92 (see later section).

Fig. 1 Predatory mite (Phytoseiidae), bunch mite *(Brevipapus),* blister mite *(C. vias)* and rust mite *(Ca. vias)* populations on sprayed and unsprayed grapevines at the Loxton Research Centre (Riverlands) during 1989/90 and 1990/91.

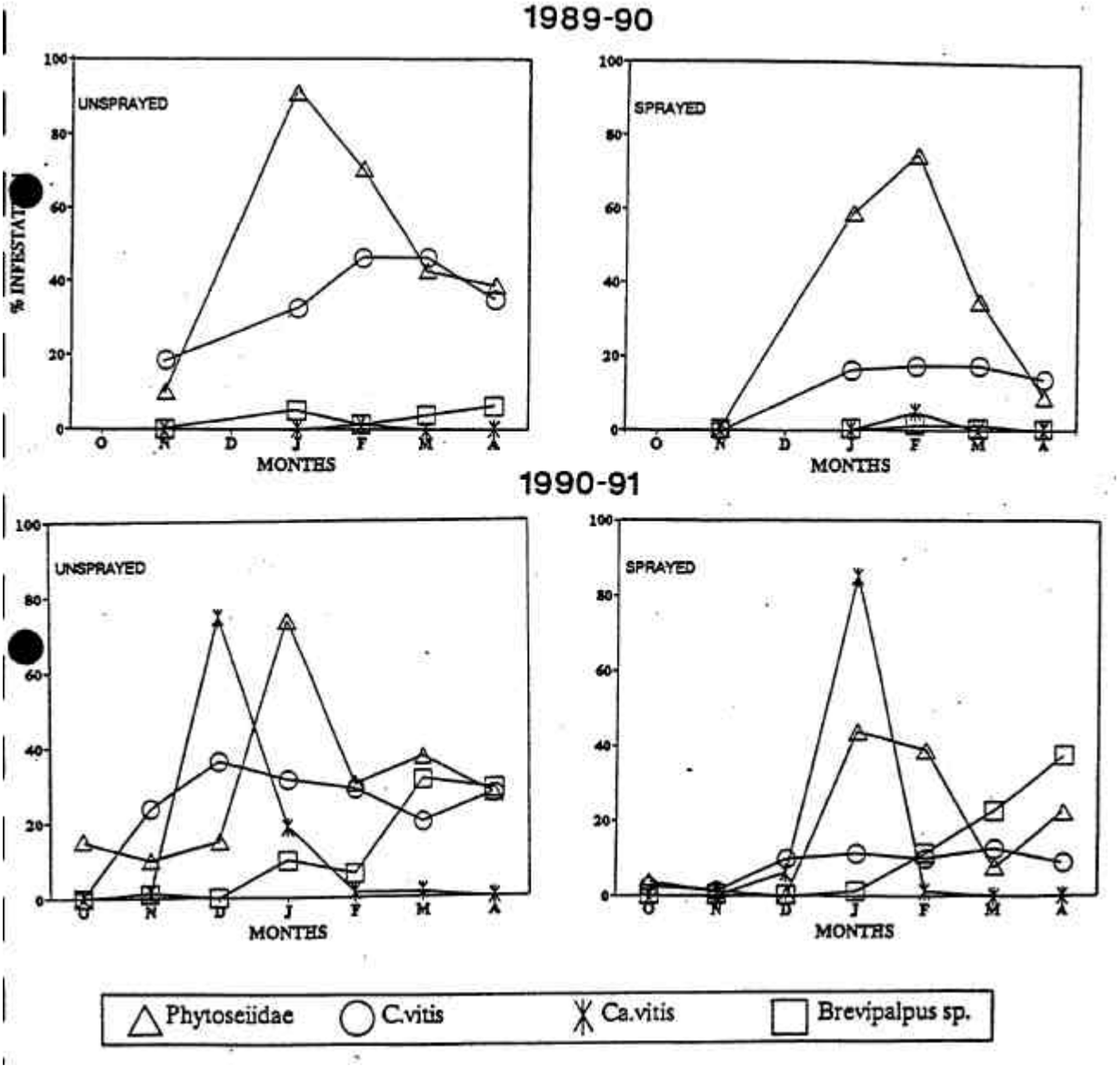


Fig. 2 Predatory mite and pest mite populations on sprayed grapevines at the Loxton Research Centre during 1991/92.

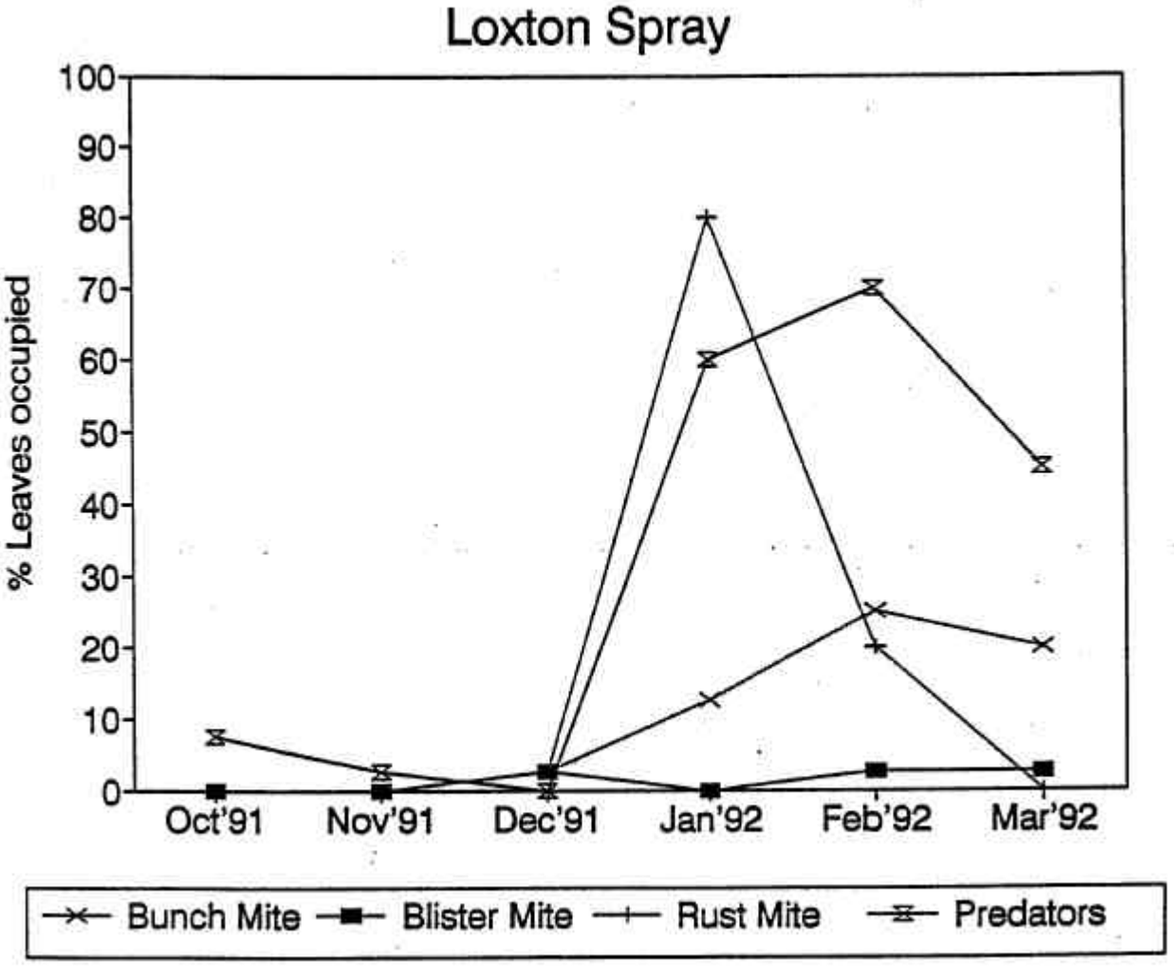


Fig. 3 Predatory mite and pest mite populations on unsprayed grapevines at the Loxton Research Centre during 1991/92.

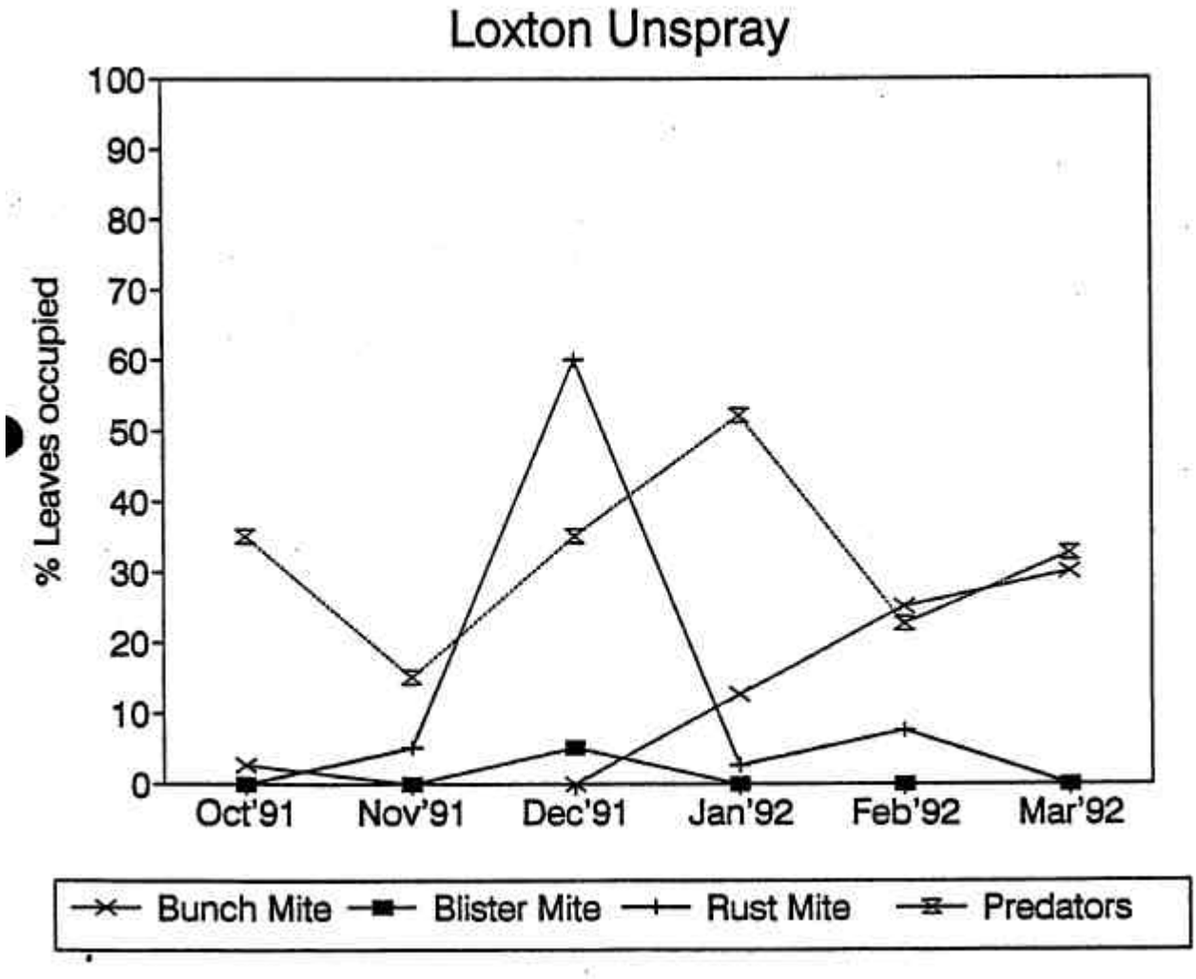


Fig. 4 Predatory mite and pest mite populations in a commercial vineyard (Trautwein) in the Riverlands during 1990/91.

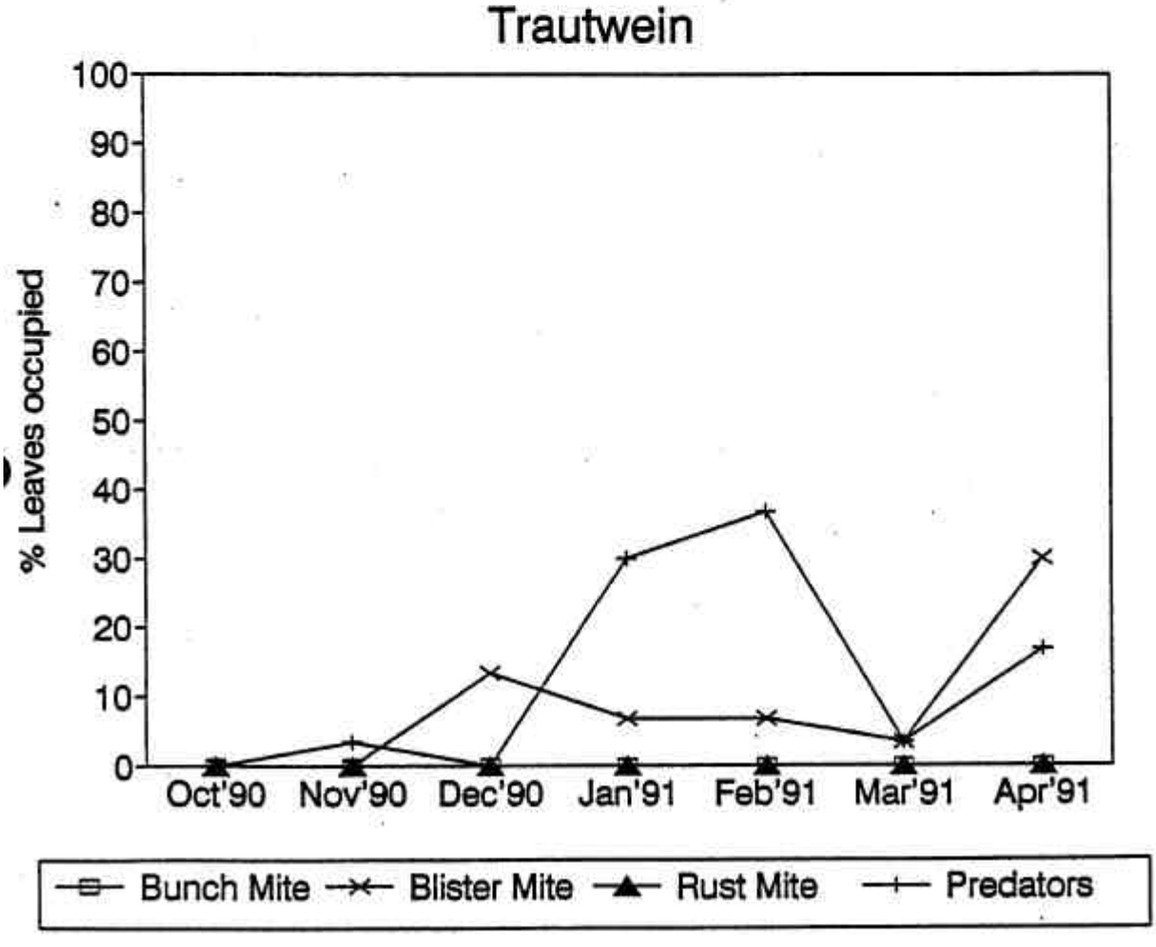


Fig. 5 Predatory mite and pest mite populations in a commercial vineyard (Nelson) in the Riverlands during 1990/91.

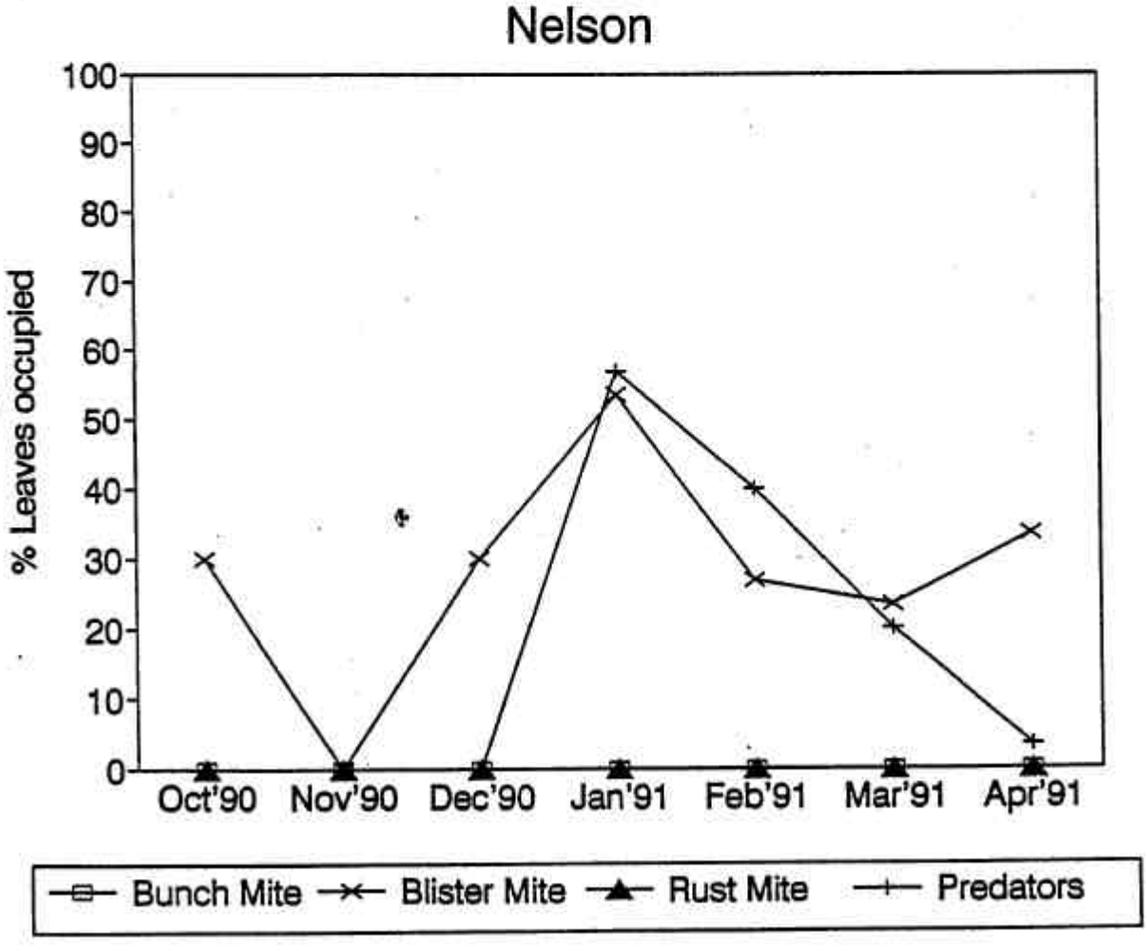


Fig. 6 Predatory mite and pest mite populations in a commercial vineyard (Coombs) in the Riverlands during 1990/91.

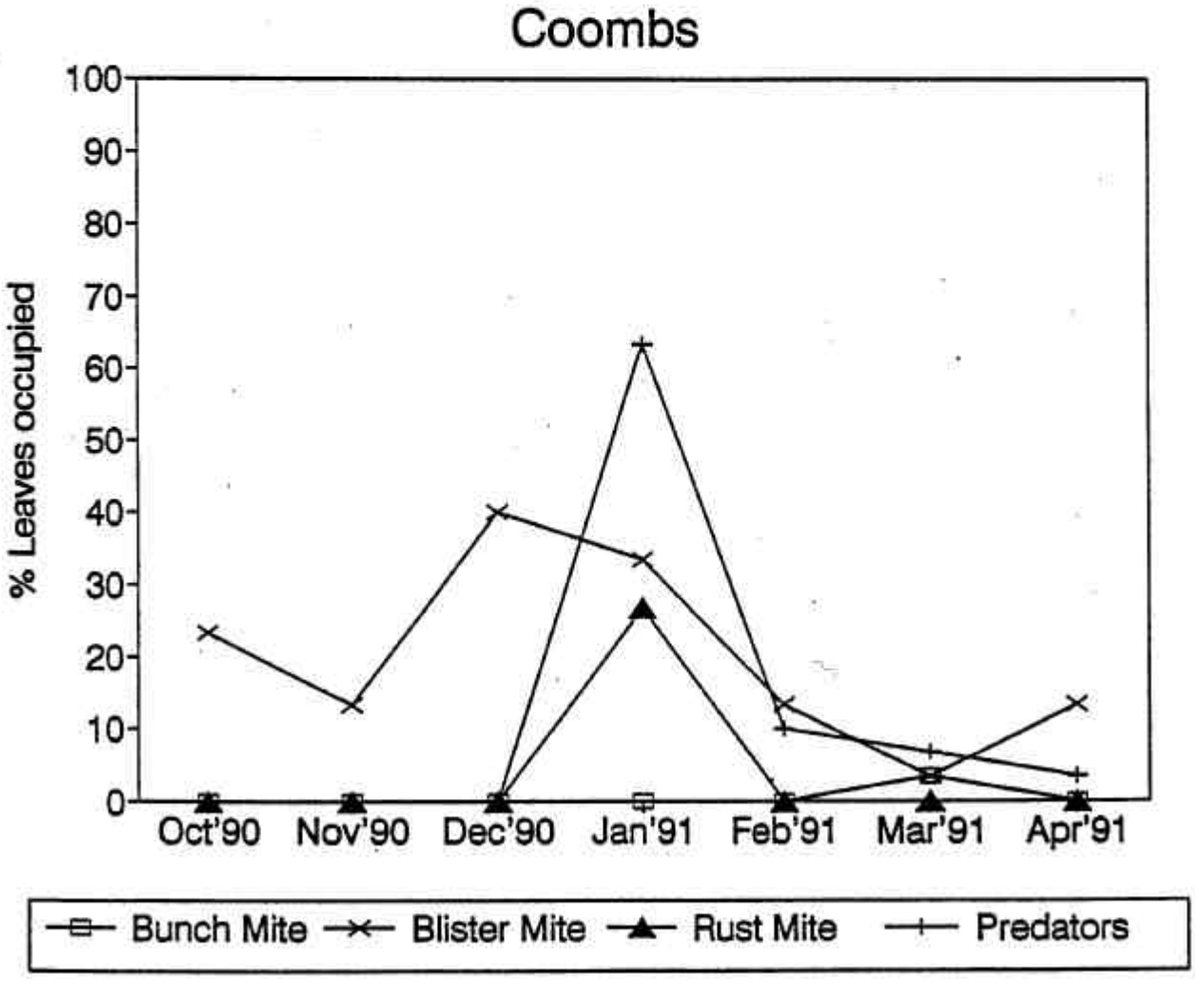


Fig. 7 Predatory mite and pest mite populations in a commercial vineyard (Panagiotopoulos) in the Riverlands during 1991/92.

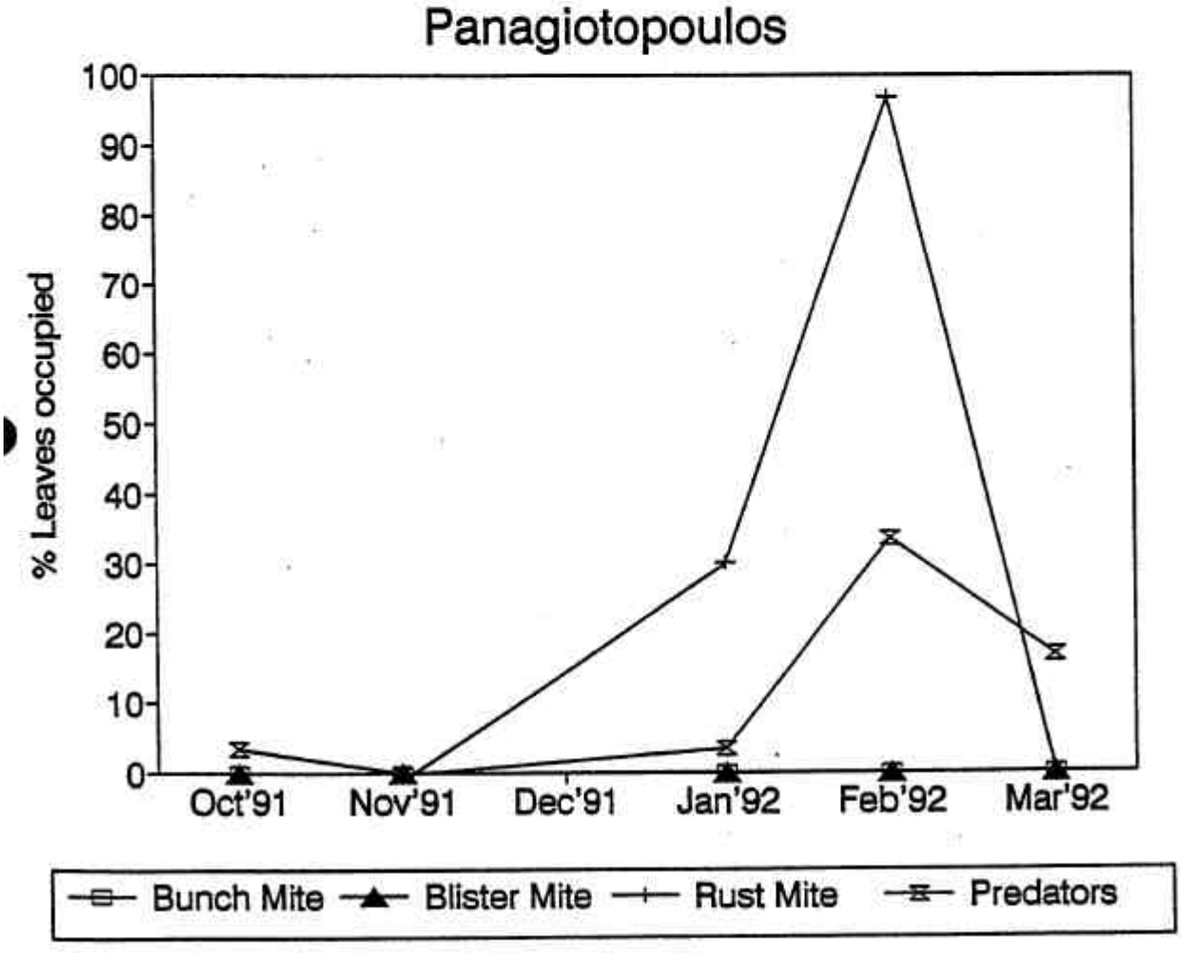


Fig. 8 Predatory mite and pest mite populations in a commercial vineyard (Ludas) in the Riverlands during 1991/92.

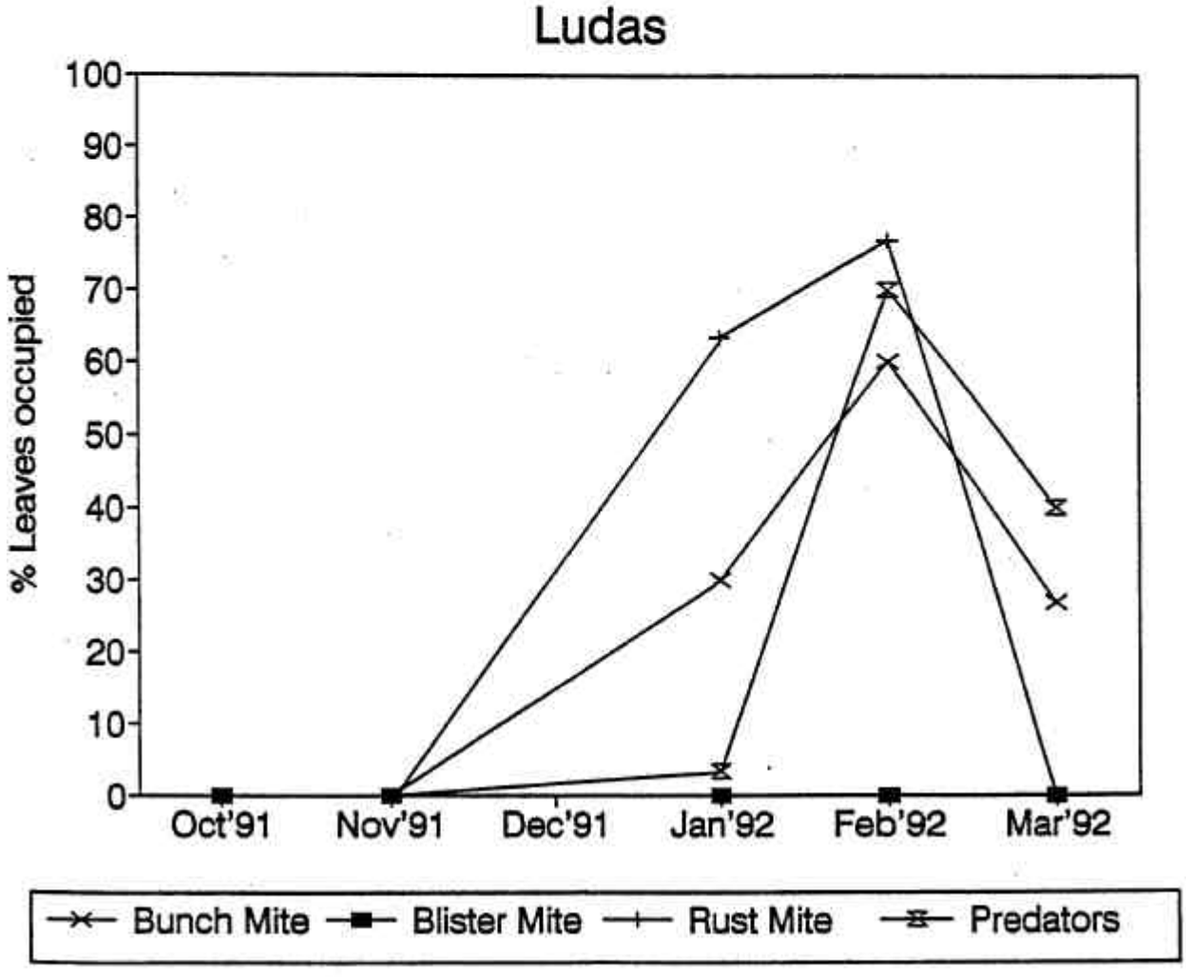


Fig. 9 Predatory mite and pest mite populations in a commercial vineyard (Duggin) in the Riverlands during 1991/92.

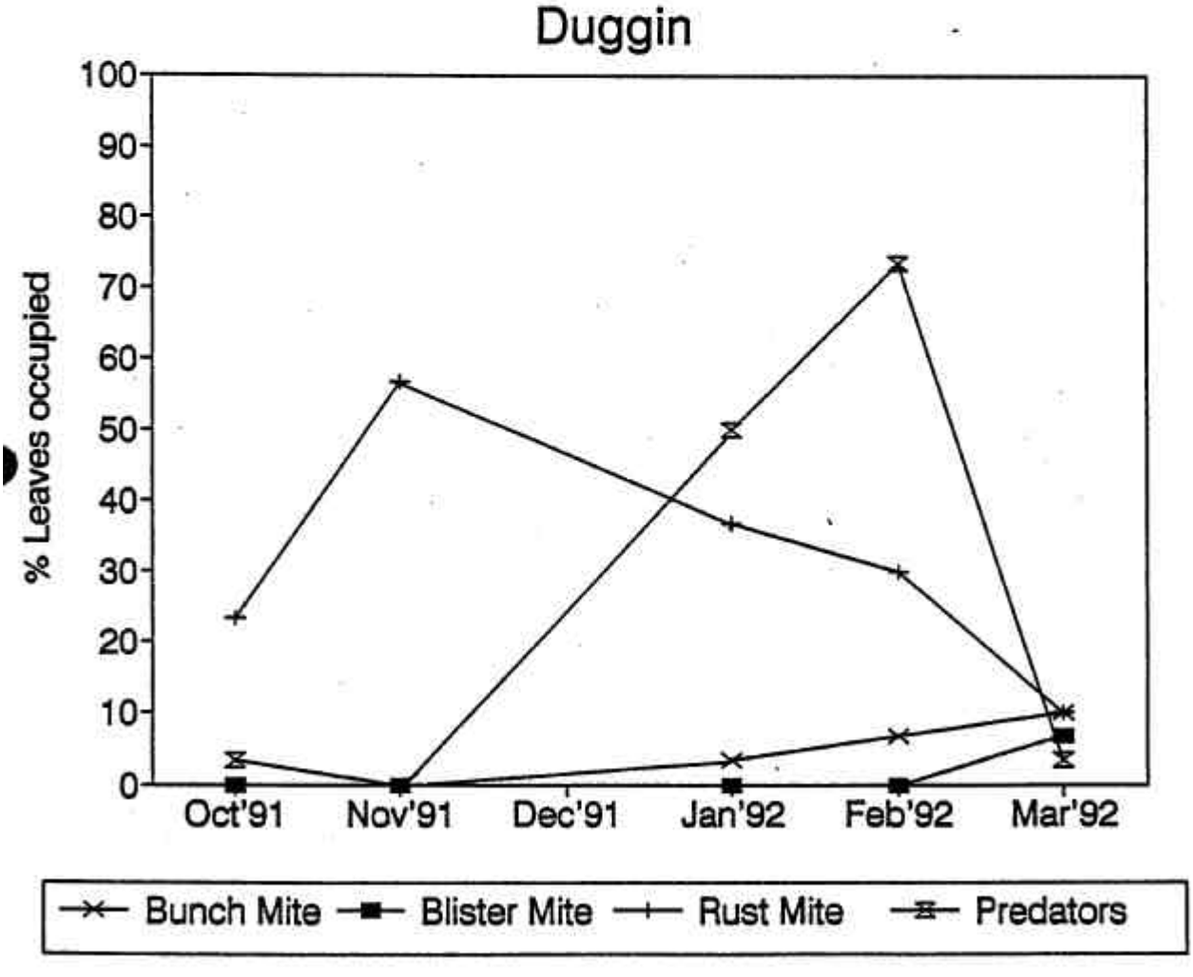


Fig. 10 Predatory mite and pest mite populations in a commercial vineyard (Angoves) in the Riverlands in 1991/92.

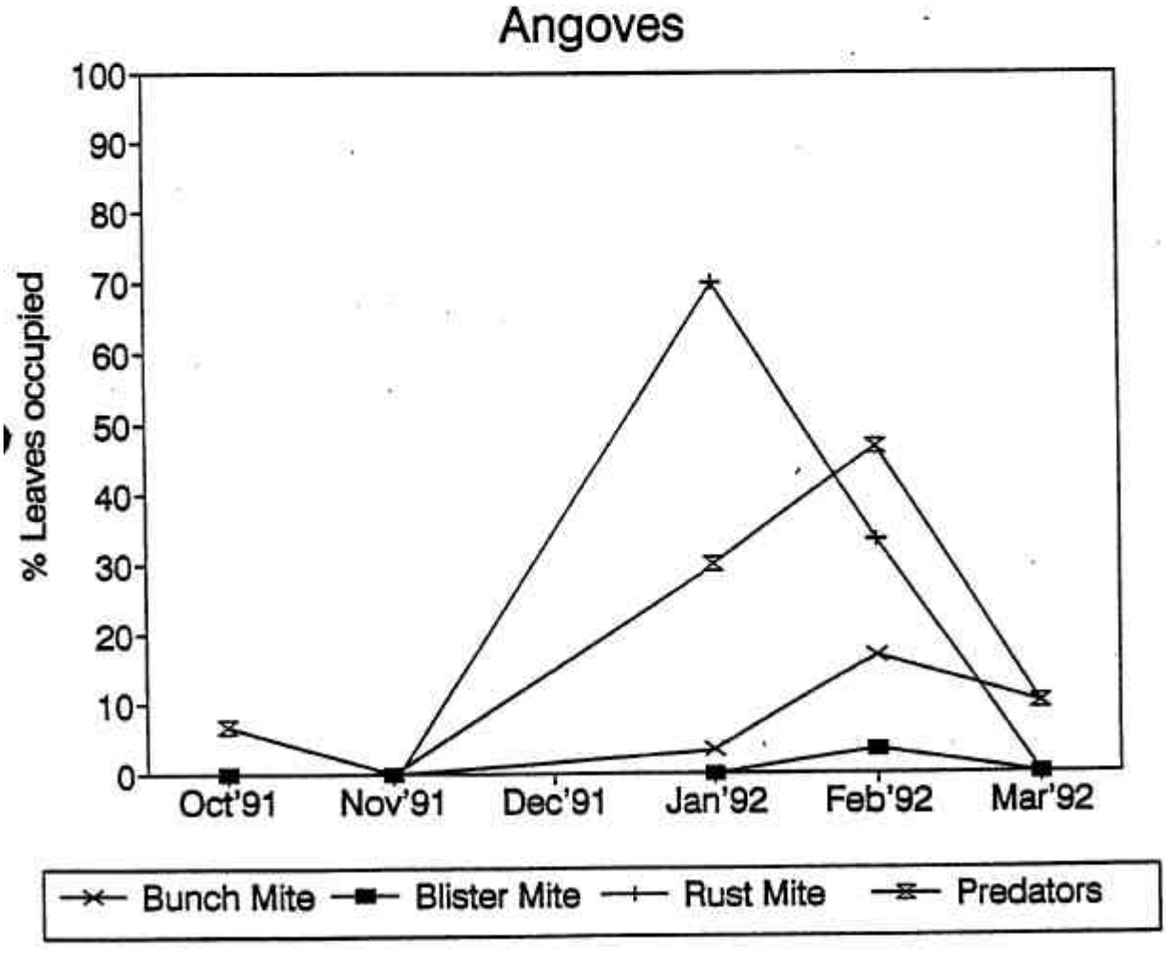


Fig. 11 Species composition (%) of predatory mites on unsprayed grapevines at the Loxton Research Centre (Combined data from 3 seasons 1989-92).

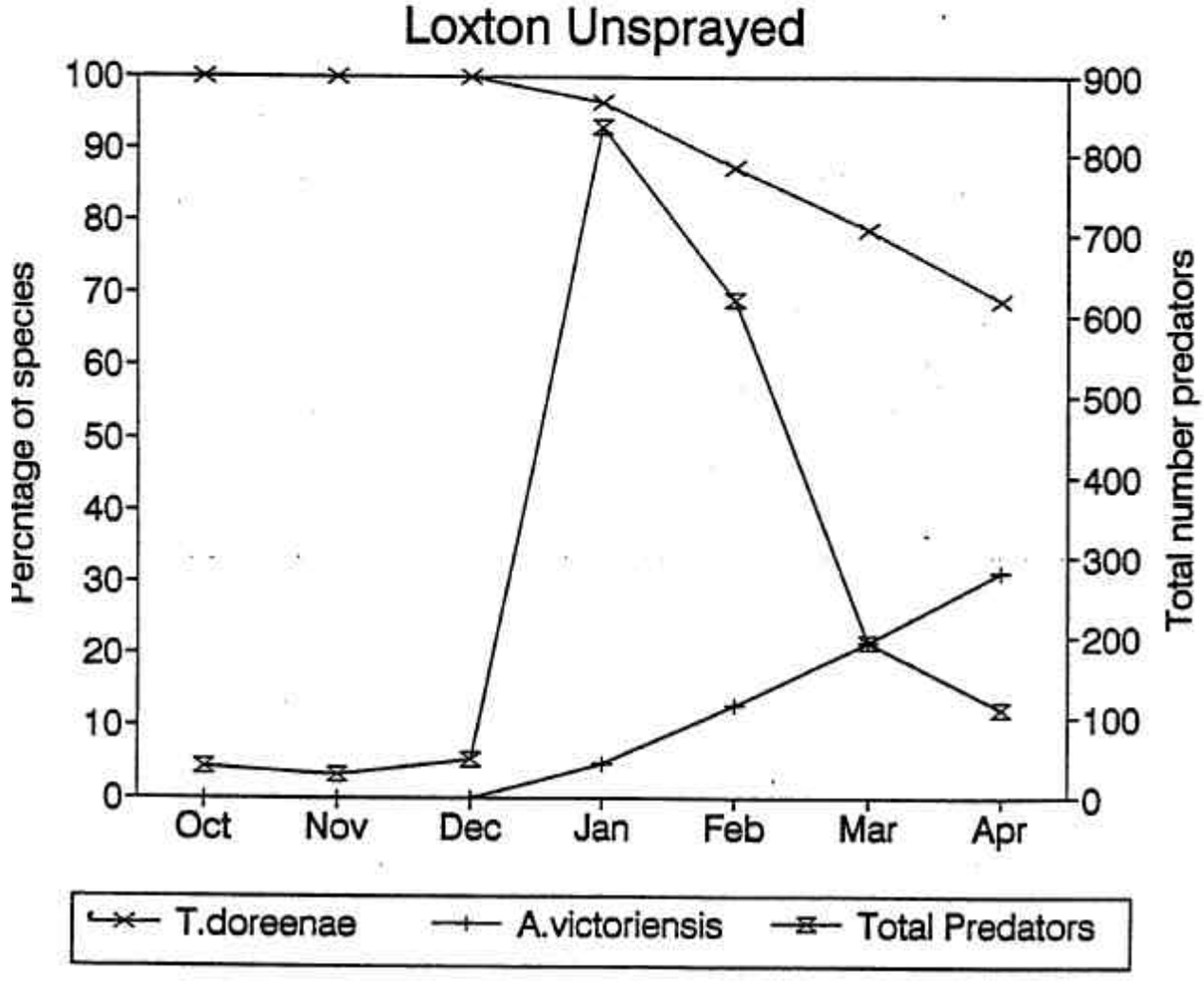


Fig. 12 Predatory mite (Phytoseiidae), bunch mite (*Brevipalpus*), blister mite (*C. vitis*) and rust mite (*Ca. vitis*) populations on sprayed and unsprayed grapevines at the Dareton Agricultural Research and Advisory Station (Sunraysia) during 1989/90 and 1990/91.

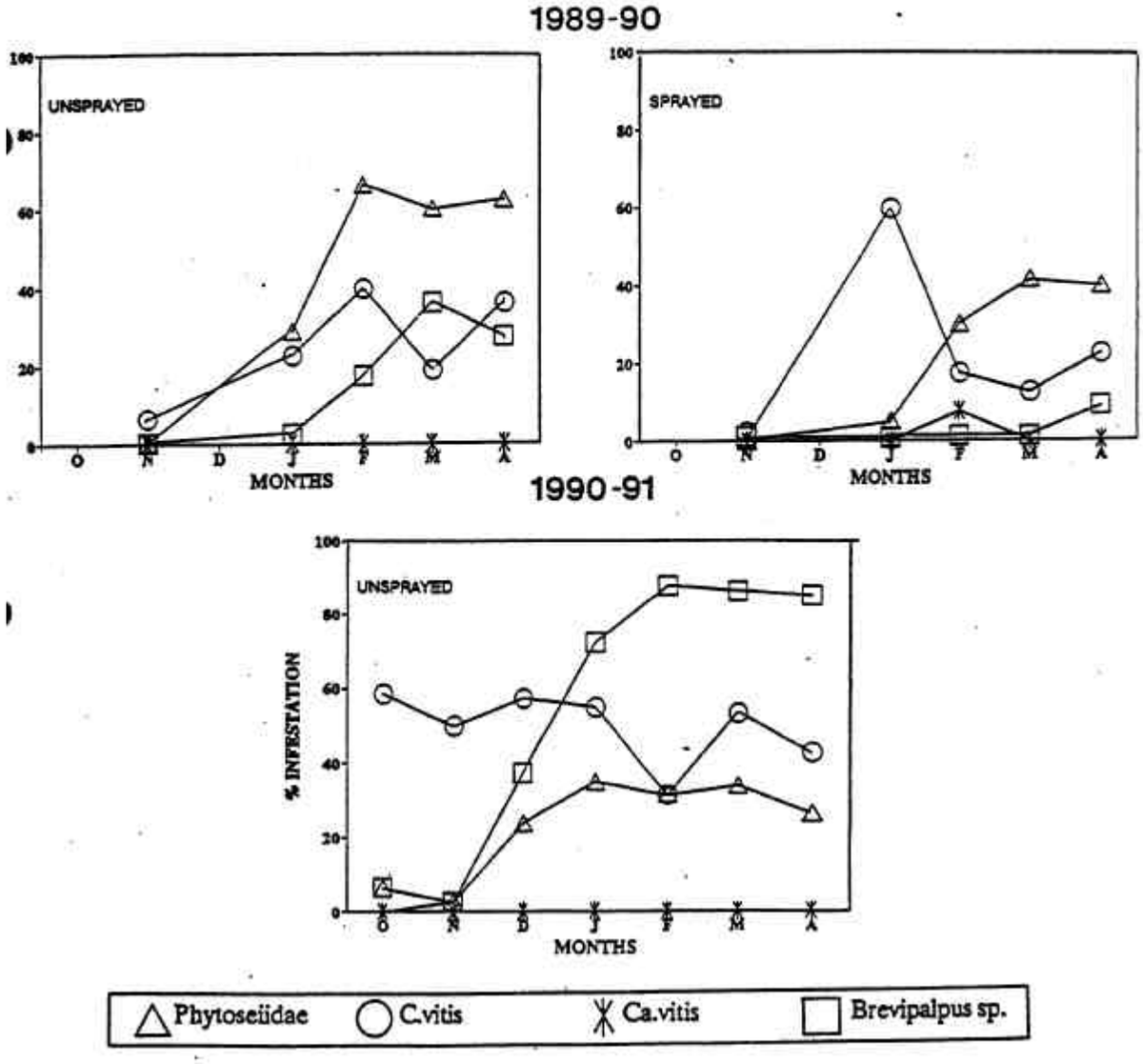


Fig. 13 Predatory mite and pest mite populations on unsprayed grapevines at the Dareton Agricultural Research and Advisory Station during 1991/92.

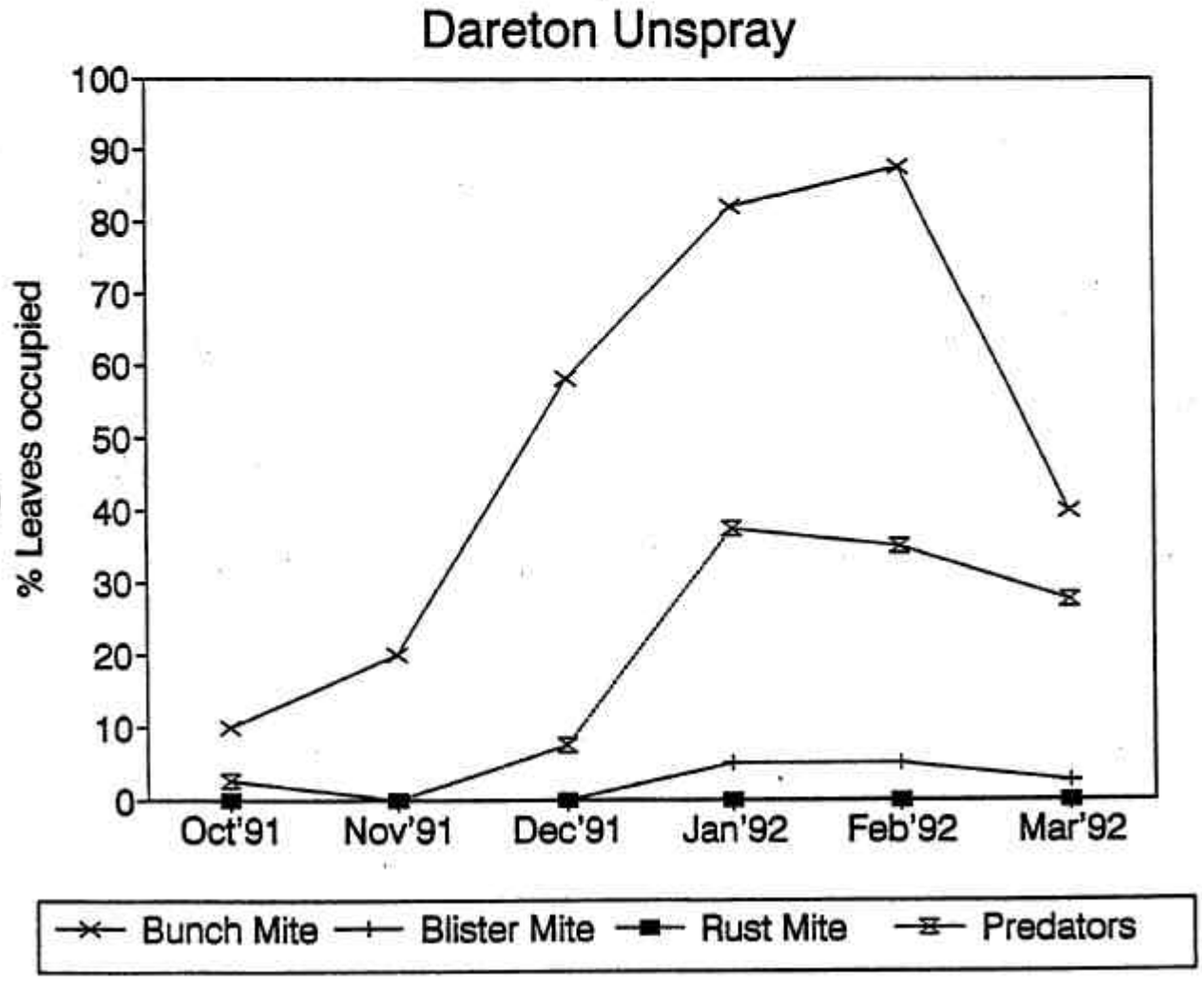


Fig. 14 Species composition (%) of predatory mites on unsprayed grapevines at the Dareton Agricultural Research and Advisory Station (Combined data from 3 seasons 1989-92).

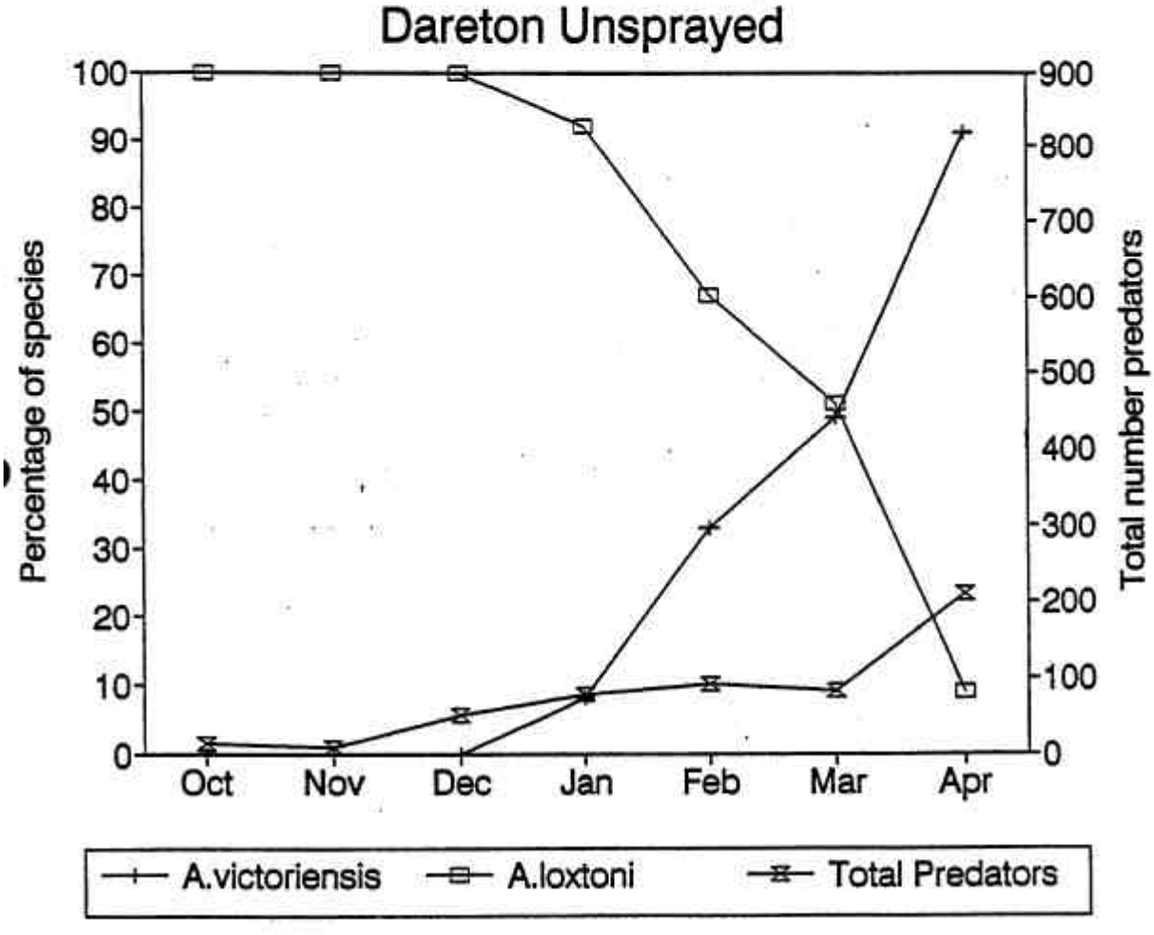


Fig. 15 Predatory mite (Phytoseiidae), bunch mite (*Brevipalpus*), blister mite (*C. vitis*) and rust mite (*Ca. vitis*) populations on sprayed and unsprayed grapevines at the Griffith Horticultural Research and Advisory Station (MIA) during 1989/90 and 1990/91.

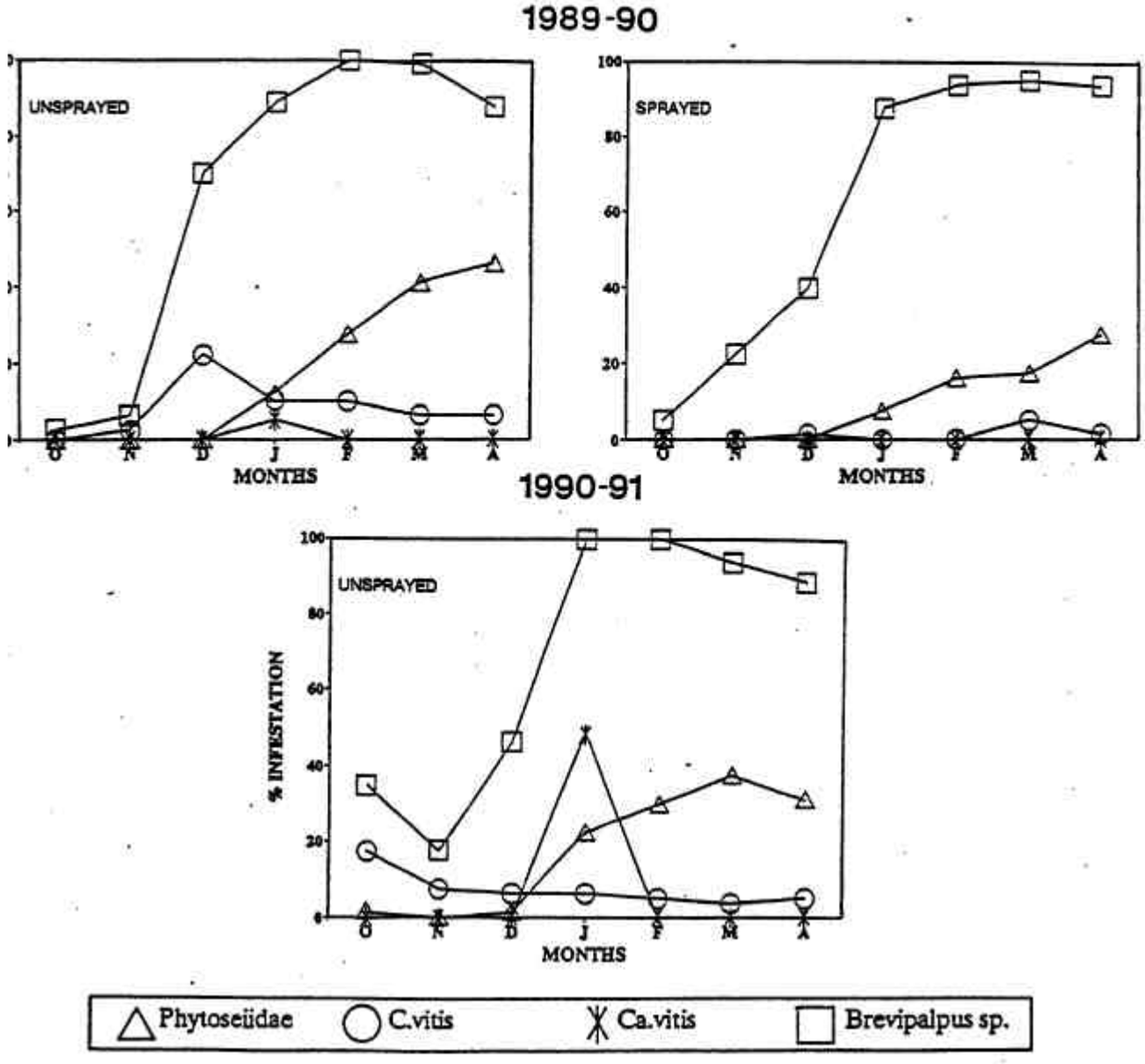


Fig. 16 Predatory mite and pest mite populations on unsprayed grapevines at the Griffith Horticultural Research and Advisory Station during 1991/92.

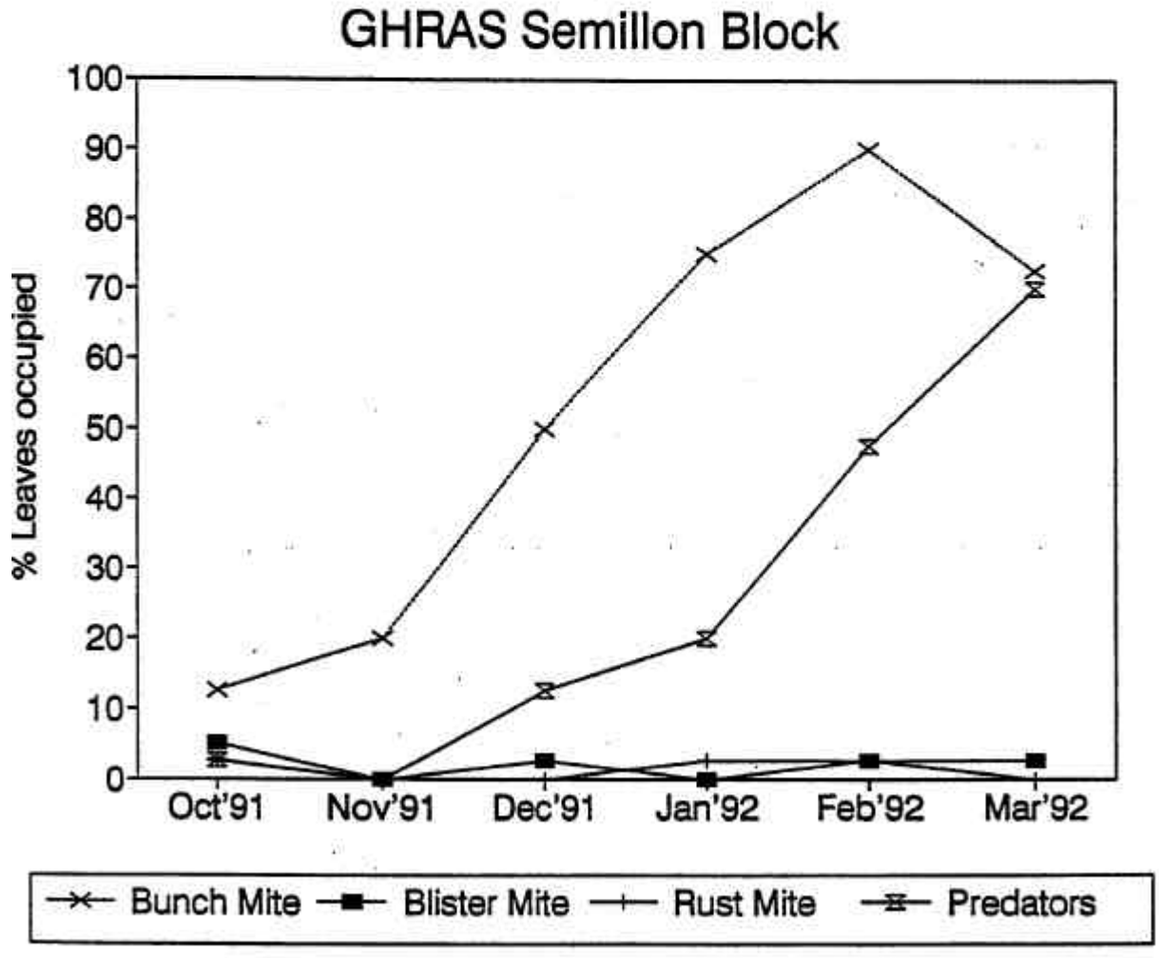


Fig. 17 Species composition (%) of predatory mites on unsprayed grapevines at the Griffith Horticultural Research and Advisory Station (Combined data from 3 seasons 1989-92).

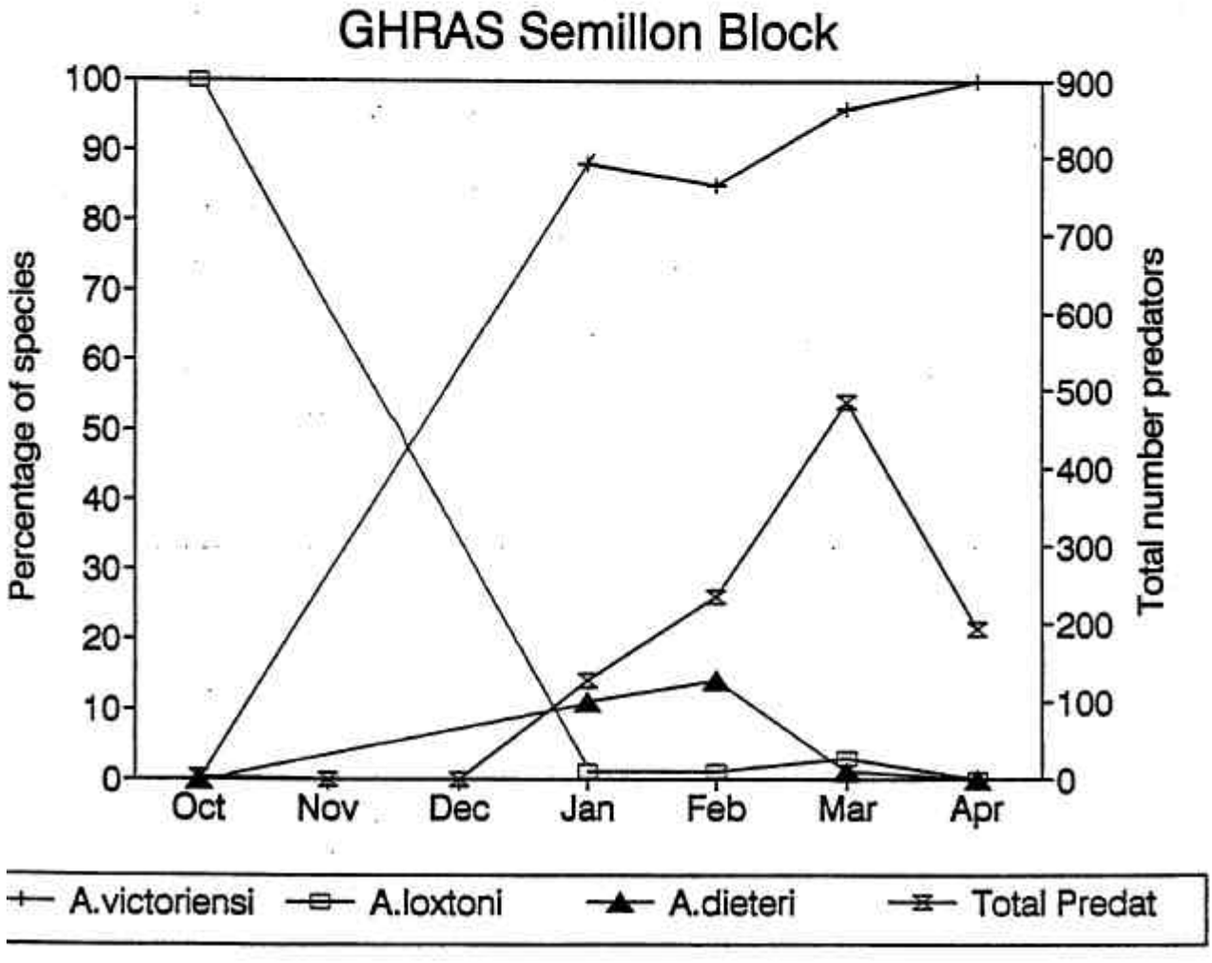


Fig. 18 Predatory mite and pest mite populations on sprayed grapevines at the Loxton Research Centre 1989-92.

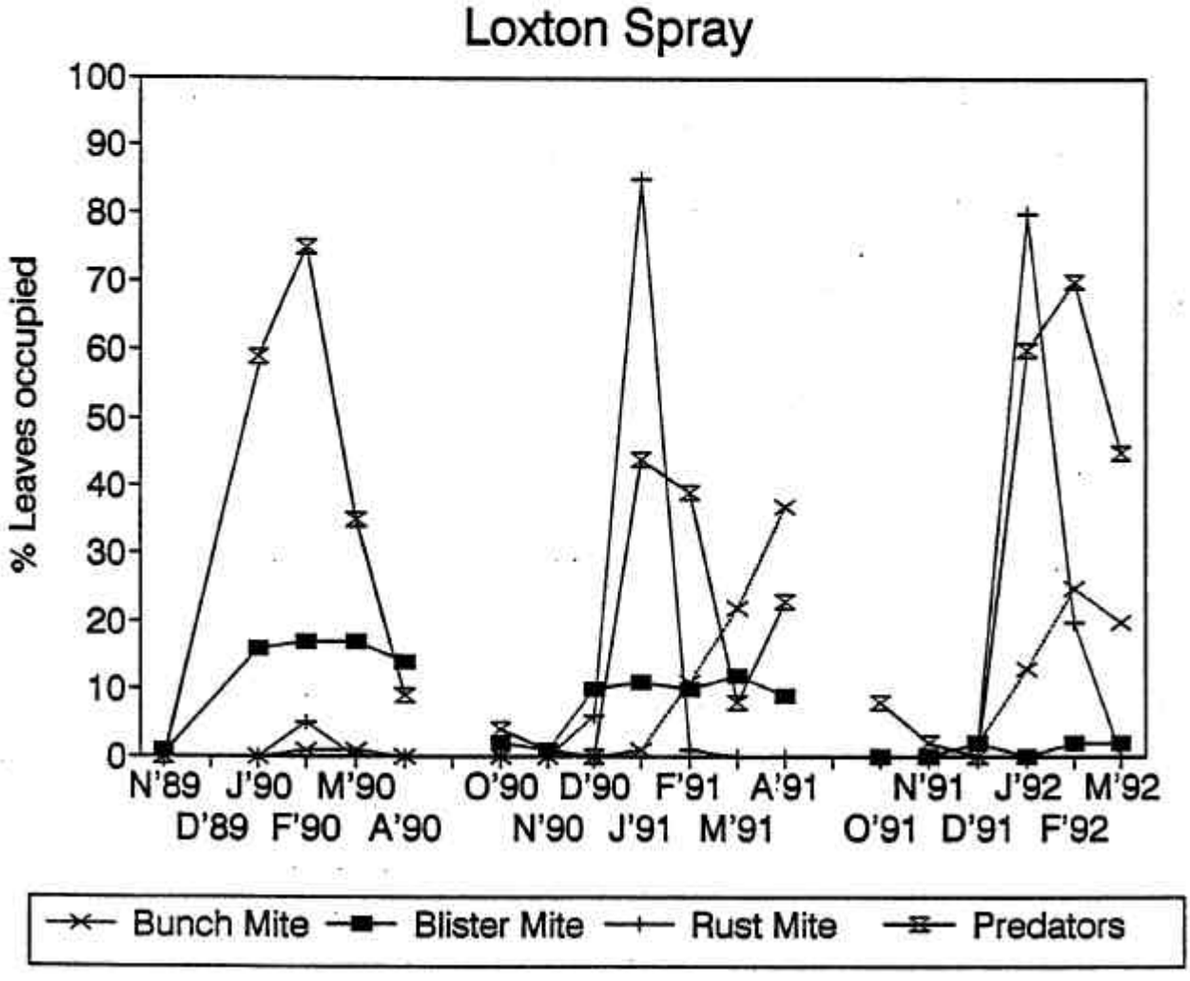


Fig. 19 Predatory mite and pest mite populations on unsprayed grapevines at the Loxton Research Centre 1989-92.

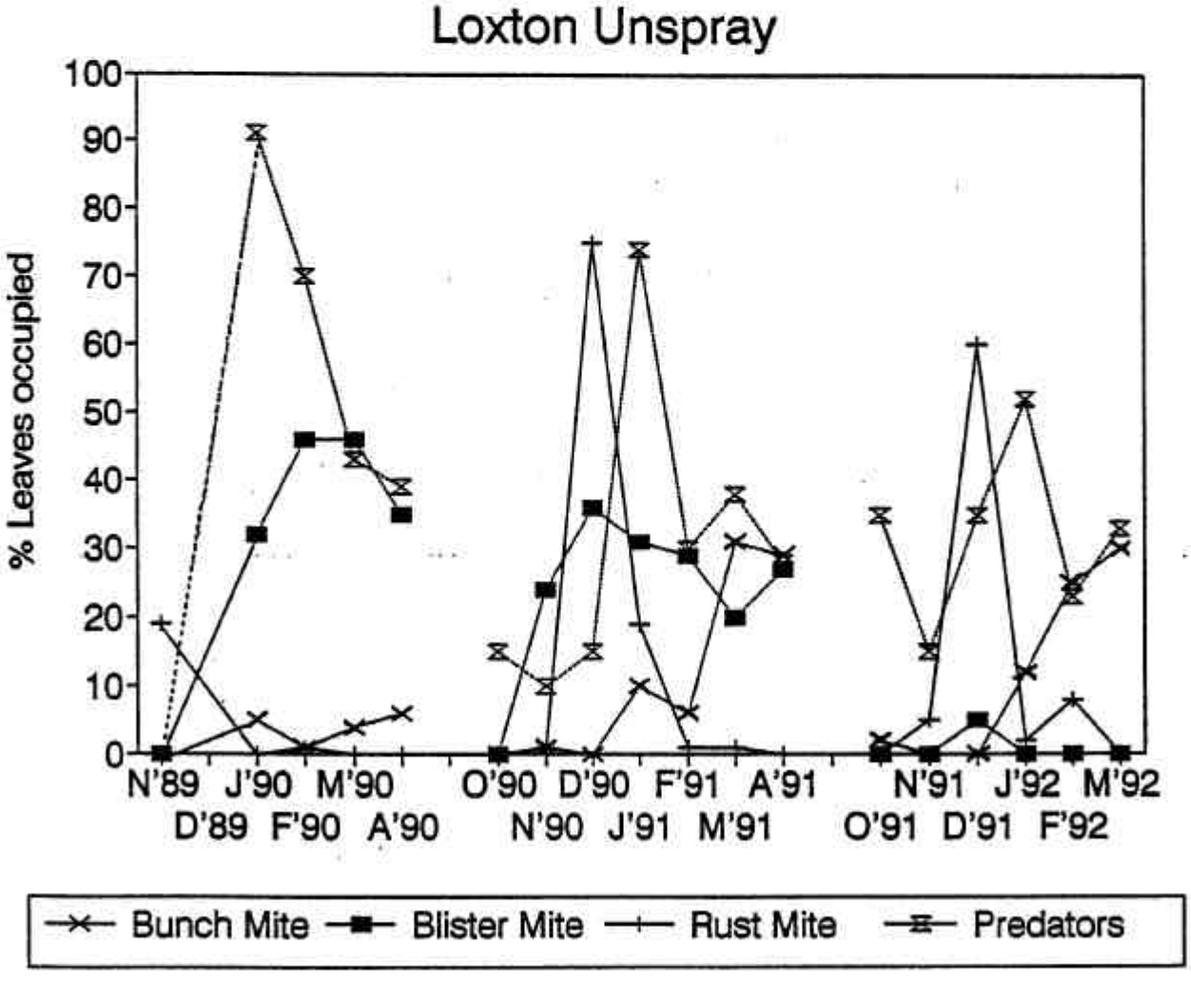


Fig. 20 Predatory mite and pest mite populations on unsprayed grapevines at the Dareton Agricultural Research and Advisory Station 1989-92.

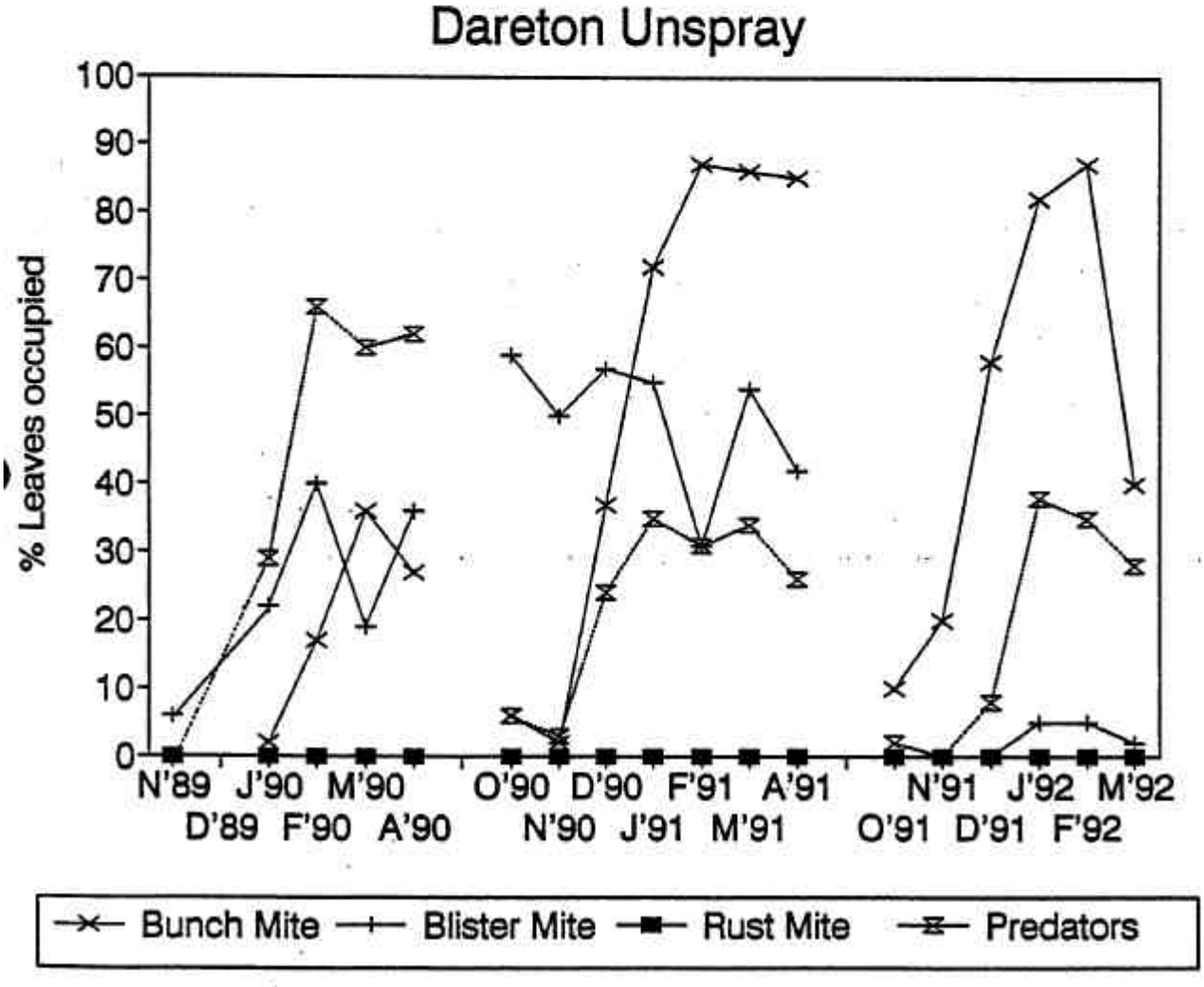


Fig. 21 Predatory mite and pest mite populations on unsprayed grapevines at the Griffith Horticultural Research and Advisory Station 1989-92.

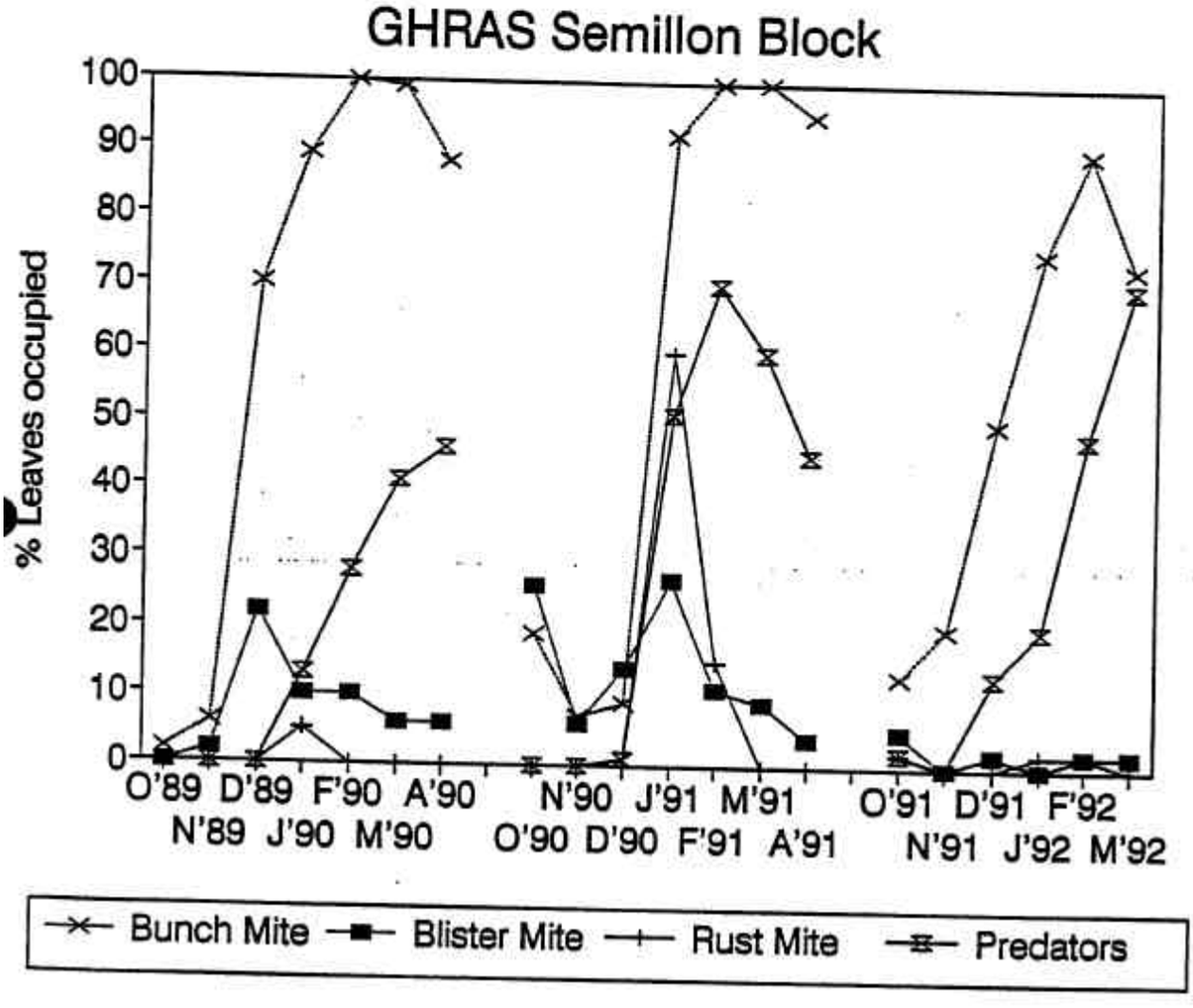


Fig. 22 Occupation of grapevine leaves by predator species on sprayed vines at the Loxton Research Centre 1989-92.

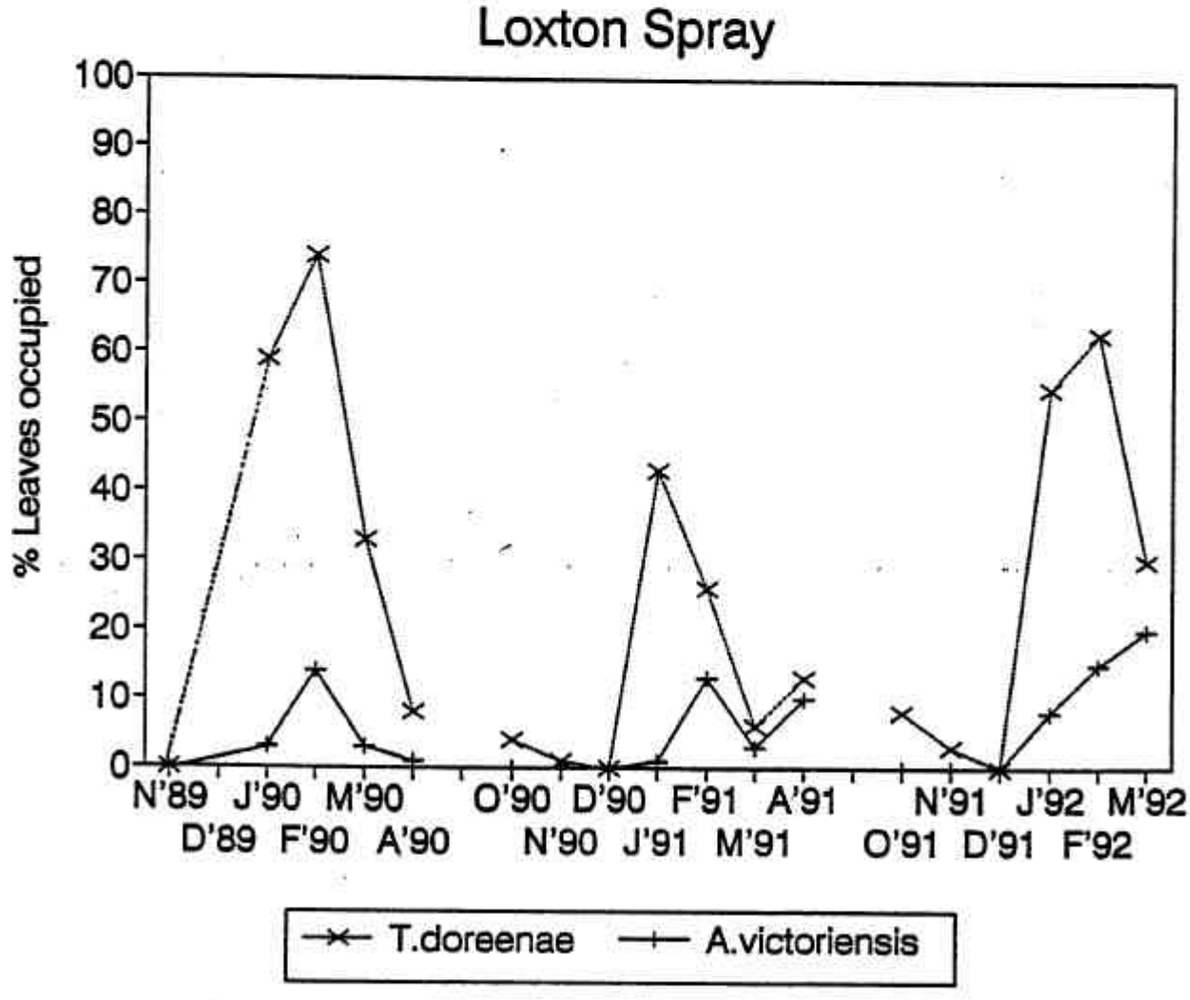


Fig. 23 Occupation of grapevine leaves by predator species on unsprayed vines at the Loxton Research Centre 1989-92.

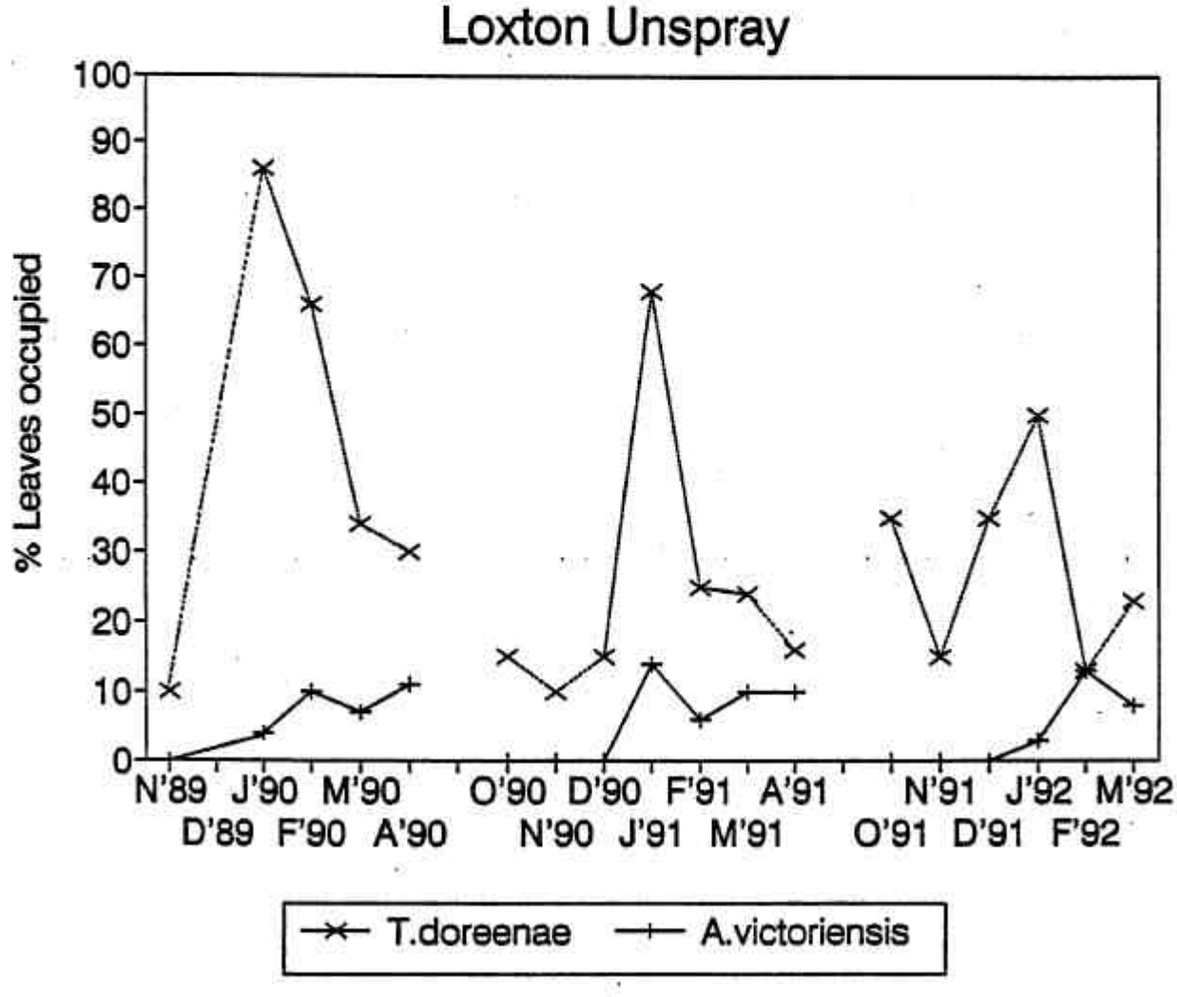


Fig. 24 Occupation of grapevine leaves by predator species on unsprayed vines at the Dareton Agricultural Research and Advisory Station 1989-92.

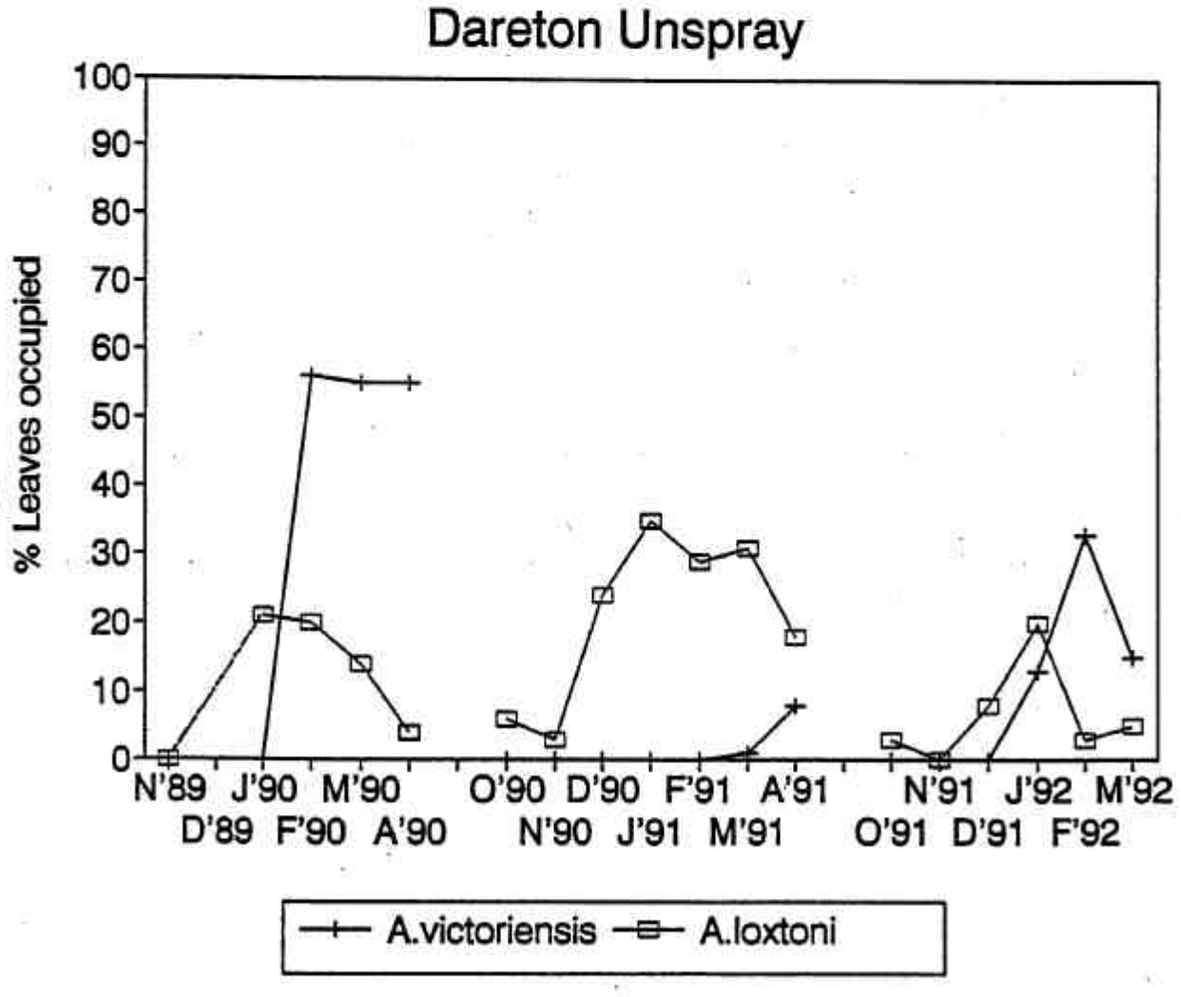
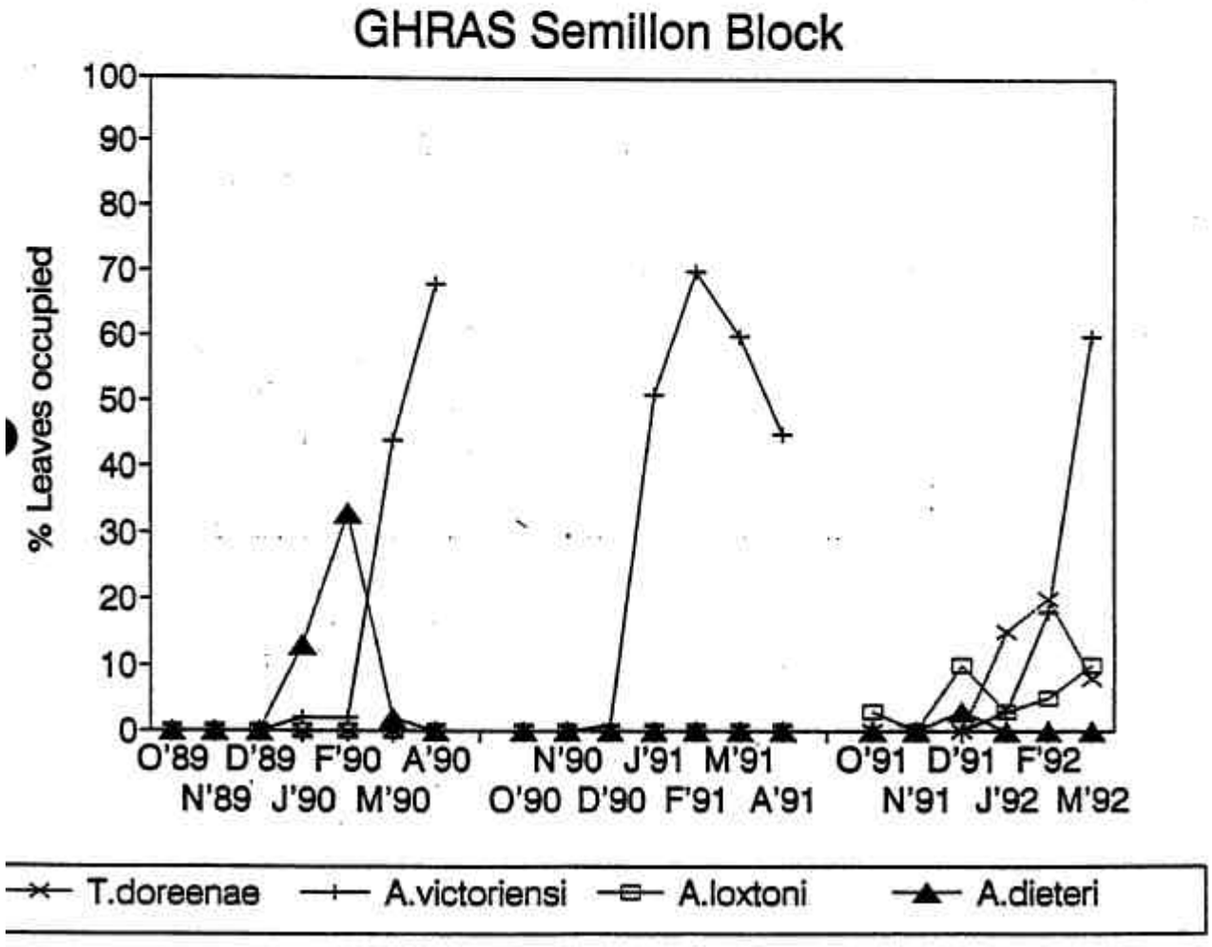


Fig. 25 Occupation of grapevine leaves by predator species on unsprayed vines at the Griffith Horticultural Research and Advisory Station 1989-92. (Note: *T. doreenae* introduced to this vineyard in 1991/92).



Discussion

Viticulture in the Riverlands region of southern Australia is a good example of an **a**gro ecosystem, which, does not suffer major pesticide disruption. Disease management is generally based on the use of sulphur and copper, with few growers resorting to synthetic fungicides. Insect pressure on grapevines in this region is generally low and the use of broad.-spectrum insecticides is rare. The high incidence of phytoseiid mites on grapevines in this region suggests ecosystem stability. T. doreenae and A. *victoriensis* were the only phytoseiids detected and T. *doreenae* dominated throughout the year. A. *victoriensis* was present during January-April only. The absence of A. *victoriensis* during winter, spring and early summer was probably a reflection of the ecology of this species rather than a result of exclusion by pesticides. In other deciduous horticultural ecosystems in southern Australia (stone and pome fruit), A. *victoriensis* is unable to over winter successfully and is slow to reappear in spring (James, 1989, 1990a).

In the Riverlands, large populations of T. *doreenae* and A. *victoriensis* were associated with small, non-damaging populations of *Brevipapus* spp., C. *vitis* and Ca. *vitis.* In commercial vineyards *Brevipapus* spp. was absent. Laboratory studies show that T. *doreenae* feeds readily on *Brevipapus* spp. and the ability of A. *victoriensis* to control eriophyid populations is well established (James, 1990a; Smith and Papacek, 1991). A. *victoriensis* is a reticent feeder on *Brevipapus* spp. in the laboratory and will ignore this prey if provided with another food source (James, unpublished data). T. *doreenae* and A. *victoriensis* appear to provide biological control of the grapevine mite complex; T. *doreenae* may feed primarily on *Brevipapus* spp. and A. *victoriensis* on the eriophyids C. *vitis* and Ca. *vitis.*

Both predators were absent in one commercial vineyard, which used synthetic fungicides and an insecticide. Laboratory bioassays have shown T. *doreenae* has a high tolerance (200 x field rate) to sulphur and copper (this report) but is susceptible to carbaryl. A. *victoriensis* is susceptible to a number of commonly used synthetic fungicides including mancozeb and benomyl (James, 1989). Preliminary laboratory studies indicate at least some tolerance to field rates of sulphur and copper (this report) and Smith and Papacek (1991) showed copper oxychloride to be harmless to A. *victoriensis.*

In MIA vineyards there was no evidence of phytoseiids regulating *Brevipapus* spp. populations. High infestation levels resulted in economic damage (scarring of fruit pedicels and shrivelling of berries) at the research station blocks. C. *vitis* and Ca. *vitis* populations remained low in the presence of A. *victoriensis.* None of the six phytoseiid species recorded in MIA vineyards prior to the appearance of A. *victoriensis* appeared to feed on *Brevipapus* spp. or were able to colonise the vines. A. *victoriensis* largely displaced other phytoseiids during February-March. Displacement of T. *occidentalis* by A. *victoriensis* in peach orchards was reported by James (1990a) and was considered to be a consequence of the generalist feeding behaviour of A. *victoriensis.* Grapevine mite and predator population dynamics in Sunraysia shared characteristics of populations in both the Riverlands and the MIA. High numbers of phytoseiids and low numbers of brevipalpids and eriophyids occurred in 1989/90. However, in 1990/91 and

1991/92, smaller numbers of phytoseiids were associated with a large population of *Brevipalpus* spp., although C. *vitis* and *Ca. vitis* remained at non-damaging levels. Summer phytoseiid populations in this region were dominated by *A. loxtoni* and *A. victoriensis.* Nothing is known of the feeding habits of *A. loxtoni* but it was observed feeding on both *Brevipalpus* spp. and C. *vitis* during this study. Like T. *doreenae* in the Riverlands, *A. loxtoni* was present on dormant as well as vegetated vines. *A. loxtoni* does not appear to be as effective a predator of *Brevipalpus* spp. as T. *doreenae* and like *A. victoriensis,* may prefer to feed on eriophyids.

The substantial regional differences reported here in mite-predator population dynamics are reflected in the levels of natural control of vine mite pests in each of these viticultural areas. Biological control of the three grapevine mite species appears to occur in the Riverlands as long as disease management is based on copper and sulphur ., and no broad-spectrum insecticides are used. T. *doreenae* and *A. victoriensis* are generalist feeders; *A. victoriensis* feeds on mites from a number of families including Tetranychidae, Tenuipalpidae, Eriophyidae and Tydeidae, as well as on honeydew, scale crawlers, whitefly larvae and pollen (James, 1989). Less information is available for T. *doreenae* although it will feed on T. *urticae* and pollen in the laboratory (James and Whitney, 1992). The generalist feeding behaviour of these predators ensures their populations are maintained even when the target prey is rare or disappears. Thus, in some Riverlands vineyards large populations of T. *doreenae* were present despite the absence of *Brevipalpus* spp.

Natural regulation of grapevine mites in Sunraysia and the MIA appears to be less satisfactory. This may be due largely to the absence of an effective brevipalpid predator such as T. *doreenae.* In both regions it is possible that such a predator is being excluded from the grapevine system by synthetic pesticides. T. *doreenae* has been stated to occur only in South Australia (Schicha, 1987) but specimens have recently been obtained from grapevines in northern New South Wales, Victoria and the Australian Capital Territory (this report). Relaxation of pesticide pressure in MIA and Sunraysia grapevines may result in the appearance of this predator in these regions.

This basic study of grapevine mite ecology provides considerable optimism that a I sustainable mite management strategy based on biological control can be developed for inland viticulture in southern Australia. The major obstacle to natural control appears to be the use of pesticides, particularly fungicides, which are harmful to phytoseiids. However, phytoseiid-friendly alternatives are available (e.g. copper, sulphur). Some synthetic fungicides are safe to *A. victoriensis* (chlorothalonil, dithianon, *J*ames, 1990b) and a full list needs to be developed for both this species and T. *doreenae.* The relatively few insect pests of Australian grapevines, consequent low insecticide input and ecosystem stability, provides viticulturists with an excellent opportunity for development of biological control strategies for minor-moderate pests such as mites.

Population dynamics of grapevine mites and mite natural enemies in the Canberra region

Introduction

The Canberra region is a good example of a warm grape growing region (Mean January temperature (20.2°C) compared to a very hot grape growing region (e.g. Riverland, MIA, Sunraysia MjT:23.5°C). Warm (MjT:19-20°C) grape growing regions in Australia include the Granite Belt, Margaret River, Coonawarra, Mornington and Geelong. Generally, only Tasmanian vineyards are exposed to a cooler climate (Halliday, 1991). The Canberra region therefore provides a good contrast to viticulture in the MIA, Sunraysia and Riverland.

The acarine fauna of grapevines in the Canberra region should represent the opposite end of the spectrum compared to the hotter, drier inland areas. The grapevine mite fauna (pests and predators) is likely to differ in composition and phenology from districts such as the MIA, Riverlands and Sunraysia. An understanding of the variation in acarine ecology between grape growing areas in southern Australia will be important in the widespread development of management strategies based on biological control. The results of a preliminary study on populations of grapevine mites and phytoseiid natural enemies in Canberra district vineyards are presented.

Materials and Methods

Leaf and Shoot Samples

Pest and predatory mite populations were monitored from August 1991 to April 1992 in five commercial vineyards (Helm's Wines, Traminer Riesling; Murrumbateman Winery, Sauvignon blanc/Chardonnay; jeir Creek Wines, Sauvignon blanc/Rhine Riesling; Brindabella Hills Winery, Cabernet Sauvignon; Lark Hill, Rhine Riesling).

Thirty leaves and 10 shoots were collected randomly from these vineyards in November, December, January, February, March and April and dealt with in the same way as described in the previous section.

Fungicides used included phosphorous acid, triadimefon, iprodione, mancozeb, benomyl and metalaxyl. No insecticides were used. One vineyard (Brindabella Hills) used no sprays at all.

Dormant Wood Samples

A single sample of dormant wood was obtained from each vineyard in August 1991 and dealt with as described previously.

Results

Vineyard mite populations in the Canberra district during 1991/92 were characterised by low populations of pests and high populations of predators (Figs. 26-30). *Brevipalpus* spp. was absent in all vineyards except Brindabella Hills where a very small infestation occurred in February (Fig. 30). C. *vitis* and *Ca. vitis* populations generally remained at levels lower than 50% occupation of leaves. Phytoseiids were present in all vineyards during November-April with populations generally increasing over this period. Greatest numbers occurred at Murrumbateman Winery where 60-85% of leaves where occupied during January-April (Fig. 29).

Phytoseiids were present in dormant wood samples from all vineyards (Lark Hill 4/200g, Brindabella Hills 0.3/200g, Murrumbateman Winery 12.8/200g, Jeir Creek 1.4/200g, Helm's Wines 0.8/200g). Low numbers of *Brevipalpus* spp. were also detected in the samples from Lark Hill and Brindabella Hills.

Six species of phytoseiids were collected from Canberra district vineyards, *T. doreenae, Phytoseius fotheringhamiae* Denmark and Schicha, *Typhlodromus dossei* Schicha, *Typhlodromus australicus* (Womersley) , *Amblyseius waltersi* Schicha and *Amblyseius elinae* Schicha. None of these except *T. doreenae,* were recorded from grapevines in the MIA, Riverlands and Sunraysia. *T. doreenae* was the most abundant species and occurred in all vineyards (Figs. 31-35). *P. fotheringhamiae* occurred in three vineyards (j eir Creek, Helm's, Murrumbateman). Greatest numbers of this species occurred at Murrumbateman where it was the dominant phytoseiid at the end of the season (Fig. 31). *dossei* occurred at Brindabella Hills and Jeir Creek but was most common at the former vineyard (Fig. 34). Only single specimens of *A. elinae* (Murrumbateman), *A. waltersi* (Murrumbateman) and *T. australicus* (Brindabella Hills) were detected.

T. doreenae was the dominant phytoseiid in dormant wood samples from Lark Hill. 18 Helms Wines and J eir Creek. *T. dossei* was found in samples from Brindabella Hills and Jeir Creek and *P. fotheringhamiae* was the dominant species in samples from Murrumbateman Winery.

Discussion

Viticulture in the Canberra region appears to be a further example of excellent natural control of mites. Mites are not a major problem on grapevines in this district and the existence of large predator populations in all vineyards examined, strongly supports the idea that biological control is the basis of this. Data from only a single season are presented and caution should be exercised in their interpretation. However, the results do indicate that non-chemical mite management on grapevines in this region should be possible. A further season's data on mite and predator populations in this region is currently being collected (1992/93).

Fig. 26 Predatory mite and pest mite populations in a commercial vineyard (Helm's) in the Canberra district during 1991/92.

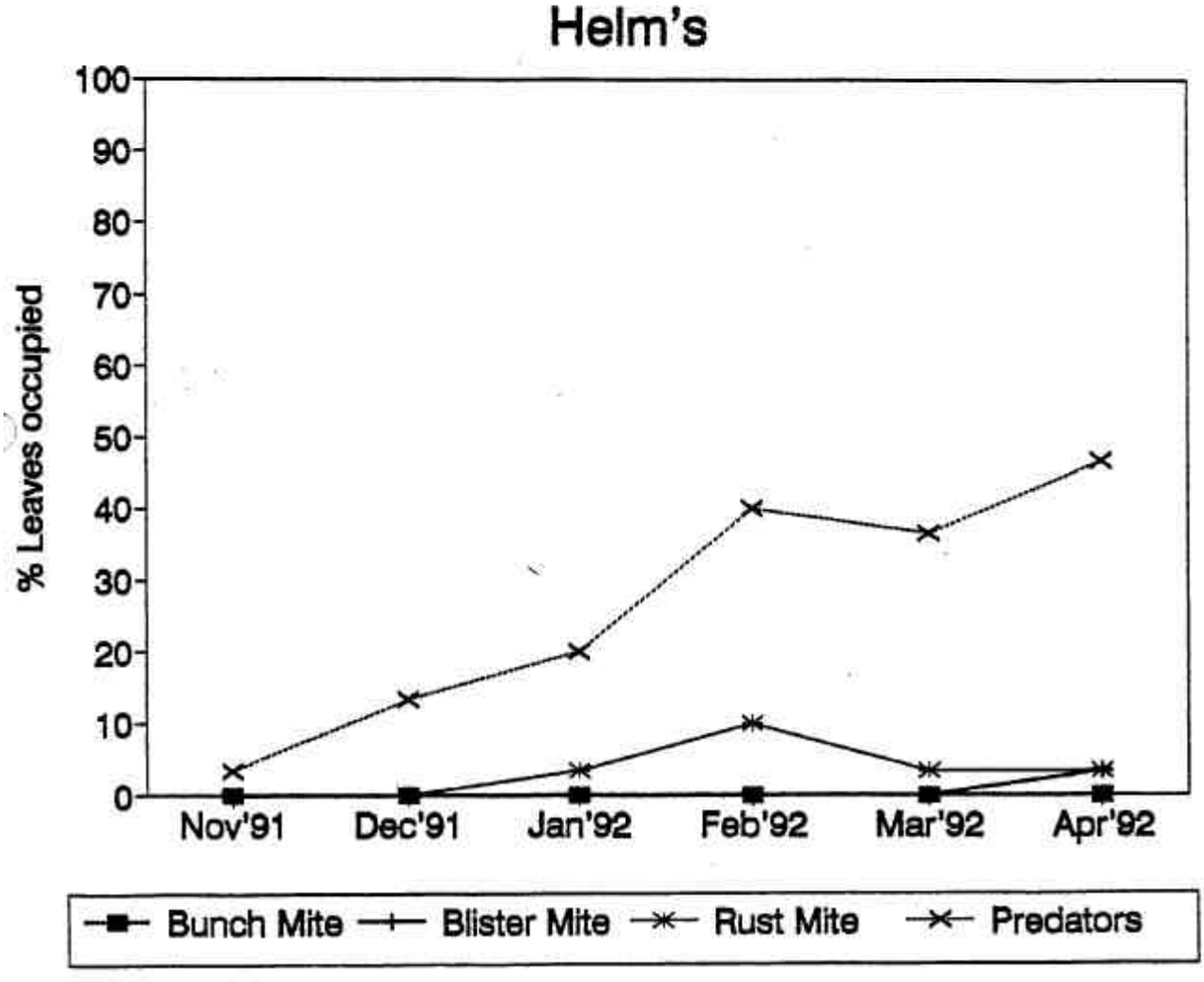


Fig. 27 Predatory mite and pest mite populations in a commercial vineyard (Jeir Creek) in the Canberra district during 1991/92.

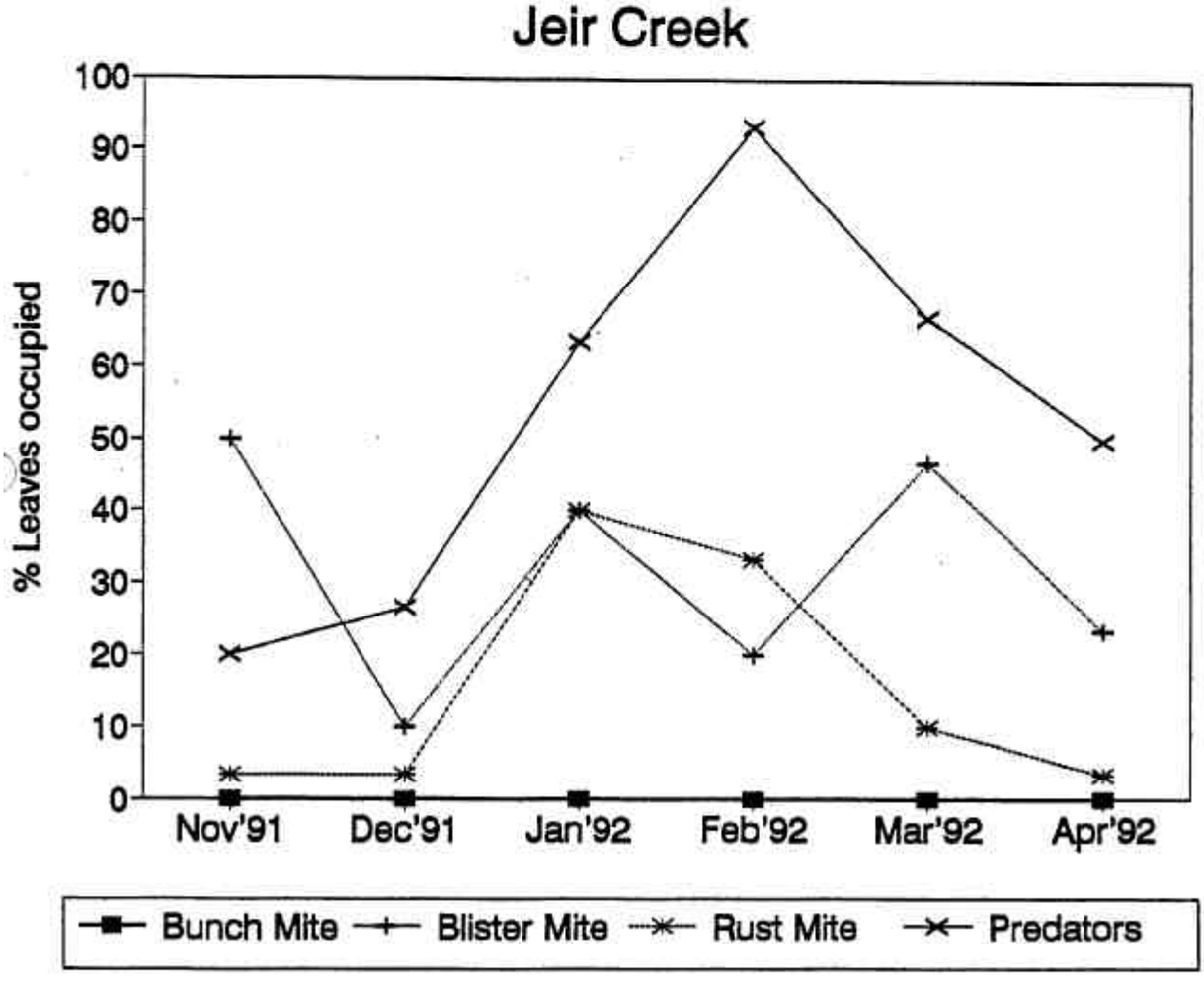


Fig. 28 Predatory mite and pest mite populations in a commercial vineyard (Lark Hill) in the Canberra district during 1991/92.

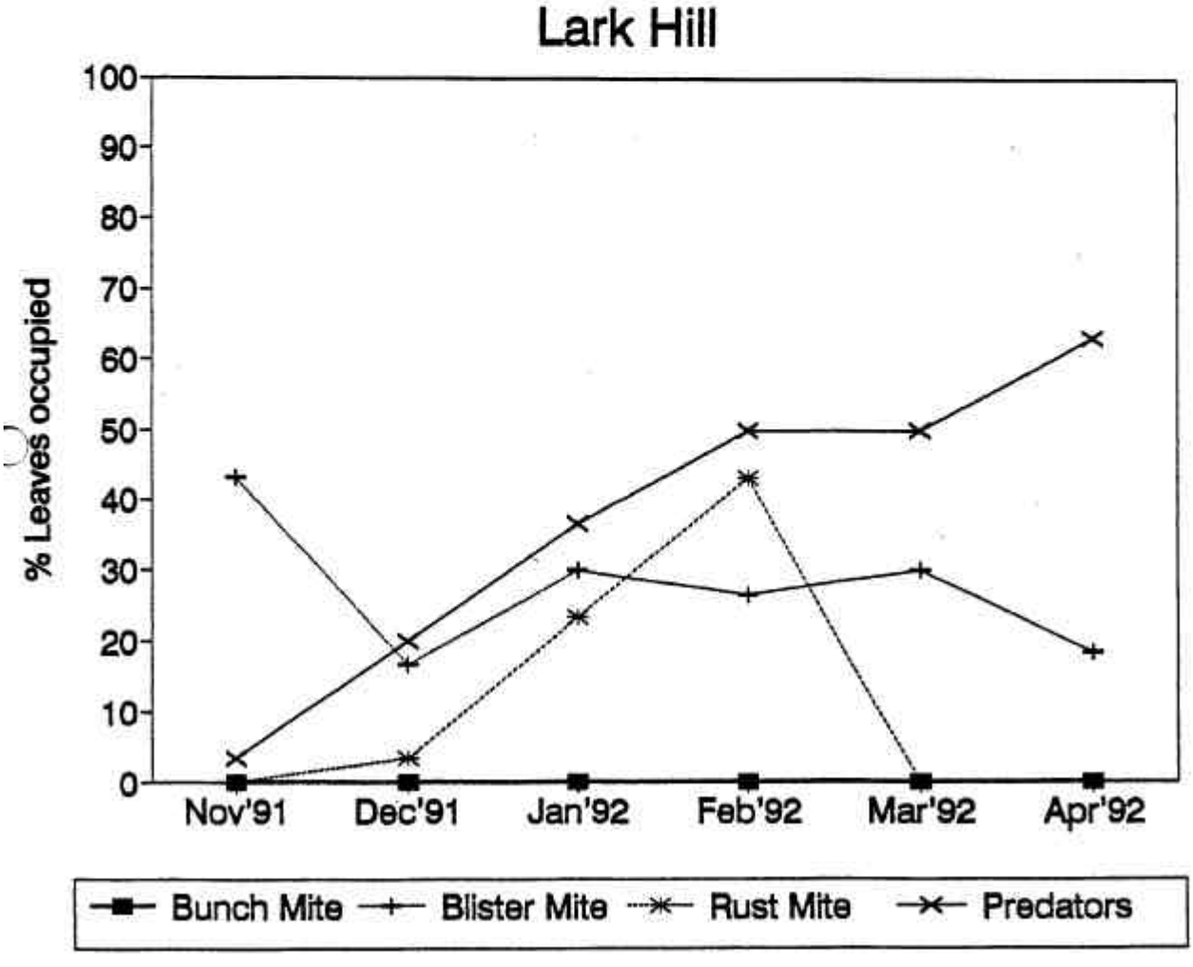


Fig. 29 Predatory mite and pest mite populations in a commercial vineyard (Murrumbateman) in the Canberra district during 1991/92.

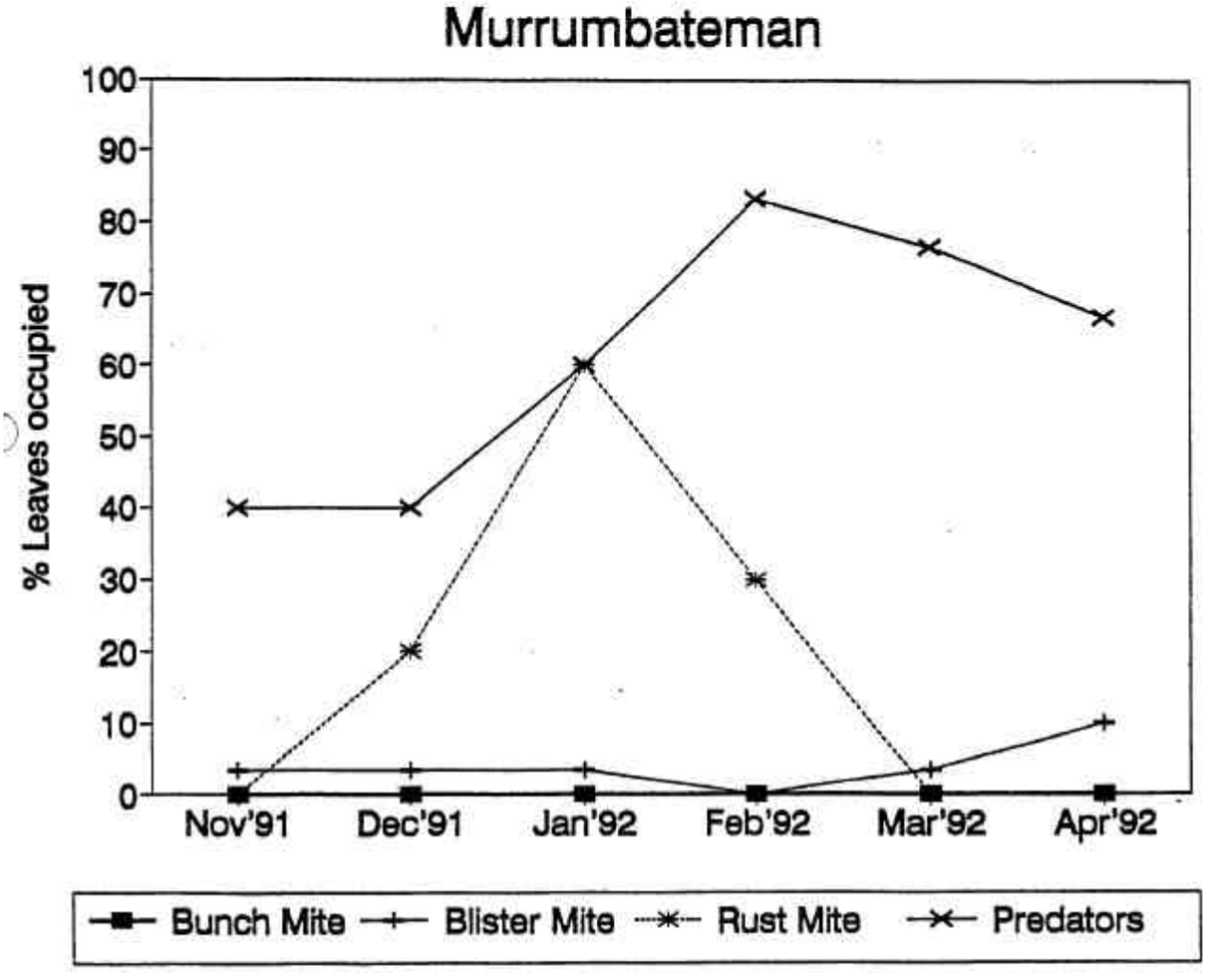


Fig. 30 Predatory mite and pest mite populations in a commercial vineyard (Brindabella Hills) in the Canberra district during 1991/92.

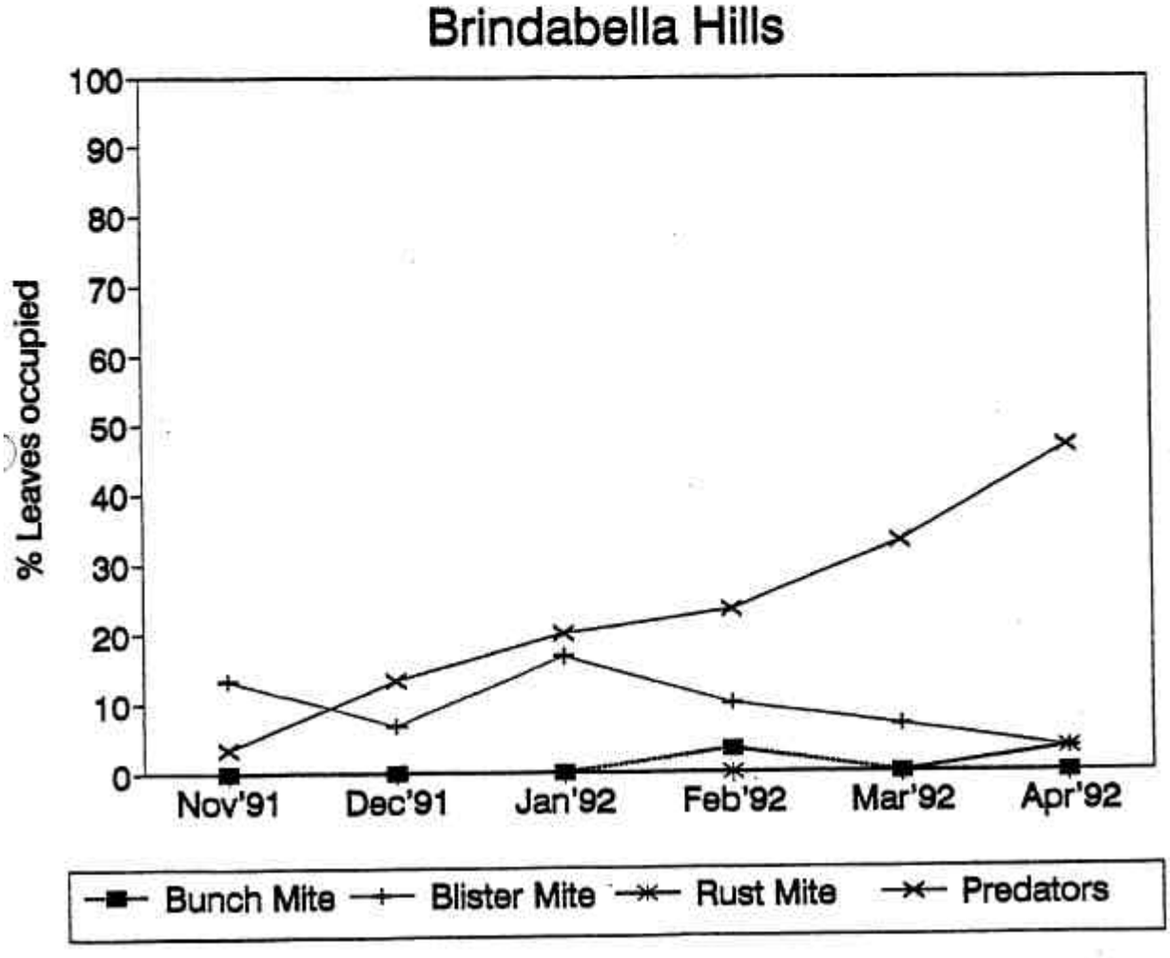


Fig. 31 Occupation of grapevine leaves by predator species in a commercial vineyard (Murrumbateman) in the Canberra district during 1991/92.

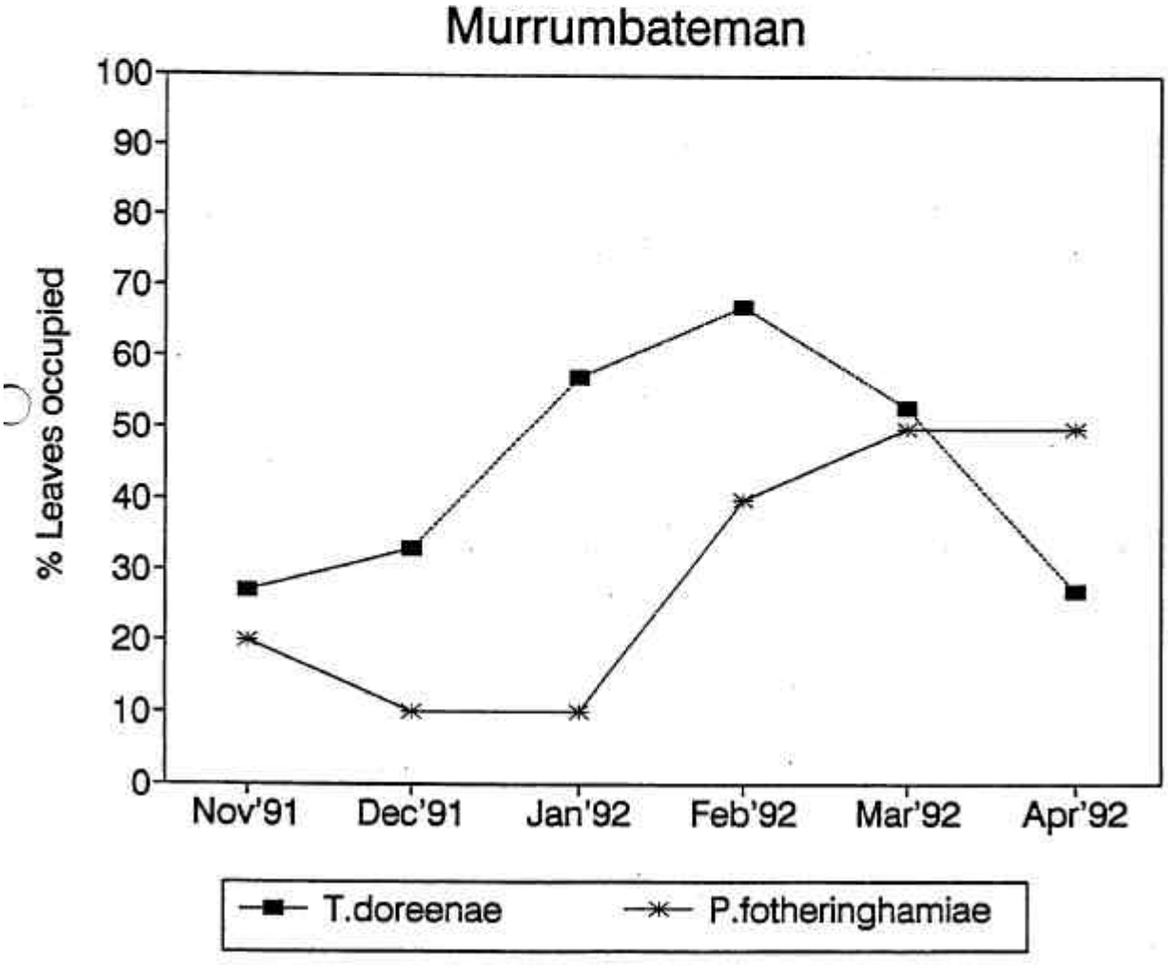


Fig. 32 Occupation of grapevine leaves by *T. doreenae*, the only predator detected at Lark Hill, a Canberra district vineyard, during 1991/92.

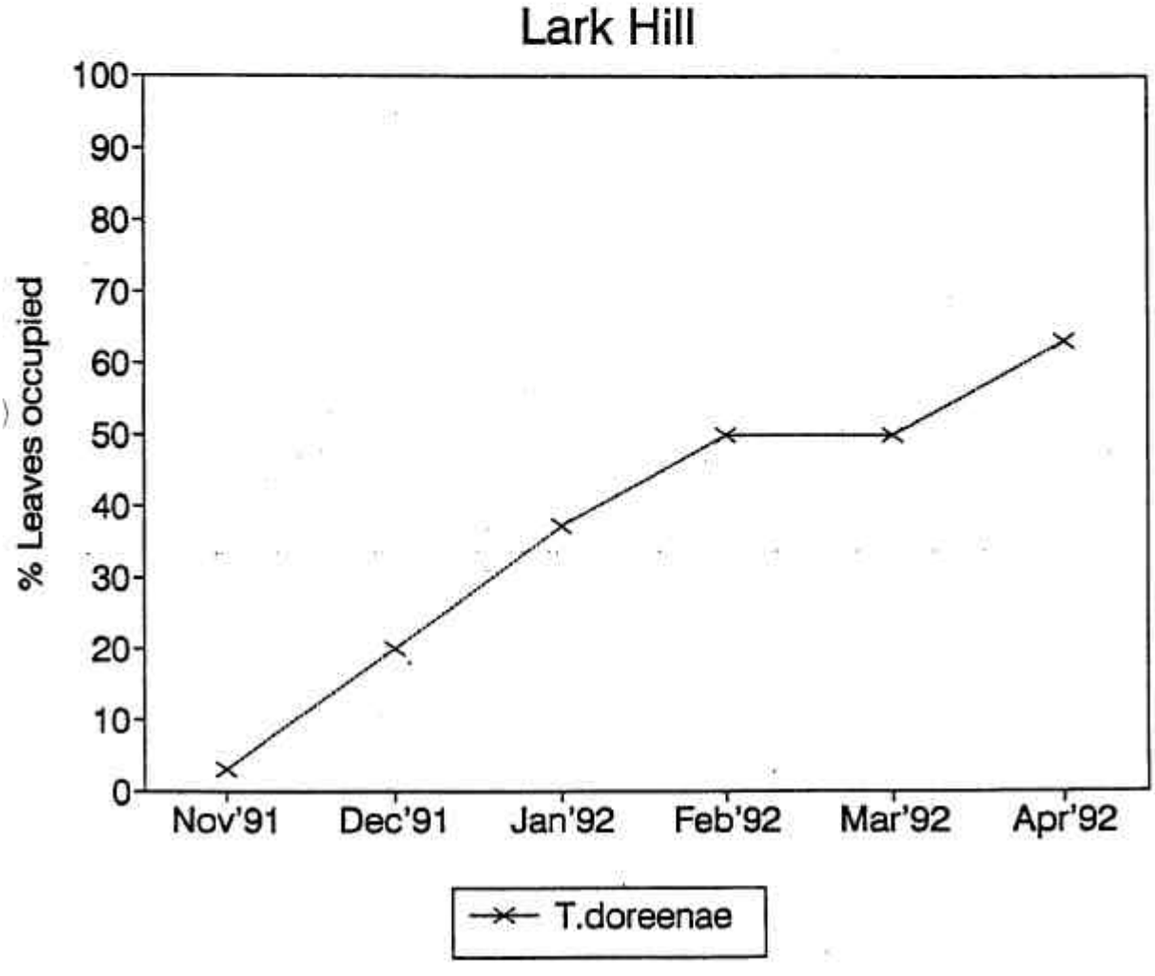


Fig. 33 Occupation of grapevine leaves by predator species in a commercial vineyard (Helm's) in the Canberra district during 1991/92.

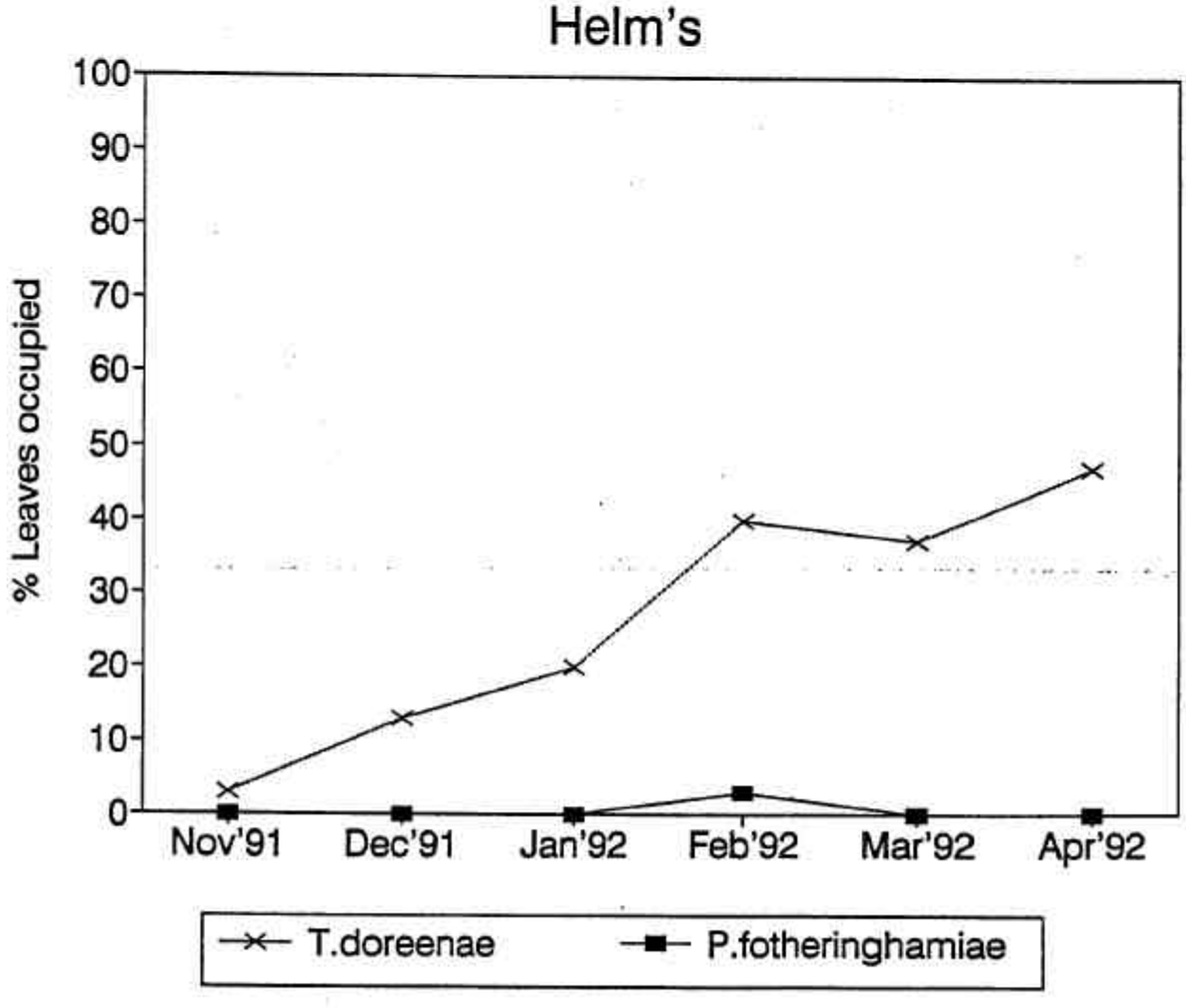


Fig. 34 Occupation of grapevine leaves by predator species in a commercial vineyard (Brindabella Hills) in the Canberra district during 1991/92.

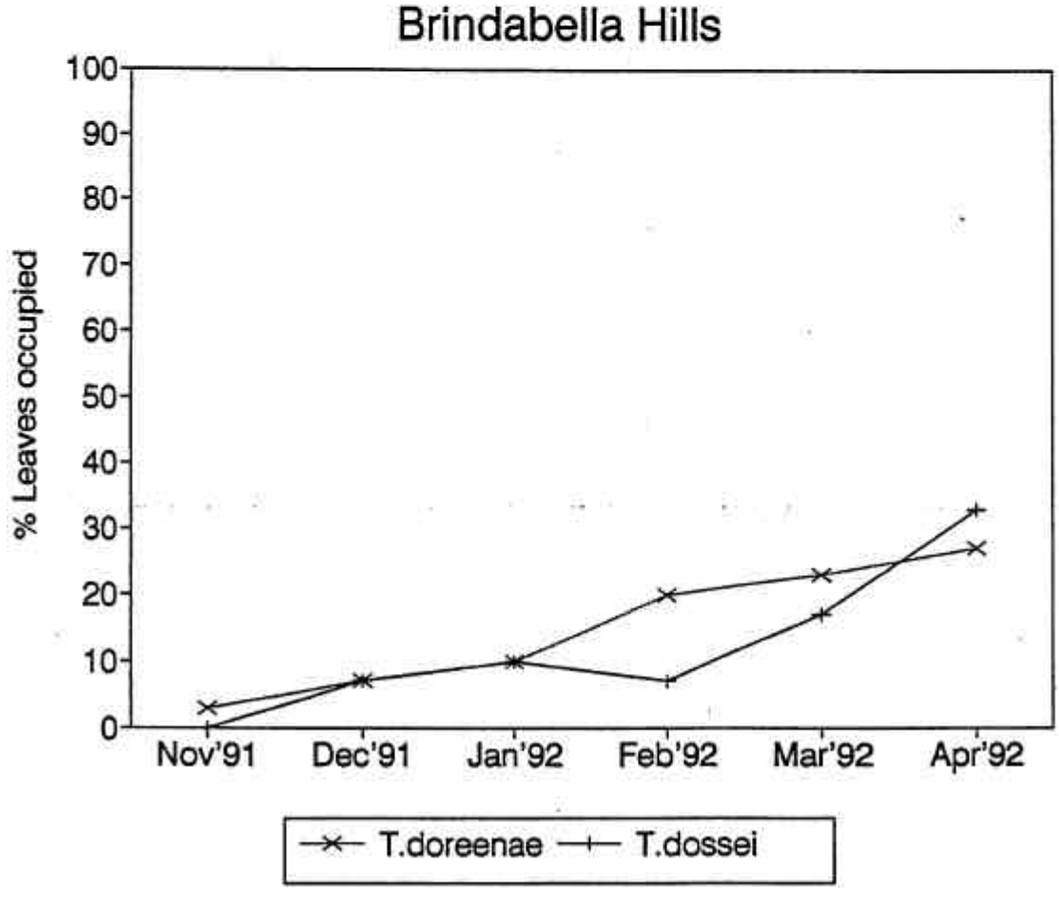
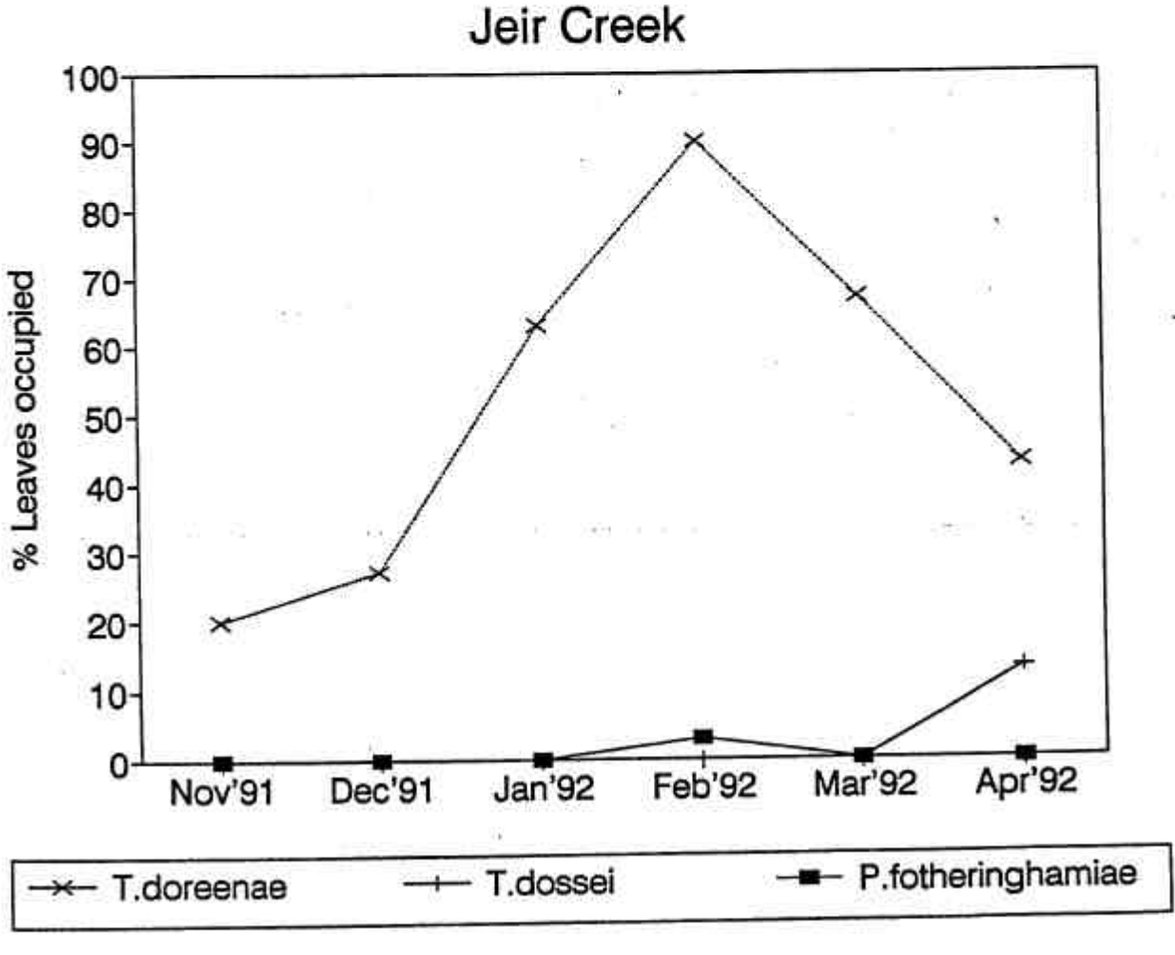


Fig. 35 Occupation of grapevine leaves by predator species in a commercial vineyard (Jeir Creek) in the Canberra district during 1991/92.



A major difference between Canberra viticulture and grape growing in the Riverlands, where good natural control of mite populations also occurs, is reduced dependence on sulphur and copper in Canberra vineyards. Cooler conditions, particularly early in the season, can make sulphur relatively ineffective against vine disease and greater use is made of synthetic fungicides. Predator populations, particularly *T. doreenae,* appeared little affected be applications of fungicides such as mancozeb, triadimefon, metalaxyl, phosphorous acid, iprodione and benomyl. The combined evidence from both Riverland and Canberra district vineyards indicates some synthetic fungicides are harmless to *T. doreenae.*

Brevipalpus spp., usually the most important grapevine mite pest, was rare in Canberra district vineyards. This may reflect the effectiveness of predators or be a result of unfavourable environmental conditions. However, it is likely to be a combination of both factors. C. *vitis* and *Ca. vitis* did not reach damaging populations in any vineyard. It is likely that both *P. fotheringhamiae* and *T. dossei* used C. *vitis* and *Ca. vitis* as prey. *IT. doreenae,* in the absence of *Brevipalpus* spp., also accepted C. *vitis* and *Ca. vitis* as prey. *T. doreenae* was often observed under the microscope feeding on these species. However, as previously noted *T. doreenae* is a generalist feeder and the extent to which it fed on alternative food sources (e.g. pollen) is unknown.

The presence and abundance of *T. doreenae* in Canberra vineyards is an important and encouraging discovery. It indicates the broad spectrum of environmental conditions in which this predator is apparently able to exist. it also bodes well for the prospects of introducing *T. doreenae* to viticultural areas such as the MIA, which currently lack this predator. *T. doreenae* clearly survives harsher winters than those experienced in the Riverlands and will develop large populations even in the absence of *Brevipalpus* spp. The indicated tolerance to a number of synthetic fungicides is another major attribute.

The absence of *A. victoriensis* from Canberra district vineyards was not expected. This 8 species has only been recorded from west of the Central Dividing Range in New South Wales. Virtually nothing is known of the biology and ecology of *P. fotheringhamiae* and *T. dossei.*

PREDATOR BIOLOGY AND ECOLOGY

Predator population: Species composition, incidence and abundance in other viticultural areas

During the course of this study, samples of grapevine leaves and shoots from other viticultural areas were also examined for the presence of predatory mites. This was not a planned component of the program, more a taking of opportunities as they presented themselves. Publicity surrounding this research frequently sparked requests for examination of vine material from diverse areas, to gauge the nature of predator populations.

Wherever possible these requests were met, particularly as our experience in the identification of phytoseiid predators, developed. Apart from being of assistance to individual growers, considered this extra information would eventually be of considerable value when it comes to developing biological control strategies for grapevine mites in all Australian viticultural regions.

Very little is known of the incidence of phytoseiids in Australian agro ecosystems, with the exception, perhaps, of pome fruit. The work of Eberhard Schicha(NSW Agriculture, Rydalmere) particularly his monograph "Phytoseiidae of Australia and Neighbouring Areas" published by Indira Publishing House (1987), remains the most up to date information on Australian Phytoseiidae. However, the current study, limited to grapevines, has produced a number of new host and distribution records for this important family of predatory mites.

Swan Hill

Dormant wood samples (August) and leaf samples (December, February, March 1991-92) were collected from 4 -5 vineyards and dealt with as described previously.

All dormant wood samples (vineyards: G. Smith, T. Lowe, T. Croft, J. Pye, H. Minchinton) contained Phytoseiids (2 -15/200g). The majority of individuals were *A. loxtoni* with a few *A. helmi.*

Good populations of predators occurred in the four vineyards sampled during Summer (Bael, Minchinton, Pye, Best) (Figs 36-39).

Brevipalpus spp. remained at non-damaging levels throughout the sampling period and was scarce in three of the vineyards. Likewise, C. *Vitis* and *Ca. Vlitis* occurred m low numbers. Predator populations increased during December-March particularly at Best's vineyard where percentage occupation of leaves reached 80%.

T. doreenae was the only phytoseiid found at the Bael and Pye vineyards and a mixed population of *T. doreenae* and *A. loxtoni* occurred at Michinton. A. *loxtoni* was the only predator found at the Best vineyard. *T. doreenae* is the dominant predator m the Riverland of South Australia and *A. loxtoni* predominates in Sunraysia. The Swan

Fig. 36 Predatory mite and pest mite populations in a commercial vineyard (Bael) in the Swan Hill district during 1991/92.

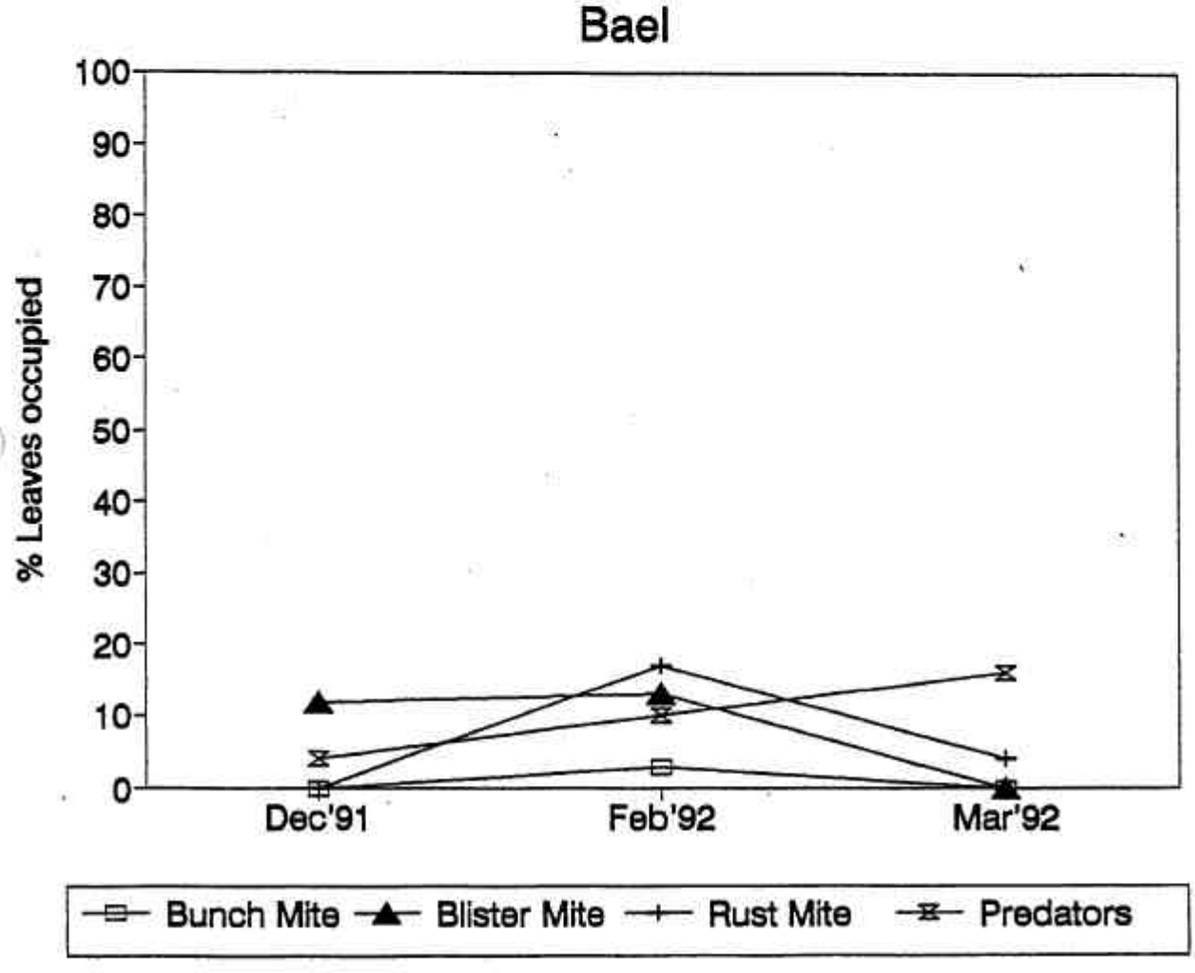


Fig. 37 Predatory mite and pest mite populations in a commercial vineyard (Best) in the Swan Hill district during 1991/92.

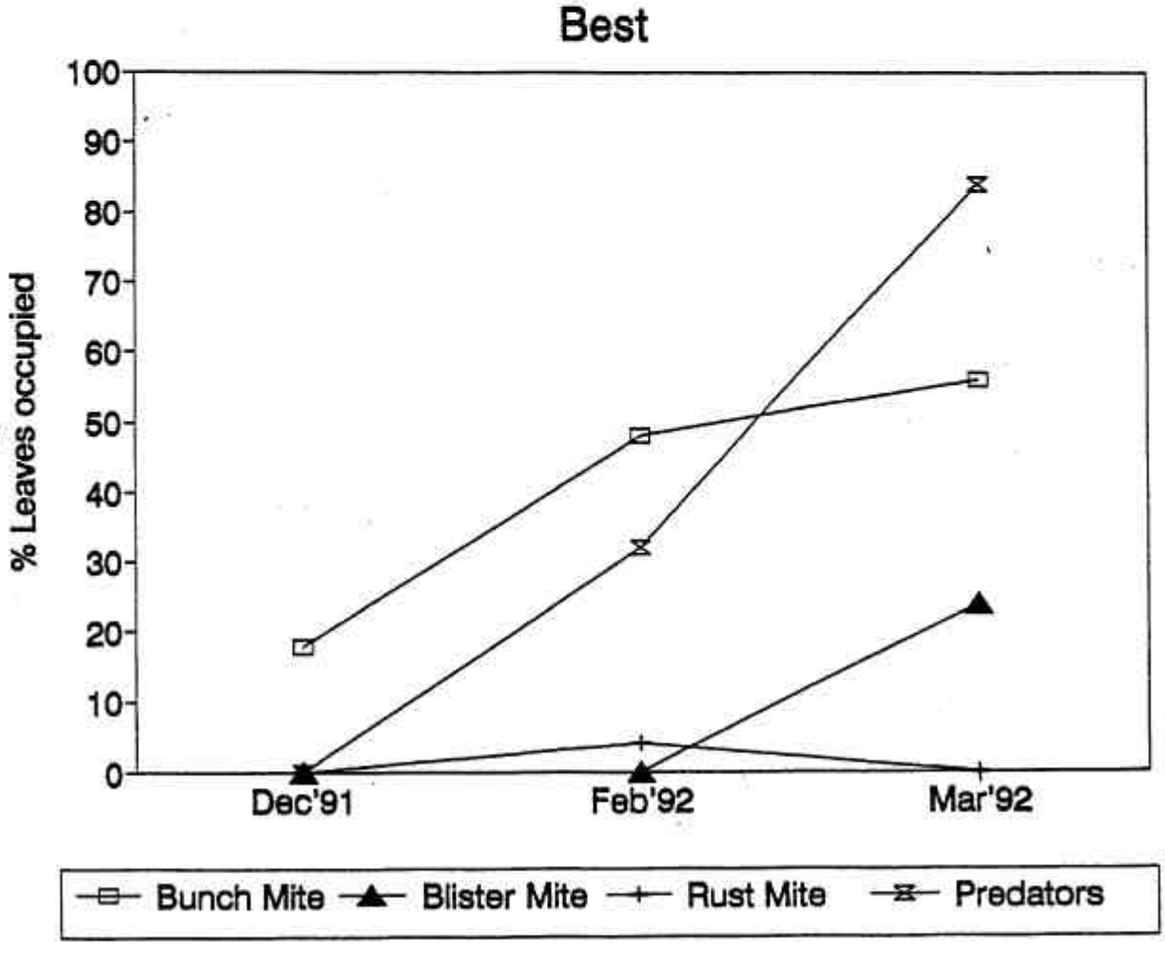


Fig. 38 Predatory mite and pest mite populations in a commercial vineyard (Minchinton) in the Swan Hill district during 1991/92.

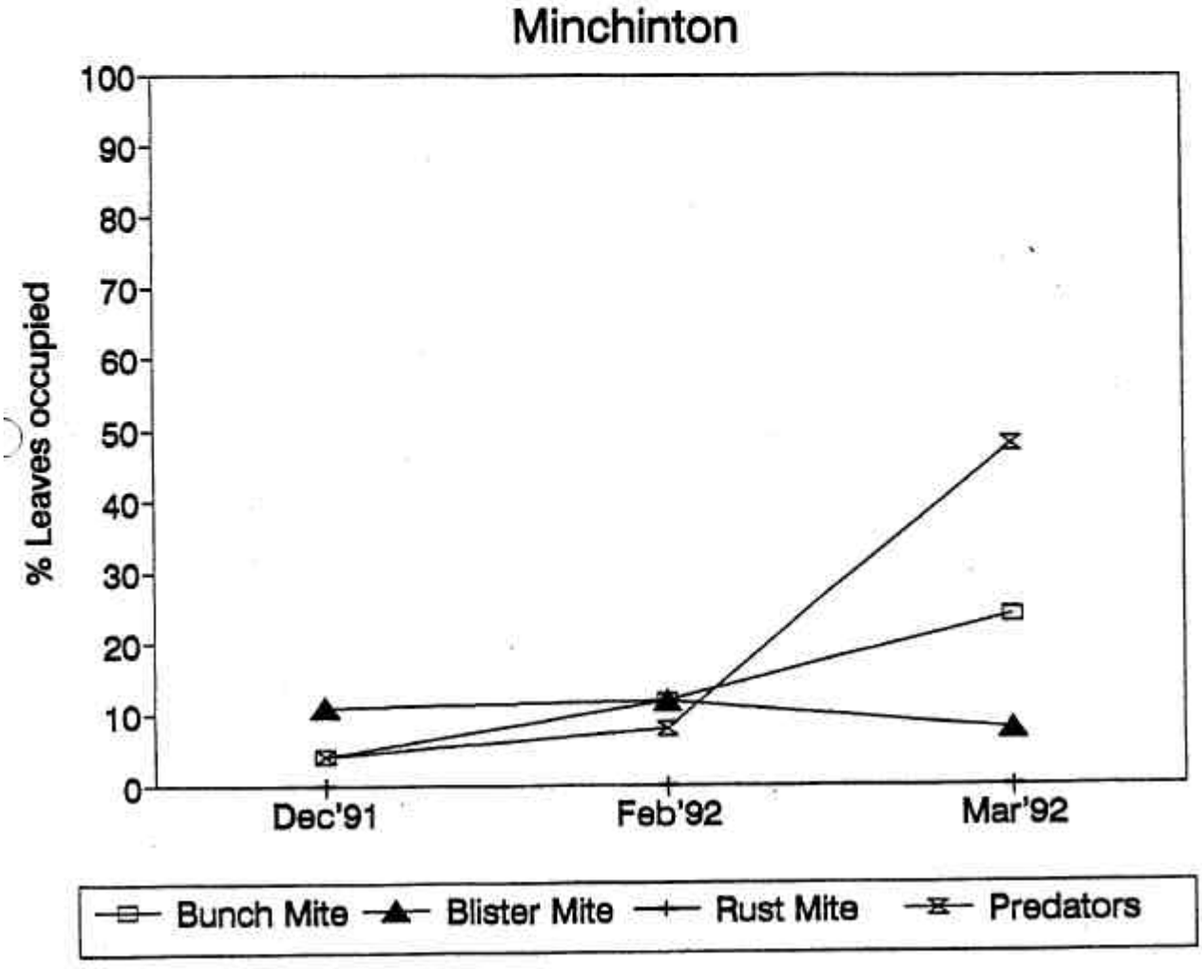
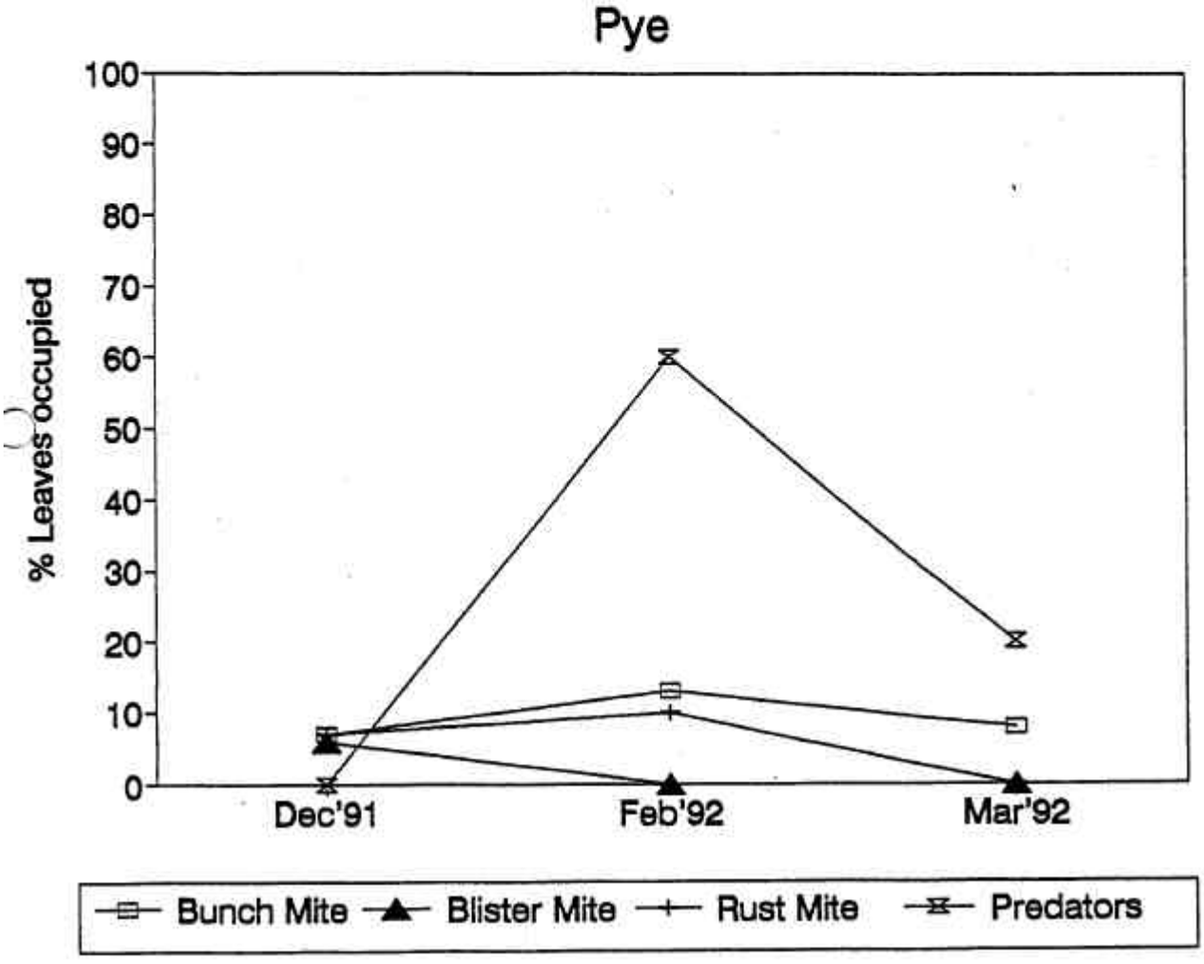


Fig. 39 Predatory mite and pest mite populations in a commercial vineyard (Pye) in the Swan Hill district during 1991/92.



Hill region has both species present in vineyards.

The vineyards of Pye and Minchinton were unsprayed whilst Best and Bael vineyards received spray programs consisting of the following:

> **Best**: lime sulphur, dithianon, copper hydroxide, wettable sulphur, *Bacillus thuringiensis*
>
> **Bael:** lime sulphur, wettable sulphur, vinclozolin, mancozeb, *Bacillus thuringiensis,* triadimefon

Lowest overall predator populations occurred at Bael, which received the greatest input of fungicides. End of season population levels of *Brevipalpus* spp. and C. *vitis* were highest at Best's, despite high predator numbers (Fig. 37). Although as pointed out previously, the predator population consisted of *A. loxtoni* only, which is not an efficient regulator of *Brevipalpus* spp. populations (see earlier section). Later results (see following sections) suggest lime sulphur is particularly detrimental to T. *doreenae* and the use of this compound may have eradicated this predator from Best's and reduced its numbers at Bael's.

South Australia (except the Riverland)

Collections from vineyards in this state were scattered and predator populations were not monitored at any site (Table 3). *T. doreenae* was the only phytoseiid collected in this limited sampling of grapevines in the Southern Vales, Barossa Valley and Eden Valley grape growing areas.

The Granite Belt and Lower Hunter Valley

Single collections of dormant wood were made at vineyards in the Granite Belt (Stanthorpe) and the Lower Hunter Valley (Broke) in June 1991. *Amblyseius lentiginosus* Denmark and Schicha was the only phytoseiid in the Stanthorpe sample and *Amblyseius masiaka* Blommers and Chazeau the only phytoseiid in the Broke sample (Accession Nos 7-13 in the Yanco collection). Little is known about either species and grapevine is a new host record for *A. masiaka.* Both species are known to prey on two spotted mite, *T. urticae* (Schicha, 1987).

Grapevine leaves were sampled at Stanthorpe in March 1992 and yielded a number of specimens of *T. dossei,* which was also found in the Canberra region (see previous section) .

King Valley and Corowa

Two collections of dormant wood were made from a number of vineyards in the King Valley district (Whitfield-Myrrhee) in August and October 1991 (Table 4). *T. doreenae, T. dossei, T. occidentalis,and A. helmi* were found in these samples. *T. occidentalis* is a well known predator of *T. urticae* but little is known of *A. helmi. A. helmi* was also found in a single sample from St Leonard's vineyard near Corowa.

Cowra

A single collection of 25 leaves from Cowra wines in April 1992 yielded a 72% infestation of *T. doreenae* and *A. helmi.* No pest mites were seen although *Beyipalpus* spp. had apparently been a problem earlier in the season. Circumstantial evidence suggested the predators had controlled this population. *T. doreenae* and *A. helmi* appeared to be present in equal numbers.

A further collection of leaves from a backyard grapevine in Cowra at the same time showed 100% infestation by *A. victoriensis* with an average 9.6 motiles per leaf. These vines had been unsprayed throughout the season.

TABLE 3 Collection data for phytoseiids from grapevines in South Australia

Yanco Accession No.	Locality	Date	Leaves/Wool	Species
1	Reynella	8/90	Wood	*T. doreenae*
2	Reynella	8/90	Wood	*T. doreenae*
3	Reynella	8/90	Wood	*T. doreenae*
5	Port Noarlunga	8/90	Wood	*T. doreenae*
6	Light Pass (Barossa)	10/90	Leaves	*T. doreenae*
89	Barossa (Kalimna vineyard)	8/91	Wood	*T. doreenae*
90	Barossa (Kalimna vineyard)	8/91	Wood	*T. doreenae*
91	Barossa (Kalimna vineyard)	8/91	Wood	*T. doreenae*
110	Eden Valley (Penfolds Woodbury)	9/91	Wood	*T. doreenae*
111	Eden Valley (Penfolds Woodbury)	9/91	Wood	*T. doreenae*
112	Eden Valley (Penfolds Woodbury)	9/91	Wood	*T. doreenae*

TABLE 4. Collection data for phytoseiids from grapevines in the King Valley /Corowa districts

Yanco Accession No.	Locality	Date	Leaves/Wool	Species
92	Whitfield	8/91	Wood	*T. dossei*
93	Whitfield	8/91	Wood	*T. dossei*
94	Whitfield	8/91	Wood	*T. dossei*
95	Whitfield	8/91	Wood	*T. dossei*
96	Whitfield	8/91	Wood	*T. dossei*
97	Whitfield	8/91	Wood	*A. helmi*
102	Whitfield	10/91	Wood	*T. doreenae*
103	Whitfield	10/91	Wood	*T. doreenae*
104	Whitfield	10/91	Wood	*T. doreenae*
105	Whitfield	10/91	Wood	*T. doreenae*
106	Whitfield	10/91	Wood	*T. doreenae*
107	Whitfield	10/91	Wood	*T. occidentalis*
108	Whitfield	10/91	Wood	*T. occidentalis*
109	Whitfield	10/91	Wood	*T. occidentalis*
113	St Leonards (Corowa)	11/91	Leaves	*A. helmi*

Additional records from the MIA

A number of samples were taken from MIA grapevines (domestic and commercial) not included in the main population study (Table 5).

The most noteworthy aspect of these data is the occurrence of *T. doreenae* in two MIA vineyards, at Toorak winery, Leeton and at Yenda near Griffith. *T. doreenae* was not detected in the more comprehensive sampling of MIA vineyards reported earlier. The two vineyards in which *T. doreenae* was detected have relatively low chemical inputs.

This discovery provides a significant boost to proposals, which aim either to introduce *T. doreenae* into MIA vineyards, or aim to encourage recolonisation of vineyards by native populations. It is quite likely that the current widespread absence of *T. doreenae* from MIA vineyards is the result of intensive pesticide use in the past.

The salient feature to arise from this relatively brief examination of grapevine phytoseiid fauna from diverse viticultural regions, is the incidence of *T. doreenae.* From the results presented earlier, it is clear that *T. doreenae* has the most important role to play in biological control of grapevine mites. It is the only predator found so far that is capable of relating populations of *Brevipalpus* spp.. *T. doreenae* was first discovered and described by E. Schicha (NSW Agriculture) from an apple tree In a suburban Adelaide backyard (Schicha, 1987). Its discovery on grapevines in the Riverland (this report) and subsequently the search in other areas has greatly extended our knowledge of this predator's distribution. *T. doreenae* is now known to occur in the Riverland, Barossa Valley and Southern Vales of South Australia, Swan Hill and the King Valley in Victoria, and Murrumbateman, Cowra, Leeton and Griffith in New South Wales. In addition, it has recently been recorded from a vineyard at Mudgee, NSW (Stephen Guilbaud-Oulton, Orlando-Wyndham, pers. comm.). The extensive distribution of *T. doreenae* in south-eastern Australia enables considerable optimism to be held for the widespread commercial use of this predator in viticultural mite management.

TABLE 5. Collection data for phytoseiids from MIA grapevines not used in the main population study.

Yanco Accession No.	Locality	Date	Leaves/Wood	Species
52	Leeton (backyard)	5/91	leaves	*Amblyseius thwaitei*
99	Yenda, Griffith	8/91	wood	*T. doreenae*
100	Yenda, Griffith	8/91	wood	*T. doreenae*
101	Yenda, Griffith	8/91	wood	*T. doreenae*
127	Toorak, Leeton	5/91	leaves	*T. doreenae*
128	Toorak, Leeton	5/91	leaves	*T. doreenae*
129	Toorak, Leeton	5/91	leaves	*T. doreenae*
130	Toorak, Leeton	5/91	leaves	*T. doreenae*
131	Toorak, Leeton	5/91	leaves	*T. doreenae*
132	Toorak, Leeton	5/91	leaves	*T. doreenae*
133	Toorak, Leeton	5/91	leaves	*T. doreenae*
134	Toorak, Leeton	5/91	leaves	*A. loxtoni*
135	Yenda, Griffith	5/91	leaves	*A. loxtoni*
136	Yenda, Griffith	5/91	leaves	*T. doreenae*
137	Yenda, Griffith	5/91	leaves	*T. doreenae*
139	Leeton (backyard)	5/91	leaves	*A. loxtoni*
140	Leeton (backyard)	5/91	leaves	*A. loxtoni*
141	Leeton (backyard)	5/91	leaves	*A. loxtoni*
142	Leeton (backyard)	5/91	leaves	*Amblyseius transvaalensis*
144	Stony Point, Leeton	5/91	leaves	*A. dieteri*
147	Yenda, Griffith	5/91	leaves	*T doreenae*
149	Yanco	1/91	leaves	*A loxtoni*
150	Yanco	1/91	leaves	*A loxtoni*

Effect of temperate on development and survival of *Amblyseis victoriensis* (Womersley).

Introduction

Amblyseius victoriensis (Womersley) is an Australian phytoseiid important in a number of integrated and biological mite control programs in perennial horticulture. It provides biological control of two spotted spider mite *Tetranychus urticae Koch,* in southern New South Wales peach orchards (James, 1990), the rust mites, *Tego1ophus australis Keifer* and *Phyllocoptruta oleivora* (Ashmead), in Queensland citrus (Smith and Papacek, 1991) and grapeleaf blister mite, *Colomerus vitis* Pagenstecher, on grapevines in Southern Australia (James and Whitney, 1990).

In order to improve the efficacy and utilisation of this predator in horticultural ecosystems studies have been conducted on aspects of *A. victoriensis* biology, ecology (James, 1989a, 1989b) and pesticide susceptibility (James, 1989c). This study presents data on the effect of temperature on rate of development and survival of *A. victoriensis.* Estimates of developmental thresholds and degree day requirements for development are derived from these data.

Materials and Methods

Eggs were obtained from *A. victoriensis* adults collected from ornamental bushes in the grounds of the Yanco Agricultural Institute and held in the laboratory on arenas (plastic tiles 7 x 7 cm) laid on saturated plastic foam in plastic containers. Eggs were laid on strands of cotton wool, removed at 0800 and 1600h each day and placed singly on arenas (2 x 2 cm) excised from citrus leaves. Leaf arenas were placed lower side up on absorbent cotton wool in a plastic dish. Rate of development and survival of eggs, At larvae and nymphs, were studied under constant temperature regimes of 20.0, 22.5, 25.0, 1-27.5**,** 30.0, 32.5, 35.0, 37.5, 40.0, 42.5 and 45.0°C, all with a variance of t 0.5°C. Environmental chambers were maintained at 15L/9D photoperiod and ambient relative humidity of 40 -60%. Data were collected twice daily (0800 and 1600h) on egg hatch, development and mortality. A small amount of cumbungi *(Typha orientalis* Presl.) pollen and a piece of broken glass cover slip were provided on each arena for food and shelter. The number of hours required for development of eggs and immature stages were determined for each temperature. The time of hatch or moult was recorded as the midpoint between two observations. Cohorts of 40 -70 eggs were used for each temperature. Experiments at each temperature were unreplicated and were conducted singly or two at a time over a period of 12 months.

To the reciprocal y (the time spent in hours in each stage), the regression $Y_i = b_i t + a_i$ was fitted, where t is temperature (°C). The developmental zero (DZ) for each stage was found by extrapolating the regression line and noting where it cut the temperature axis (ie, DZ = ai/bi). The degree days (DD) above the DZ required to complete a stage of development was estimated by the reciprocal of the slope (bJ of the fitted regression line (i.e., DD = 1/24 b_i. Formulae for calculating the errors associated with the parameters DZ and DD are given by Campbell *et al(1974).*

Results

A. *victoriensis* developed successfully from egg to adult over a temperature range of 20 -40°C (Table 6). No development occurred at 42.5 or 45°C except for a single egg at 45°C. There was no difference in development rate of males and females at any temperature (P>0.05) and data were pooled. The ratio of males and females averaged 1:1 over the experiments.

The relationship between temperature and rate of egg development was approximately linear within the range 20 -30°C. Eggs developed at a similar rate between 30 -40°C.
A linear regression yielded a coefficient of determination of 0.71. An estimate of 15.0°C was obtained for the DZ and 23.4 degree days was estimated to be the thermal requirement for development (Table 7).

The rate of larval/nymphal development was approximately linear between 20-35°C with an estimated DZ of 9.3°C and thermal requirement of 60.3 degree days. Egg to adult development was linear over the same range with a DZ of 10.3°C and thermal requirement of 93.1 degree days. 35°C was considered to represent the upper developmental threshold based on the lower rate of development recorded at 37.5 and 40°C (Table 7).

Survival of developing A. *victoriensis* from egg to adult was 89% or greater at all temperatures except 35 and 40°C (Table 8).

Discussion

The relationship between temperature and rate of development in insects and mites is usually calculated as linear, but it is actually curvilinear (Sharpe and DeMichele, 1979).
Algorithms have been developed using a variety of non-linear functions that describe the temperature/growth rate relationship (Wagner *et a1.* 1984), but for most species the linear approximation is acceptable. In this study, the temperatures considered are in the linear region and a simple linear model is used.

The rate of egg to adult development in phytoseiids generally increases in a linear fashion between 15 and 30°C (Sabelis, 1985). For example, *Galendromus helveolus* (Chant) took 12.4 days to complete development at 18°C reducing to 4.6 days at 30°C (Caceres and Childers, 1991). Similarly, *Euseius mesembrinus* (Dean) took 11.5 and 4.4 days at the same temperatures (Abou-Setta and Childers, 1987). In both species, 30°C was the developmental maximum with growth rates declining at higher temperatures. A developmental maximum of 32°C was recorded for *Euseius stipulatus* (Athias-Henriot), *Typh1odromus phialatus* Athias-Henriot (Ferragut *et a1.* 1987), *Typhlodromus occidenta1is* (Nesbitt) and *Phytoseiu1us persimi1is* Athias Henriot (Sabelis, 1985). The rate of development in A. *victoriensis* increased linearly between 20 -35°C. The developmental maximum (35°C) appears to be the highest recorded for a phytoseiid with an average 3.9 days required for egg-adult development at this temperature. Some individuals completed development in less than 3 days. Development at 37.5 and 40 C was still rapid (4.1 -4.5 days) with 57% of individuals surviving at 40°C. Survival was greater

than 82% at all other temperatures.

A.victoriensis is common on native and introduced vegetation throughout inland south- eastern Australia, west of the Great Dividing Range. Summer mean maximum temperatures in this region are generally >30°C and maxima frequently exceed 35°C. Successful development at high temperatures is clearly an important factor in exploitation of this inland environment by *A. victoriensis.* It is also an important factor contributing to the success of *A. victoriensis* as a biological control agent of *Tetranychus urticae* Koch in inland stone fruit orchards (James, 1990). Development of T. *urticae* also peaks at around 35°C (Mori, 1961; Sabelis, 1985) and the differential, which exists between the developmental maximum of most phytoseiids, and T. *urticae* can have an important negative influence on effectiveness of predation (Helle and Sabelis, 1985).

Using 30 year temperature means for Yanco in southern New South Wales from September 1 -April 30 (the approximate period of reproduction of *A. victoriensis* (James, 1989a, 1990) and the developmental threshold and degree day values obtained in this study, 20 generation of *A. victoriensis,* could occur during this period. In summer (December -February) 4 -5 generations could occur monthly. There is clearly considerable potential for population increase of *A. victoriensis* during the warmer months. This notion is supported by the large populations frequently recorded in late summer/autumn from stone fruit orchards (James, 1990) and vineyards in south-eastern Australia.

A. victoriensis over winters in southern New South Wales as non-reproductive but active feeding females (James, 1989a). Mean maximum winter (June/July) temperatures in this region are 13 - 14°C, just below the estimated DZ for eggs of *A. victoriensis.* Oviposition of *A. victoriensis* generally ceases during May (James, 1990) when mean daily maximum temperatures are about 18°C recommencing in September when temperatures reach the same level, indicating a higher temperature threshold for oviposition than egg development.

TABLE 6. Development time (days) for egg and immature stages of *A. victoriensis* at selected temperatures

Temp °C	Egg stage(n)[a]	Larvae/ Nymphs (n)[b]	Egg to adult	% develop-ment/d
20.0	5.6 (46)	8.1 (22)	13.7	7.3
22.5	2.9 (37)	4.3 (24)	7.2	13.9
25.0	2.4 (47)	3.5 (33)	5.9	16.9
27.5	1.9 (52)	3.6 (24)	5.5	18.2
30.0	1.7 (42)	2.9 (25)	4.6	21.7
32.5	1.6 (35)	2.6 (27)	4.2	23.8
35.0	1.6 (50)	2.3 (29)	3.9	25.6
37.5	1.5 (29)	2.6 (26)	4.1	24.4
40.0	1.6 (54)	2.9 (24)	4.5	22.2
42.5	- (0)	-	-	-
45.0	4.0 (1)	-	-	-

[a]n, number of eggs that hatched
[b]n, number of nymphs that reached the adult stage

TABLE 7. Regression[a] of developmental rate on temperature and estimated developmental zeros (OZ) and degree days (DO) for stages of *A. victoriensis*

Stage	Slope	Intercept	r^2	DZ°C x±SE[b]	DD x±SE[b]
Egg	0.00178	-0.02677	0.71	15.0(0.4)[b]	23.4(2.3)[b]
Larvae and nymphs	0.00069	-0.00644	0.65	9.3(1.0)[b]	60.3(8.1)[b]
Egg to adult	0.00044	-0.00461	0.75	10.3(0.7)[b]	93.1(9.6)[b]

a Regression equations significant at the 1 % level.

b Standard errors calculated according to Campbell *et* a1 (1974).

TABLE 8. Survivorship of developing A. *victoriensis* under constant temperature regimes

Temp. °c	% Survival	
	Egg	Egg to Adult
20.0	98	92
22.5	100	96
25.0	100	97
27.5	98	89
30.0	100	100
32.5	100	93
35.0	100	83
37.5	97	90
40.0	93	57
42.5	0	0
45.0	0	0

Effect of population density on rate of oviposition in *Amblyseius victoriensis* , (Womersley) and *Typhlodromus doreenae* Schicha

Intraspecific relationships of phytoseiid mites have received far less study than phytoseiid-prey interactions. However, they may be important in understanding the dynamics of acarine biological control systems or in the development of mass rearing techniques.

The effect of population density on the oviposition rate of phytoseiids has been studied in *Typhlodromus longipilus* Nesbitt (Kuchlein, 1966), *Phytoseiulus persimilis* Athias- Henriot (Fernando and Hassell, 1980) and *Amblyseius linlandicus* Oudeman (Schausberger, 1992). In all three species oviposition rate decreased with increased predator population density. *T. longipilus* and *P. persimilis* were fed mite prey and influences of varying prey density and predator-prey interactions on oviposition rate could not be discounted. Such influences did not impinge on the investigations with *A. finlandicus, which* was fed pollen. Here we report the effect of population density on oviposition rate in two phytoseiids, *Amblyseius victoriensis* (Womersley) and *Typhlodromus doreenae* Schicha, important in Australian horticulture (James, 1990, James and Whitney, 1990, Smith and Papacek, 1991).

victoriensis and *T. doreenae* were reared in the laboratory on plastic tile arenas using pollen of *Typha orientalis* Presl. as a food source (James and Whitney, 1992). Cultures were initiated using individuals collected from grapevines and experiments were conducted on 2 x 2cm leaf arenas excised from citrus leaves. Leaf arenas were placed on saturated cotton wool in plastic containers. Female predators were selected from young, vigorous cultures and placed on leaf arenas at densities of either one or 10 per arena. Leaf arenas and phytoseiid cultures were held at 25 t 0.5°C, 60-70% RH, L:D, 15.0:9.0 and pollen of *T. orientalis* was supplied as a food source. Leaf arenas were examined daily for egg production for 10-14 days. If predators on the high population density arenas became trapped in the wet cotton wool, they were replaced. The usual loss of one or two predators each day resulted in adjusted population densities of 7.7/4cm2 arena *(A. victoriensis)* and 9.0/4cm2 arena *(T. doreenae)* during the period of study.

The effect of predator population density on oviposition rate of *A. victoriensis* and *T. doreenae* is shown in Table 9. Oviposition rate in both species was significantly greater on arenas containing a single predator than on arenas with 10 predators. Egg production in *T. doreenae* held singly was double that obtained for groups of 10. With *A.victoriensis* the difference between the two population densities was 3.4 x.

Schausberger (1992) showed that the oviposition rate of singly held *A. linlandicus* was 1.7 x greater than that obtained for groups of eight predators. Kuchlein (1966) demonstrated an almost three-fold increase in oviposition rate of *T. longipilus* when held singly compared to groups of 10. The results presented here for *A. victoriensis* and *T. doreenae* are very similar to those obtained for *A. linlandicus* and *T. longipilus* and suggest that reduced oviposition rates with increased predator density may be common in the Phytoseiidae.

The use of prey, a limited resource which requires active location and overpowering, in the experiments of Kuchlein (1966) and Fernando and Hassell (1980), may have contributed to lower oviposition rates in high density predator groups. Mutual disturbance of predators in locating and overpowering prey could reduce prey consumption and egg production. In contrast, pollen on leaf arenas can be considered an unlimited food resource requiring little effort to locate and utilise. Mutual

disturbance of predators in this case is unlikely to limit consumption and egg production. However, frequent disturbance of predators by co specifics may reduce oviposition simply by interfering with oviposition behaviour. Little is known of the oviposition behaviour of phytoseiids. It is possible that successful completion of a behavioural sequence may have to occur prior to the act of oviposition itself. Interruption of this sequence may require a restart.

Oviposition by *A. victoriensis* and *T. doreenae* on leaf arenas appeared to be random with no preference for any site e.g., along veins. Consequently, it is unlikely that reduced oviposition on high population density arenas was due to a shortage in oviposition sites. Schausberger (1992) suggested that reduced oviposition amongst high density populations may be a kind of "biological self-control".

Schausberger (1992) also suggested that faster moving phytoseiids with greater potential for mutual disturbance, may exhibit the high population density -low oviposition rate phenomenon, to a greater degree than slower moving species. The results in this study tend to support this idea with *A. victoriensis,* a fast moving species (James, 1989), showing a greater reduction in oviposition than *T. doreenae,* a slower moving species. This relationship, if widespread, would also support the disturbance of oviposition behaviour theory expounded above.

The occurrence of high population density -low oviposition rate in phytoseiids may have important implications for the mass production of some species, particularly those reared on artificial substrates. Optimal arena production of predators over a fixed time frame may require an optimum number of seeding predators. Elucidation of the factors involved in population density effects on oviposition rate will improve our knowledge of phytoseiid intraspecific relationships and may have practical benefit.

TABLE 9. The effect of population density on oviposition rate in *A. victoriensis* and *T. doreenae*

Predator density ($4cm^2$)	n	Rate of oviposition (eggs/day/female)		
		Minimum	Maximum	Mean (± SE)
A. victoriensis				
1	10	1.50	2.90	*2.10 (0.5)
7.7	12	0.42	1.02	0.62 (0.2)
T. doreenae				
1	11	1.20	1.50	*1.40 (0.1)
9.0	11	0.25	0.87	0.70 (0.2)

* Significantly greater than corresponding value for high density population ($P<0.05$, t test).

PREDATOR REARING

Cumbungi pollen: A laboratory diet for *Amblyseius victoriensis* (Womersley) and *Typhlodromus doreenae* Schicha

Amblyseius victoriensis (Womersley) and *Typhlodromus doreenae* Schicha are native phytoseiid mites important in integrated and biological mite control programs in perennial horticulture. *A. victoriensis* controls two spotted mite, *Tetranychus urticae* Koch, in southern New South Wales peach orchards (James, 1990), the rust mites *Tegolophus australis* Keifer and *Phyllocoptruta oleivora* (Ashmead) in Queensland citrus (Smith and Papacek, 1991) and grapeleaf blister mite, *Colomerus vitis* Pagenstecher on grapevines in southern Australia (James and Whitney, 1990). T. *doreenae* is an effective sulphur-tolerant predator of bunch mite, *Brevipalpus* spp. on grapevines in South Australia (James and Whitney, 1990). It has also been reported as a predator of Bryobia mite, *Bryobia rubrioculus* (Scheuten), in South Australia almond orchards (J Altmann pers. corom). Their usefulness would be enhanced through augmentative or inundative releases if a suitable mass rearing technique could be developed.

The inability of *A. victoriensis* to develop or reproduce when fed *T. urticae* (James, 1989) precluded use of the bean plant-To *urticae* mass rearing system used for *Typhlodromus occidentalis* Nesbitt and *Phytoseiulus persimilis* Athias Henriot (Koppert, 1980; Hoy *et al.,* 1982). The apparent favour ability of pollen as a food source for both *A. victoriensis* (James, 1989) and *T. doreenae* (James unpublished data) prompted the investigation of various pollens as a laboratory diet.

The standard rearing unit for phytoseiids fed pollen was developed by McMurtry and Scriven (1965). This unit, generally referred to as an arena, consists of a cardboard, plastic or metal platform laid on plastic foam saturated with water. The foam is placed in a suitable container filled with water. Minor modifications to this system were made by Overmeer *et al.* (1982) and Ball (1980).

Arenas for rearing *A. victoriensis* and *T. doreenae,* based on units developed by McMurtry and Scriven (1965), were 18 x 14 cm tiles of plastic placed on plastic foam in 20 x 26 cm plastic Decor<8 containers. Small pieces of sparsely stranded cotton wool were overlaid with cover slips to provide shelter and egg laying sites. Pollen was placed in upturned plastic specimen tube lids cut in half and 2-3 were provided per arena. Pollen from native trees *(Eucalyptus* spp. (2), *Casuarina cunninghamiae, Melaleuca hypericifolia)* , ornamentals *(Lagerstoemia indica, Rosa* sp., *Viburnum tin us)* , horticultural crops *(Citrus limon, Lycopersicon esculentum)* and a native water plant *(Typha orientalis)* was tested as a diet for the predators. Pollen of *T. orientalis* was collected during November, which is the major flowering period of this plant in southern New South Wales. Flower spikes were removed, placed in paper bags and shaken to dislodge pollen. Considerable quantities of pollen can be collected in this way. Pollen was stored in a freezer for up to 12 months without losing its viability as a phytoseiid food source.

Arenas were held in a constant temperature room at 25°C and 60-70% RH. Reduction

of RH below 50% caused declines in phytoseiid populations by decreasing egg viability. RH above 70% promoted development of mould on the pollen. Arenas were maintained for 1-2 months before populations were sub-cultured on new arenas by transferring mite infested cotton wool and cover slips. Estimated populations of 250-300 mites per arena were achieved.

Only pollen from *T. orienta1is* (cwnbungi) supported continuous laboratory cultures of both *A. victoriensis* and *T. doreenae* for 12-18 months. With all other pollens development and reproduction were initially successful as reported for *A. victoriensis* by James (1989), however, culture populations declined rapidly after the second generation. Reasons for this appeared to be reduced oviposition and sterility of the eggs, which were laid.

Pollen of the North American bulrush, *Typha latifolia,* produced a high reproductive response in *Amblyseius hibisci* (Chant) in the laboratory and citrus groves treated with this pollen showed higher population densities of this predator than untreated groves (Kennett *et a1..* 1979). Large populations of *A. victoriensis* without an obvious food source are common on stone fruit and citrus during summer in the Murrumbidgee Irrigation Area of southern New South Wales (James, 1990). *T. orientalis* is also abundant in the many waterways and channels, which are a feature of this area, and its pollen may be a factor in summer population development of *A. victoriensis.*

Pollen of *T. orientalis* is a simple, effective, storable and easy to collect food source for *A. victoriensis* and *T. doreenae.* An arena-based rearing technique using *T. orientalis* should facilitate laboratory mass rearing of these important biological control agents.

IMPACT OF PESTICIDES ON PREDATORS

Effect of sulphur and copper on survival of *Typhlodromus doreenae*

The major factor preventing natural control of mites in inland viticulture is the use of synthetic pesticides. In particular, the use of broad-spectrum insecticides such as malathion, carbaryl, methidathion, azinphos-ethyl etc, severely affects the natural enemy fauna of grapevines and exacerbates mite problems.

The best example of pesticide induced outbreaks of mite pests in horticulture occurred in stone and pome fruit crops during the 1950's, 1960's and 1970's. Key pests such as codling moth in apples and oriental fruit moth in peaches were controlled by regular applications of broad-spectrum insecticides such as DOT and azinphos-ethyl. As well as killing the target pests, these compounds killed all other insects in orchards including the many beneficial species, which prey on mites. Consequently, outbreaks of mite pests such as two spotted mite became routine and further pesticide applications were required to control them. Mites were very quick to develop tolerances to most orchard pesticides further increasing the problem.

Fortunately the use of broad-spectrum insecticides on inland grapevines in Australia is fairly limited and has probably decreased in many regions in recent years. This relatively low use of broad-spectrum insecticides is probably the major reason inland viticulture does not generally suffer from problems with two spotted mite. This species and related spider mites are major problems in North American and European grape growing areas, reflecting the more intense and widespread use of broad-spectrum insecticides.

The level of pesticide usage that we do have in Australian vineyards is apparently sufficient in many areas to prevent biological control of mites. In addition to insecticides, some fungicides are also known to be harmful to some natural enemies like predatory mites. However, different predatory mite species do not respond in the same way to particular fungicides. There are often great differences between species in their susceptibility.

Previous sections of this report have indicated large populations of predatory mites and low populations of mite pests occur in some areas when pesticide inputs are small or based on compounds such as copper and sulphur. Areas like the MIA and Sunraysia, which use greater amounts of synthetic fungicides than is the case in the Riverlands, have smaller populations of predatory mites.

The impact of viticultural pesticides targeted at diseases and insect pests, on predatory mite populations, is critical to development of vine mite management strategies based on biological control. "Predator-friendly" compounds need to be identified so they can be used without fear of disrupting biological mite management. Such compounds can then be safely used within the framework of biological mite control.

This section presents data on the effect of wettable sulphur, lime sulphur and copper

hydroxide on the major grapevine mite predator, *Typhlodromus doreenae.*

Material and Methods

Adult *T. doreenae* from laboratory cultures established from Riverland vineyard populations, were used in these bioassays. Predators were transferred with a fine hair brush from cultures to 2 x 2 cm citrus leaf arenas laid on saturated cotton wool. Approximately 10 predators were placed on each leaf arena. Lime sulphur (215 g/L), wettable sulphur (800 g/kg wettable powder: Lansul®) and copper hydroxide (500 g/kg wettable powder: Kocide® were tested against *T. doreenae* using a Potter precision spray tower. For lime sulphur, the field rate (2.15%), half and double this rate were tested. With wettable sulphur, field (0.32%) 100 and 200 x this rate were tested. Copper hydroxide was tested at the field rate (.03%) and 333 x this rate. Spraying pressure was 50 kPa and 2 mL of fungicide solution was sprayed per concentration. Four or five replicates (on different dates) were performed giving a total number of 35-70 predators tested for each concentration. After spraying leaf arenas were placed at 25°C under 15L:9D. Mortality was assessed after 48 hours. Individuals were considered dead if they were unable to make coordinated movement when prodded. A water only treatment was included in each test as a control and mortality data were corrected for control mortality (Abbott, 1925).

Results

Bioassay data are presented in Table 10. Field rates of wettable sulphur and copper hydroxide were not toxic to adult *T. doreenae.* A rate of wettable sulphur 200 x the field rate produced less than 50% mortality. At this rate predators were heavily crusted with sulphur and death probably occurred through suffocation rather than toxic effects. A similar situation occurred with copper hydroxide at 333 x the field rate but few predators died.

The field rate of lime sulphur was very toxic to *T. doreenae* killing 98% of predators tested. The lower rate (1.075%), which is the recommended rate for some states, killed 60% of predators (Table 10).

TABLE 10. Toxicity of lime sulphur, wettable sulphur and copper hydroxide to adult T. *doreenae.*

Fungicides and rates (% a.i) tested	number tested	number dead	% mortality
Lime sulphur			
4.3	34	34	100
2.15*	44	43	98
1.075	35	21	60
Control	53	0	0
Wettable sulphur			
64	63	29	46
32	76	14	18
0.32*	50	0	0
Control	76	1	1
Copper hydroxide			
10			
0.03*	42	2	5
Control	50	0	0
	35	0	0

* Registered field rate

Discussion

The laboratory bioassay data presented here show *T. doreenae* is highly tolerant to wettable sulphur and copper hydroxide. Field rates of these compounds should have no impact on vineyard populations of this predator. This is supported by the field data presented earlier in this report, which showed high *T. doreenae* populations in Riverlands vineyards subjected to sulphur and copper sprays.

In contrast, lime sulphur appears to be very toxic to *T. doreenae* at recommended rates. Applications of this fungicide are recommended in late/winter early spring and will devastate *T. doreenae* populations present on the dormant wood. Vineyards treated with lime sulphur are likely to begin the growing season with very few predators and are unlikely to develop good biological mite control. The current recommendation of applying lime sulphur for mite control may be one of the major reasons for poor natural mite control in areas such as the MIA.

This limited examination of the effect of fungicides on vine mite predators illustrates the importance and value of such studies. Clearly, all viticultural pesticides should be screened for their impact on vineyard predatory mites. Preliminary testing suggests that *T. doreenae* may be tolerant to a wide range of fungicides. Some information has previously been obtained for *Amblyseius victoriensis* (James, 1990) but much more is required. Similarly, information is needed for other phytoseiids identified as being important in grapevine mite control *(Amblyselus loxtom, Typhlodromus dossel, Phytoseius fotheringhamiae).*

INTRODUCTION OF T. *DOREENAE* TO AN MIA VINEYARD

The information presented in this report strongly indicates that *Typhlodromus doreenae* will be the major component in biological control strategies developed for grapevine mites. It is the only predator so far found which effectively controls bunch mite, the most important mite problem in inland vineyards. In fact, there are few if any phytoseiids worldwide, reported as effective predators of *Brevipalpus* spp. Other factors which heighten the importance of T. *doreenae* to viticulture include its ability to persist on vines throughout the year, its generalist feeding behaviour allowing it to persist in the absence of prey mites and its tolerance to sulphur, copper and probably a wide range of other pesticides. T. *doreenae* is a remarkably valuable phytoseiid and may well have application in overseas as well as Australian viticulture/horticulture.

One current problem to effective utilisation of T. *doreenae* in all inland viticulture, is its relatively limited distribution (see earlier sections) T. *doreenae* does not occur in significant numbers in the MIA and Sunraysia, two of the most important grape growing areas of south-eastern Australia. The occurrence of T. *doreenae* in climatically distinct zones such as the Riverlands and the Canberra district, suggests that there should be few constraints to introducing this predator to MIA and Sunraysia vineyards. Both regions have a similar climate to the Riverlands (Sunraysia is only 150 km from the Riverlands).

This section reports the results of a preliminary study investigating the feasibility and practically of introducing T. *doreenae* to MIA vineyards.

Material and Methods

All stages of T. *doreenae* on grapevine leaves collected from the unsprayed Loxton research centre vine block (Riverlands), were released in the unsprayed (Semillon) vine block at the Griffith Horticultural Research and Advisory Station. Four releases were made (February, March, April 1991 and February 1992). Release details are shown in Table 11. The Semillon block contains 399 vines in ten rows. T. *doreenae* -infested leaves were distributed evenly through the block on each or alternate vines. Leaves were stapled to the vines. An estimate of the total number of motile T. *doreenae* released in the vineyard was made by counting predators on a sample of 30-50 leaves.

Predatory mite and pest mite populations in this vineyard were monitored as part of the study reported earlier in this report.

Table 11. Release details for T. doreenae introduced into Semillon vines at the Griffith Horticultural research and Advisory Station during 1991/92

Date	No of leaves	No of motiles/leaf	Estimated total No of motiles released	No of motiles/vines
19 Feb 1991	1407	0.31	436	1.09
18 Mar 1991	690	0.25	173	0.43
19 April 1991	395	0.21	83	0.21
3 Feb 1991	600	0.98	588	1.47
TOTAL	3092	1.75	1280	3.2

Results

T. *doreenae* was first detected in leaf samples collected from the vineyard in January 1992. It was also present in samples taken in February, March and May. In the final sample (May) T. *doreenae* occupied 28% of 50 sampled leaves.

The population levels (motiles/leaf) of *Brevipapus* spp. in 1990/91 *(T. doreenae* absent) and 1991/92 *(T. doreenae* present) are presented in Fig. 40. Population levels of phytoseiids in both seasons are shown in Fig. 41. Substantially lower *Brevipapus* spp. populations and higher numbers of phytoseiids occurred in the second season.

Discussion

The results from this preliminary study are very encouraging. Establishment of T. *doreenae* in the Griffith vineyard has occurred with only an estimated 1280 individuals released. The presence of eggs on introduced leaves would have boosted this total but it is still a fairly small number for successful establishment. A little over 3 predators per vine were released over a lengthy period. The occurrence of T. *doreenae* on sampled leaves in January 1992, prior to the 1992 release, indicates establishment occurred with only an estimated 692 predators released in 1991. Mass rearing of T. *doreenae* should enable far greater numbers to be released in vineyards.

The progress of this introduction will be closely monitored in 1992/93 to gauge the impact of T. *doreenae* on the previously high bunch mite populations in this block. Dispersal of the predator to surrounding vineyards will also be monitored. The data on bunch mite population levels in 1990/91 and 1991/92 (Fig. 40) indicates T. *doreenae* may be having an impact already.

Fig. 40 Bunch mite (*Brevipalpus* spp.) population on unsprayed vines at Griffith Horticultural Research and Advisory Station in 1990/91 (*T. doreensae* absent) and 1991/92 (*T. doreensae* present).

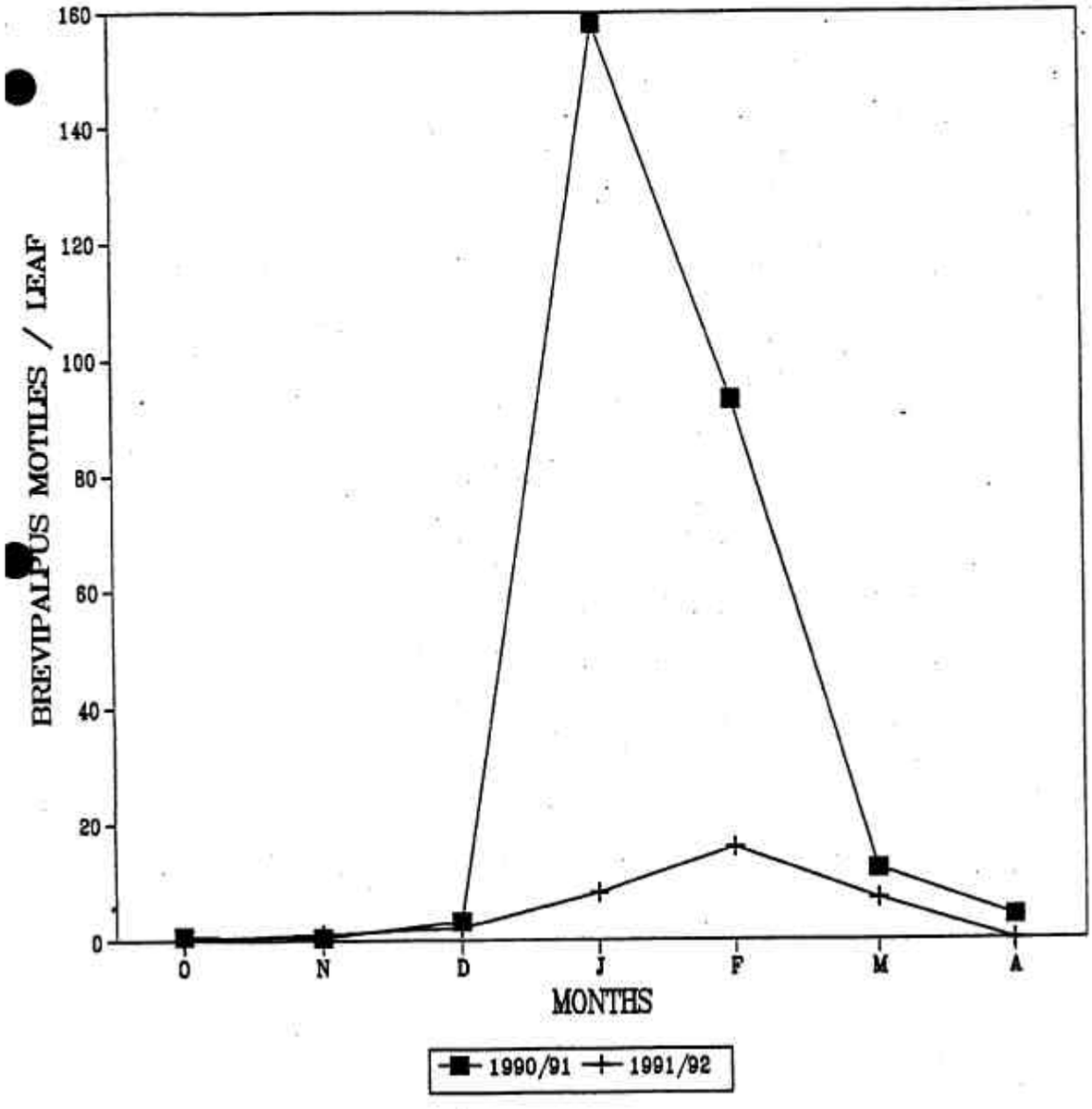
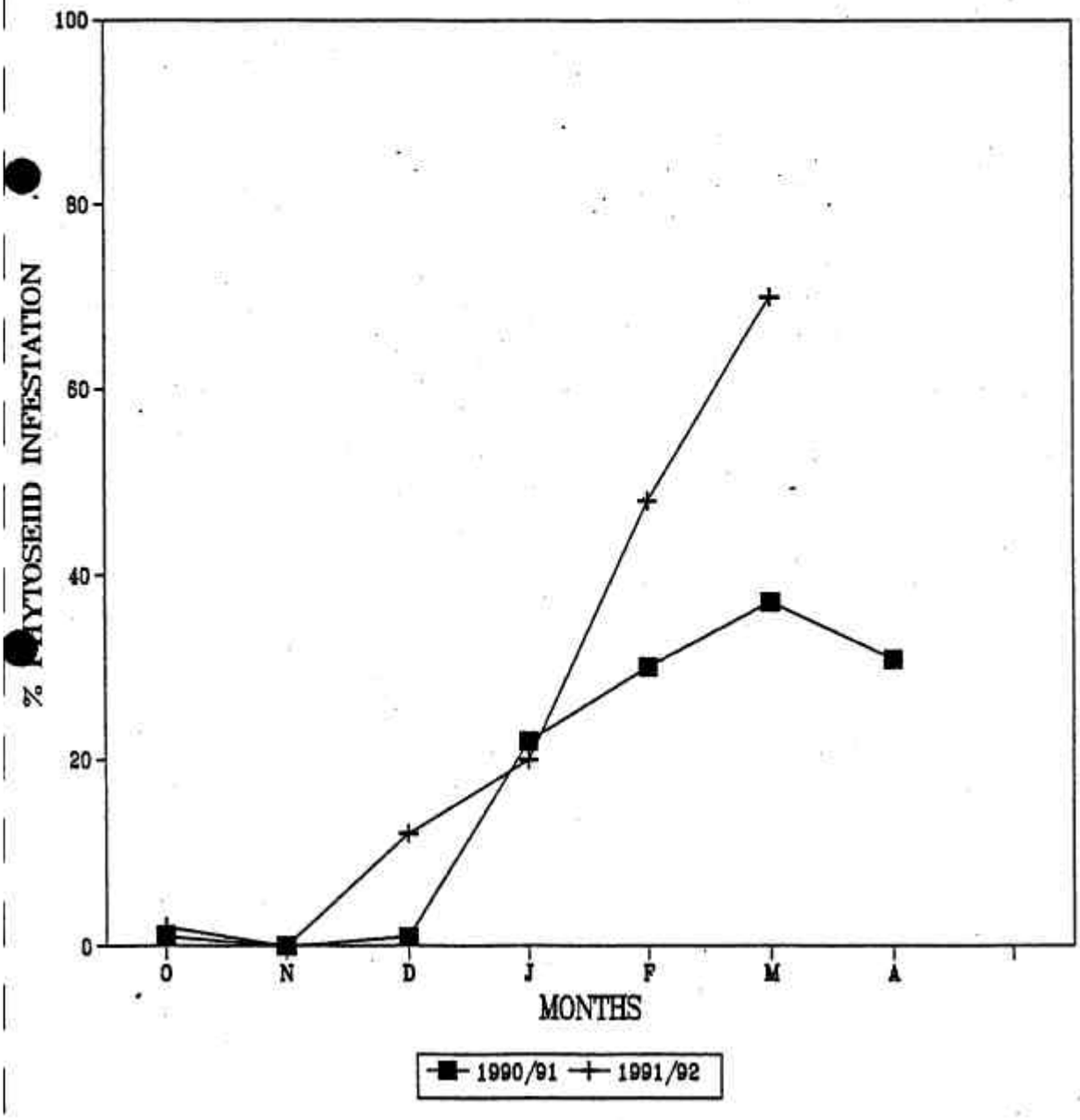


Fig. 41 Phytoseiid populations in the Griffith Horticultural research and Advisory Station unsprayed vineyard in 1990/91 and 1991/92.



GENERAL DISCUSSION:

PROSPECTS FOR BIOLOGICAL CONTROL OF MITFS IN INLAND VITICULTURE

This three year study was initiated to investigate the potential and practicality of using predatory mites as biological control agents for blister, rust and bunch mites on inland grapevines in south-eastern Australia. These objectives have clearly been met. Furthermore, this report provides considerable optimism that the longer term goal of developing sustainable vineyard mite management based on biological control, can be achieved.

Biological control of grapevine mites is already a reality in at least two viticultural areas of south-eastern Australia. Mite populations on grapevines in the Canberra district and in the Riverlands of South Australia are regulated at below economic injury levels by two or three species of predatory mites. In the Riverlands this is despite applications of wettable sulphur for mite control. These applications are clearly a waste of money and effort and neither enhance or diminish the natural control provided by *Typhlodromus doreenae.* In the Canberra district mites are not really considered to be a problem, due most probably, to the action of *T. doreenae, Phytoseius fotheringhamiae* and *Typhlodromus dossei.*

We therefore have two successful working models of grapevine mite biological control occurring in quite different climatic and environmental zones. Biological control in both areas is provided by indigenous predators, which are presumably extremely well adapted to inland Australian environments. They have existed in these habitats for thousands of years and are therefore a product of the environment. This is the safest and most reliable type of biological control agent, least likely to unbalance the ecosystem.

As well as being native, these predators have the benefit of not being restricted to a single food source. *T. doreenae* and *Amblyseius victoriensis,* in particular, are generalist predators able to survive and develop in ecosystems without obvious food sources. Consequently, they are "grower-friendly" predators requiring minimal monitoring once established. It is not necessary to routinely monitor prey and predator population levels, as it is in some other examples of biological mite control (e.g. in pome fruit). Once established in a vineyard they should persist indefinitely as long as harmful chemicals are not used. *T. doreenae* will remain on vines throughout the year, even feeding on over wintering pest mites hidden in buds, under bark and in fissures.

Another major attribute of *T. doreenae,* in particular, is tolerance to wettable sulphur, copper and probably an array of synthetic fungicides. This predator is ideally suited for use in a system, which currently must receive some pesticide input.

Although *A. victoriensis, P. fotheringhamiae* and *Amblyseius loxtoni* all have potential to play important roles in biological grapevine mite management, *T. doreenae* appears to be the species most likely to play the largest role. The establishment and management of this predator in a wide range of viticultural areas, is the key to implementation of biological control of mites in inland viticulture.

Replication of the mite-predatory mite system seen in the Riverlands and in the Canberra district, should result in the complete removal of miticides from inland viticulture in Australia. The apparent success in introducing *T. doreenae* into an MIA vineyard reported here is a very promising sign. The establishment of this predator in the MIA and Sunraysia should not entail too many problems. Laboratory mass production of *T. doreenae* would further improve the chances of success of introducing *T. doreenae* to new areas. It would also be a lot more practical and amenable to commercialisation than distributing infested leaf material from other vineyards. The early stages of a new GWDRC funded project "Biological control of mites in inland viticulture" have seen significant advances made in development of mass rearing procedures for *T. doreenae* and *A. victoriensis* (September, 1992). It is expected that by mid 1993 mass rearing systems for both predators will have been developed.

The only other uncertainty regarding widespread use of *T. doreenae* as the major component of biological vine mite control, is its response to synthetic fungicides and insecticides. To manage this predator effectively in a vineyard it is essential that we know which chemicals can be used without adversely affecting biological control. The safety of pesticides to predatory mites can be rapidly established through laboratory bioassays. The complete range of viticultural pesticides is currently being tested against *T. doreenae* and *A. victoriensis* at Yanco and will provide comprehensive data on pesticide safety to these predators. The way will then be open to widespread and large-scale introductions of *T. doreenae* to most viticultural regions of southern Australia, including WA and Tasmania. The implementation of biological mite management in Australian viticulture will form the basis of a further project.

This research is an excellent example of the practical benefits which can be obtained from study of a natural system, i.e. mite pest and predator population biology on grapevine in inland south-eastern Australia. This system had not previously received any attention from entomologists. The knowledge presented in this report was gained quickly and at little cost, but will revolutionise mite control in Australian vineyards. It is estimated that controlling mites using insecticides currently costs the viticultural industry in Australia $2.8m per annum. Therefore savings to the industry from removing spray costs alone will be considerable. The cost benefits in terms of reduction of environmental contamination and enhancement of product appeal (produced without miticides) are less tangible, but nonetheless still considerable.

It is difficult to see why implementation of biological mite control in most viticultural regions should not succeed. The only question mark may hang over coastal or sub- coastal areas such as the Lower Hunter Valley. It is unknown whether *T. doreenae* can survive in higher humidity coastal areas (although the species was found in coastal vineyards south of Adelaide in this study). It would be unusual for a phytoseiid to be equally well adapted to coastal and inland areas but it is possible. *A. victoriensis* certainly does not occur in coastal NSW but can occur in Coastal Queensland. If *T. doreenae* does not occur in the Hunter Valley and cannot be introduced there, an alternative species may be found to fill this role.

As mentioned previously one of the major advantages of using native biological control agents such as T. *doreenae* and *A. victoriensis,* is their high degree of adaptation to Australian conditions. This ensures relative stability of populations if undisturbed by outside influences such as pesticides. For example, heat waves are unlikely to significantly affect populations of *A. victoriensis* and T. *doreenae,* having been exposed to them for millennia. It would likely be a very different story for phytoseiids introduced into Australia from elsewhere. This stability of T. *doreenae* and *A. victoriensis* populations is further enhanced by their generalist feeding behaviour. Populations do not "crash" or die out If a particular food source is depleted, as is the case with many introduced phytoseiids (e.g. *Phytoseiulus persimilis, Typhlodromus occidentalis).* Therefore, we have the potential to maintain and manage relatively high level predator populations continuously in the vineyard ecosystem. There are things we can do to further improve this stability, particularly in the provision of extra habitat and food resources. *A. victoriensis* can suffer a large winter decline in population levels simply because of limited refugia. This species requires evergreen hosts and a food supply to over winter and in a deciduous crop ecosystem such as a vineyard has to find an alternative habitat. In the MIA, Sunraysia and the Riverlands this is usually surrounding citrus orchards. However, dispersal from this habitat back into vineyards during spring, can be slow, particularly when the distance between citrus and vines is more than a few metres. One way of maintaining large predator populations within vineyards during winter and hastening transfer back to the vine, is to provide over wintering habitats. Recent research has demonstrated that some types of trees and bushes are more attractive to phytoseiids than others. Leaves, which bear domatia (pits, pouches, or hair tufts) are more likely to be occupied by phytoseiids than smooth leaves (James, 1989; Walter and O'Dowd, 1992). Even during this study the value of domatia- bearing bushes/trees as over wintering phytoseiid refugia was noted. In 1991 some vineyards in the Swan Hill district supported dense over wintering populations of *A. victoriensis* on ornamental *Viburnum tinus* bushes, usually grown near farmhouses. It is likely that cultivation of a few domatia-bearing bushes like *V. tinus* adjacent to the vineyard, would significantly enhance establishment and development of spring populations of *A. victoriensis.* The use of domatia-bearing vegetation as an aid to biological mite control in horticulture needs researching, but could become a significant feature of sustainable horticulture in the future.

Another factor, which might enhance early season population development of phytoseiids in vineyards, is the provision of additional food resources. This could be achieved by scattering pollen on early vine growth. The ease with which pollen of cumbungi (see earlier section) can be collected and stored makes this a possibility, which should be examined.

In conclusion, this research provides the basis for widespread, implementation of biological mite management in inland viticulture. There is little reason to doubt that miticides can be entirely removed from inland viticulture.

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