NSW Agriculture

# BIOLOGICAL CONTROL OF MITES IN AUSTRALIAN VITICULTURE: IMPLEMENTATION AND SUSTAINABILITY

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# Final Report

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## SUMMARY

This report represents the culmination of research conducted since 1989. Although most of the information presented here was collected during 1993-96, it should be considered in context and in association with earlier reports.

During studies of mite populations on grapevines in Australia from 1989-96, 31 species of predatory mite from the family Phytoseiidae, including three undescribed species, were recorded. The most dominant and widespread species were *Typhlodromus doreenae* Schicha and *Typhlodromus dossei* Schicha which occurred in 17 and 14 viticultural regions, respectively. A further four species (*Amblyseius lentiginosus* Denmark and Schicha, *Amblyseius helmi*, Schicha and *Typhlodromus transvaalensis* (Nesbitt) were each recorded in six to nine regions and *Amblyseius victoriensis* (Womersley), *Amblyseius loxtoni* Schicha, *Amblyseius dieteri* Schicha and *Typhlodromus occidentalis* Nesbitt were each recorded in three to four regions.

Data on population dynamics of grapevine mites and predatory mites were collected from eight major viticultural regions (Upper Hunter, Mudgee, Cowra, Southern and Central Victoria, Tasmania, South Australia, Western Australia, Queensland Granite Belt) during 1993-96.

Upper Hunter: Biological control of grapevines mites in the Upper Hunter Valley appears to be ineffective. Spray pressure is too high preventing the establishment of a stable predatory mite fauna. The occurrence of small numbers of the important predator, *Typhlodromus doreenae*, in some blocks suggests that with relaxation of spray pressure this species could become dominant and provide better biological control.

Mudgee: Predatory mites appear to be relatively common in this district, particularly when pesticide use is minimised. Biological control of grapevine mites is achievable in the Mudgee district but some rationalisation of fungicide use (particularly number of sprays per season) is necessary to minimise adverse impacts on the dominant predator species, *T. doreenae*.

Southern and Central Victoria: Vineyards in the Great Western and Geelong Regions are generally characterised by a good predatory mite fauna, dominated by *Typhlodromus dossei*. Relatively low pesticide inputs based on generally predator friendly materials, encourage good predator populations and biological control. In contrast, vineyards in the Yarra Valley are home to few predatory mites and biological control of grapevine mites is virtually non-existent. This is directly attributable to the high use of broad spectrum insecticides which are also responsible for precipitating outbreaks of two-spotted spider mite.

Tasmania: Small populations of pest and predatory mites appear characteristic of Tasmanian vineyards. *T. dossei* is the dominant predator.

South Australia: Predatory mites, principally *T. doreenae*, are abundant in Barossa and

Clare Valley vineyards and provide good biological control. In some seasons predator establishment may be slow. *T. doreenae* is less common in the cooler McClaren Vale region being replaced by *T. dossei*. Biological control is achievable in this region. Pest and predatory mites are virtually absent in Coonawarra due to widespread use of insecticides. Biological control provided by *T. dossei* and *T. doreenae* would likely occur in the absence of disruptive sprays.

Western Australia: *T. doreenae* is resident in Perth district vineyards but numbers are generally too small to provide effective biological control. Biological control of grapevine mites in the Margaret River, Manjimup and Mount Barker districts is achievable if fungicide use is minimised and based on predator-friendly materials. *T. dossei* is the principal predator.

Granite Belt (Queensland): A rich predatory mite fauna exists in this region, but is comprised of a large number of species, indicating some instability to the ecosystem, probably due to insecticide use in adjacent crops. Good biological control occurs when fungicide inputs are minimised.

"Snapshot" sampling indicated poor biological control of mites in NSW coastal vineyards (Port Macquarie, Nowra) and good biological control in NSW Central Tableland vineyards (Ilford, Rylstone). Very few predatory mites were found in isolated hot region vineyards at Wee Waa (NSW) and Alice Springs.

*T. doreenae* was mass reared and released into six vineyards in the Murrumbidgee Irrigation Area. Rapid establishment of the predator occurred at four sites. Large populations of *T. doreenae* were present in the vineyards by the second season, contributing to control of grapevine mites.

The effect of residues of the fungicide benomyl on egg production in *A. victoriensis* and *T. doreenae* was examined in the laboratory. Egg production by *A. victoriensis* was significantly lower (0.05-0.03 eggs/♀/day on benomyl-treated leaf discs than on untreated discs (1.0-1.97 eggs/♀/day). Egg production by *T. doreenae* was not significantly different on benomyl-treated or untreated discs in most tests (0.66-0.86 eggs/♀/day). Benomyl is not recommended for use in grapes when *A. victoriensis* is used to control mites, but might be used when *T. doreenae* is the principal predator.

The new insecticide tebufenozide used at the recommended field rate, did not cause mortality to *A. victoriensis* and *T. doreenae* when tested in laboratory bioassays. Exposure of the predators to 10 times the recommended field rate also did not produce significant mortality. Tebufenozide, an insect growth regulator, did not interfere with egg-adult development or reduce fecundity of *A. victoriensis* and *T. doreenae*.

Eight fungicides and one insecticide were bioassayed against *T. dossei* in the laboratory. No mortality was caused by field or 10 times field rates of dithianon, propiconazole, wettable sulphur, systhane, fluquinconazole and a new Bayer fungicide (KBR 2738). The insecticide imadacloprid, was also harmless. Mancozeb produced minimal mortality

(<5%) at both rates while Zineb was harmless at the field rate but caused 20% mortality at the higher rate.

A number of research institutions in the Netherlands and United Kingdom were visited in July 1995 and discussions held with appropriate staff concerning mass rearing of phytoseiid mites and other biological control agents. Fundamental and detailed information on a number of rearing systems, some of which have been exploited commercially, was obtained and should provide the basis for research on developing a similar system for the Australian phytoseiids, *T. doreenae* and *A. victoriensis*. Of particular importance was information gained on a 'volume' rearing system based on bran and flour mites. This system is considered to be the most appropriate for cost-effective commercialisation. Development of a volume culturing system for *T. doreenae*, in particular, should enhance the prospects of commercialisation of this important predator.

A video, "Wine, women and vineyard mite control" was produced by NSW Agriculture in 1994. This explains the fundamentals of biological control of grapevine mites and ways of achieving it.

Biological control of grapevine mites (bunch mite, blister mite, rust mite) is now considered to be achievable in commercial vineyards in most of Australia's viticultural regions. Most successful and easily achievable biocontrol occurs in inland South Australia (Riverland, Barossa, Clare) and inland New South Wales (Canberra, Mudgee, Central Tablelands). In these regions, *T. doreenae*, the most important grapevine mite predator, is endemic and occurs in large numbers. Current spray practices in these areas focus on minimal use of predator-friendly pesticides, and encourages development of *T. doreenae* populations and biocontrol. A similar level of biocontrol should also be achievable in the Murrumbidgee Irrigation Area in those vineyards colonised by *T. doreenae*. Viticultural regions in which *T. dossei* is the major predator (Tasmania, Southern and Central Victoria, Western Australia), may have greater problems in achieving biological control due to poorer predatory capabilities of *T. dossei* and cooler, moister climates necessitating greater spray use. However, introduction of *T. doreenae* to these regions should improve this situation.

Commercial availability of *T. doreenae* is highly desirable and perhaps critical to adoption of biological control by the entire Australian viticultural industry. Consequently, future research should be targeted at developing an effective and commercially acceptable mass production technique for this predator.

## BACKGROUND

In 1992 a three year research program funded by GWRDC (DAN4GW) established 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 (James, D.G., Biological control of grapevine mites - Final report GWRDC 1992). In this report, considerable optimism was expressed that the longer term goal of developing sustainable vineyard mite management based on biological control, could 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*.

In 1993 a two year study on pest and predatory mite populations in five commercial vineyards in the Canberra region was completed (DAN92/3). Vineyard mite populations were characterised by low populations of pests and high populations of predators. *Typhlodromus doreenae* was the dominant mite species with *Phytoseius fotheringhamiae* and *Typhlodromus dossei* also common in some vineyards. Biological control is considered to be the major regulation mechanism for pest mites on grapevines in the Canberra district.

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 victorensis*, 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 overwintering pest mites hidden in buds, under bark and in fissures (James, et al; 1992).

Another major attribute of *T. doreenae*, in particular, is tolerance to wettable sulphur, copper and an array of synthetic fungicides. This predator is ideally suited for use in a system which currently must receive some pesticide input. In DAN 92/3, twenty fungicides, eight insecticides and two miticide were tested for direct and residual toxicity to adult female *T.*

*doreenae* and *A. victorensis* in laboratory bioassays. None of 14 synthetic fungicides tested against *T. doreenae* were toxic. Wettable sulphur and copper hydroxide were also non-toxic even when used at many times the field rate. Lime sulphur, however, was highly toxic at the field rate. Most insecticides/miticides were medium to highly toxic. Methidathion, dimethoate, carbamult, diazinon and chlorphyrifos produced 100% (or near to) mortality at field rates. Azinphos-methyl and carbaryl were least toxic with the former causing only 24% mortality at 10X field rate, Synthetic fungicides varied in their toxicity to *A. victorensis*: benomyl, chlorothalonil, iprodine and procymidone were least toxic and mancozeb and triadimefon, most toxic. Wettable and lime sulphur were highly toxic but copper hydroxide and phosphorus acid were harmless. All insecticides/miticides except endosulfan were highly toxic to *A. victorensis.*

Although *A. victorensis*, *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. Initial success in introducing *T. doreenae* into an MIA vineyard (DAN4GW, DAN 92/3) provide optimism that this predator could be established in most viticultural areas that currently lack this predator.

The current project sought to establish the status of biological mite control in all major and many small grapegrowing regions of Australia. Management strategies which enhance biological control of mites in grapevines were also researched and developed.

## OBJECTIVES

1. Identification of the mite pest and predator fauna and status of biological control in all major viticultural regions.

2. Mass production of the predator, *Typhlodromus doreenae.*

3. Introduction of *Typhlodromus doreenae* into viticultural regions lacking effective biological control of mites.

4. Development of regional strategies for biological control of grapevine mites.

# A. THE PREDATORY MITE (PHYTOSEIIDAE) FAUNA OF GRAPEVINES IN AUSTRALIA

## INTRODUCTION

Studies on pest and predatory mite populations on grapevines during 1989-96 have provided the basis for development and implementation of biological mite control in Australian vineyards. Biological control of eriophyid and tenuipalpid mites based on conservation of endemic phytoseiids and re-distributing a key species (*Typhlodromus doreenae* Schicha), is likely to become the industry standard for mite control in Australian viticulture.

Identification and mapping of the phytoseiid fauna occurring on Australian grapevines was fundamental to the applied studies. Schicha (1987) recognised seven species from grapevines and James and Whitney (1993a) and James *et al.* (1995) increased this to 15. This report adds a further 16 species and provides information on the distribution and abundance of all 31 species.

## MATERIALS AND METHODS

A total of 153 vineyard sites from 29 viticultural regions throughout Australia was sampled for phytoseiids during 1989-96 (Fig. 1). Most sites were sampled monthly or bi-monthly during August-May (Winter-Autumn) for two to four years. The remainder were sampled minimally or once only (Table 1). Sampling and examination of leaves, shoots and dormant wood was conducted as described in James and Whitney (1993a) and James *et al.* (1992, 1995). Leaves were sampled at all sites in all seasons; shoots and dormant wood were only sampled during the first three seasons.

Representative samples (range: 1 to 12 adults per site sample) of phytoseiids were transferred from vine material to 70% ethanol prior to preparation. They were cleared in Essig's solution over gentle heat then slide mounted in Hoyer's medium. Species identifications follow Schicha (1987) and were made by the senior author.

Estimates of the abundance of each species on grapevines in each region were arbitrarily derived from consideration of the numbers of individuals prepared in this study together with published (James and Whitney 1993a, James *et al.* 1995) and unpublished population data.

## RESULTS

Thirty one species of phytoseiid were recorded including three undescribed species (Table 2). Two species, *T. doreenae* and *Typhlodromus dossei* Schicha, were the most widely distributed occurring in 17 and 14 regions, respectively, with each dominant in at least eight regions. *T. doreenae* was most abundant in the warm, dry inland regions of New South Wales and South Australia and the milder tableland (Canberra, Mudgee) areas, whilst *T. dossei* was dominant in southern (Tasmania, Victoria, Western Australia) cool

climate viticultural regions, and the mild tableland Granite Belt region of Queensland.

*Amblyseius lentiginosus* Denmark and Schicha, *Amblyseius helmi* Schicha, *Phytoseius fotheringhamiae* Denmark and Schicha and *Typhlodromus transvaalensis* (Nesbitt) were each found in six to nine regions and occasionally were abundant (e.g. *A. lentiginosus* in the Upper Hunter and *P. fotheringhamiae* in Canberra).

*Amblyseius victoriensis* and *Amblyseius loxtoni* Schicha were recorded from three and four regions, respectively. *A. victoriensis* was abundant in all three regions, as was *A. loxtoni* in Sunraysia and the Murray Valley. *Amblyseius dieteri* Schicha and *Typhlodromus occidentalis* Nesbitt were both recorded from four separate regions but only occurred in small numbers.

The remaining species (*Amblyseius thwaitei* Schicha, *Amblyseius harveyi* McMurtry and Schicha, *Amblyseius masiaka* Blommers and Chazeau, *Amblyseius deleoni* Muma and Denmark, *Amblyseius elinae* Schicha, *Amblyseius waltersi* Schicha, *Amblyseius bellinus* (Womersley), *Amblyseius noosae* McMurtry and Schicha, *Amblyseius christinae* Schicha, *Amblyseius tareensis* Schicha, *Amblyseius lailae* Schicha, *Typhlodromus applegum* Schicha, *Typhlodromus brisbanensis* Schicha, *Typhlodromus australicus* (Womersley), *Typhlodromus pyri* Scheuten, *Phytoseius woolwichensis* sp. nr. *P. woolwichensis* Schicha, *Phytoseius woolwichensis* sp. nr. *P. leaki* Schicha/*hongkongensis* Swirski and Shechter, *Phytoseiulus persimilis* Athias-Henriot and undescribed spp. A, B and C) were each recorded from only one or two regions and were generally uncommon.

## DISCUSSION

This study represents the first comprehensive survey of phytoseiids on grapevines in Australia and substantially extends our knowledge on the distribution and abundance of these important biological control agents in this crop.

Schicha (1987) recorded *A. victoriensis, A. bellinus, A. lentiginosus, A. loxtoni, A. helmi, T. dossei* and *P. fotheringhamiae* from grapevines in Australia. James and Whitney (1993a) and James *et al.* (1995) added *T. doreenae, T. occidentalis, T. applegum, T. australicus, A. masiaka, A. dieteri, A. waltersi* and *A. elinae* to this list. The current study increases this by 16 to a total of 31 species. The majority of these species appear to be fairly uncommon on grapevines and individually may be of little importance in biological control. However, there are at least seven species (*T. doreenae, T. dossei, A. lentiginosus, A. helmi, A. victoriensis, A. loxtoni and P. fotheringhamiae*) that can occur as large populations and provide significant biological control of phytophagous mites. The importance of *T. doreenae* and *A. victoriensis* in controlling populations of eriophyids and tenuipalpids in the Riverland of South Australia and the Canberra district has been reported previously (James and Whitney 1993a; James *et al.* 1995).

*T. doreenae* was described by Schicha (1987) from specimens obtained from an apple tree in Adelaide, South Australia. It was the most abundant phytoseiid in this study, occurring in 17 of the 29 viticultural regions. Its occurrence in hot, dry (e.g. Riverland) and milder

(Canberra, Geelong) climates demonstrates suitability of a range of environmental conditions. *T. doreenae* is now considered to be the most important phytoseiid involved in biological control of mites in Australian vineyards (James and Whitney 1993a, 1994; James *et al.*1995). Previously, *T. doreenae* was absent in the Murrumbidgee Irrigation Area (MIA) (in the Riverina of New South Wales) and biological control was poor in comparison to the Riverland of South Australia where *T. doreenae* was dominant (James and Whitney 1993a). In 1991, *T. doreenae* was released at one vineyard site in the MIA and six sites in 1994. Establishment of *T. doreenae* at most of these sites is now confirmed, with high populations recorded during the 1995-96 season (Section D this report, James and Whitney 1996). Virtually all specimens of this species recorded from the Riverina in this study, were from these sites.

*T. dossei* was described by Schicha (1978) and Schicha (1987) recorded it from grapevines or other hosts in all states except South Australia and Western Australia. In this study it was recorded from grapevines in all states but only occurred in the milder (more southerly or elevated) grapegrowing regions. At some sites it occurred in very large numbers (up to a mean of 6.8 motiles per leaf) and appeared to provide good control of eriophyids.

Despite their relatively wide distribution, *A. lentiginosus, P. fotheringhamiae* and *A. helmi* only occasionally occurred in large numbers, e.g. *A. helmi* and *A lentiginosus* in the Upper Hunter. *A. lentiginosus* has been recorded as a predator of eriophyids and tetranychids on apple (Schicha 1975a) and citrus (Beattie 1978) in New South Wales but is not the dominant phytoseiid on either crop. *P. fotheringhamiae,* another eriophyid/tetranychid predator (Schicha 1975b), occurred in very large numbers at a single vineyard in the Canberra district (James *et al.* 1995) and was also the dominant phytoseiid on unsprayed apples at Bathurst in Central West New South Wales (Schicha 1975b). Walter (1992) reported *P. fotheringhamiae* to be the most abundant and widely distributed species in a study of phytoseiids inhabiting coastal or near coastal native forest plants from Tasmania to Queensland. However, it occurred only on plants with well developed leaf hairs and the degree of leaf hairiness in different grape varieties may strongly influence the abundance of *P. fotheringhamiae* on grapevines.

*A. victoriensis*, whilst occurring in only three regions, was abundant and is considered to be an important factor in biological control of grapevine mites in these hot, dry viticultural regions (James and Whitney 1993a). *A. victoriensis* is also an important biological control agent of eriophyid and tetranychid mites on peaches (James 1990) and citrus (Smith and Papacek 1991) in inland Australia. Its absence on grapes in other regions can be explained by its requirement for hot, dry conditions; it does not occur in milder and more humid coastal and elevated regions. James and Taylor (1992) demonstrated successful egg-adult development of *A. victoriensis* at 40°C. *A. loxtoni* was abundant only in Sunraysia and along the Murray Valley in Victoria (James and Whitney 1993a).

It is apparent from this study that grapevines in Australia are a good habitat for phytoseiid mites. The majority of species recorded here are native, only *T. occidentalis, T. transvaalensis, T. pyri, A. masiaka, A. deleoni* and *P. persimilis* have a recognised overseas distribution and none of these occurred commonly in this study. The presence of a

substantial native phytoseiid fauna on Australian grapevines is indicative of the relative stability of this horticultural ecosystem. In comparison to European and North American viticulture, grapes grown in Australia are exposed to few insecticide inputs (James and Whitney 1993) and are thus able to be readily exploited by phytoseiids.

**Table 1. Australian viticultural regions and seasons sampled**

| VITICULTURAL REGION (State) | | SEASON (August - May) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1989-90 | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 |
| Riverina | (NSW) | X | X | X | X | X | X | X |
| Upper Hunter | (NSW) | | | | | X | X | |
| Lower Hunter | (NSW) | | | M | | X | X | |
| Mudgee | | | | | | X | | X |
| | (NSW) | | | X | | X | X | X |
| Central West | (NSW) | | | | | | | M |
| Far North West | (NSW) | | | | | | | M |
| North Coast | (NSW) | | | | | | | M |
| South Coast | (NSW) | | | X | X | | X | |
| Canberra | (ACT/NSW) | X | X | X | | | | |
| Riverland | (SA) | | X | X | | X | | X |
| Barossa Valley | (SA) | | X | | | X | | X |
| McLaren Vale | (SA) | | | | | X | | X |
| Clare Valley | (SA) | | | | | X | | |
| Coonawarra | (SA) | | | M | | | | |
| Adelaide Hills | (SA) | X | X | X | | | X | X |
| Sunraysia | (Vic/NSW) | | | | | X | X | |
| Geelong | (Vic) | | | | | X | X | |
| Great Western | (Vic) | | | | | X | X | |
| Yarra Valley | (Vic) | | | M | | | | |
| N.E. Victoria | (Vic) | | | X | | | | |
| Murray Valley | (Vic) | | | | | X | | |
| North Tasmania | (Tas) | | | | | X | | |
| S.E. Tasmania | (Tas) | | | X | | X | X | |
| Granite Belt | (Qld) | | | | X | X | X | |
| Perth | (WA) | | | | X | X | X | |
| Margaret River | (WA) | | | | X | X | X | |
| Mt. Barker | (WA) | | | | X | X | X | |
| Manjimup | (WA) | | | | | | M | |
| Alice Springs | (NT) | | | | | | | |

M = sites sampled once only or minimally

## Table 2. Phytoseiidae recorded on Australian grapevines during 1989-96

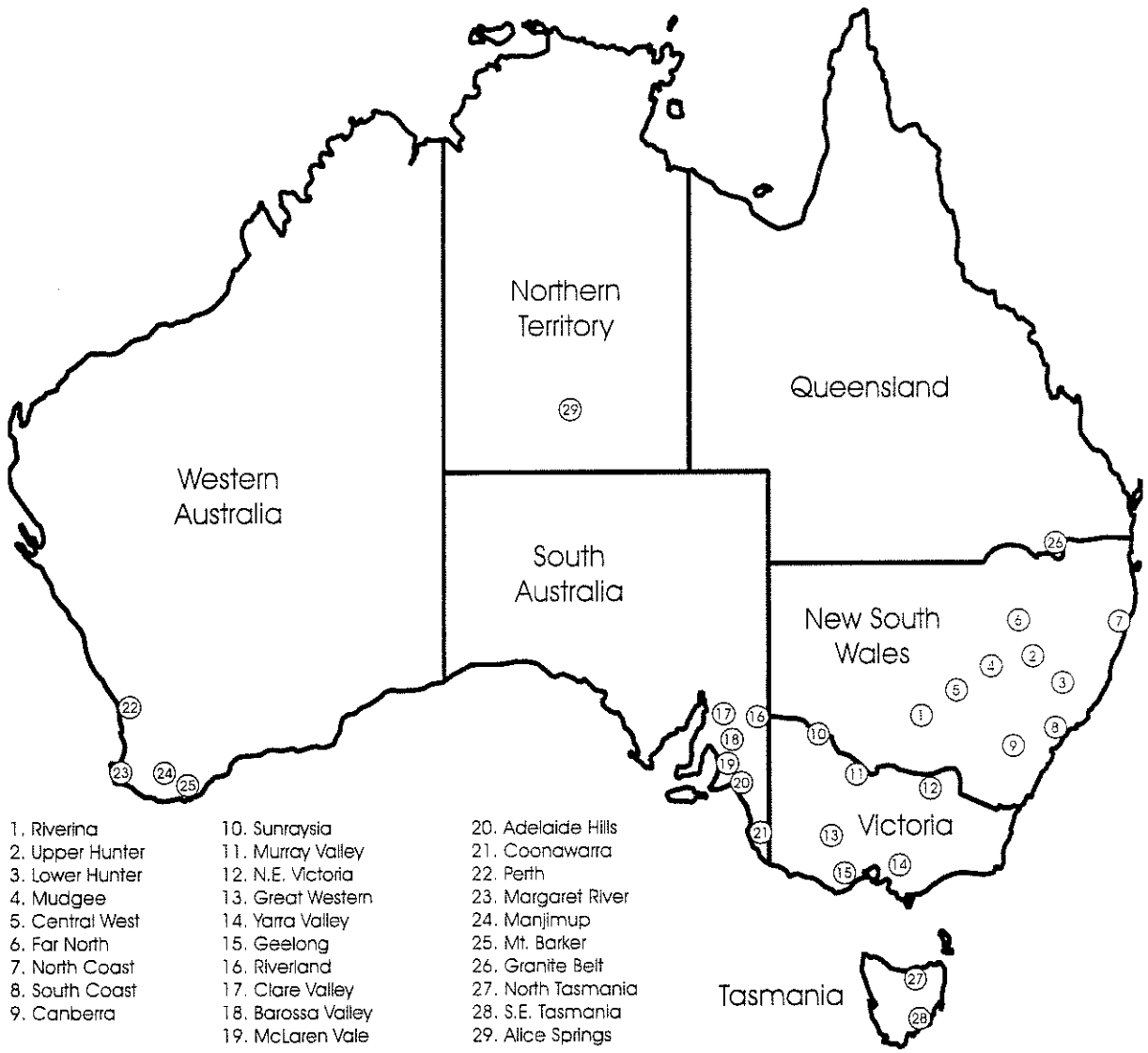
| Viticultural region (State) | Phytoseiid species | ^No. held | *Estimated abundance | Viticultural region (State) | Phytoseiid species | ^No. held | *Estimated abundance |
|---|---|---|---|---|---|---|---|
| Riverina (NSW) | *A. victoriensis* | 131 | +++ | North Coast (NSW) | *A. lentiginosus* | 3 | ++ |
| | *T. doreenae* | 190 | ++ | | *T. brisbanensis* | 2 | + |
| | *T. occidentalis* | 26 | ++ | | *A. deleoni* | 1 | + |
| | *A. helmi* | 69 | ++ | | *P. fotheringhamiae* | 1 | + |
| | *A. loxtoni* | 72 | ++ | | *P. woolwichensis sp.* | 1 | + |
| | *A. dieteri* | 6 | + | | *(nr. P. teaki/hongkongensis)* | | |
| | *T. transvaalensis* | 7 | + | | | | |
| | *T. applegum* | 1 | + | | | | |
| | *A. thwaitei* | 1 | + | South Coast (NSW) | *A. deleoni* | 2 | + |
| | *A. lentiginosus* | 1 | + | | *P. woolwichensis sp.* | 1 | + |
| | undescribed sp. A. | 8 | + | | *(nr. P. woolwichensis)* | | |
| Upper Hunter (NSW) | *A. helmi* | 29 | +++ | Canberra (ACT/NSW) | *T. doreenae* | 175 | +++ |
| | *A. lentiginosus* | 28 | +++ | | *P. fotheringhamiae* | 24 | +++ |
| | *T. doreenae* | 2 | + | | *T. dossei* | 28 | ++ |
| | *A. dieteri* | 1 | + | | *T. australicus* | 1 | + |
| | *A. harveyi* | 1 | + | | *A. elinae* | 3 | + |
| | *P. fotheringhamiae* | 6 | + | | *A. waltersi* | 1 | + |
| | undescribed sp. B. | 1 | + | | *P. persimilis* | 1 | + |
| Lower Hunter (NSW) | *T. doreenae* | 4 | + | Riverland (S.A.) | *T. doreenae* | 188 | +++ |
| | *A. masiaka* | 2 | + | | *A. victoriensis* | 15 | +++ |
| Mudgee (NSW) | *T. doreenae* | 46 | +++ | Barossa Valley (S.A.) | *T. doreenae* | 22 | +++ |
| | *A. lentiginosus* | 5 | ++ | | | | |
| | *P. fotheringhamiae* | 6 | ++ | | | | |
| | *undescribed sp. C.* | 1 | + | McLaren Vale (S.A.) | *T. doreenae* | 15 | +++ |
| | | | | | *T. dossei* | 10 | ++ |
| Far North West (NSW) | *nil* | | | | *A. messor* | 1 | + |
| | | | | Clare Valley (S.A.) | *T. doreenae* | 17 | +++ |
| Central West (NSW) | *T. doreenae* | 32 | +++ | | *T. transvaalensis* | 1 | + |
| | *A. helmi* | 14 | ++ | | | | |
| | *T. transvaalensis* | 1 | + | Coonawarra (S.A.) | *T. dossei* | 3 | + |
| | *T. occidentalis* | 1 | + | | | | |
| | *A. lentiginosus* | 1 | + | | | | |
| | *A. loxtoni* | 1 | + | Adelaide Hills (S.A.) | *T. doreenae* | 3 | + |
| | *P. fotheringhamiae* | 1 | + | | | | |

## Table 2. Phytoseiidae recorded on Australian grapevines during 1989-96

| Viticultural region (State) | Phytoseiid species | ^No. held | *Estimated abundance | Viticultural region (State) | Phytoseiid species | ^No. held | *Estimated abundance |
|---|---|---|---|---|---|---|---|
| *Sunraysia* (Vic/NSW) | *A. loxtoni* | 155 | +++ | *Perth* (W.A.) | *T. doreenae* | 45 | +++ |
| | *A. victoriensis* | 86 | +++ | | *T. dossei* | 7 | + |
| | *A. helmi* | 16 | + | | *A. dieteri* | 5 | + |
| | | | | | *A. helmi* | 1 | + |
| *Geelong* (Vic) | *T. dossei* | 75 | +++ | | *A. elinae* | 4 | + |
| | *T. doreenae* | 18 | ++ | | | | |
| | *T. transvaalensis* | 2 | + | *Margaret River* (W.A.) | *T. dossei* | 78 | +++ |
| | *P. persimilis* | 1 | + | | *A. lentiginosus* | 1 | + |
| | *undescribed sp. C.* | 1 | + | | *T. transvaalensis* | 1 | + |
| | | | | | *A. elinae* | 13 | + |
| *Great Western* (Vic) | *T. dossei* | 58 | +++ | | *A. christinae* | 18 | + |
| | | | | | *T. doreenae* | 1 | + |
| | | | | | *P. persimilis* | 2 | + |
| *Yarra Valley* (Vic) | *T. dossei* | 15 | + | | | | |
| | *A. bellinus* | 1 | + | *Mt. Barker* (W.A.) | *T. dossei* | 67 | +++ |
| | | | | | *A. lentiginosus* | 8 | + |
| *N.E. Victoria* (Vic) | *T. dossei* | 10 | ++ | | *A. christinae* | 1 | + |
| | *T. doreenae* | 7 | ++ | | *A. tareensis* | 1 | + |
| | *T. occidentalis* | 1 | + | | *A. lailae* | 4 | + |
| | *A. helmi* | 2 | + | | | | |
| | *P. fotheringhamiae* | 1 | + | *Manjimup* (W.A.) | *T. dossei* | 93 | +++ |
| | | | | | *A. christinae* | 7 | ++ |
| *Murray Valley* (Vic) | *A. loxtoni* | 40 | +++ | | *A. dieteri* | 2 | + |
| | *T. doreenae* | 24 | ++ | | *A. lentiginosus* | 4 | + |
| | *A. helmi* | 8 | + | | *A. lailae* | 1 | + |
| | *A. masiaka* | 1 | + | | *A. elinae* | 10 | + |
| | | | | | *A. victoriensis* | 1 | + |
| *North Tasmania* (Tas) | *T. dossei* | 19 | +++ | | *A. harveyi* | 1 | + |
| | *T. pyri* | 8 | ++ | | *P. persimilis* | 1 | + |
| | *P. fotheringhamiae* | 1 | + | | | | |
| | | | | *Alice Springs* (N.T.) | *nil* | | |
| *S.E. Tasmania* (Tas) | *T. dossei* | 29 | +++ | | | | |
| *Granite Belt* (Qld) | *T. dossei* | 132 | +++ | | | | |
| | *T. pyri* | 23 | ++ | | | | |
| | *T. occidentalis* | 11 | ++ | | | | |
| | *A. lentiginosus* | 29 | ++ | | | | |
| | *P. fotheringhamiae* | 3 | ++ | | | | |
| | *T. transvaalensis* | 1 | + | | | | |
| | *T. doreenae* | 1 | + | | | | |
| | *A. noosae* | 2 | + | | | | |

*^ Number of mounted specimens held in collection. * Estimate of abundance on grapevines within regions from samples examined. +++common, ++occasional, +rare.*

Figure 1 Australian Viticultural Regions surveyed for Phytoseiidae, 1989/96.



## B. POPULATION DYNAMICS OF GRAPEVINE MITES AND PREDATORS IN AUSTRALIAN VITICULTURAL REGIONS 1993-96.

The earlier reports for the projects DAN4GW and DAN92/3 presented comprehensive data on pest and predatory mite population dynamics on grapevines in the Riverland of South Australia, Sunraysia, the Murrumbidgee Irrigation Area, the Canberra district and limited information for the Swan Hill district. During 1993-96 comparable studies on mite populations were conducted in vineyards from all other major viticultural regions of Australia. In some regions studies were conducted over the three seasons while in others they were conducted in only a single season or two seasons.

Similar protocols for sampling leaves and assessing mite populations were used as described in DAN4GW and DAN92/3. Cooperating personnel in each region collected leaf samples and forwarded them to Yanco for analysis. In some instances (notably Western Australia and the Granite Belt in Queensland), leaves were examined in local laboratories and results forwarded to Yanco. In these cases, specimens of predatory mites found on the leaves were also forwarded to Yanco for identification to species.

In each region a number of grapevine blocks from different vineyards (usually 1-4) were selected for sampling, usually on the basis of being fairly 'low-input' in terms of pesticide, particularly insecticide, use. It was considered this type of vineyard would provide the best opportunity to determine the 'natural' dynamics of pest and predatory mite populations in each region.

Monthly samples of 30 mature leaves were randomly sampled from each block, usually during October to April. Leaves were collected over as large and representative an area as possible with usually only one or two leaves selected from each row. Leaves were sampled from both inside and outside canopies. They were immediately placed into a single plastic bag and kept cool, usually in an esky. The leaves were then immediately shipped within an esky containing a 'cold brick' to Yanco for analysis. On arrival at Yanco the samples were stored at 5°C until examined under a stereomicroscope, usually within a few days.

Each leaf was examined for the presence of pest and predatory mites and recorded. All individuals and eggs of bunch mite (*Brevipalpus* spp.) and predatory mites (Phytoseiidae) were recorded. Rust mites (*Calepitrimerus vitis*) and blister mites (*Colomerus vitis*) were recorded as low, medium or high infestations as follows:

*Calepitrimerus vitis*: Low = 1-10 individuals per leaf
Medium = 11-100 individuals per leaf
High = > 100 individuals per leaf

*Colomerus vitis*: Low = 1-20% of leaf area blistered
Medium = 21-50% of leaf area blistered
High = 51-100% of leaf area blistered

Whilst individuals of *Calepitrimerus vitis* were readily seen and recorded, this was not true

for individuals of *Colomerus vitis* which were usually 'hidden' within blisters. Consequently, the degree of leaf blistering was used as the index of abundance for this species. For all mites abundance was ultimately expressed as 'percentage infestation' to provide consistency and comparison with the earlier reports and publications.

Predatory mites were collected from leaves by immobilising them with a small drop of ethanol and then transferring them, using a fine paintbrush, to a small screw cap glass vial filled with 70% ethanol. In most cases a single vial was used for predators from each sample of leaves. Usually one to 12 predators were collected per sample of leaves but occasionally greater numbers were collected. The above procedures were also followed by regional cooperators when processing leaf samples. For identification, predators were cleared in Essig's solution over gentle heat then slide mounted in Hoyer's medium. Species identifications follow Schicha (1987) and all were made by Jenny Whitney.

For most sampling sites complete or partial records of spray programs were obtained from the cooperating grower. These were essential for informed interpretation of the mite and predator population data.

## 1) THE UPPER HUNTER VALLEY (NSW)

Three vine blocks were sampled in the Upper Hunter Valley during the 1993/94 and 1994/95 seasons. Two blocks 'Richmond Grove-Chardonnay' and 'Richmond Grove-Traminer' were in the same vineyard at Sandy Hollow, about 40 km west of Muswellbrook (Orlando-Wyndham). The other block 'Hollydeen-Cabernet Sauvignon' was in another Orlando-Wyndham vineyard at Hollydeen 35 km west of Muswellbrook. Another block at Hollydeen (Chardonnay) was sampled for 3 months (Sept-Nov 1993) but was then discontinued.

Pest and predatory mite population data for the 3 blocks are presented in Figures 2-4 and data on predator incidence are shown in Table 3 and Figures 5-7

Similar trends of mite and predator abundance were observed in both seasons. All three blocks were characterised by relatively small numbers of predatory mites and large numbers of rust mites for most of the season. Rust mites were a significant problem in all blocks with medium-high densities prevalent. Predators generally appeared late in the season and did not reach sufficient densities (mostly around 20-30% infestation) to exert regulatory pressure on rust mite populations. Seven species of phytoseiid were identified in samples from these vineyards including one unidentified species. The most common species' were *Amblyseius lentiginosus* and *Amblyseius helmi*. Curiously, the former was most abundant in 1993/94 and the latter in 1994/95, illustrating, perhaps, the 'instability' of the phytoseiid fauna on grapevines in this district; no single species predominates. *Phytoseius fotheringhamiae* occurred in small numbers in both seasons, whilst very small numbers of *Typhlodromus doreenae* were recorded in two of the blocks in 1994/95.

A heavy spray program was conducted in all the blocks during both seasons with around 25

applications of fungicides/insecticides per season in each block. A range of fungicides (e.g. dithane, iprodione, chlorothalonil, wettable sulphur, copper) was used as well as *Bacillus thuringiensis* for caterpillar control and dicofol for mite control. Many of these compounds are known to be harmful to phytoseiids, particularly dithane and dicofol, and it is likely that the heavy spray program was primarily responsible for the slow buildup of predator numbers during the season.

Biological control of grapevine mites in the Upper Hunter Valley appears to be ineffective under present circumstances. Spray pressure is too high preventing establishment of a stable phytoseiid fauna. The occurrence of *T. doreenae* in albeit small numbers in 2 blocks in 1994/95, is significant, and suggests that with relaxation of spray pressure, this species could become dominant and provide the degree of mite control which it does in other regions. *T. doreenae* is the dominant phytoseiid at Mudgee which is only 90 km from Sandy Hollow/Hollydeen and it seems likely that the higher spray pressure of the Upper Hunter is the primary reason for its general absence.

**Table 3 Predatory mite species incidence in Upper Hunter Valley sampling 1993-95.**

| **NEW SOUTH WALES** | | | **SPECIES PERCENTAGES** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1993-94** | | | | | | | | | |
| Region | Vineyard | Total Predator No. | *A. lentiginosus* | *A. helmi* | *A. harveyi* | *A. dieteri* | *T. doreenae* | *P. fotheringhamiae* | *Other* |
| Upper Hunter | Richmond Grove (traminer) | 35 | 60 | 18.9 | 0 | 0 | 0 | 21.1 | 0 |
| | Richmond Grove (chardonnay) | 30 | 53 | 39.7 | 0 | 0 | 0 | 0 | 7.3 |
| | Hollydeen (chardonnay) | 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| | Hollydeen (cab. Sav.) | 37 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **1994-95** | | | | | | | | | |
| | Richmond Grove (traminer) | 34 | 0 | 85.3 | 0 | 0 | | 11.8 | 2.9 |
| | Richmond Grove (chardonnay) | 26 | 0 | 96.2 | 0 | 0 | 3.8 | 0 | 0 |
| | Hollydeen (cab. Sav.) | 8 | 52.5 | 0 | 0 | 17.5 | 30 | 0 | 0 |

Figure 2 Pest and predatory mite populations at Richmond Grove (traminer Riesling), Upper Hunter during 1993/95.

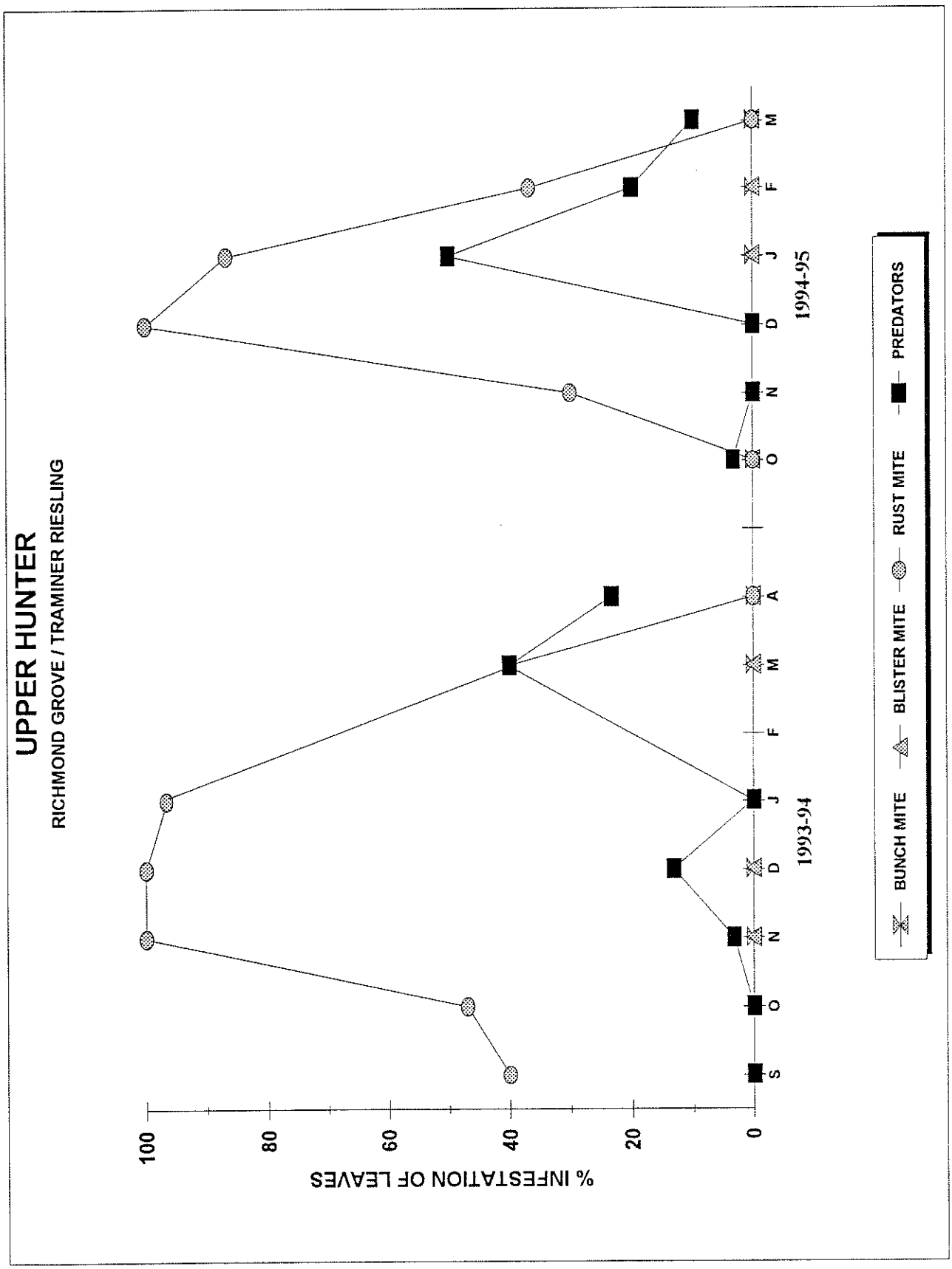


Figure 3. Pest and predatory mite populations at Richmond Grove (Chardonnay), Upper Hunter, during 1993/95

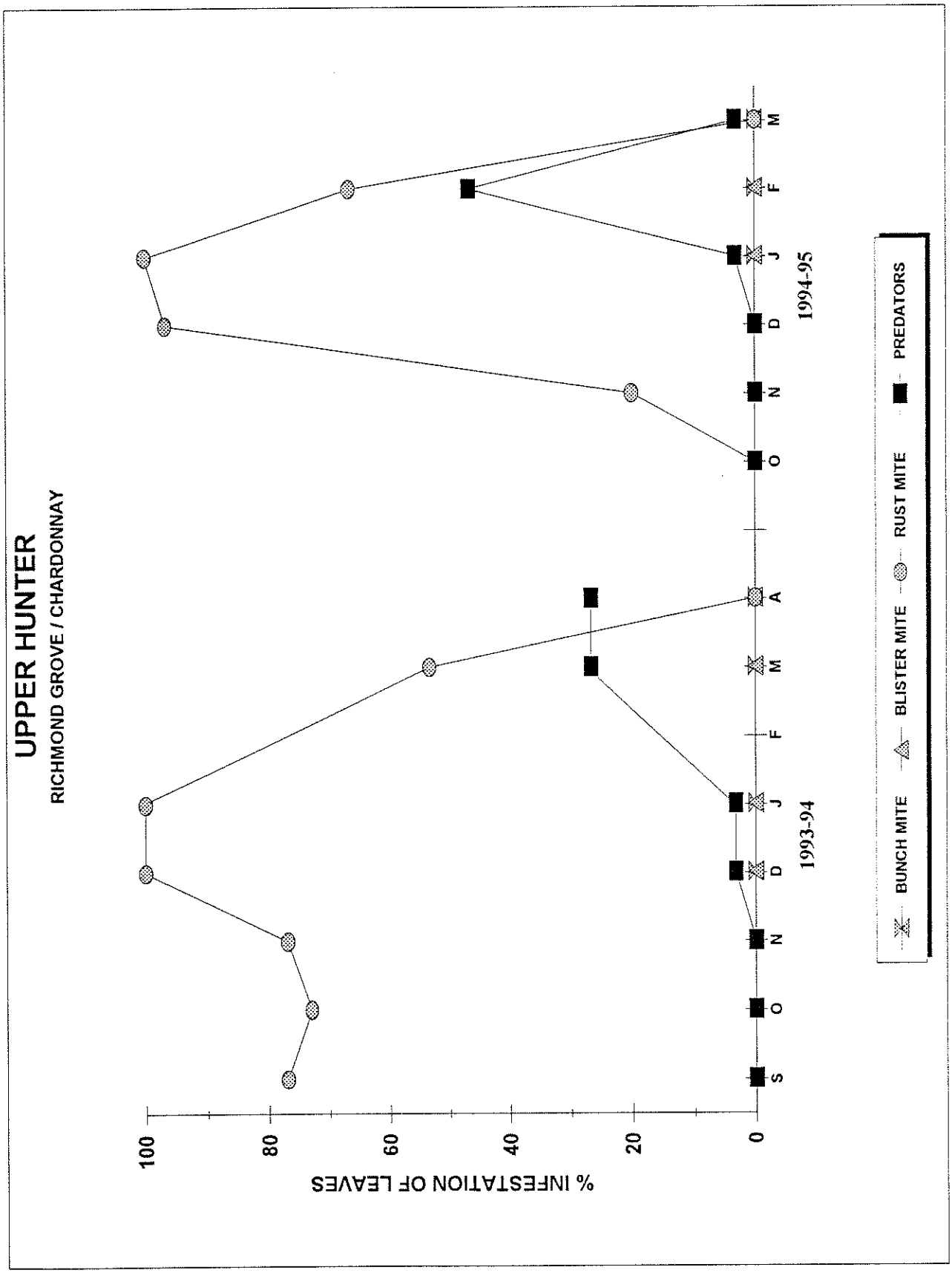


Figure 4. Pest and predatory mite populations at Hollydeen, Upper Hunter, during 1993/95.

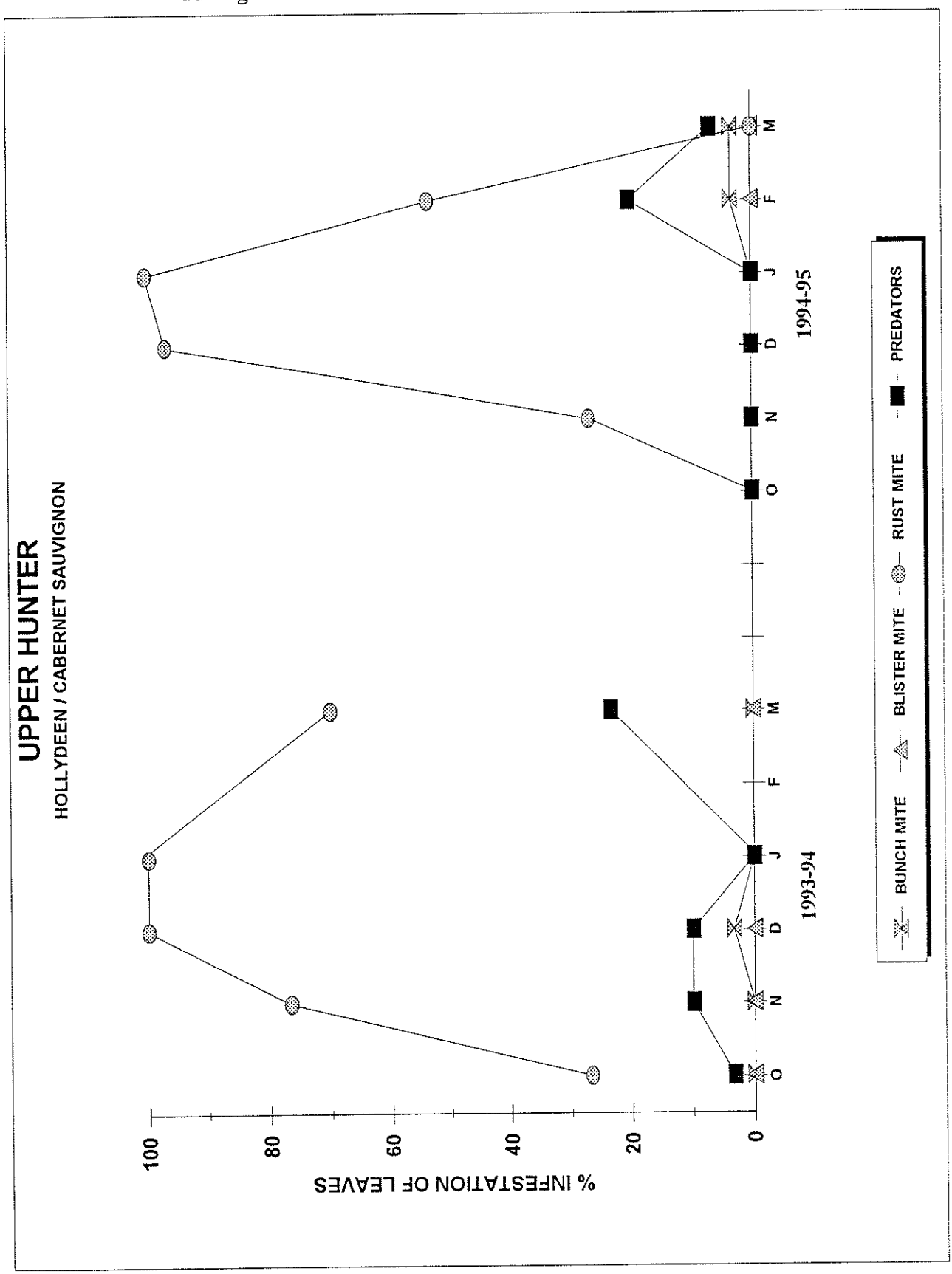


Figure 5. Predator species percentages at Richmond Grove (Chardonnay), Upper Hunter, during 1994/95.

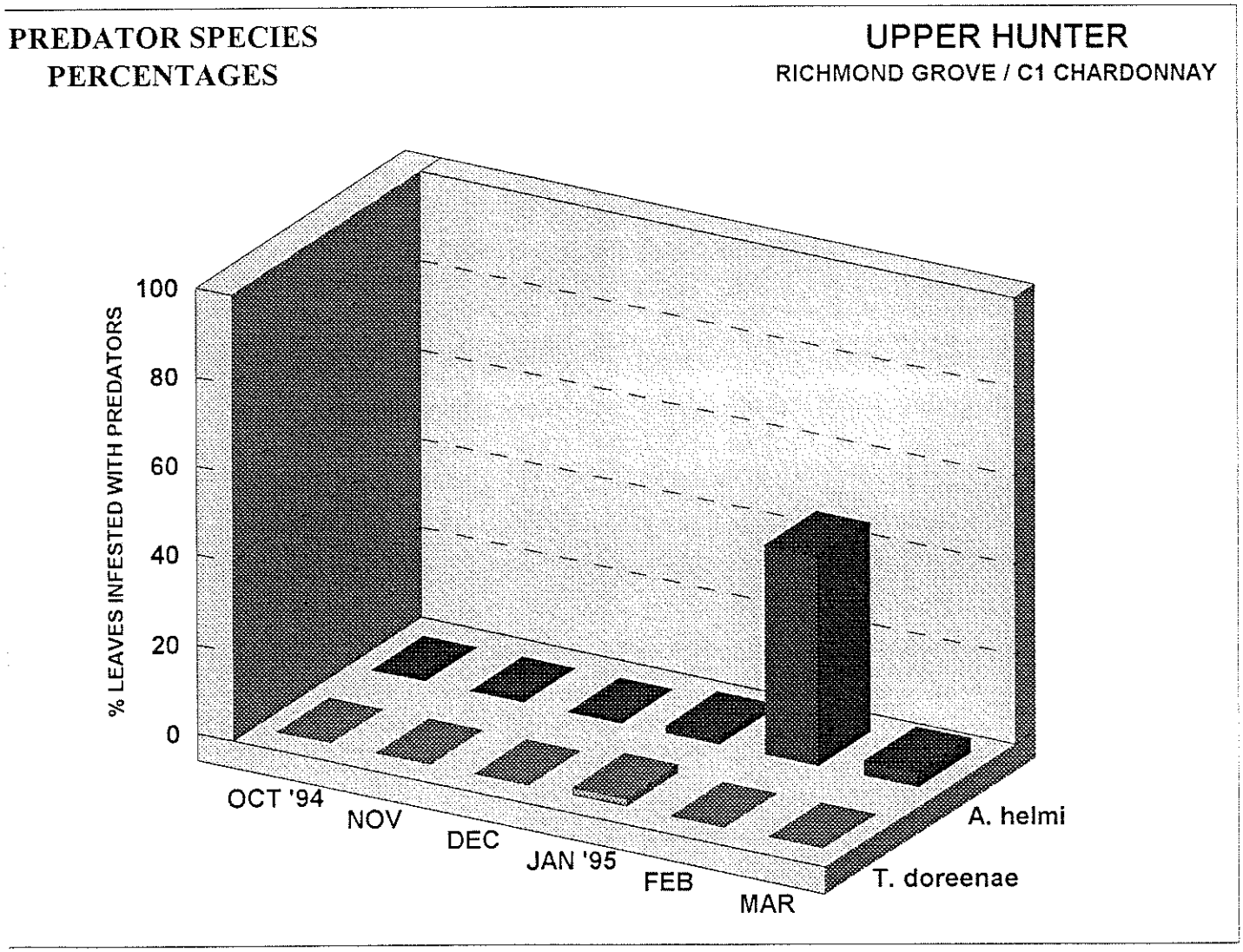


Figure 6. Predator species percentages at Richmond Grove (Traminer Riesling), Upper Hunter, during 1994/95.

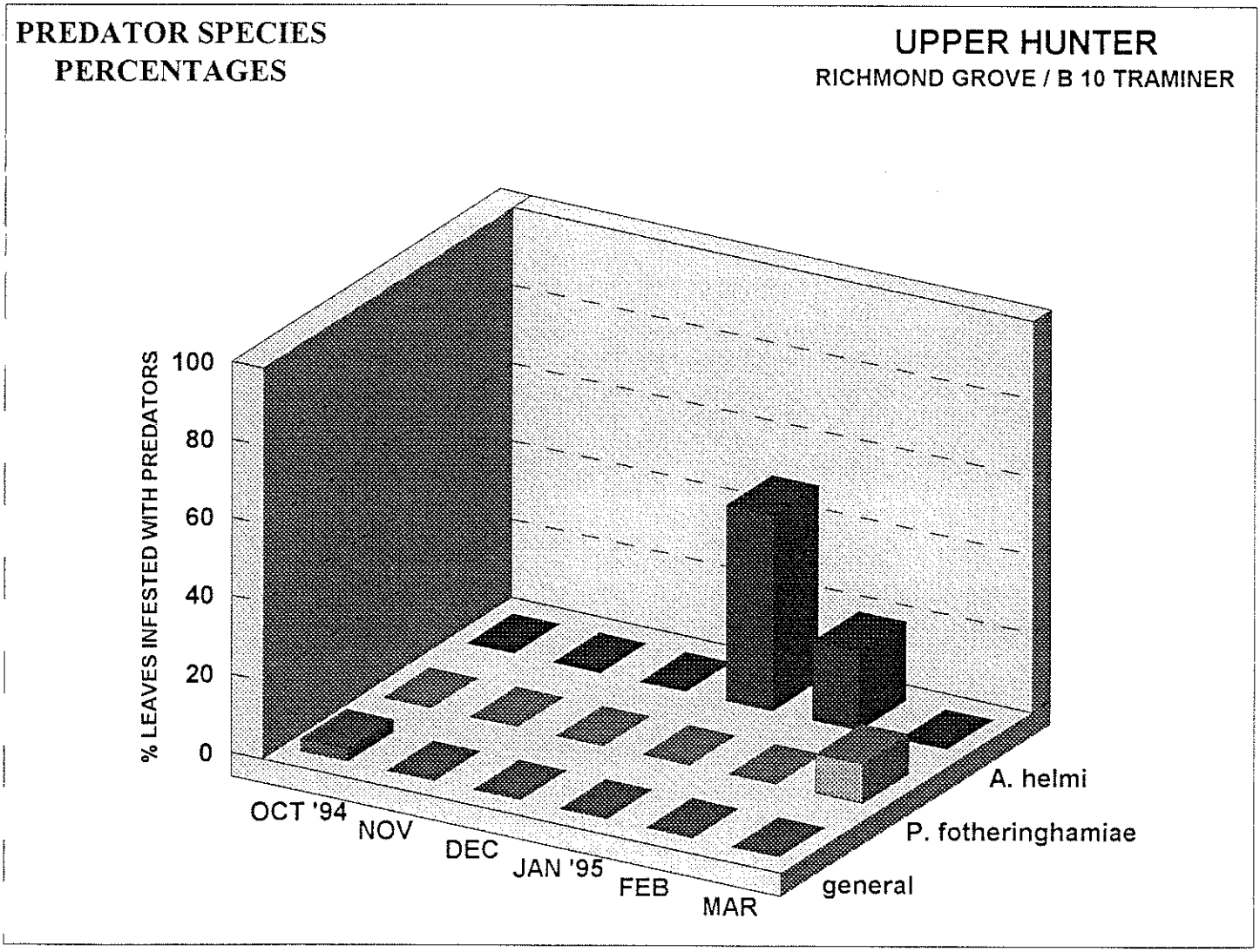
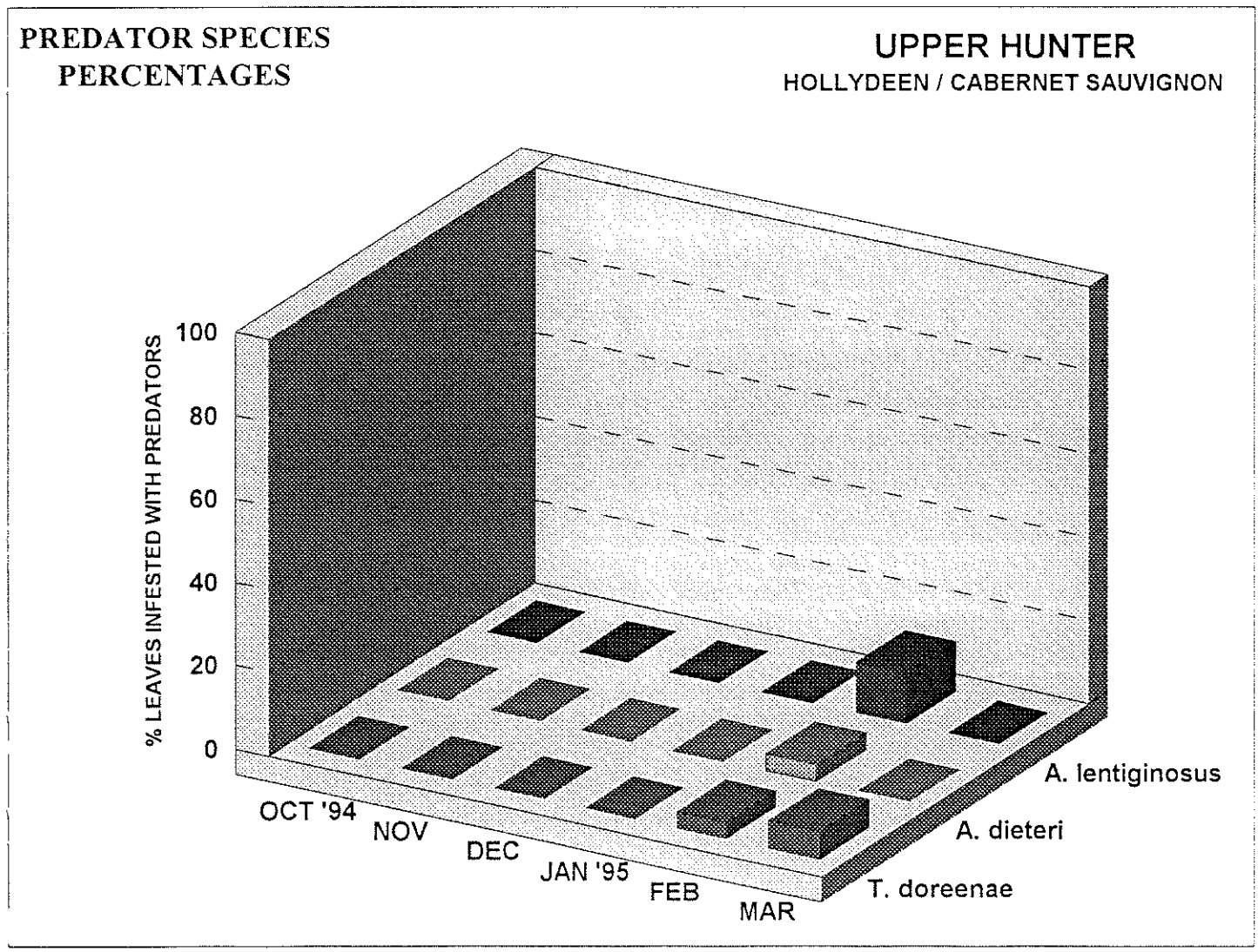


Figure 7. Predator species percentages at Hollydeen, Upper Hunter, during 1994/95.



## RECOMMENDATIONS

Attempts should be made to reduce the use of broad-spectrum insecticides (e.g. dicofol) and synthetic fungicides, particularly those more likely to be harmful to phytoseiids like dithane.
This will allow better establishment of stable phytoseiid populations with development of a predominant species or species', which will result in improved regulation of rust mite populations.

*A. lentiginosus* may be the region's predominant phytoseiid species on grapevines but it is also possible that *T. doreenae* could assume this role if dicofol was not used in spray programmes. This compound is the only one used in the 3 blocks known to be harmful to this predator. It is recommended that dicofol not be used in vineyards in this region to see if *T. doreenae* is able to colonise and exert the same level of biological control of rust mites as it does at Mudgee and in other regions. It is possible that *T. doreenae* and *A. lentiginosus* could 'coexist' and provide good control as *T. doreenae* and *Amblyseius victoriensis* do in the Riverland of South Australia.

Colonisation of *T. doreenae* in Upper Hunter vineyards could be hastened by man-assisted introduction of the predator. Once this predator is available commercially, it could be purchased by vignerons and introduced to their vineyards. Alternatively, *T. doreenae*-infested leaves from Mudgee could be collected after harvest (when predator populations are usually highest) and transferred to Upper Hunter vineyards. Predators moved in this way soon establish new populations. The introduction of *T. doreenae* to Upper Hunter vineyards must naturally be accompanied by avoidance of the use of dicofol or other broad-spectrum insecticides.

## 2) MUDGEE (NSW)

Three vine blocks in 3 vineyards in the Mudgee district were sampled during the 1993/94 season only (Montrose: Chardonnay, Craigmoor: Chardonnay, Stoney Creek: Chardonnay, all Orlando-Wyndham).

Pest and predatory mite population data for the 3 blocks are presented in Figures 8-10 and Table 4.

**Table 4 Predatory mite species incidence in Mudgee sampling 1993-94**

| NEW SOUTH WALES 1993-94 | | | SPECIES PERCENTAGES | |
|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *A. lentiginosus* | *T. doreenae* |
| Mudgee | Montrose | 195 | 0 | 100 |
| | Craigmoor | 102 | 4.9 | 95.1 |
| | Stoney Creek | 4 | 25 | 75 |

Figure 8. Pest and predatory mite populations at Montrose, Mudgee, during 1993/94.

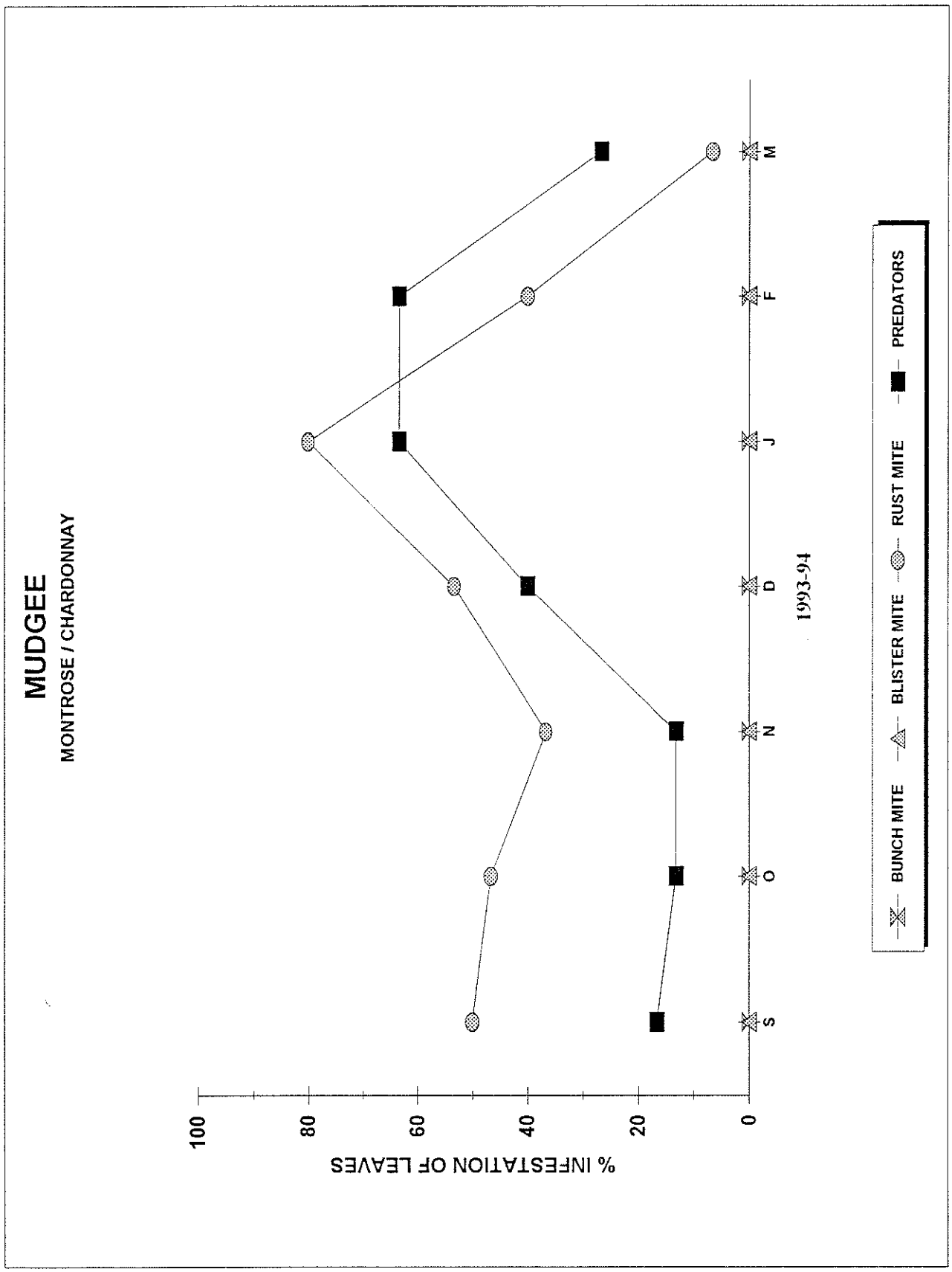


Figure 9. Pest and predatory mite populations at Stoney Creek, Mudgee, during 1993/94.

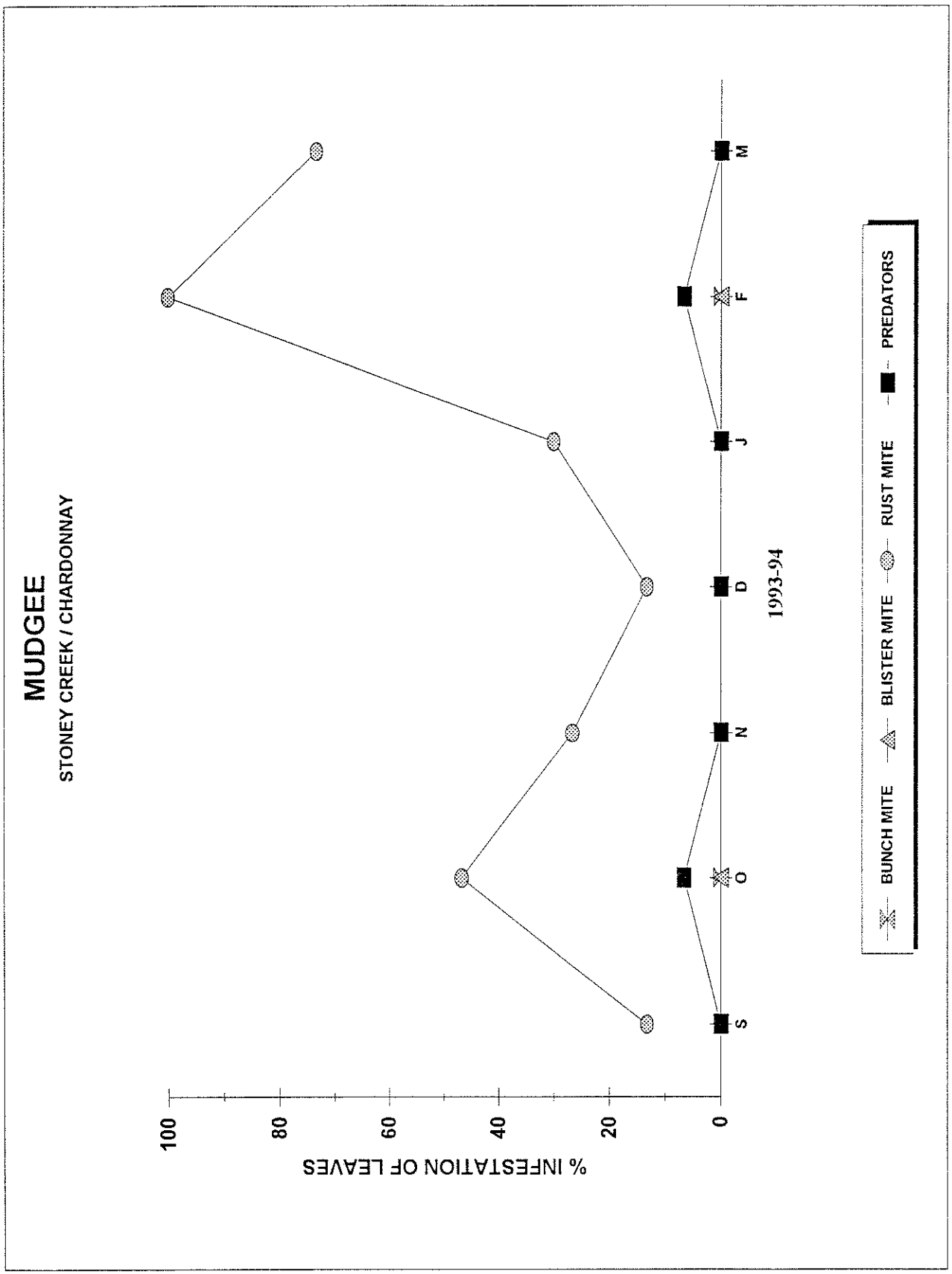
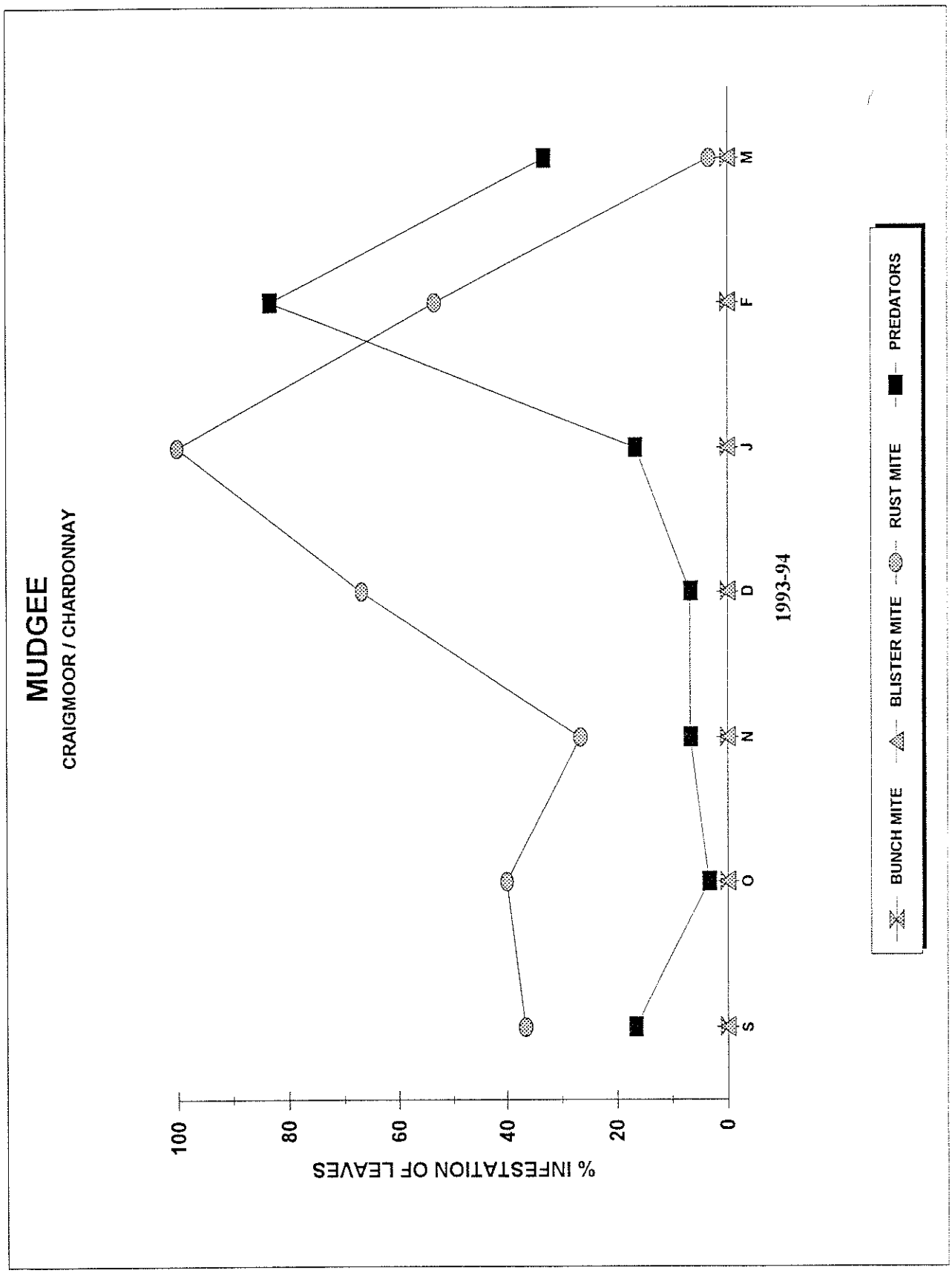


Figure 10. Pest and predatory mite populations at Craigmoor, Mudgee, during 1993/94.



Predatory mites were reasonably common in 2 (Montrose, Craigmoor) of the 3 blocks but were clearly being suppressed early in the season, presumably by the heavy spray programs conducted in these blocks. The dominant predator species was *Typhlodromus doreenae* with just a few individuals of *Amblyseius lentiginosus*. Up to 30 sprays were applied in these blocks during September to December and although only fungicides and a predator-friendly insecticide (*Bacillus thuringiensis)* were used at Montrose and Craigmoor, the sheer cumulative volume of applications suppressed population build up of *T. doreenae*. At Stoney Creek, chlorpyrifos (Lorsban) was used in December wiping out the small early season population of *T. doreenae* and preventing its establishment for the whole season. Rust mites were the only pest mites occurring with generally 20-50% infestation of leaves during the first half of the season. Peak infestations of 80-100% occurred briefly in January/February but were lowest at Montrose where populations of *T.doreenae* were greatest (~60% infestation) at this time. At Craigmoor a small population of *T. doreenae* (<20% infestation) in January rose in February (80% infestation) and rapidly brought rust mite numbers down. Very low levels (<10% infestation) of rust mites were present at the end of the season at both Montrose and Craigmoor where *T. doreenae* populations had not been disrupted by chlorpyrifos during the season. In contrast, 70% of leaves at Stoney Creek (where chlorpyrifos was used) were infested with rust mites at the end of the season.

Biological control of mites on grapevines in the Mudgee district appears to be achievable but there needs to be some rationalisation of fungicide use, to minimise adverse impacts on the dominant predator species in the district, *T. doreenae*.

## RECOMMENDATIONS

To maximise biological mite control potential on grapevines in the Mudgee district, the use of pesticides needs to be modified. The frequency of applications should be reduced with preference given to wettable sulphur, copper and phosphorus acid. The use of chlorpyrifos or other broad-spectrum insecticides must be avoided at all costs. Good populations of *T. doreenae*, the most important and effective predator of grapevine mites, clearly exist in the Mudgee district. They should be given every opportunity to colonise vineyards and provide biological control of mites.

## 3) COWRA (NSW)

Three vine blocks in a single vineyard (Richmond Grove, Orlando-Wyndham) in the Cowra district were sampled during 1993/94 only (Sauvignon blanc, Semillon, Chardonnay).

Pest and predatory mite population data are presented in Figures 11-12 and Table 5.

Predatory mite populations were very small until the second half of the season. Rust mite populations (the only pest mite species) were also small initially in the semillon block but increased to high levels during November-January. A similar trend occurred in the Chardonnay block although numbers early season (September) were also high (60%

**Table 5. Predatory mite species incidence in Cowra sampling 1993/94.**

| NEW SOUTH WALES 1993-94 | | | SPECIES PERCENTAGES | | | | | |
|---|---|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *A. lentiginosus* | *A. helmi* | *A. loxtoni* | *T. doreenae* | *T. occidentalis* | Other |
| Cowra | Richmond Grove (chardonnay) | 72 | | 73.9 | | 26.1 | | |
| | Richmond Grove (semillon) | 42 | | 10 | 10.5 | 74.8 | | 4.7 |
| | Richmond Grove (sauvignon blanc) | 22 | 13.6 | | | 4.6 | 9.1 | 72.7 |

infestation). Greatest numbers of predators occurred in the Chardonnay block and appeared to be responsible for a late season decline in rust mite populations. Six species of phytoseiid were recorded from these blocks indicating the instability of populations. In the Chardonnay block *Amblyseius helmi* was dominant with some *T. doreenae* also present. In the Semillon block this was reversed with *Amblyseius loxtoni* also occurring in small numbers. In the Sauvignon blanc block the small numbers of phytoseiids found were dominated by an undescribed species.

Spray pressure was high in this vineyard with 20-30 sprays applied to each block during September to January. No broad-spectrum insecticides were used but the fungicides seemed to have had a suppressive effect on predator populations. It is unclear from this limited sampling whether *T. doreenae* is the dominant phytoseiid in this district. If *T. doreenae* can be encouraged to colonise vineyards, then prospects for biological control of grapevine mites are good for the Cowra district.

RECOMMENDATIONS

Spray programs in the Cowra district should be rationalised to consist of as few applications as possible of chemicals which have least impact on predatory mites e.g. wettable sulphur, copper, phosphorus acid, *Bacillus thuringiensis* etc. It is likely that *T. doreenae*, which occurs in the district, can be encouraged to successfully colonise vineyards and provide effective biological control of vine mites.

Figure 11. Pest and predatory mite populations at Richmond Grove (semillon), Cowra, during 1993/94.

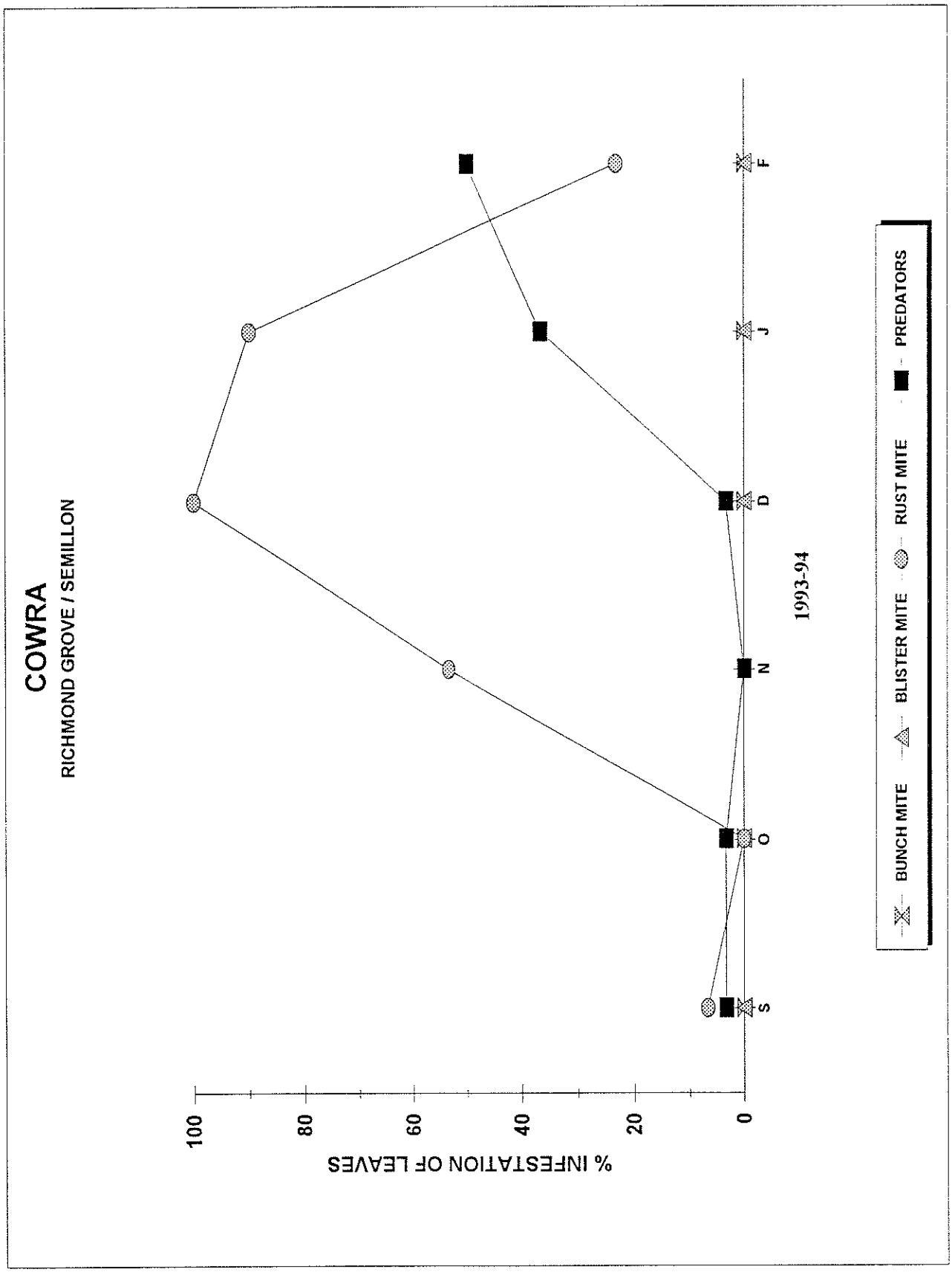
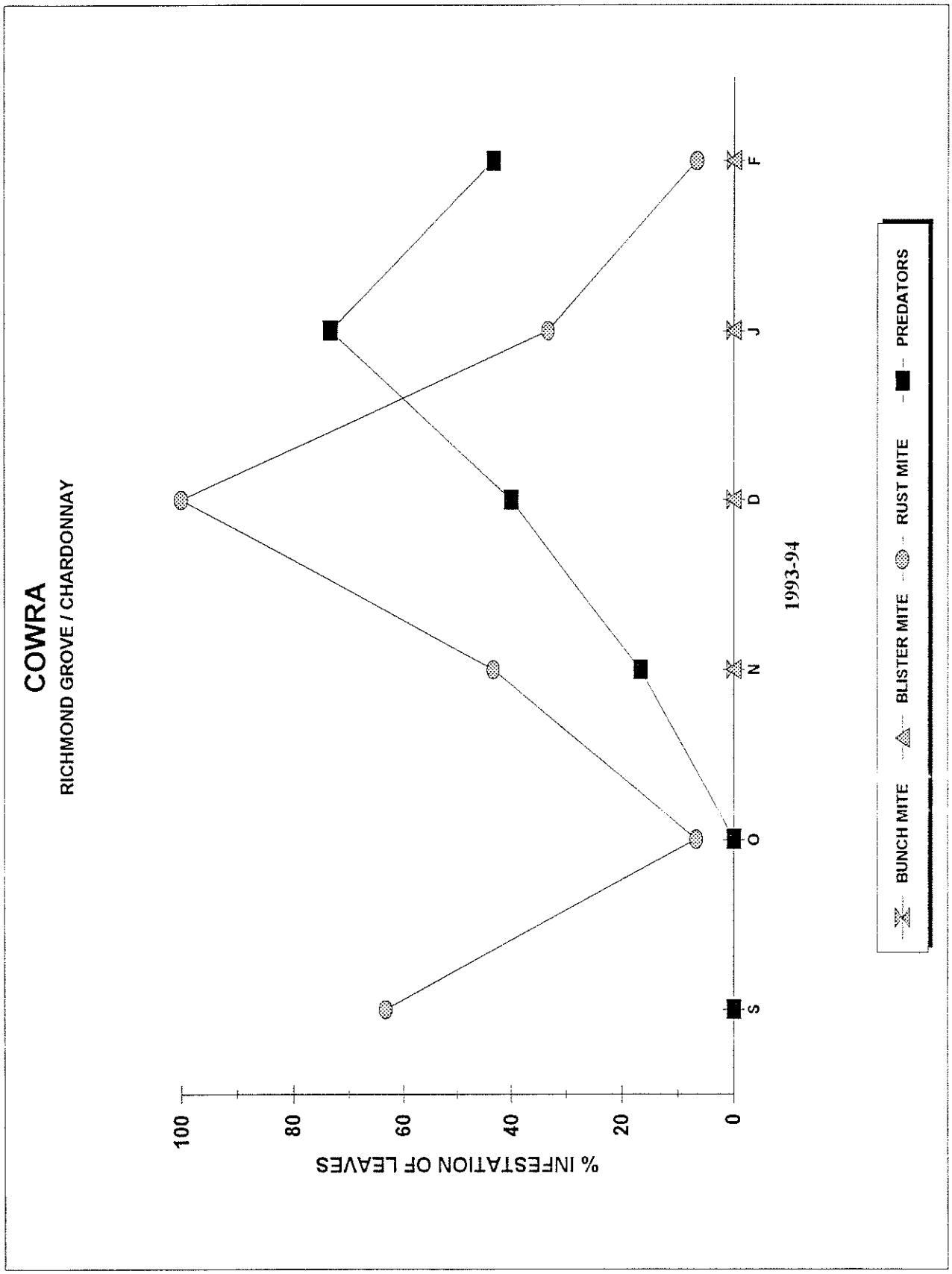


Figure 12. Pest and predatory mite populations at Richmond Grove (Chardonnay), Cowra, during 1993/94



## 4) SOUTHERN AND CENTRAL VICTORIA

(a) Great Western

Three blocks from 3 vineyards in the Great Western district were sampled (Montara Vineyards, Ondec, 3 km south of Ararat; Best's Vineyards, mixed varieties, 9 km north of Ararat; Seppelt Great Western, Shiraz, 8 km north of Ararat). The Montara and Seppelt blocks were sampled only in 1993/94, whilst the block at Best's was sampled for the three seasons 1993/96.

Pest and predatory mite population data for these blocks are given in Figures 13-17 and Table 6.

**Table 6. Predatory mite species incidence in Great Western sampling 1993-96.**

| VICTORIA 1993-94 | | | SPECIES % | |
|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *T. doreenae* |
| Great Western | Seppelts | 76 | 100 | |
| | Best's | 124 | 100 | |
| | Montara | 130 | 100 | |
| Great Western | Best's 1994/95 | 34 | 82.4 | 17.6 |
| | 1995/96 | 119 | 100 | |

In 1993/94 good predator populations (*Typhlodromus dossei*) occurred at all sites, particularly during December to April at Best's and Montara (Figs. 14-15). Rust mite was the principal pest mite at all sites but was controlled very well by *T. dossei* at Best's, only reaching a maximum infestation rate of 20% in January. Predator occupancy of leaves at this time was around 60-70%. Rust mites were less well controlled at the other 2 sites climbing to nearly 100% infestation in February. However, in both cases *T. dossei* eventually exerted enough regulatory pressure to bring rust mite populations down to low levels by the end of the season.

The pesticide spray program was fairly moderate and appeared to have little impact on predator populations. In particular, phosphorus acid, wettable sulphur, mancozeb and triadimenol used during December-January at Best's did not interfere with population development of *T. dossei*. Blister mite was a minor problem at both Best's and Montara early in the season which may have aided development of *T. dossei* populations. The relatively late appearance of *T. dossei* at Montara may have been caused by use of the insecticide, carbaryl which was used 3 times during November-January, the last being on 16 January.

Figure 13. Pest and predatory mite populations at Seppelts, Ararat, Central Victoria, during 1993/94.

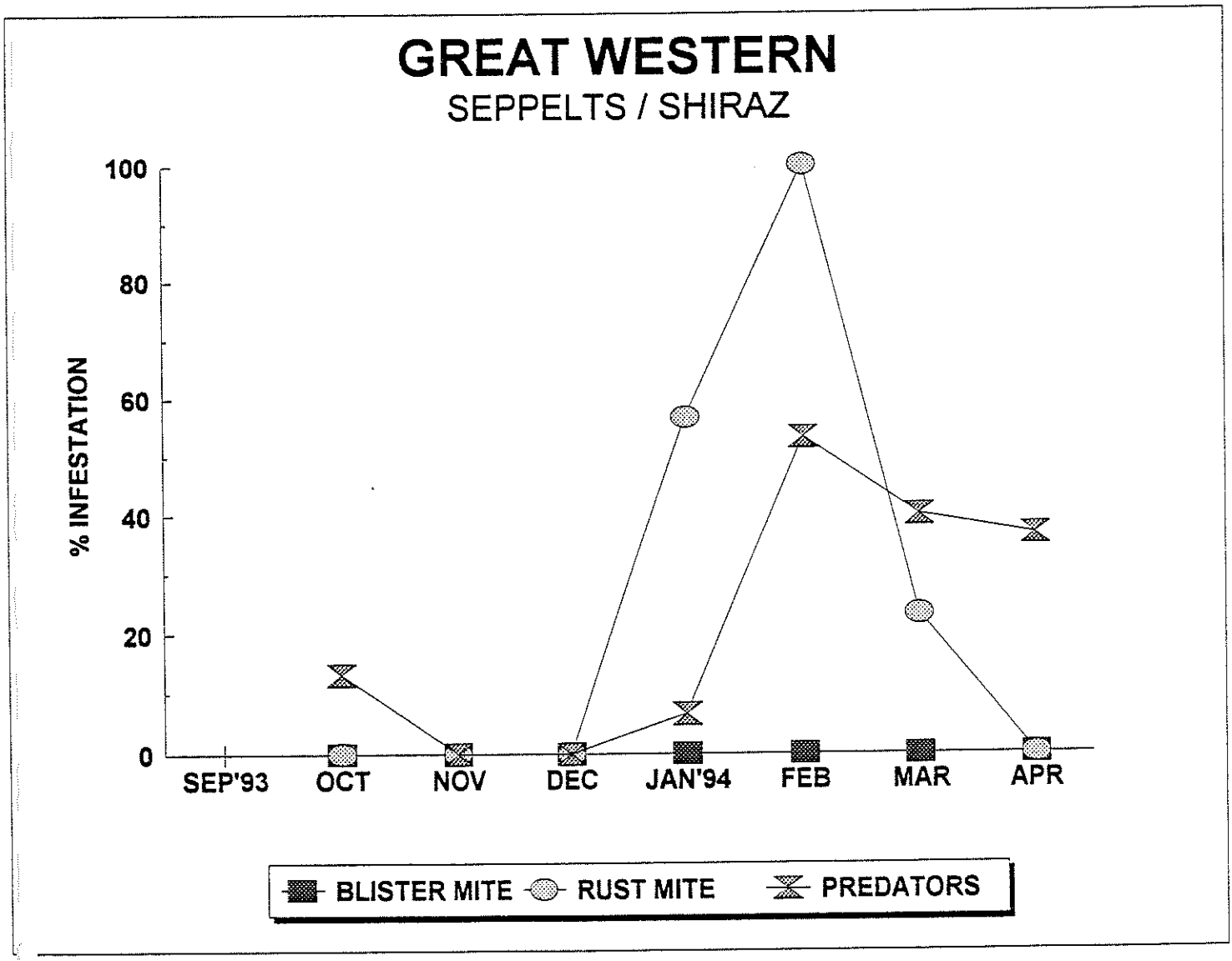


Figure 14. Pest and predatory mite populations at Montara, Ararat, Central Victoria, during 1993/94.

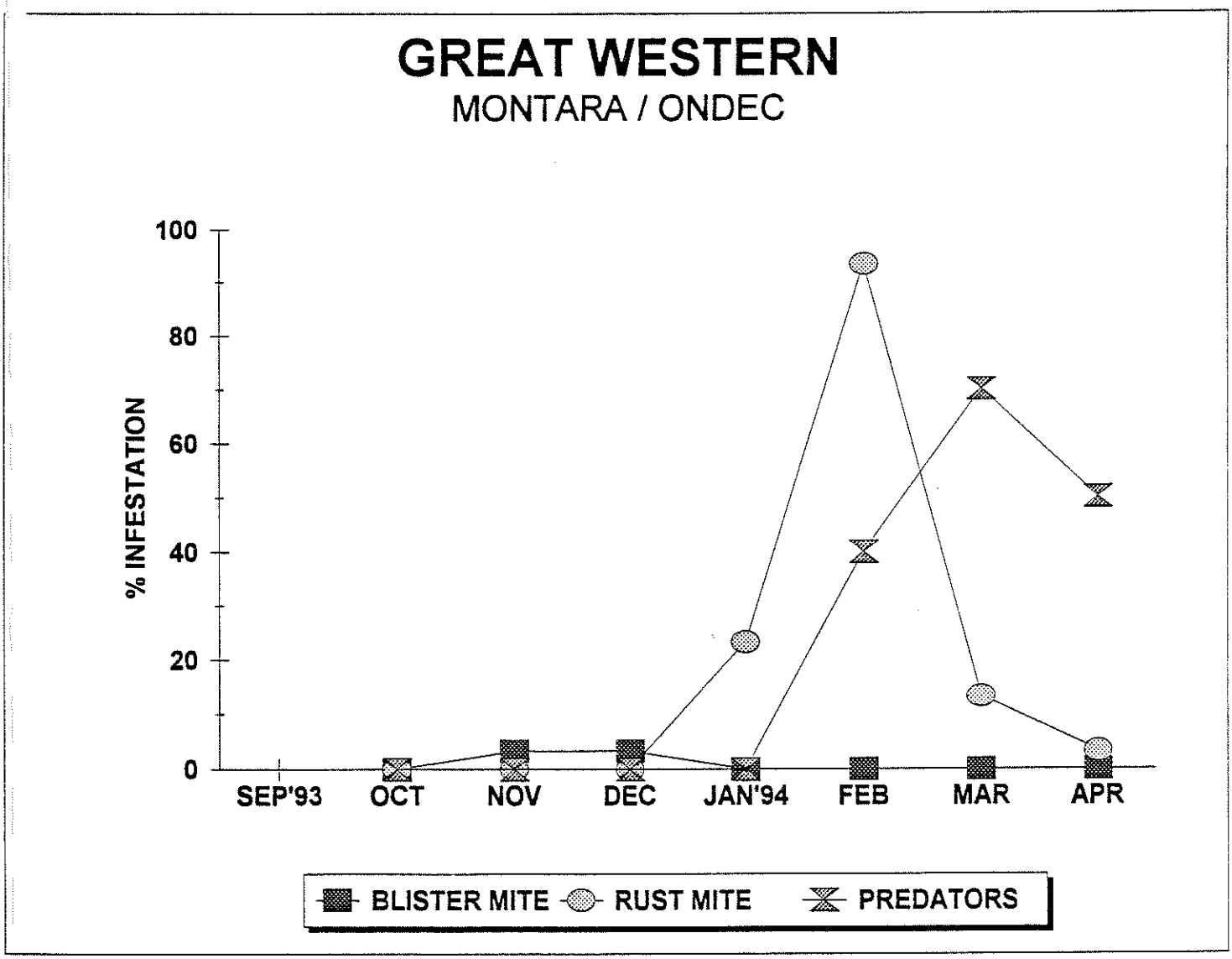


Figure 15. Pest and predatory mite populations at Best's, Ararat, Central Victoria, during 1993/96.

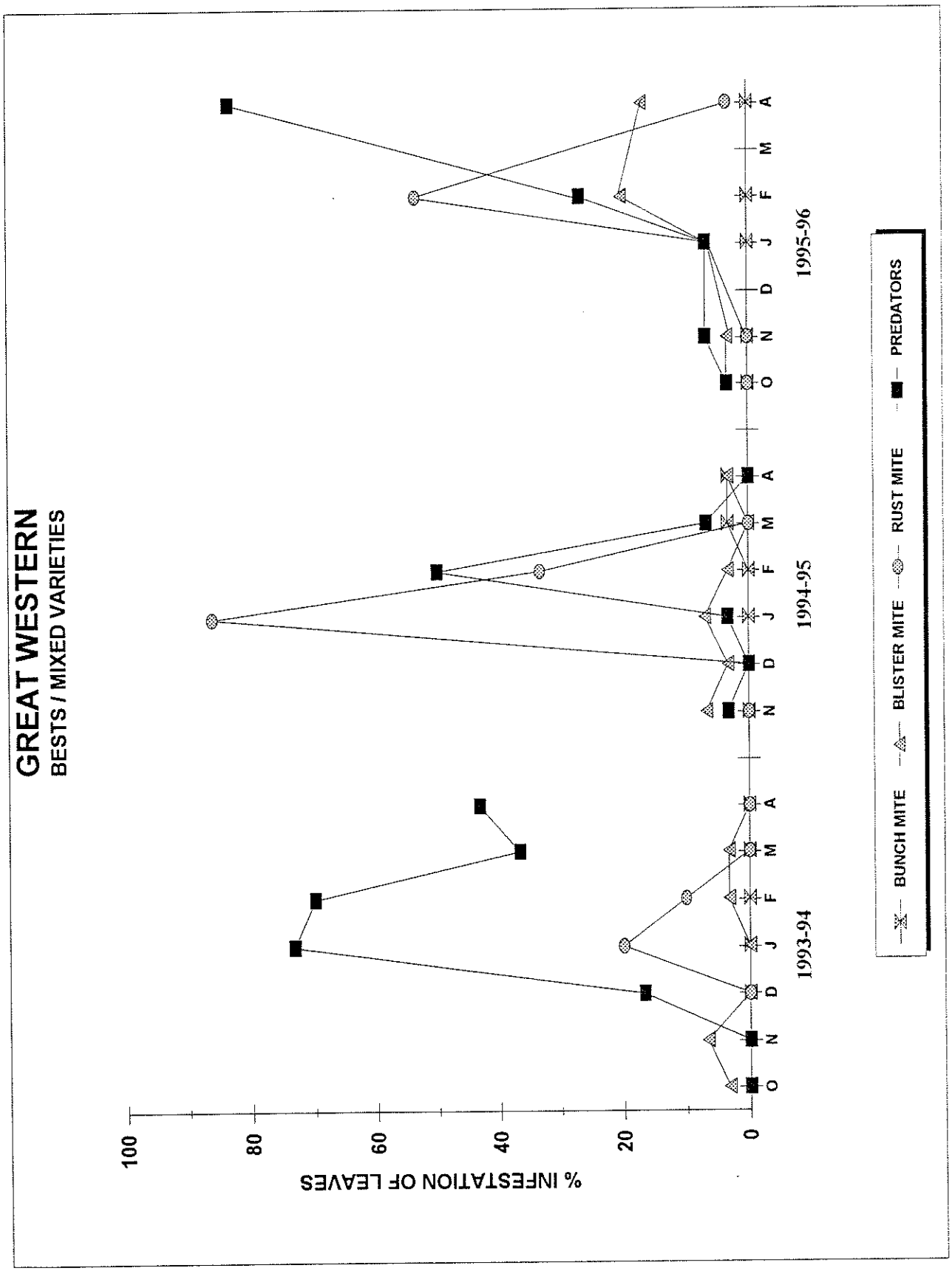


Figure 16. Predator species percentages at Best's, Ararat, Central Victoria during 1994/95.

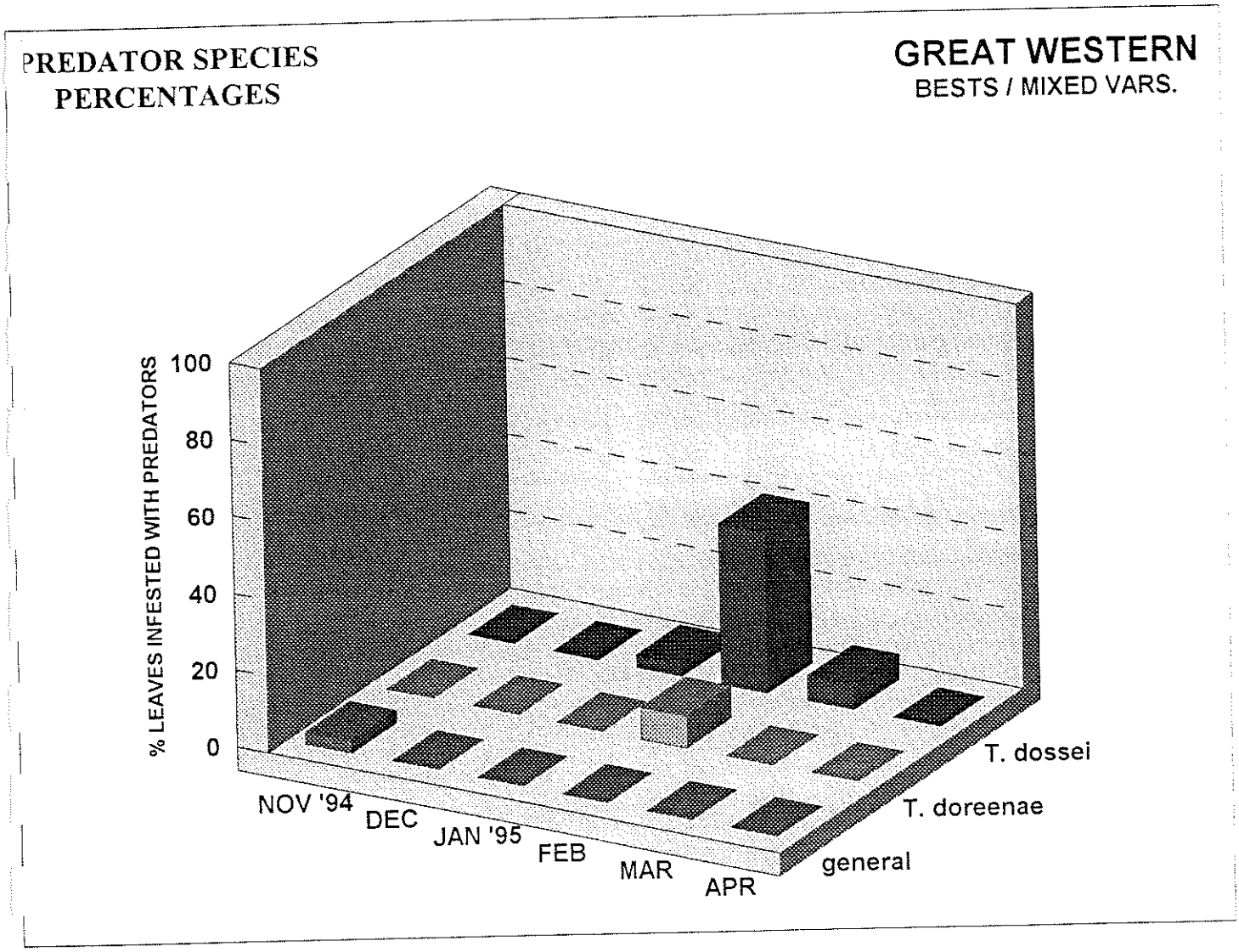
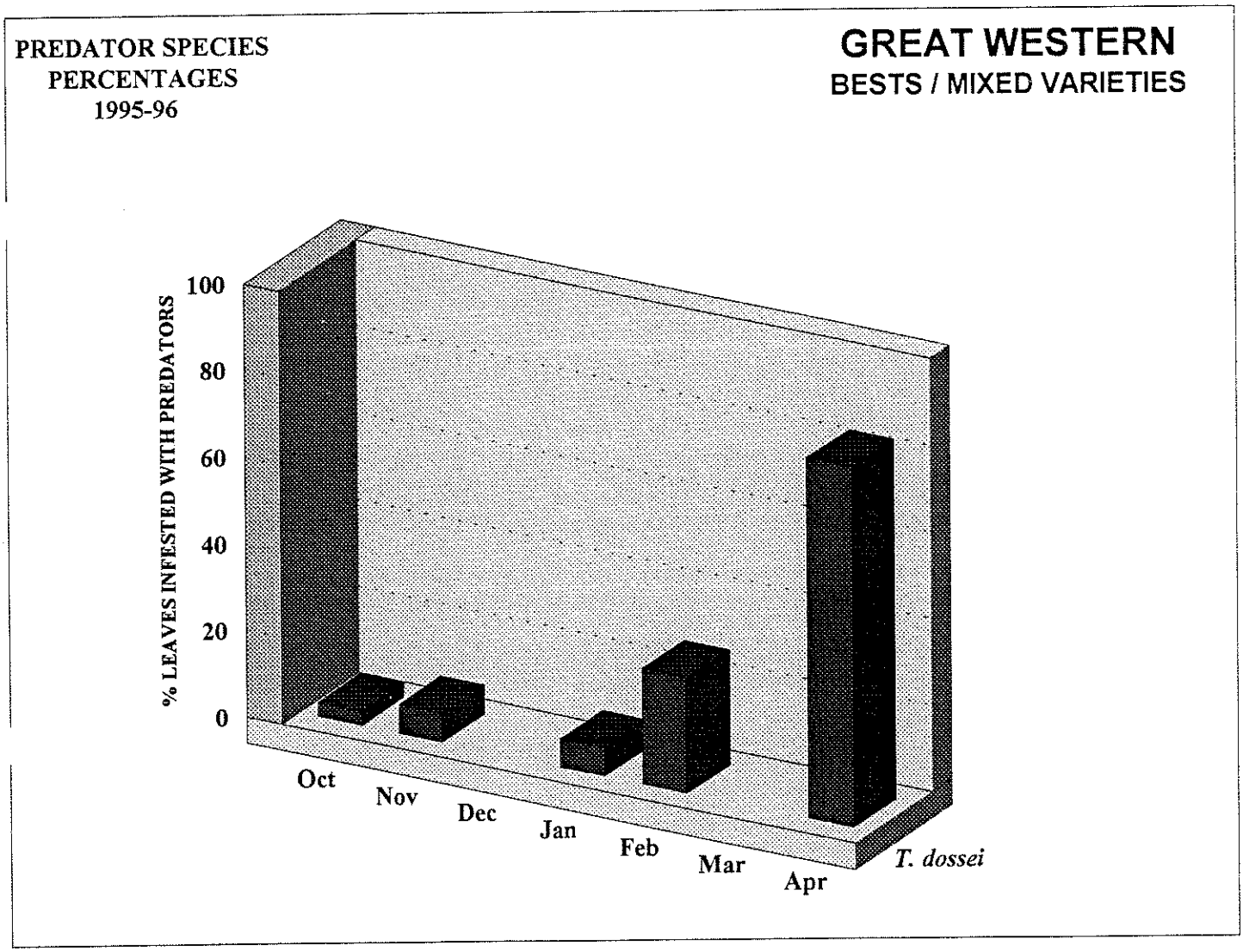


Figure 18. Predator species percentages at Best's, Ararat, Central Victoria, during 1995/96.



In 1994/95, lower overall numbers of *T. dossei* were recorded and there was a significant but short-lived outbreak of rust mites in January. However, the predators had this outbreak under control by the following month. Interestingly, a small number of individuals of *T. doreenae* were also recorded late in the season. In 1995/96 larger numbers of predators (all *T. dossei*) occurred with over 80% infestation of leaves by the end of the season. The mid season outbreak of rust mite was more rapidly brought under control, although blister mites were fairly common late in the season.
Vineyards in the Great Western region appear to be characterised by a good phytoseiid fauna, dominated by *T. dossei*. Relatively low pesticide inputs based on generally predator-friendly materials like phosphorus acid, copper and wettable sulphur encourage predator populations and biological control.

## RECOMMENDATIONS

Vineyards in the Great Western region appear to be suitable for the natural control of grapevine mites if chemical inputs are carefully controlled. *T. dossei* was by far the most dominant phytoseiid in the vineyards sampled, with a few individuals of *T. doreenae* being the only other phytoseiid encountered. Dominance by a single or very small number of phytoseiid species is considered to indicate a stable ecosystem. Thus, the vineyards examined appear to be little disrupted by pesticides. Most of the chemicals used in the studied vineyards were fairly 'soft' on *T. dossei* (see section G) and allowed good population development. An exception was the insecticide carbaryl which appeared to disrupt biological control of mites at Montara.

*T. dossei* does appear to be slow to increase populations during spring. This species overwinters on vines and its poor population growth may be caused by poor overwintering survival.

It is recommended that chemical inputs are minimised as much as possible and based on known predator-friendly materials. It is possible that *T. doreenae* may eventually become better established in this region and therefore provide improved biological control. Alternatively, this species could be introduced into this region.

(b) Geelong

Three blocks from 3 vineyards in the Geelong district were sampled (Mount Anakie Estate, Cabernet Sauvignon, 30 km north of Geelong; Mount Duneed Winery, Shiraz, 10 km south of Geelong; Prince Albert Vineyard, Pinot Noir, 10 km south west of Geelong). The Prince Albert block was sampled in 1993/94 only, Mount Duneed in 1993/94 and 1994/95 and Mount Anakie in all 3 seasons 1993/96.

Pest and predatory mite population data for these blocks are given in Figures 18-24 and Table 7.

Large populations of predatory mites were characteristic of these sites from mid-season onwards, providing good late season control of rust and blister mites. Rust mite

**Table 7. Predatory mite species incidence in Geelong sampling 1993-96.**

| VICTORIA 1993-94 | | | SPECIES PERCENTAGES | | | | |
|---|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *T. doreenae* | *T. transvaalensis* | *P. persimilis* | undescribed sp. |
| Geelong | Prince Alberts | 97 | 92.6 | | | 7.4 | |
| | Mt Duneed | 462 | 99.8 | | 0.2 | | |
| | Anakie | 93 | 36.8 | 63.2 | | | |
| **1994-95** | | | | | | | |
| Geelong | Mt Duneed | 481 | 92.8 | | | | 7.2 |
| | Anakie | 101 | 43.3 | 55.7 | | | |
| **1995-96** | | | | | | | |
| Geelong | Anakie | 21 | 90.5 | 9.5 | | | |

populations generally reached a high level around December-January but were rapidly brought under control by predators. Total predator numbers in the season's samples were extremely high (460-480) at Mount Duneed during both seasons that this site was sampled. Excellent biological control of mites accompanied these high populations (Figs. 19-20). The dominant predator species was *T. dossei* at all sites except Anakie in 1993/94 and 1994/95 when *T. doreenae* was dominant. Small numbers of *Phytoseiulus persimilis, Typhlodromus transvaalensis* and an undescribed species were also recorded at Prince Albert and Mount Duneed.

Pesticide use was moderate in these vineyards and may have contributed to the generally late appearance of predators each season. Lime sulphur (lethal to predators) was used early in the season in 1993/94 which may have caused the appearance of predators to be delayed until February/March. It was also used as an early season spray at Anakie each year, although in this case, predators did appear by January. Removal of lime sulphur from the spray program at Anakie would probably result in an earlier seasonal appearance of predators and greater total numbers (like those recorded at Mount Duneed).

RECOMMENDATIONS

Good biological control of mites should be achievable in vineyards in this region, providing pesticide inputs are kept to a minimum. Disease control should be based on sulphur, copper and/or phosphorus acid where possible and the number of applications kept to a minimum. Lime sulphur should not be used, nor broad spectrum insecticides like chlorpyrifos and carbaryl. The two predator species, *T. dossei* and *T.doreenae* appear to be resident in this region although more widespread studies are required to determine which species is the most abundant.

Figure 18. Pest and predatory mite populations at Prince Albert, Geelong, Southern Victoria, during 1993/94.

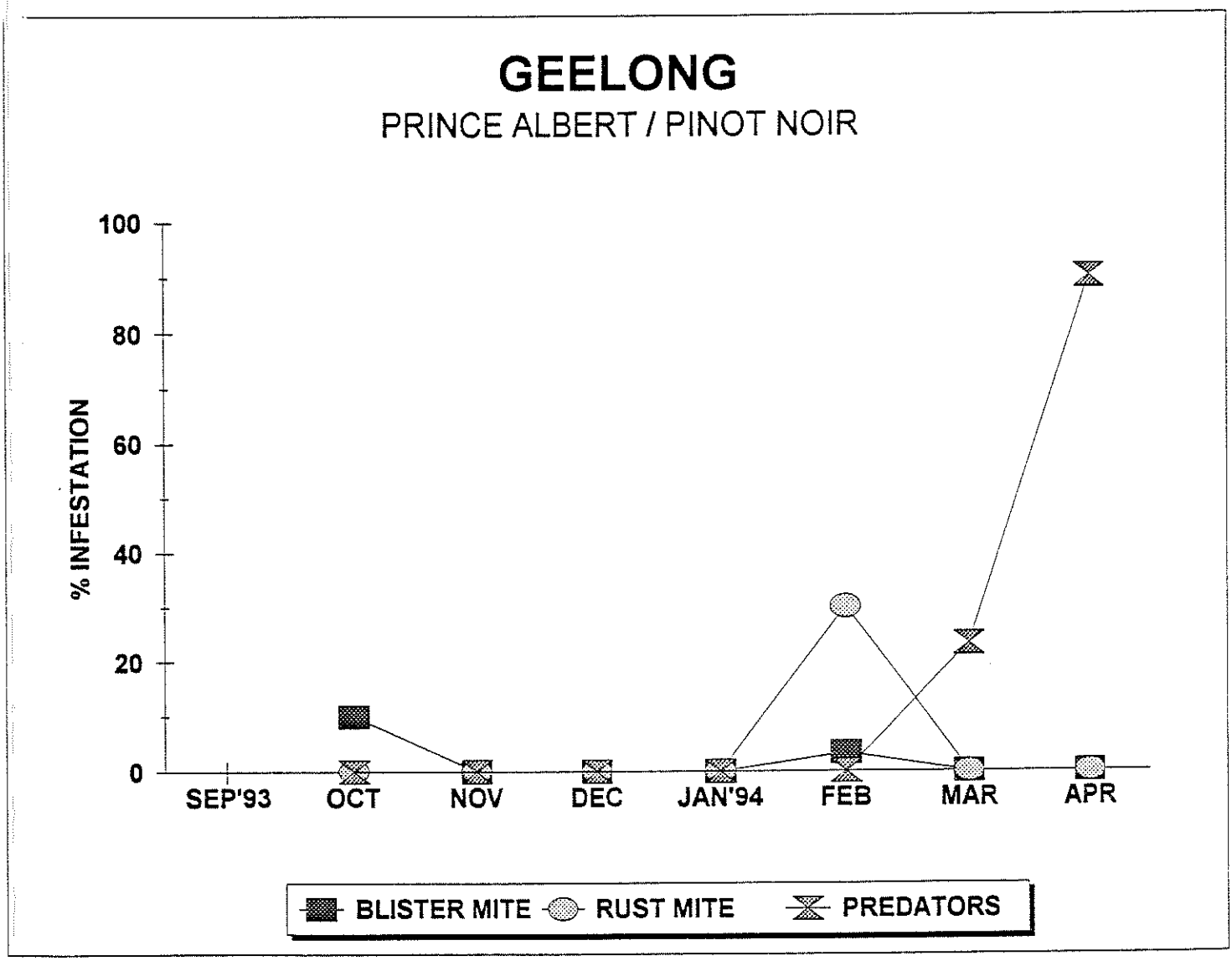


Figure 19. Pest and predatory mite populations at Mount Duneed, Geelong, Southern Victoria, during 1993/94.

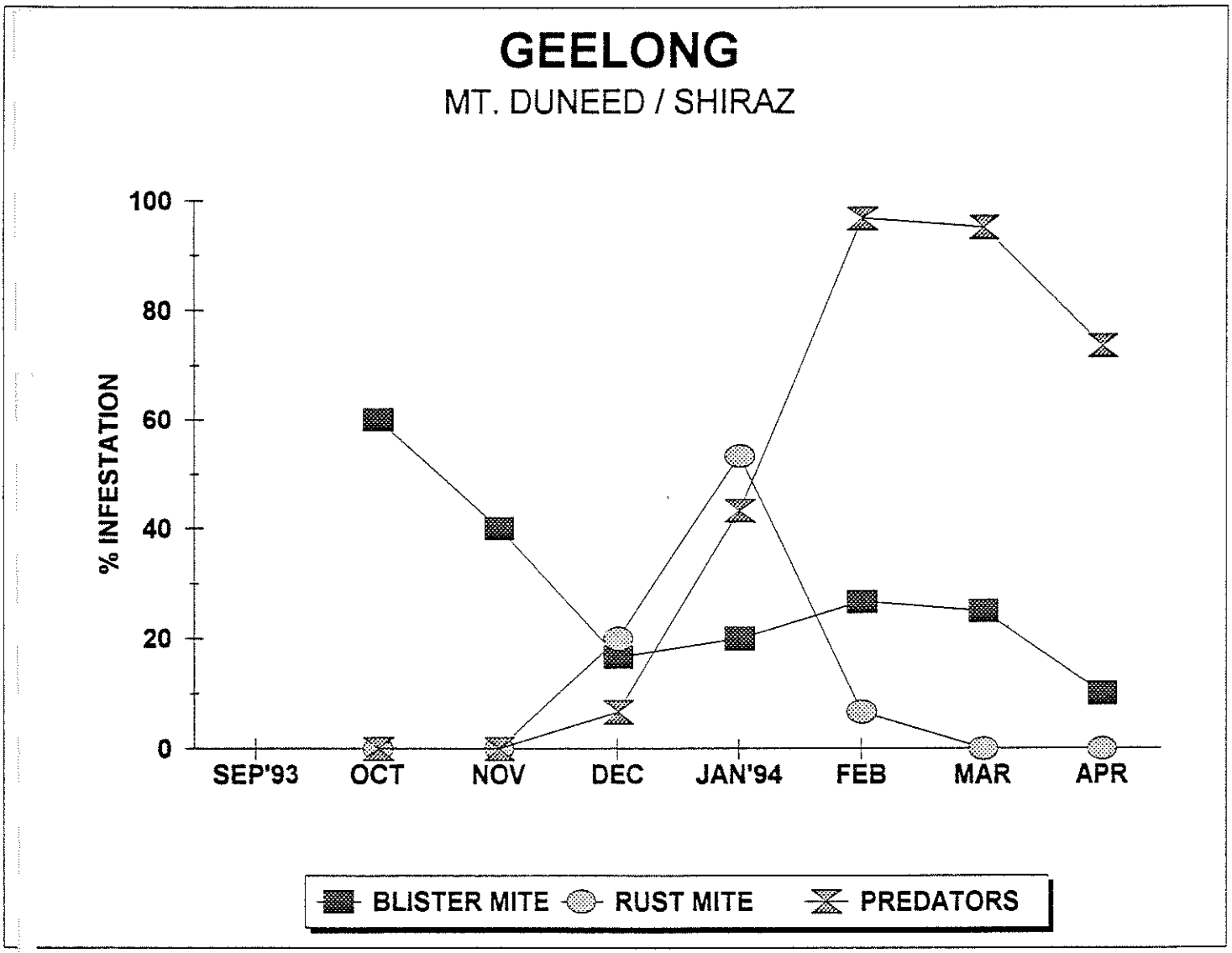


Figure 20. Pest and predatory mite populations at Mount Duneed, Geelong, Southern Victoria, during 1994/95.

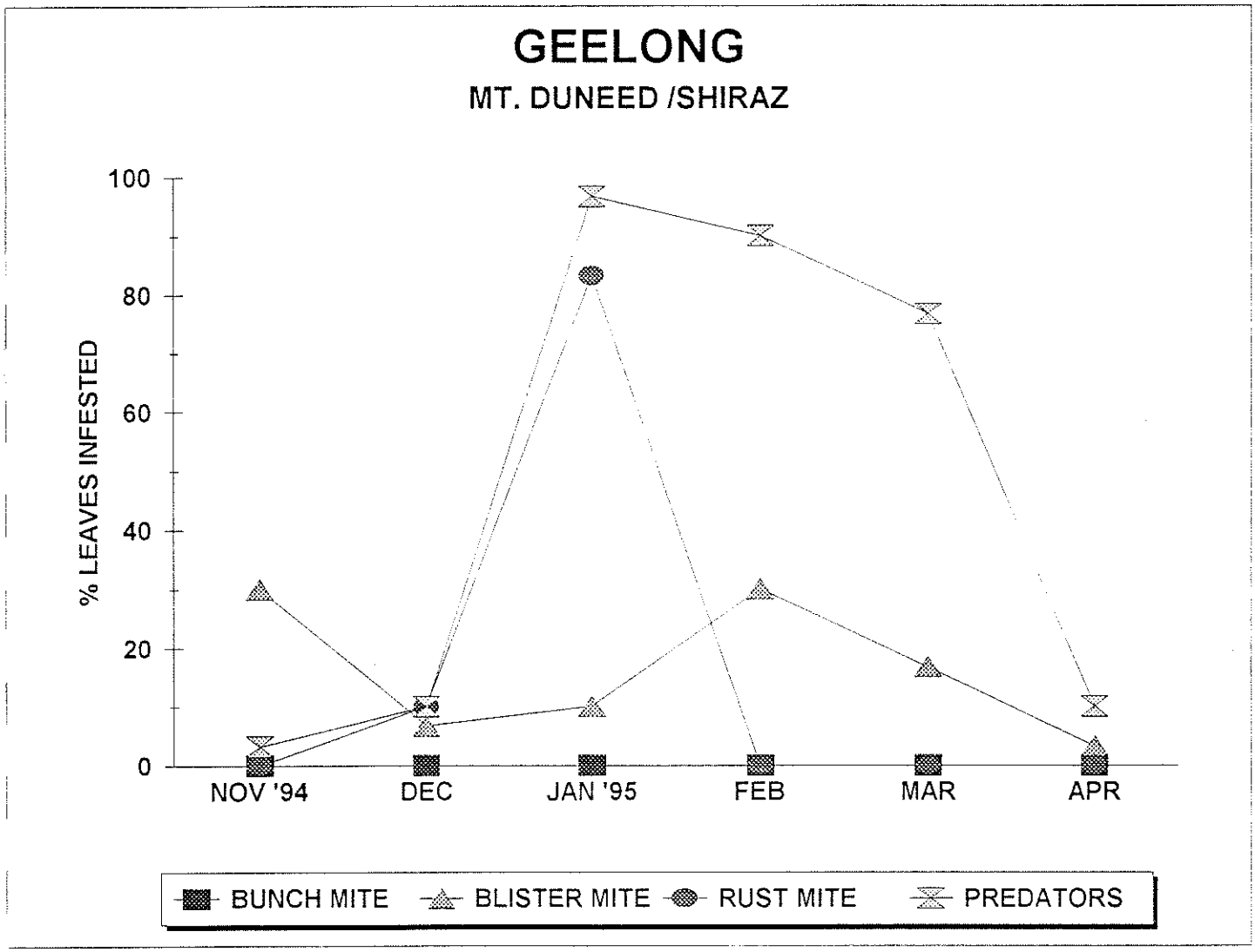


Figure 21. Pest and predatory mite populations at Anakie, Geelong, Southern Victoria, during 1993/96.

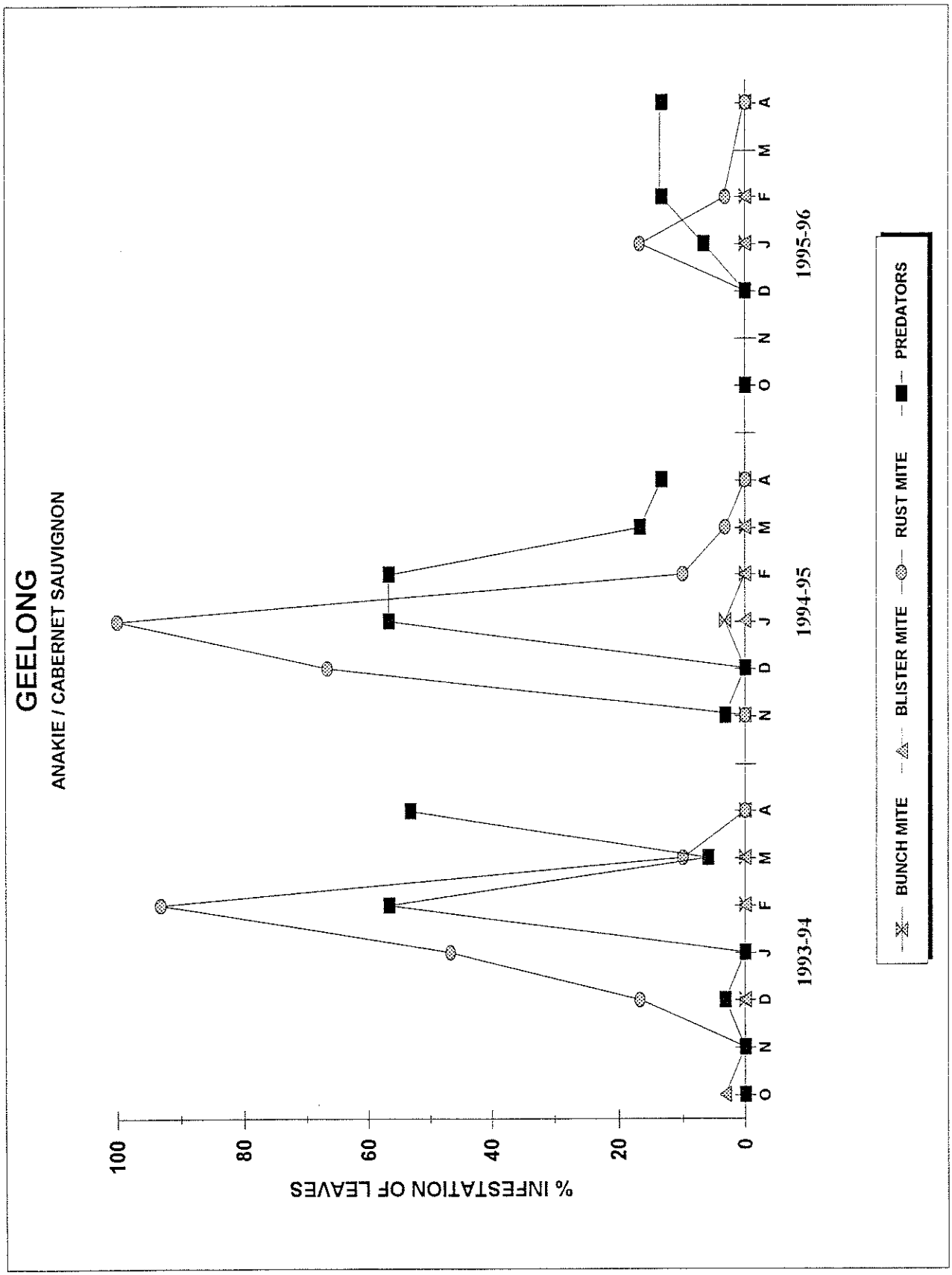


Figure 22. Predator species percentages at Anakie, Geelong, Southern Victoria, during 1994/95.

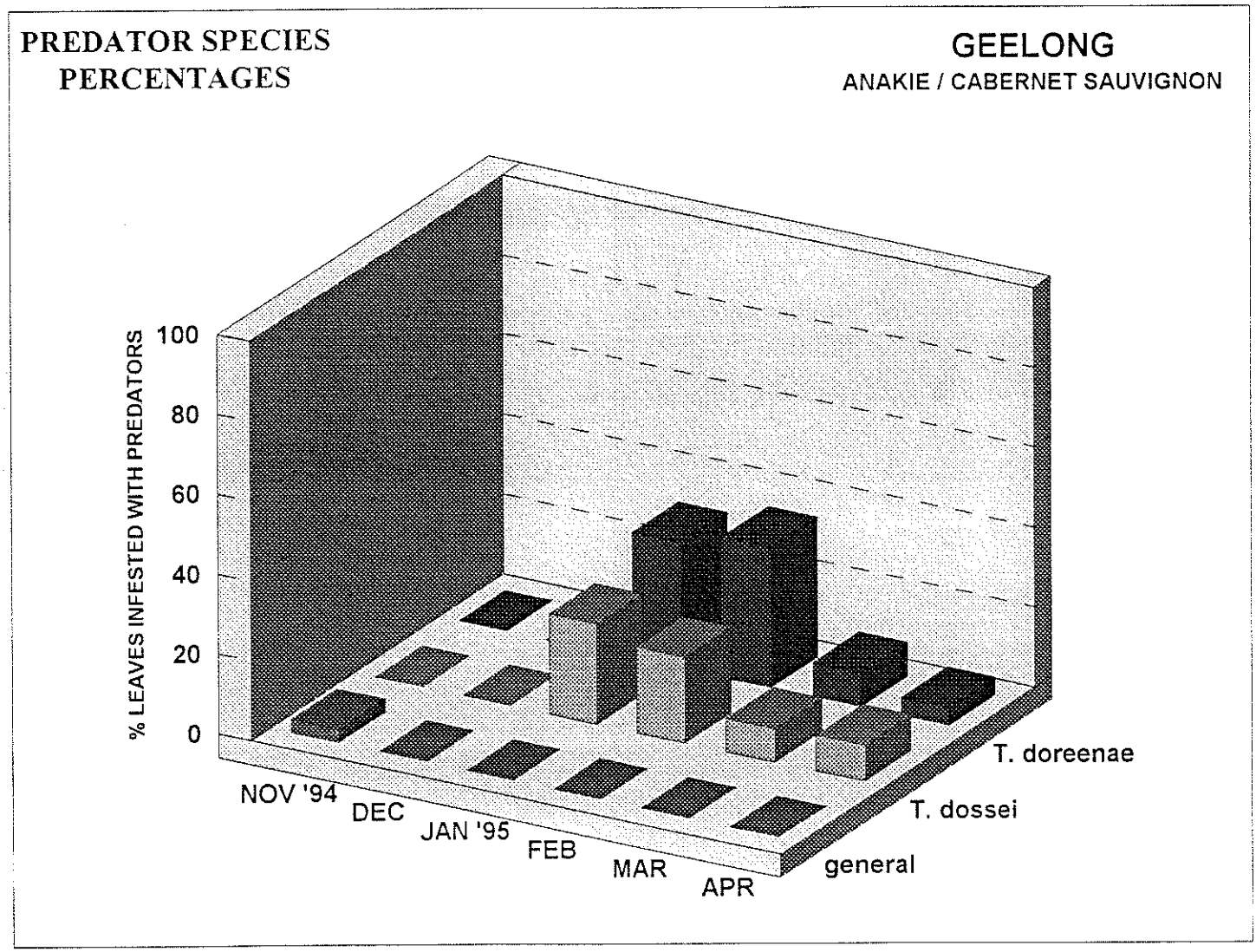


Figure 23. Predator species percentages at Anakie, Geelong, Southern Victoria, during 1995/96.

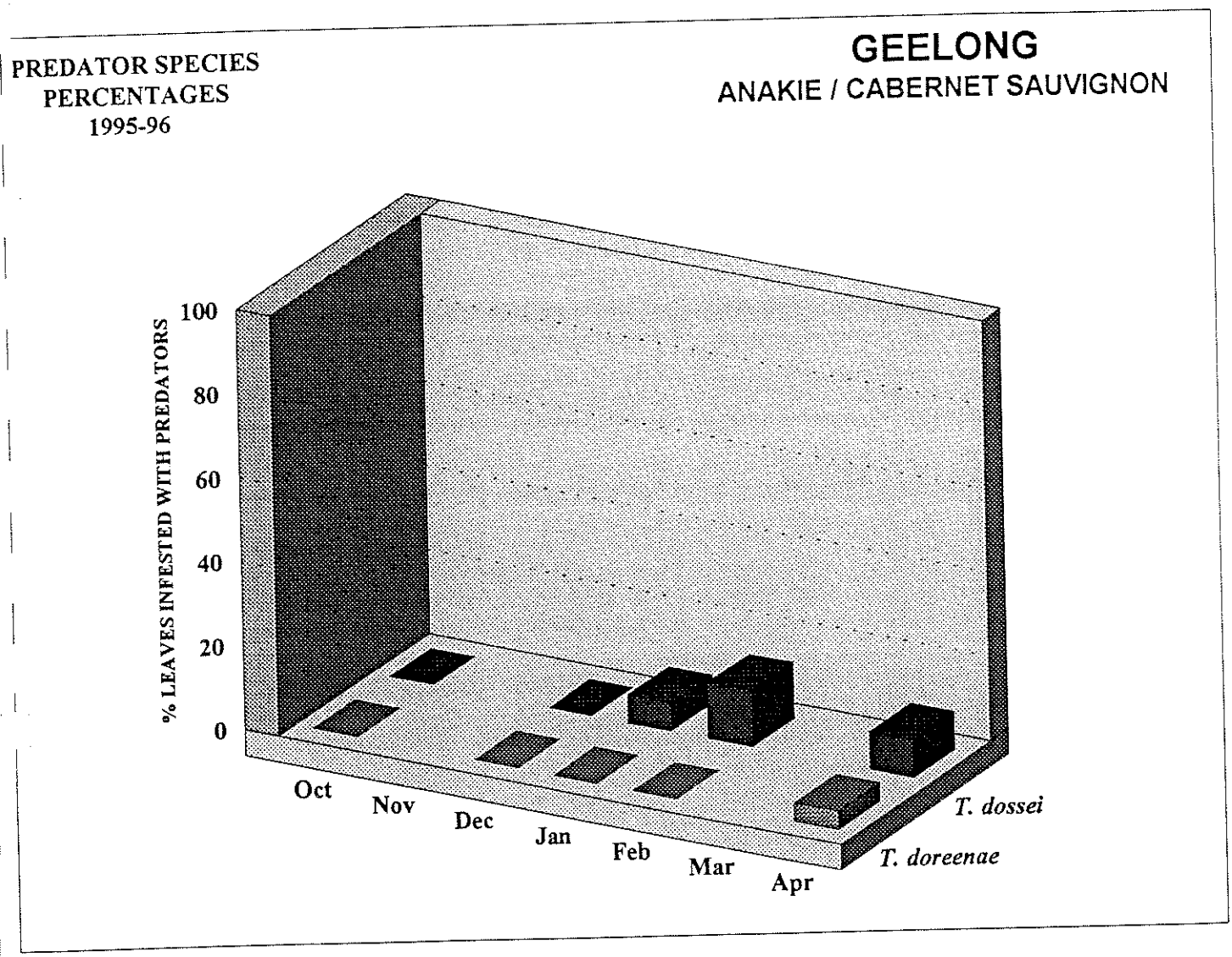
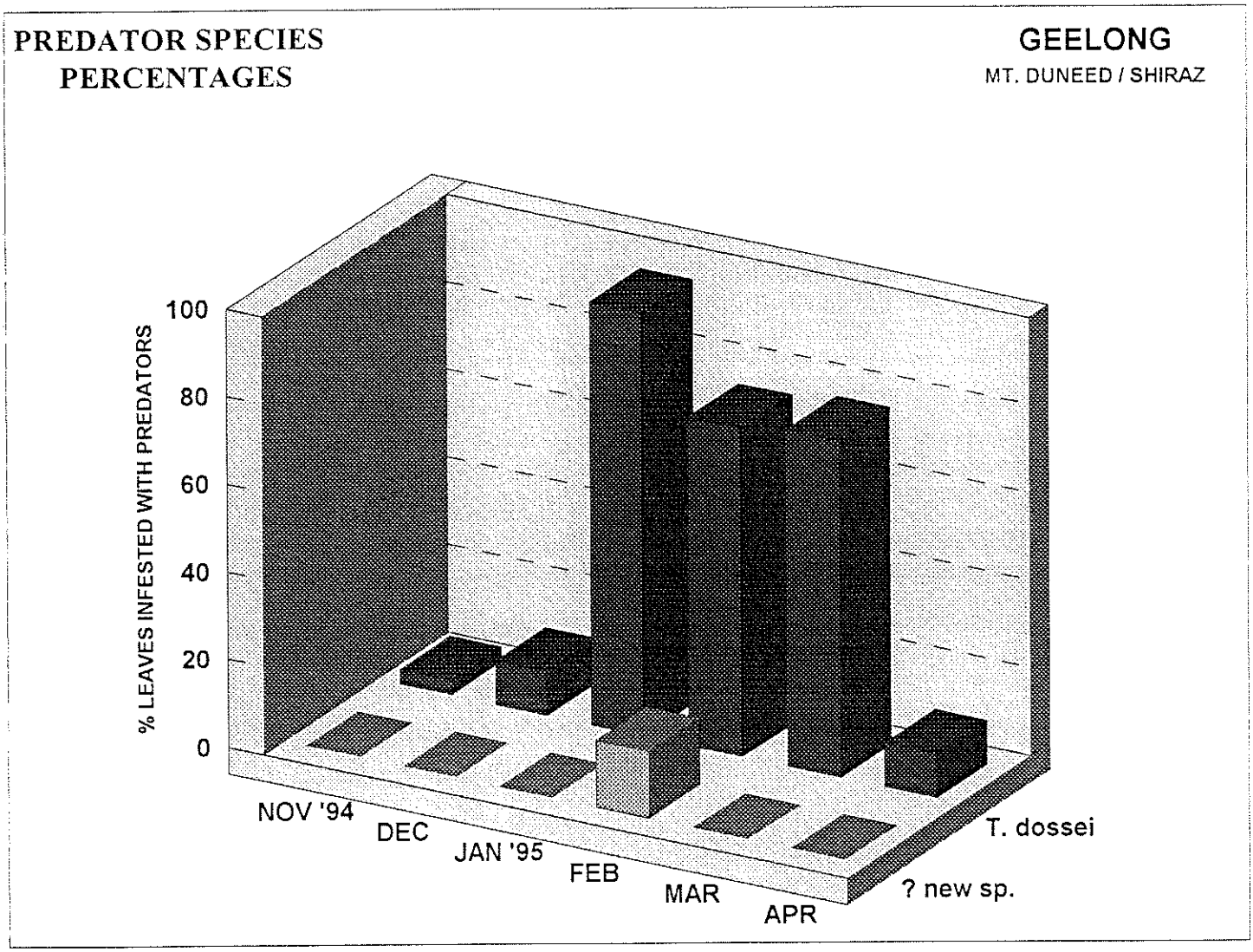


Figure 24. Predator species percentages at Mount Duneed, Geelong, Southern Victoria during 1994/95.



c) Yarra Valley
Three blocks from 3 vineyards were sampled in this region during 1993/94 (Mt Mary, Chardonnay, 5 km north of Lilydale; Hoddles Creek, Pinot Noir, 30 km south east of Lilydale; Lilydale, Chardonnay, 10 km east of Lilydale) and the latter 2 also in 1994/95.

Pest and predatory mite population data are presented in Figures 25-29 and Table 8.

**Table 8. Predatory mite species incidence in Yarra Valley sampling 1993/95**

| VICTORIA 1993-94 | | SPECIES PERCENTAGES | | |
|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | undescribed sp. |
| Yarra Valley | Mt Mary | NIL | | |
| | Hoddles Creek | NIL | | |
| | Lilydale | 19 | 94.7 | 5.3 |
| **1994-95** | | | | |
| Yarra Valley | Hoddles Creek | NIL | | |
| | Lilydale | 4 | 100 | |

These sites stood in stark contrast to the other southern/central Victorian sites with very small or absent predatory mite and pest mite populations. This was undoubtedly due to the very high spray pressure (20-38 applications per season) and use of broad-spectrum materials like chlorpyrifos. As in all the regions studied, these sites were chosen for their 'relatively' low chemical input, thus only one of the three sites used chlorpyrifos (Hoddles Creek, 2-4 times a season). However, this chemical is in widespread use in the Yarra Valley district and has been for many years, principally to control light brown apple moth (LBAM). Consequently, there is likely to have been a 'district-wide' suppressive effect on predatory mite and pest mite populations, resulting in only small populations developing even in specific vineyards like Mt Mary and Lilydale which attempt to control LBAM using non-disruptive materials. The persistent use of broad-spectrum insecticides in this region has resulted in outbreaks in some vineyards, of two-spotted spider mites as an induced pest.

The only predators were recorded at Lilydale (19 in 1993/94 and 4 in 1994/95); the majority were *T. dossei* with a few individuals of an undescribed species.

**RECOMMENDATIONS**
There is no prospect of biological mite control occurring in vineyards in the Yarra Valley until the use of non-disruptive insecticides (like *Bacillus thuringiensis* and the new insect growth regulator, tebufenozide) replaces predator-hostile sprays like chlorpyrifos. However, rust and blister mites are not a major problem in this region probably because they are being controlled by the broad spectrum insecticides. *T. dossei* is likely to be the major predator species on vines in this region once insecticide pressure is reduced or

Figure 25. Sampling results for Mount Mary, Yarra Valley, Southern Victoria, during 1993/94.

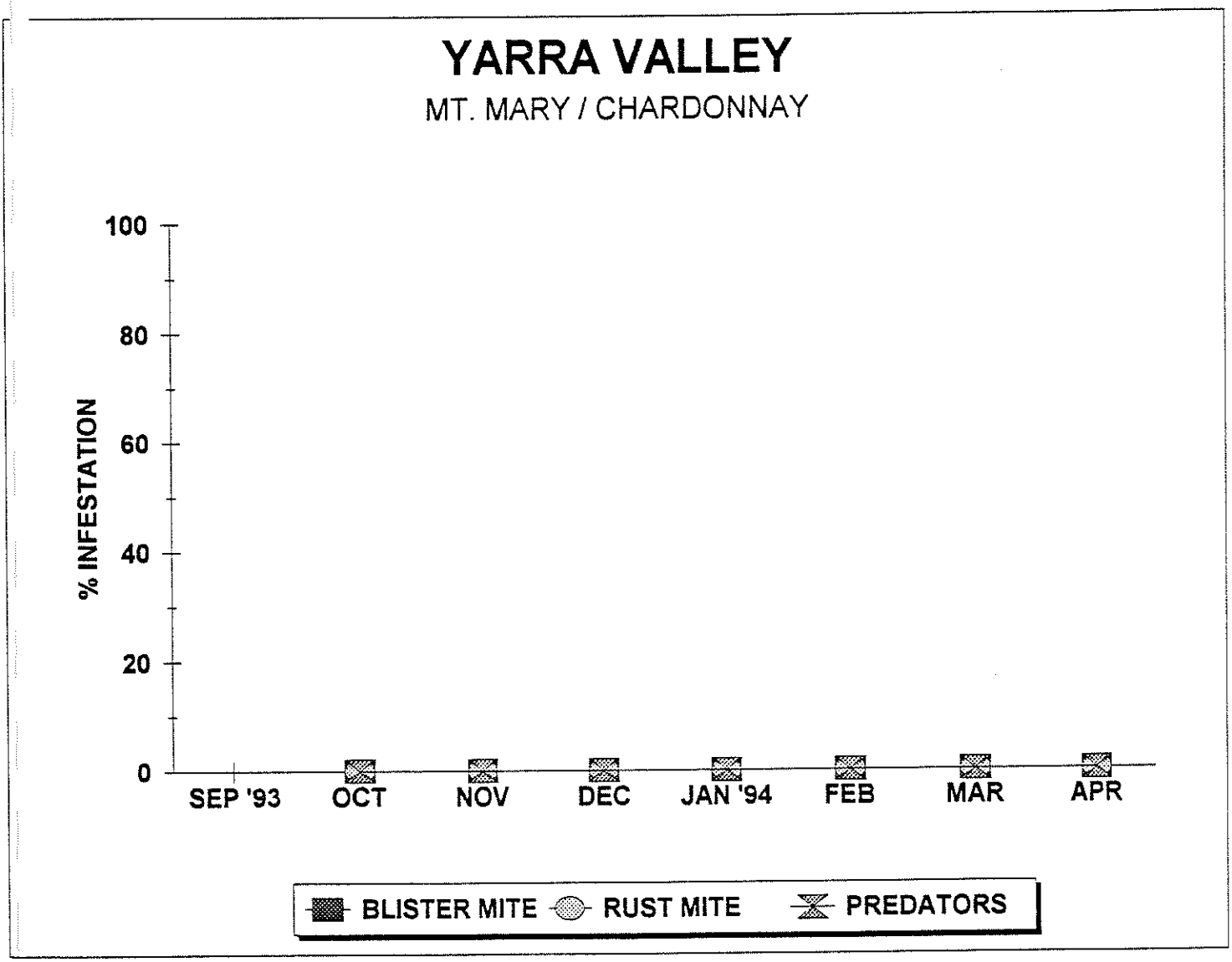


Figure 26. Sampling results for Hoddles Creek, Yarra Valley, Southern Victoria, during 1993/94.

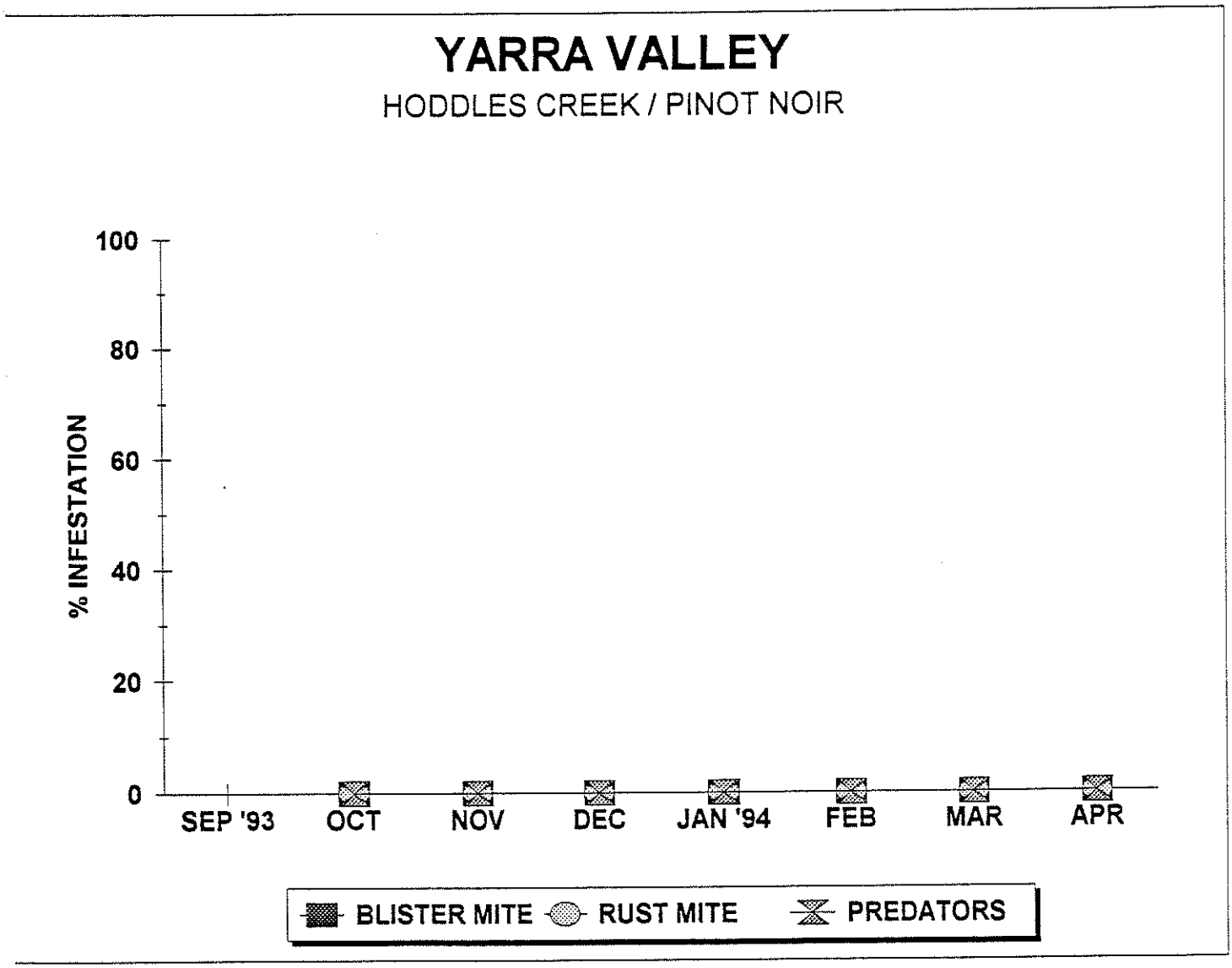


Figure 27. Pest and predatory mite populations at Lillydale, Yarra Valley, southern Victoria during 1993/95.

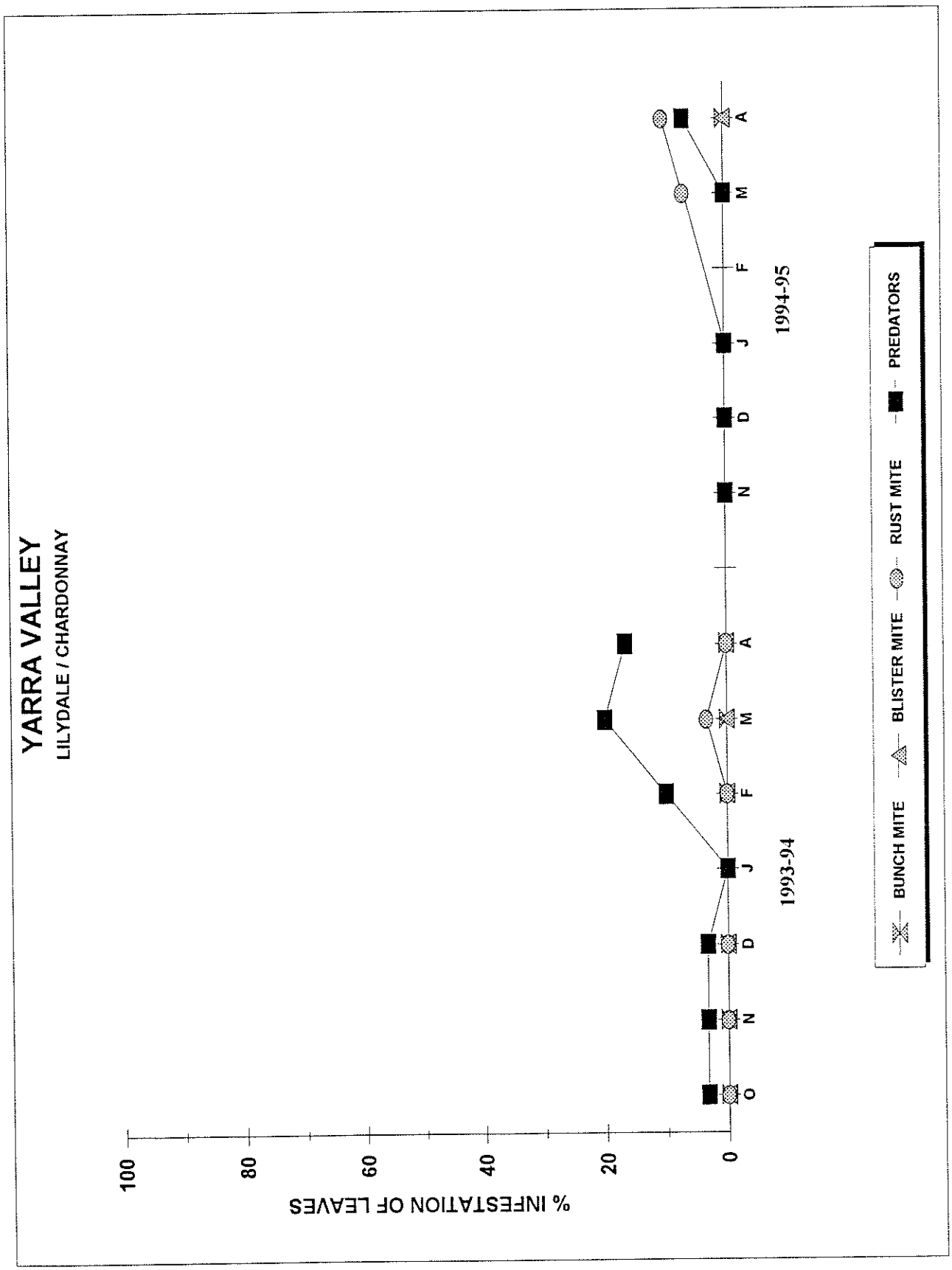


Figure 28. Sampling results for Hoddles Creek, Yarra Valley, southern Victoria during 1994/95.

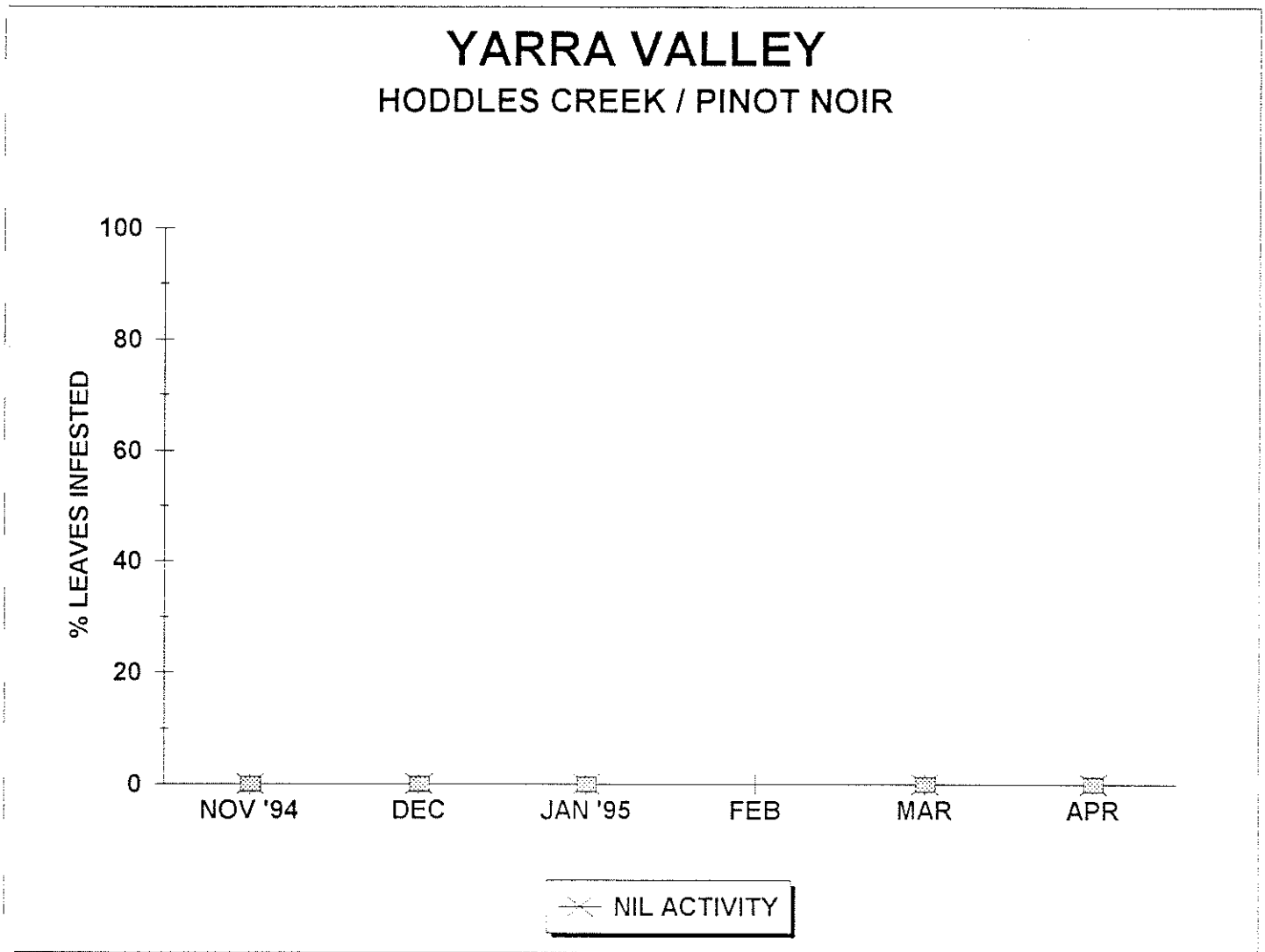
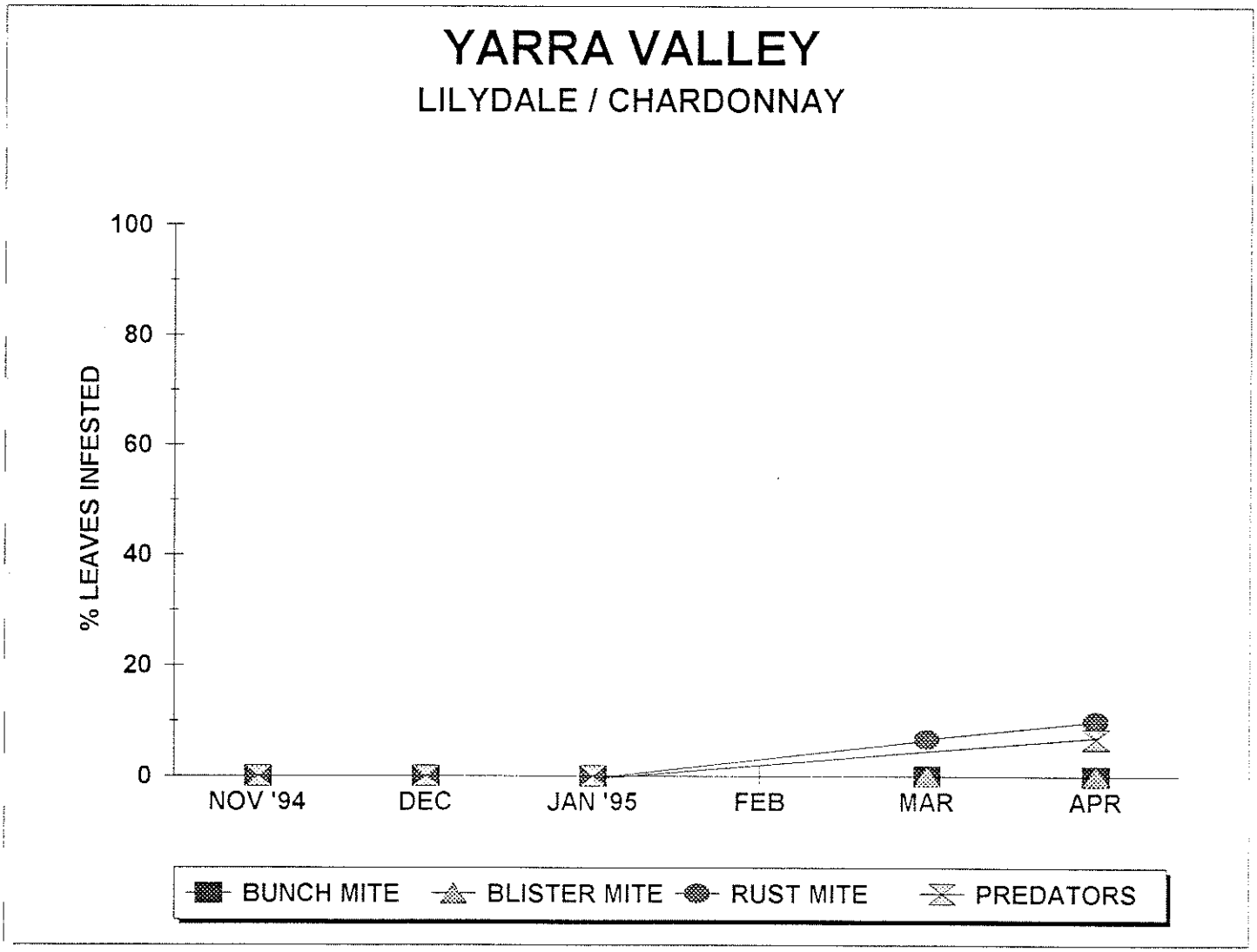


Figure 29. Pest and predatory mite populations at Lilydale, Yarra Valley, southern Victoria during 1994/95.



removed. Transition from chemical control of mites (as is occurring now) to biological control must be conducted cautiously and carefully as pest mite numbers may 'explode' before predators become fully established. The introduction of *T. doreenae* would be of value once broad spectrum insecticide inputs have been removed.

## 5) TASMANIA

(a) Tamar Valley (North Coast)

Two vine blocks in a single vineyard in this region (Legana [Rotherhythe], Cabernet Sauvignon, unsprayed/sprayed, 20 km north west of Launceston) were sampled in 1993/94.

Pest and predatory mite population data are shown in Figures 30-31 and Table 9.

Pest and predatory mite populations were small in both blocks. Curiously, more predators were recorded in the sprayed block (60) than in the unsprayed (3). The only sprays used in the sprayed block were wettable sulphur, copper and benomyl; the first two are known to be safe to *T. dossei* (see section G), the major predator species present and it is likely that benomyl is safe too. In the sprayed block *T. dossei* appeared to regulate developing populations of rust and blister mites from January onwards. A small rust mite population in the unsprayed block in January may have also been brought under control by predators.

### RECOMMENDATIONS

Although only based on data from a single site in a single season, it is reasonable to believe that the 'natural' vine mite situation in the Tamar Valley is likely to be characterised by small populations of pest mites and predatory mites (primarily *T. dossei*), occurring in a reasonable balance and presenting no significant economic problem. If pesticides are used excessively, or predator-harmful materials are used, then this balance will not occur.

(b) Coal River Valley (South Coast)

Two blocks in 2 vineyards in this region (Stoney Vineyard, Cabernet Sauvignon, 25 km north east of Hobart; Tolpuddle Vineyards, Chardonnay/Pinot Noir, 16 km north east of Hobart) were sampled in 1993/94.

Pest and predatory mite population data are shown in Figures 32-33 and Table 9.

Pest and predatory mite numbers were low in both vineyards although a reasonable population of predators (*T. dossei*) developed at Stoney Vineyard during January to April. In both vineyards it appeared that predators successfully regulated blister and rust mite populations. At Stoney Vineyard, this was despite 5 applications of fungicides and 2 applications of the miticide, dicofol during spring. The use of a miticide in October and November was clearly not warranted (< 20% infestation) and it is surprising that *T. dossei* only suffered a temporary setback in numbers (December).

Table 9. Predatory mite species incidence in Tasmania sampling in 1993/94.

| TASMANIA 1993-94 | | SPECIES PERCENTAGES | | |
|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *P. fotheringhamiae* |
| North Coast (Launceston) | Legana (unsprayed) | 3 | 67 | 33 |
| | Legana (sprayed) | 60 | 100 | |
| South Coast (Hobart) | Stoney Vineyard | 73 | 100 | |
| | Tolpuddle | 5 | 100 | |

## RECOMMENDATIONS

Similar to the northern grape growing area in Tasmania, the southern area appears to be characterised by low pest and predatory mite populations, thus good ecological balance. Again, it is important that this system remains relatively undisrupted by pesticides to preserve biological control of mites.

Figure 30. Pest and predatory mite populations at Legana (unsprayed), Tamar Valley, Tasmania, during 1993/94.

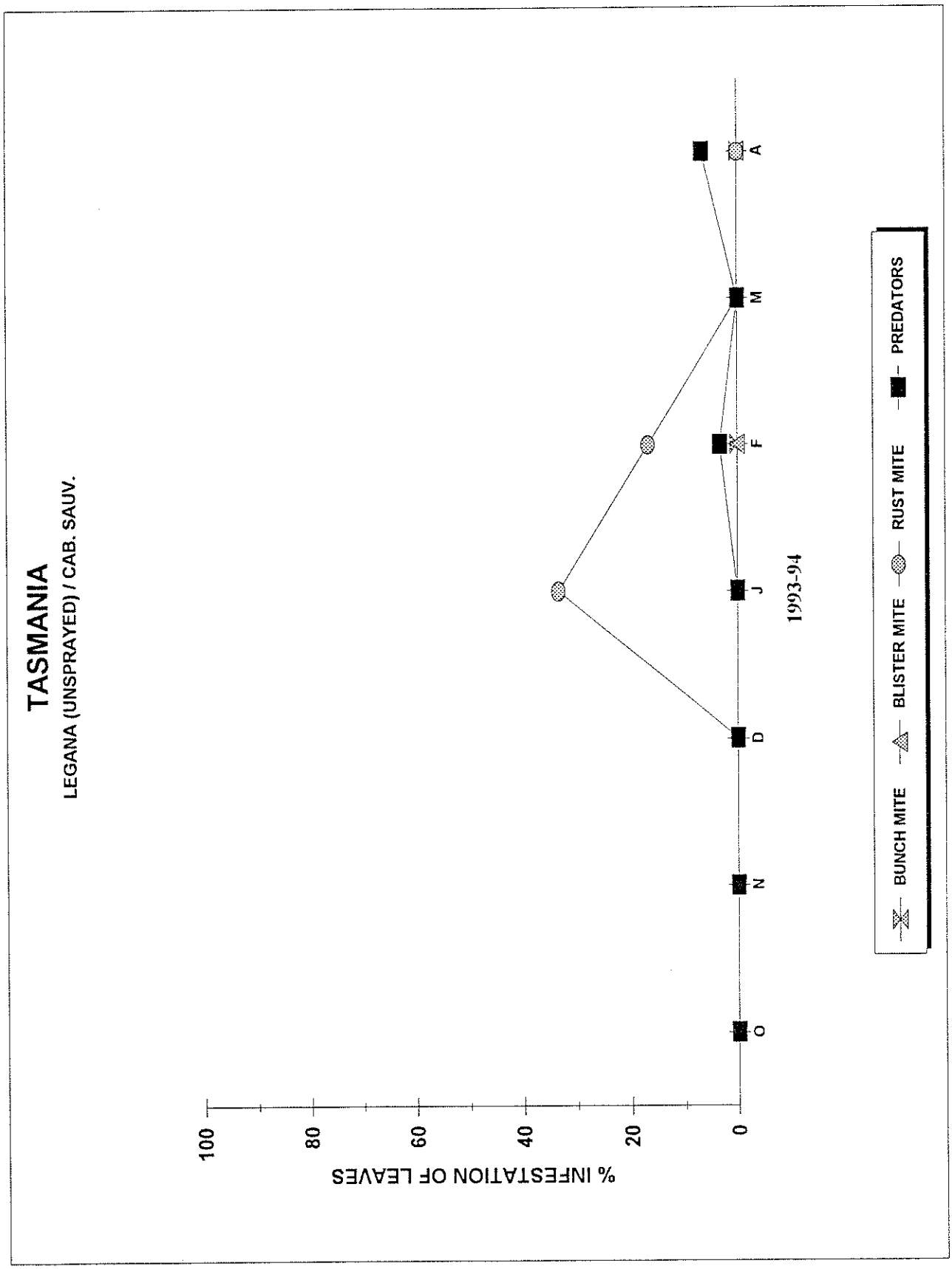


Figure 31. Pest and predatory mite populations at Legana (sprayed), Tamar Valley, Tasmania during 1993/94.

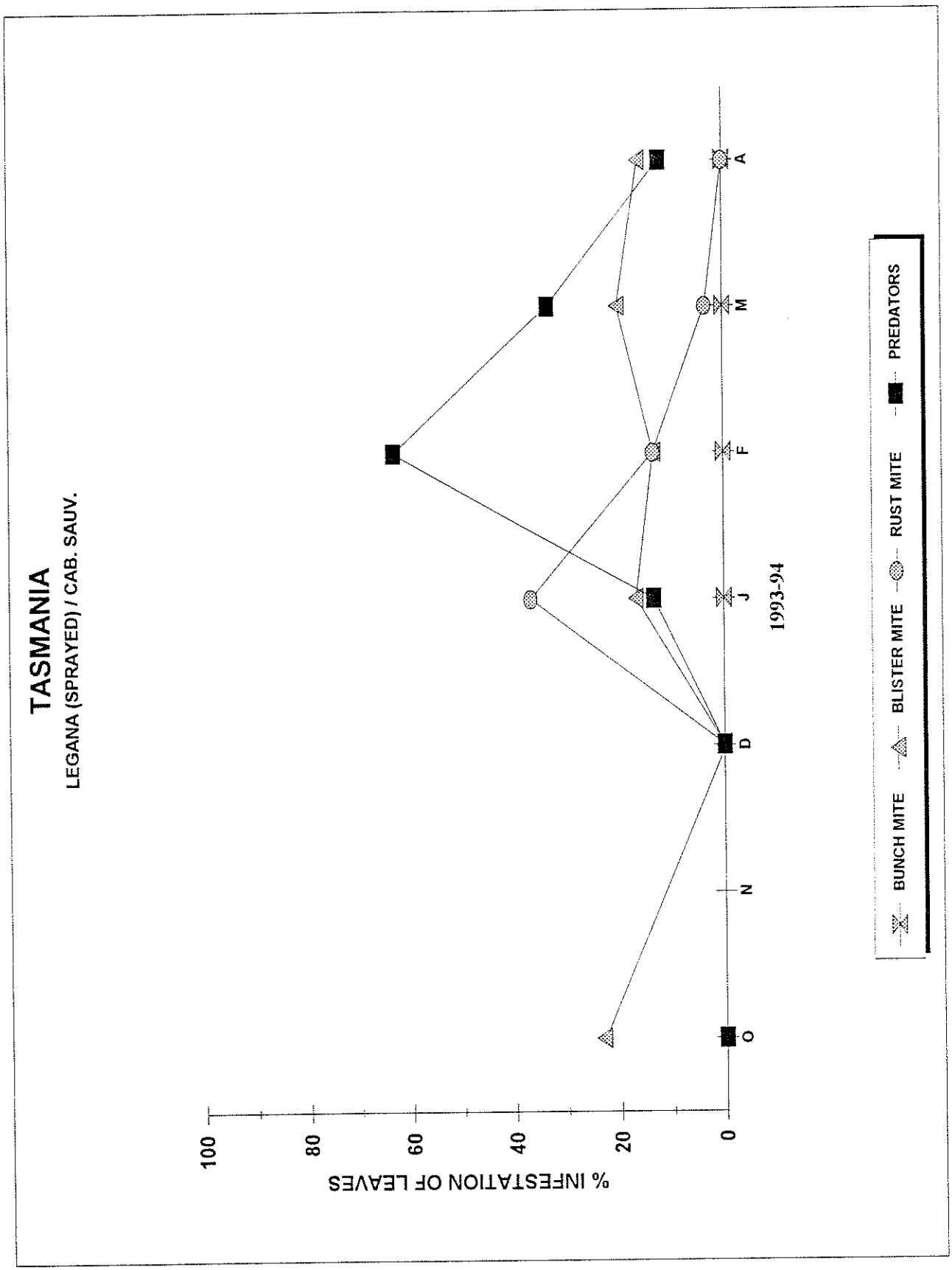


Figure 32. Pest and predatory mite populations at Stoney Vineyard, Coal River Valley, Tasmania, during 1993/94.

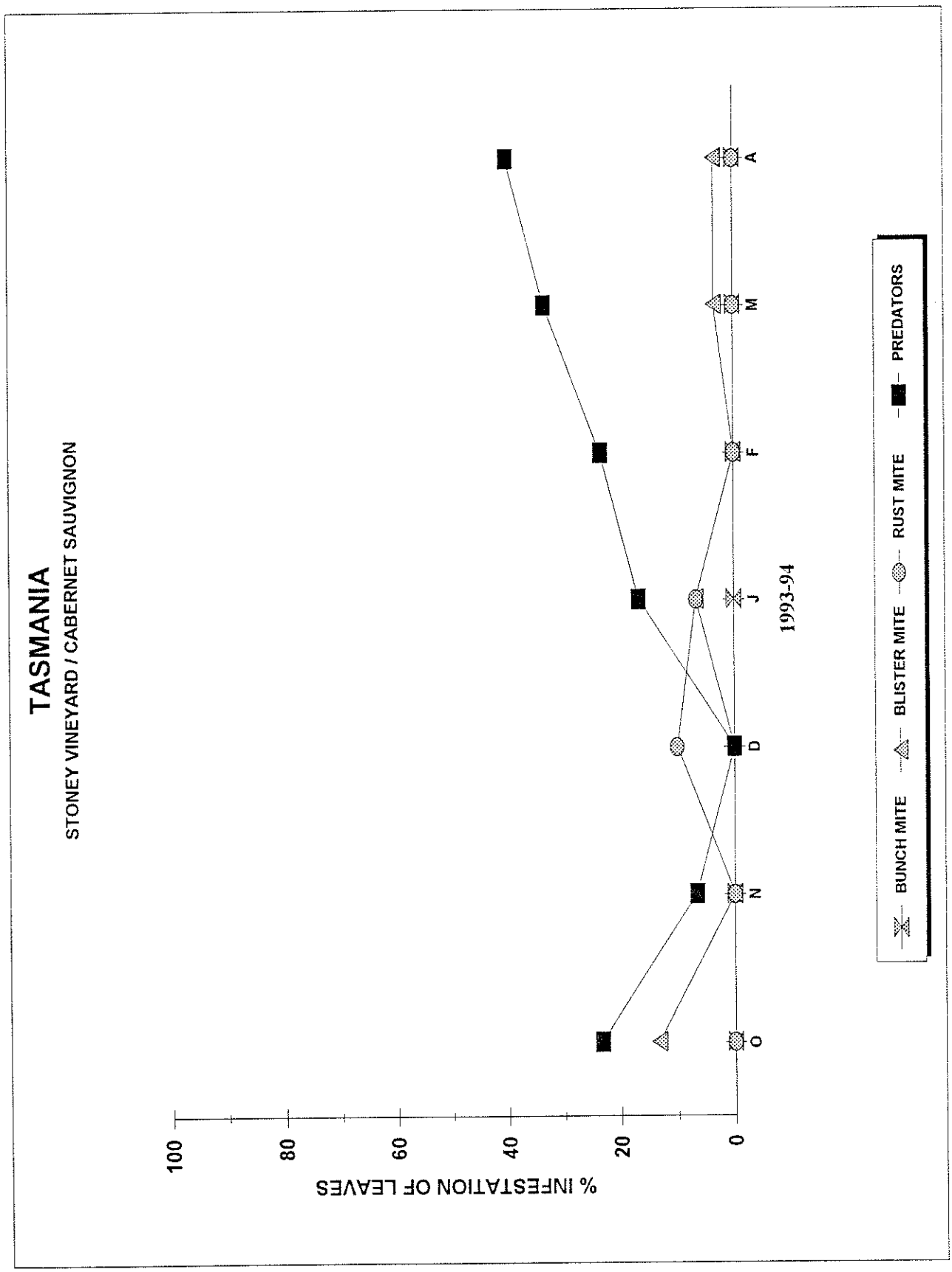
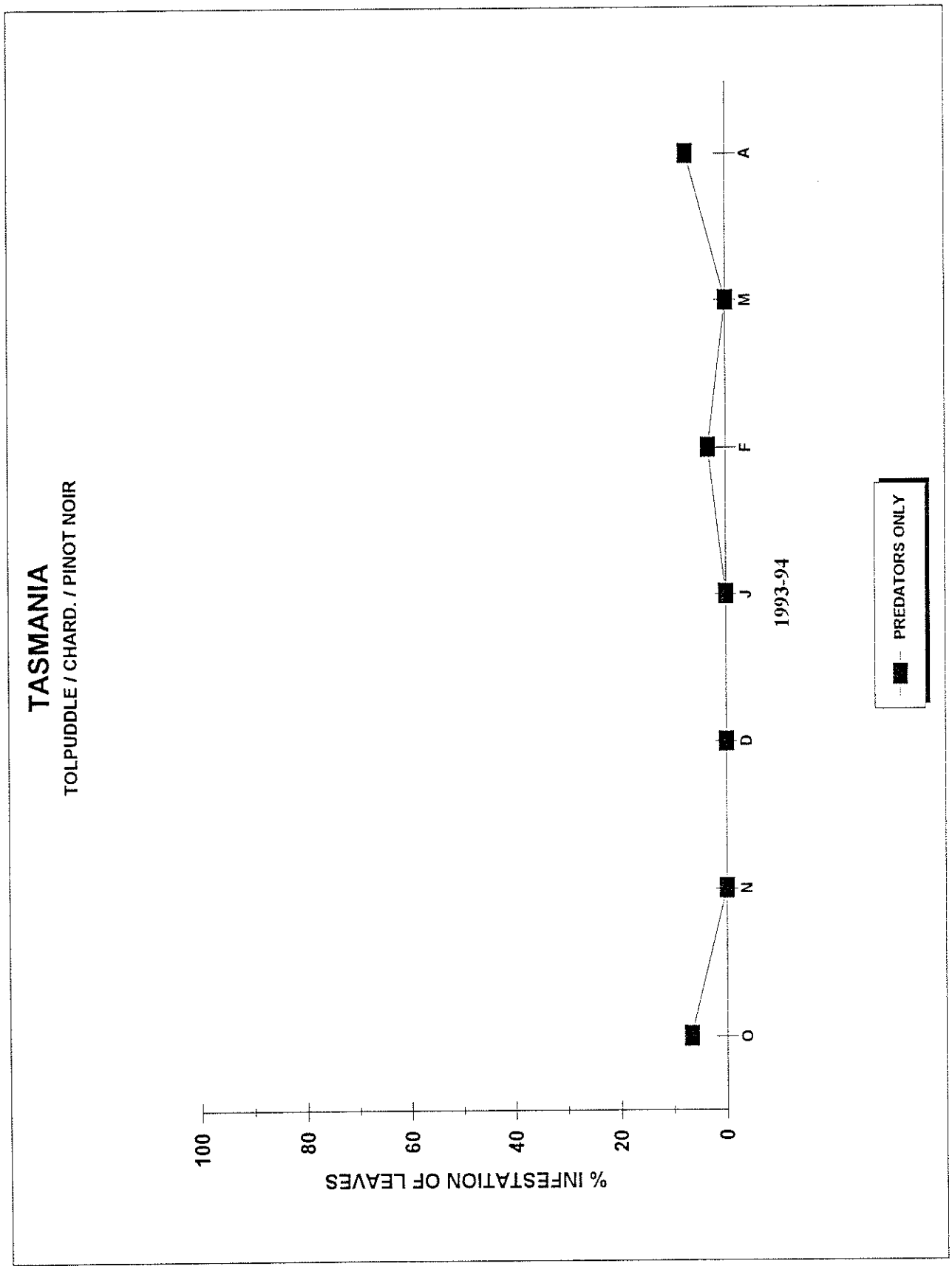


Figure 33. Predatory mite population at Tolpuddle, Coal River Valley, Tasmania during 1993/94.



## 6) SOUTH AUSTRALIA

(a) Barossa Valley

Two vine blocks in 2 vineyards (Kalimna, Shiraz, Nuriootpa; Schultz, Chardonnay, Nuriootpa) were sampled in 1993/94. Both vineyards are owned by Southcorp Pty Ltd.

Pest and predatory mite population data are shown in Figures 34-35 and Table 10.

**Table 10. Predatory mite species incidence during sampling in South Australia in 1993-94.**

| SOUTH AUSTRALIA 1993-94 | | | SPECIES PERCENTAGES | | | | |
|---|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *T. doreenae* | *T. transvaalensis* | *A. messor* | Other |
| Barossa Valley | Schultz | 24 | | 100 | | | |
| | Kalimna | 36 | | 100 | | | |
| Coonawarra | Gartner | NIL | | | | | |
| | Seppelts | NIL | | | | | |
| | House block | 19 | 100 | | | | |
| McLaren Valley | Seaview | 79 | 98.1 | 1.9 | | | |
| | Hickinbotham | 11 | | 81.8 | | 9.1 | 9.1 |
| Clare Valley | Bryksy | 170 | | 88.7 | 11.3 | | |
| | Clare Est. | 142 | | 100 | | | |

Early season populations of pests and predators were small. Rust mite numbers increased in December-January briefly reaching high levels in February-March. Predators appeared in February, reached low-moderate levels and appeared to contribute to regulation of rust mites. All predators were *T. doreenae*. Spray programs at both vineyards were restrained and did not involve materials known to be harmful to *T. doreenae*. The relatively small and late appearing populations of *T. doreenae* and subsequent poor performance in controlling rust mites is difficult to understand. However, records of the spray program in these blocks in the previous season were not available and it is possible more deleterious materials were used then.

### RECOMMENDATIONS

There is little reason to believe that mite control by *T. doreenae* in the Barossa Valley is any less successful than that recorded in The Riverland, 100 km to the east. This is supported by earlier observations in this region. The relatively low chemical input in vineyards in this region combined with a traditional dependence on predator-friendly materials (e.g. wettable sulphur/copper) should ensure that biological control of mites, provided primarily by *T. doreenae*, is readily achieved.

Figure 34. Pest and predatory mite populations at Schultz, Barossa Valley, South Australia during 1993/94.

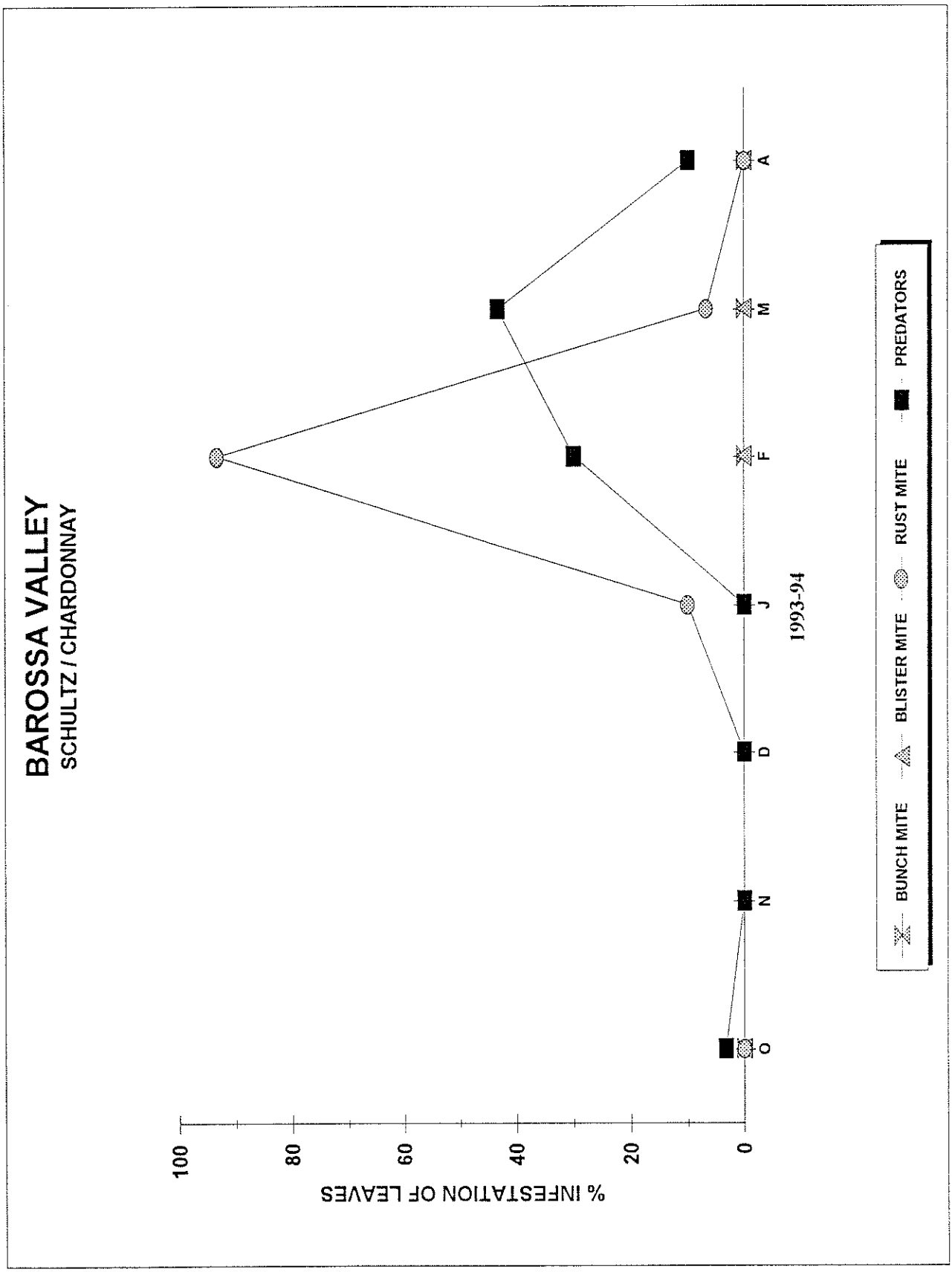
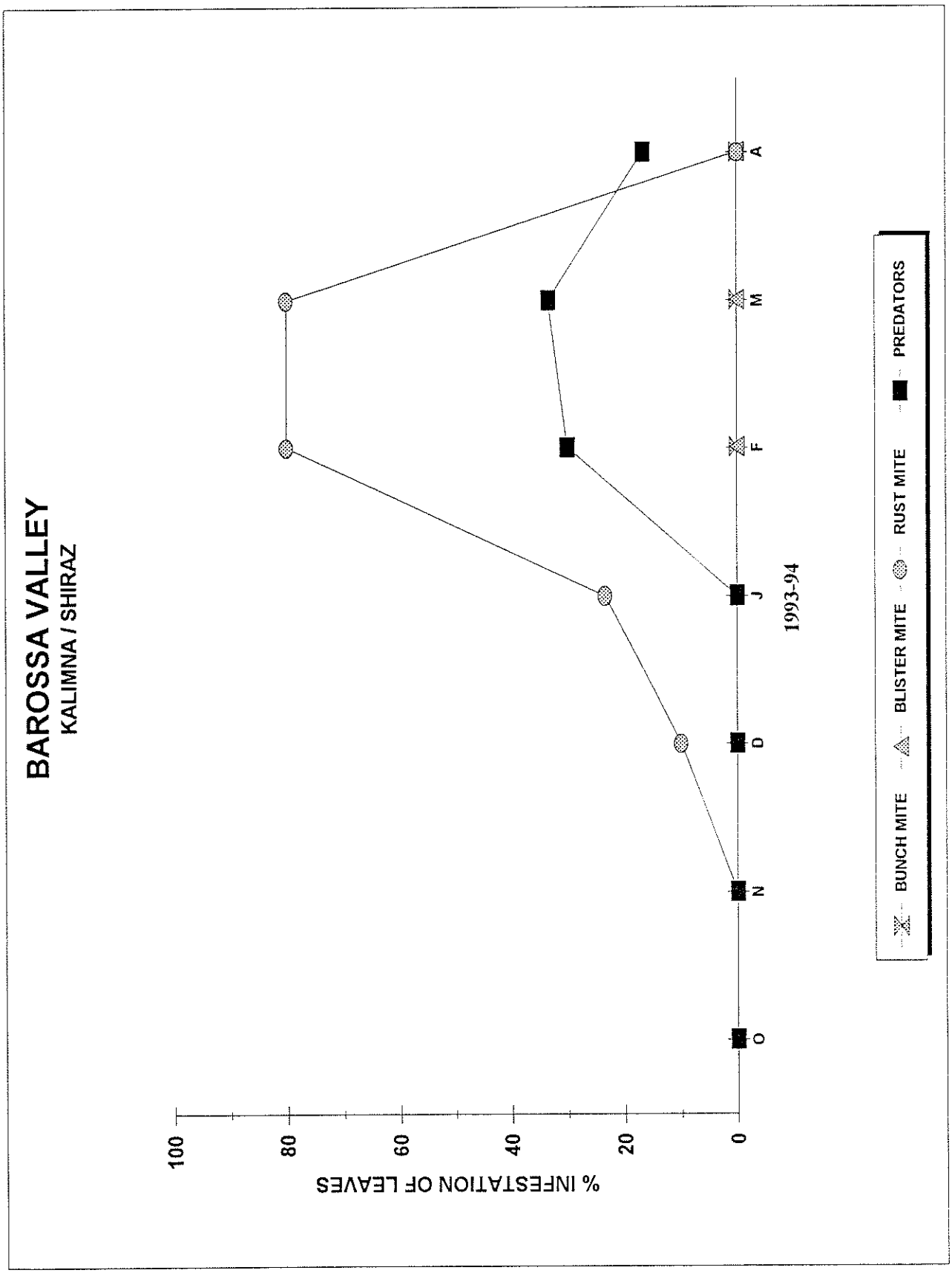


Figure 35. Pest and predatory mite populations at Kalimna, Barossa Valley, South Australia during 1993/94.



(b) Clare Valley
Two vine blocks in 2 vineyards (Clare Estate Vineyard, Sauvignon blanc/Chardonnay, Clare; L. Bryksy, Rhine riesling, Watervale) were sampled in 1993/94.

Pest and predatory mite population data are shown in Figures 36-37 and Table 10.

Generally small populations of blister and rust mites with large numbers of predators mid-late season suppressing pest mite numbers. Predators (primarily *T. doreenae*) were rare until January at Bryksy and then became very abundant during February-March. They were slightly later in appearing at Clare Estate (February) but were very common in March. Both sites had low input spray programs with wettable sulphur and copper the primary materials used.

**RECOMMENDATIONS**
Similar to the Barossa Valley and Riverland, Clare Valley vineyards should have little problem in using predatory mites to provide mite control. The reasons for late establishment of *T. doreenae* in some seasons/vineyards in these regions are unknown but may be related to poor overwintering survival. If this is the case, then inoculative releases of this predator during spring would be valuable in ensuring the presence of good populations prior to the normal summer development of rust mite populations.

(c) McClaren Vale

Two vine blocks in 2 vineyards (Seaview Vineyard, Shiraz, McClaren Vale; Hickinbotham Vineyard, Pinot Noir, Clarendon) were sampled in 1993/94.

Pest and predatory mite population data are presented in Figures 38-39 and Table 10.

Generally small populations of rust mite except for February-March at Seaview. Predator numbers were fairly large at this site as they responded to the rust mite outbreak bringing it under control by the end of the season. Numbers of pests and predators were both low at Hickinbotham. The predator population at Seaview was dominated by *T. dossei*; however, *T. doreenae* was the dominant predator at Hickinbotham and *T. dossei* was absent. Insecticides were not used at either site and fungicide use was low to moderate with few materials likely to have been harmful to predators. However, there was substantial district-wide spraying of chlorpyrifos for light brown apple moth , which may have adversely affected district populations of predators.

**RECOMMENDATIONS**

A cooler region than the Barossa and Clare Valleys as indicated by the predominance of *T. dossei* at one site. As such the region probably has more in common mite control-wise with the Geelong region. Biological mite control would appear to be very achievable as long as low input chemical strategies are followed, particularly avoiding broad-spectrum insecticides for light brown apple moth. The introduction of *T. doreenae* to vineyards in this region which lack this predator would be useful.

Figure 36. Pest and predatory mite populations at Bryksy, Clare Valley, South Australia during 1993/94.

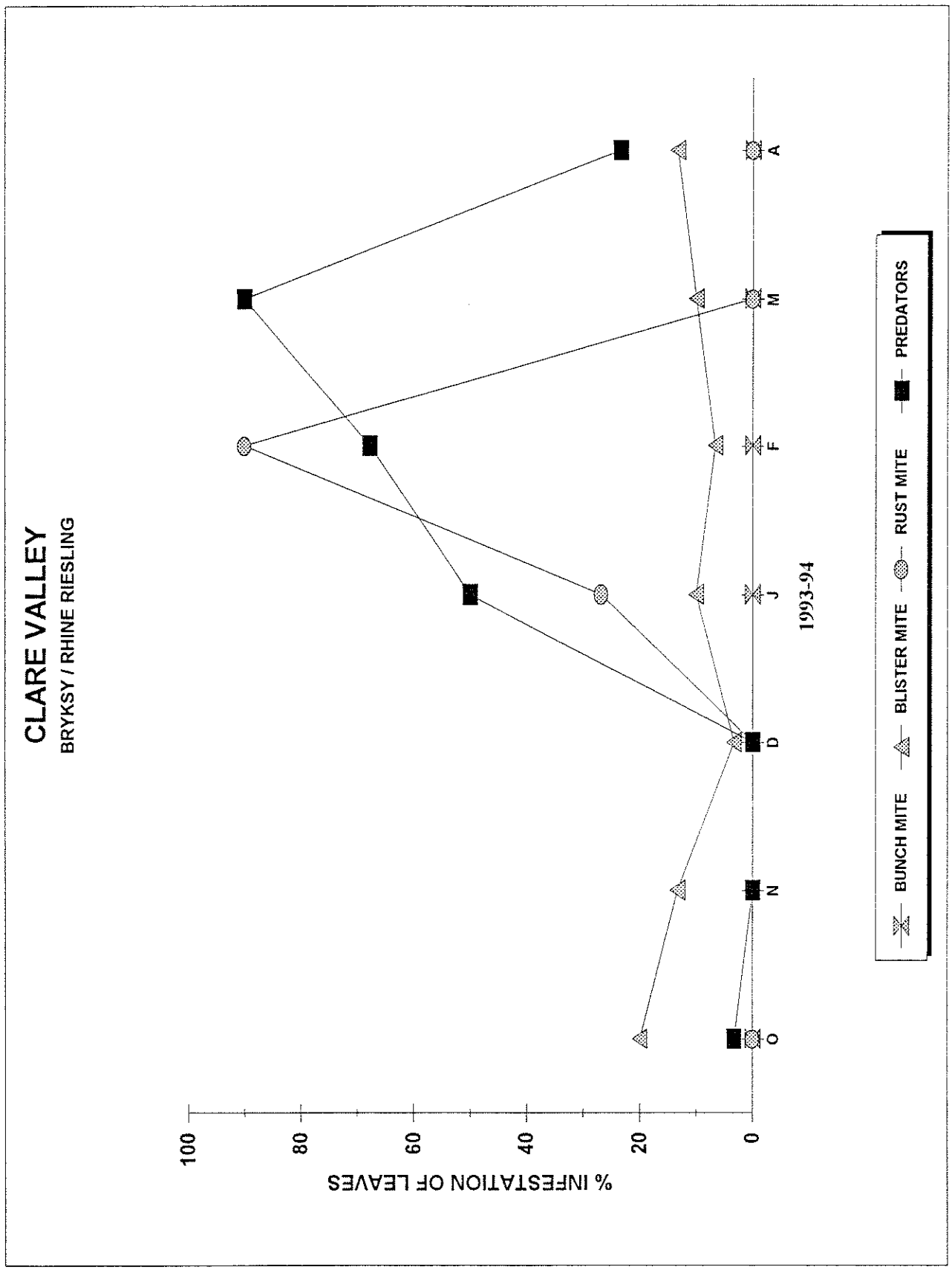


Figure 37. Pest and predatory mite populations at Clare Estate, Clare Valley, South Australia during 1993/94.

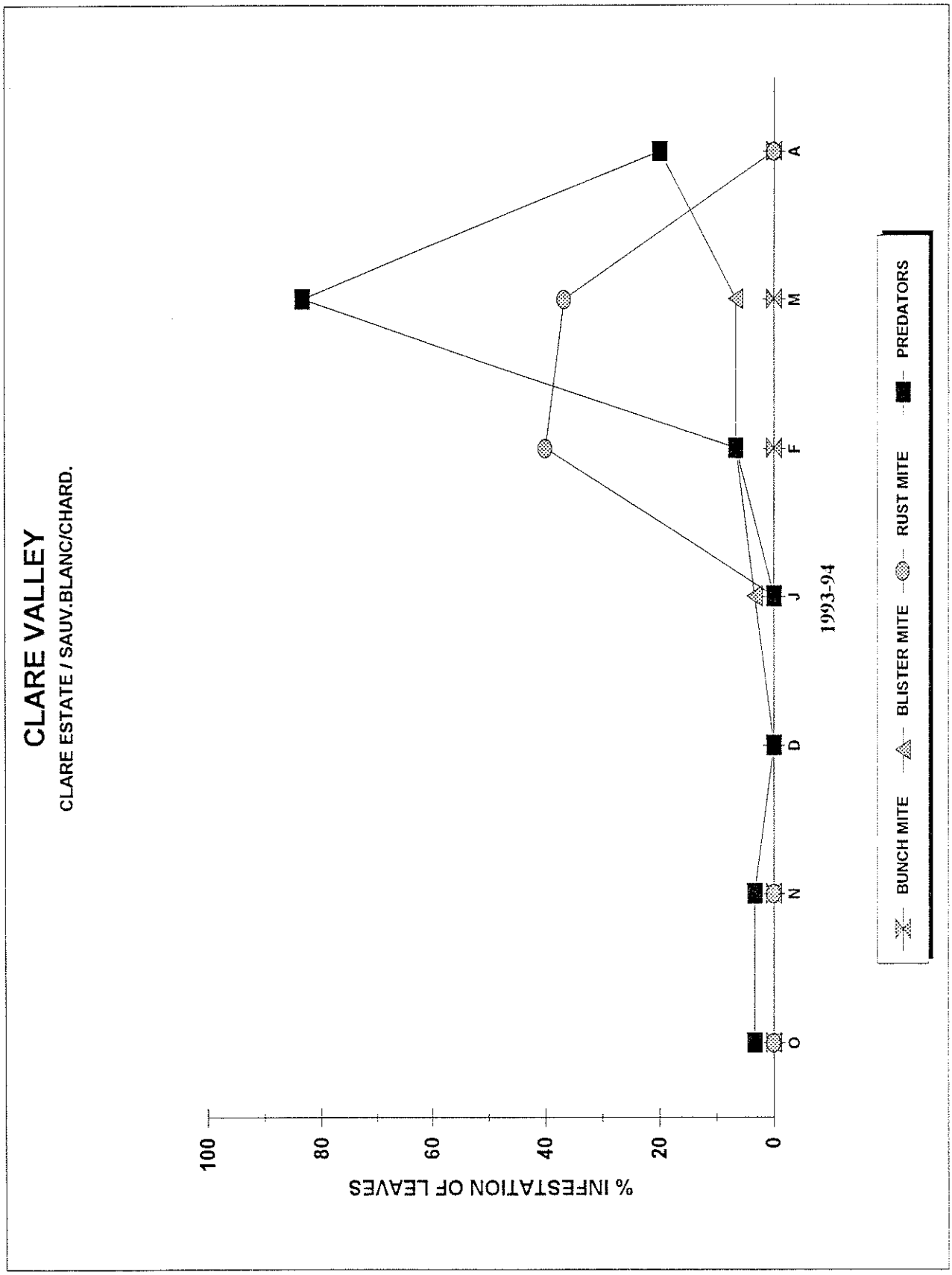


Figure 38. Pest and predatory mite populations at Hickinbotham, McClaren Vale, South Australia during 1993/94.

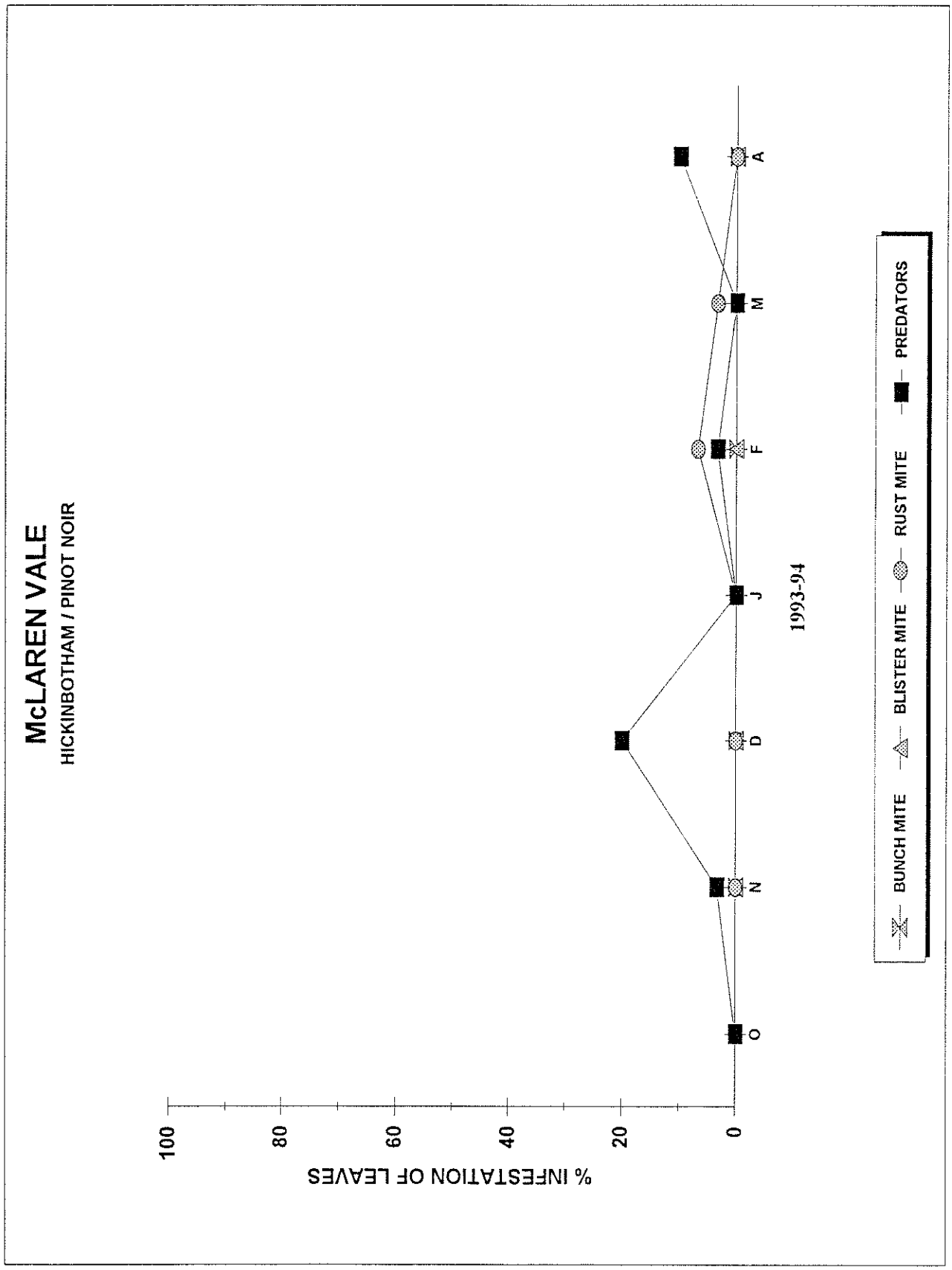
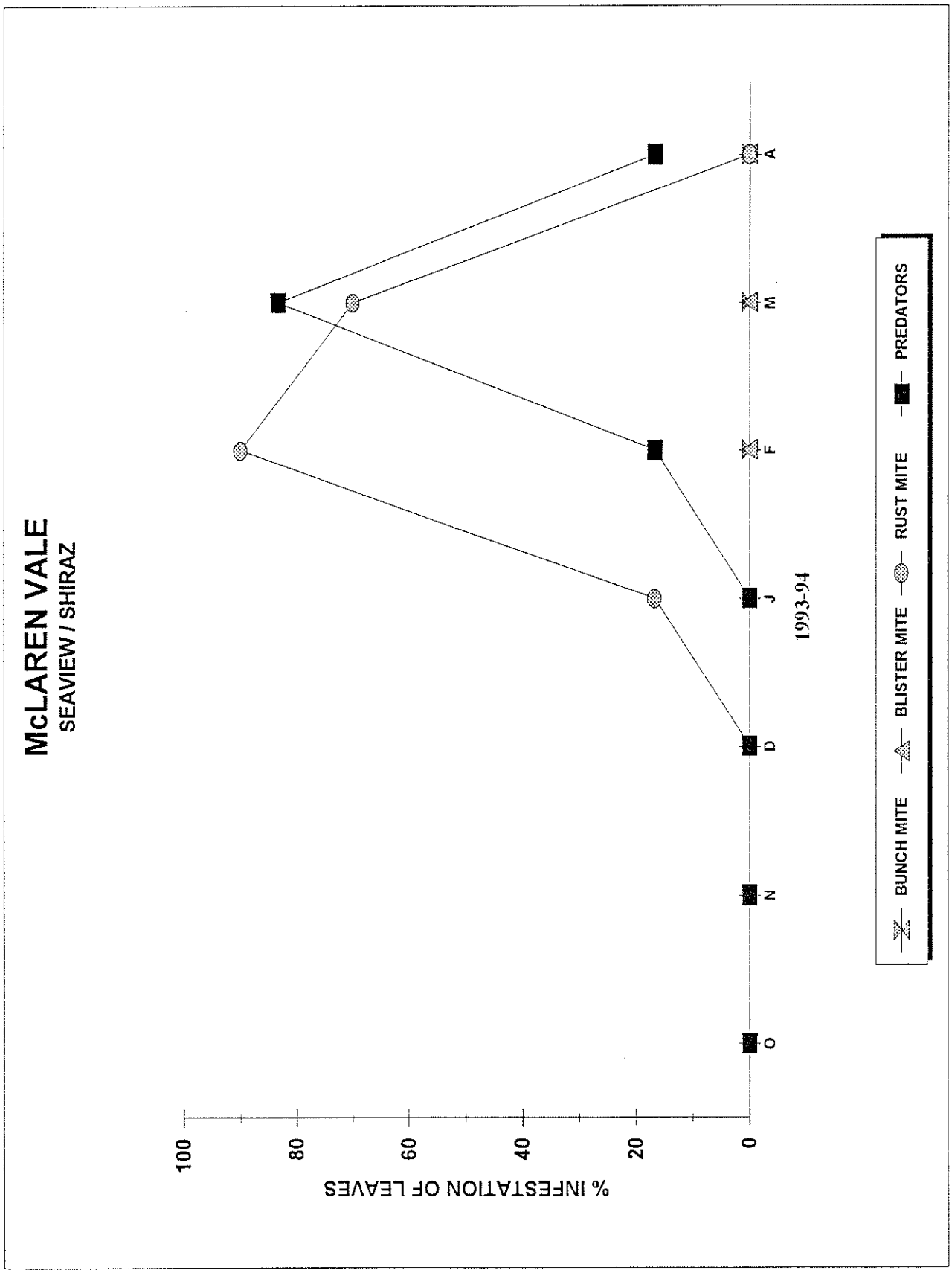


Figure 39. Pest and predatory mite populations at Seaview, McClaren Vale, South Australia during 1993/94.



d) Coonawarra

Three vine blocks in 3 vineyards (Gartner, Chardonnay; Seppelts, Chardonnay; House block, mixed varieties) were sampled during 1993/94.

Pest and predatory mite population data are presented in Figures 40-42 and Table 10.

Pest and predatory mites were virtually absent in the Gartner and Seppelts blocks. These blocks had a moderate fungicide spray program and were also exposed to chlorpyrifos sprays for light brown apple moth. The House block had a similar spray program the previous season but in 1993/94 was exposed only to wettable sulphur and copper. This was the only block in which a reasonable population of predators (all *T. dossei*) had developed by the end of the season. A single predator egg was found in the April sample at Gartner.

## RECOMMENDATIONS

Chlorpyrifos sprays for light brown apple moth are routine in this region and clearly this has had a substantial impact on the predatory mite population. Removal of chlorpyrifos from the House block spray program resulted in a strong appearance of *T. dossei* by the end of the season. If chlorpyrifos was removed from district spraying then it is likely that *T. dossei* would become the dominant predator and provide biological control. *T. doreenae* could also be introduced to the region. Coonawarra and the Yarra Valley have a lot in common, both being pesticide-disturbed ecosystems preventing natural mite control. Both will experience short term mite problems during any shift towards low-input and biological mite control as predator populations 'find their feet'.

Figure 40. Predatory mite populations at Gartner, Coonawarra, South Australia during 1993/94.

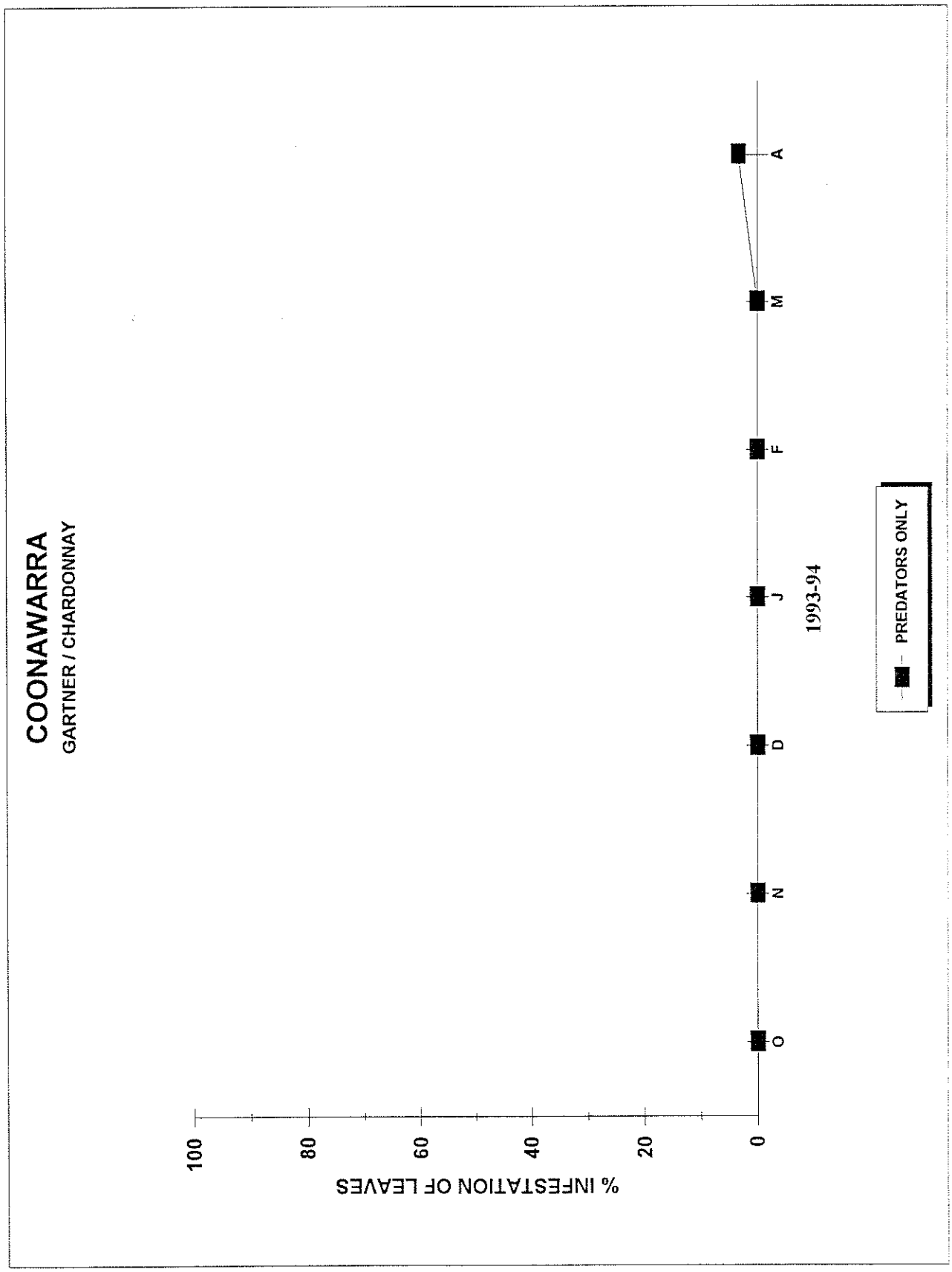


Figure 41. Blister mite population at Seppelts, Coonawarra, South Australia during 1993/94.

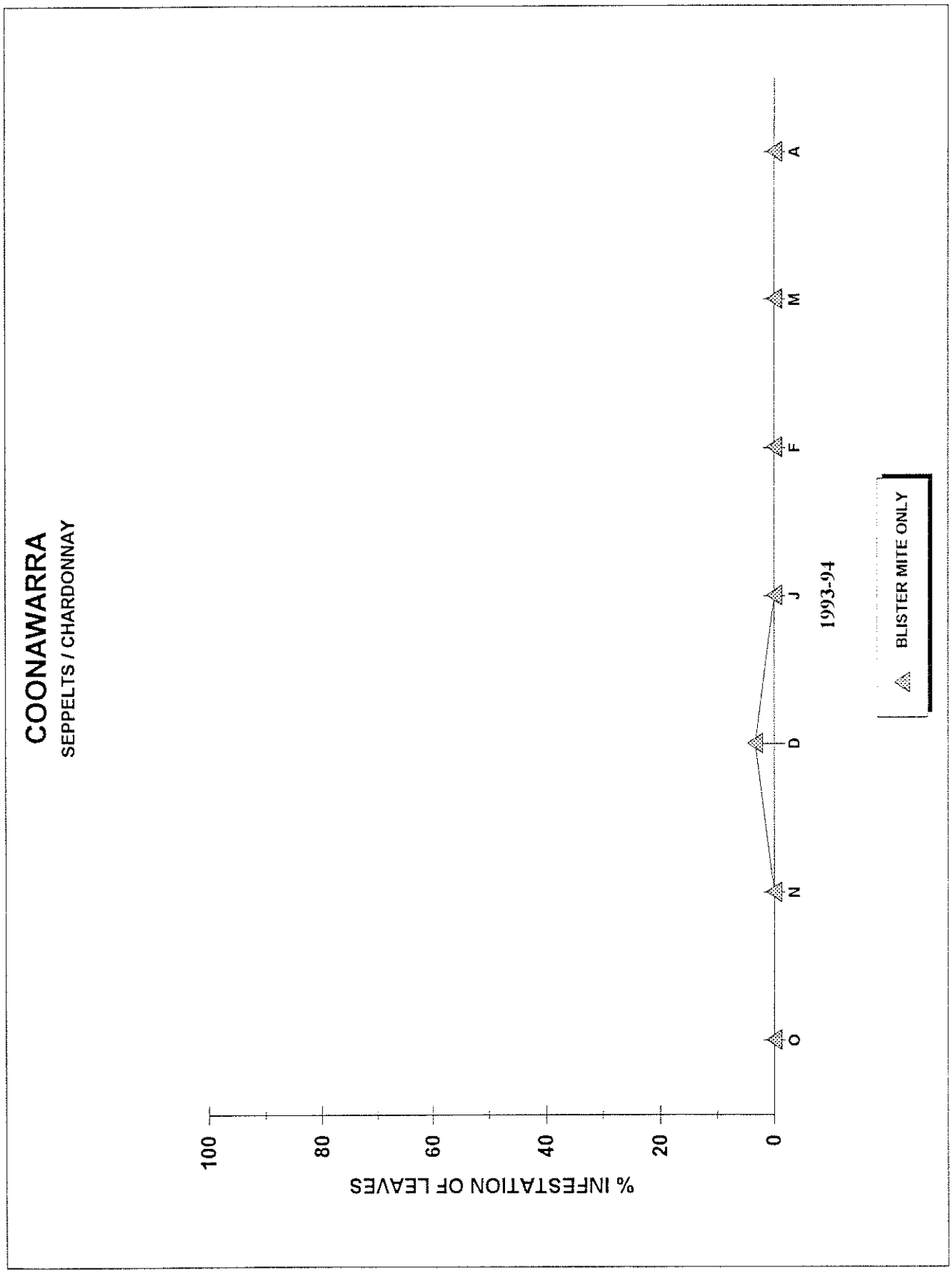
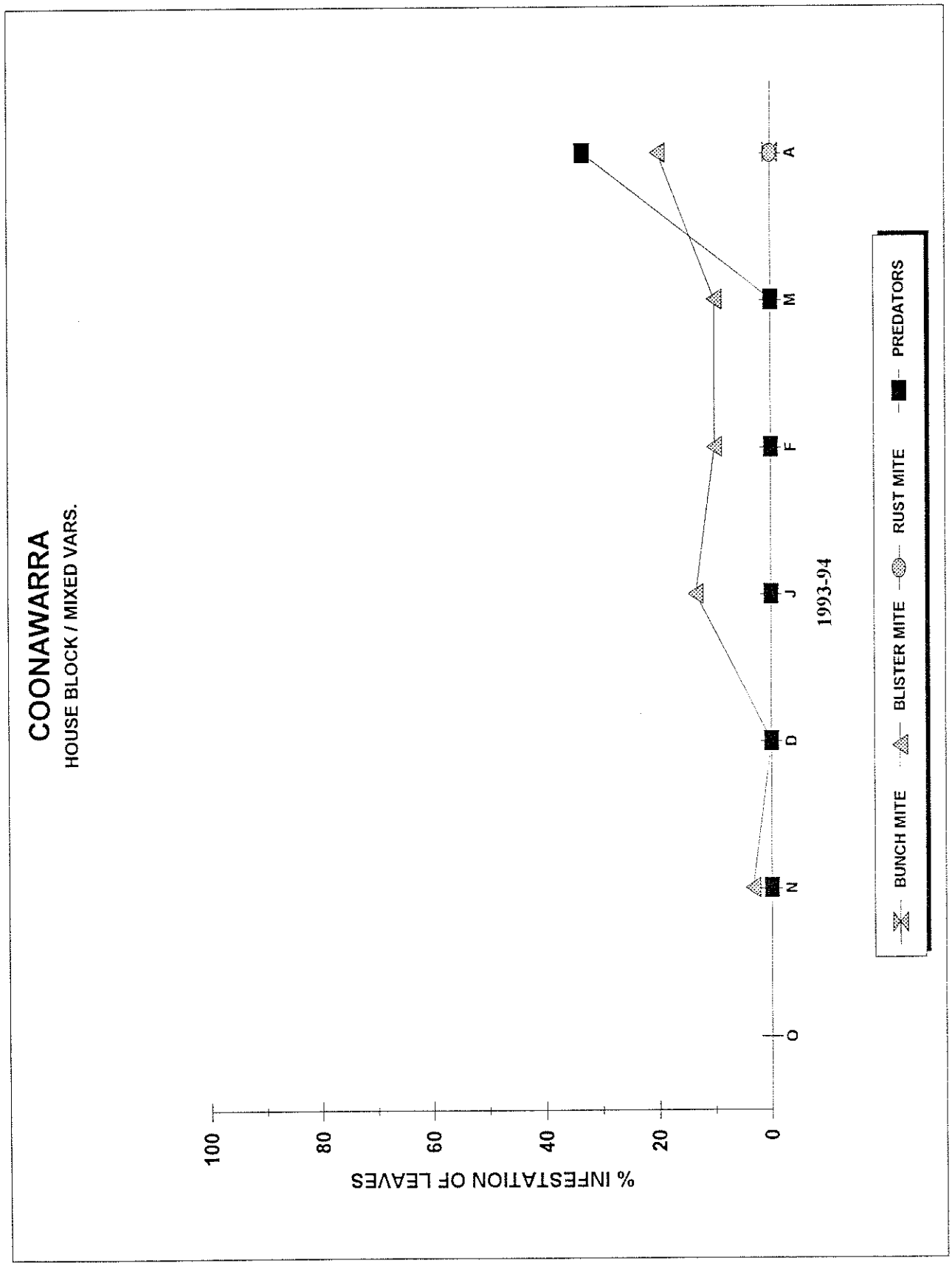


Figure 42. Pest and predatory mite populations at House block, Coonawarra during 1993/94.



## 7) WESTERN AUSTRALIA

(a) The Perth District

Seven vine blocks in 6 vineyards (Piesse Brook [2 blocks]-Kalamunda, Conti Wines-Wanneroo, Evans and Tate-Midland, Houghton Wines-Middle Swan, Innamincka-Lower Chittering, Sandalford Wines-Guildford), were sampled in the Perth and Swan Valley district during 1993/94. In addition, 3 blocks of Table grapes in 3 vineyards (Trease-Herne Hill; Waldek- Bindoon; Taylor-Guildford) in the same district were also sampled. Vine varieties in sampled blocks were not recorded. The Houghton and Innamincka blocks were also sampled in 1994/95.

Pest and predatory mite population data are presented in Figures 43-52 and Table 11.

**Table 11. Predatory mite species incidence during sampling in the Perth region (Western Australia) during 1993/94 and 1994/95. Figures in parentheses represent 1994/95 data.**

| WESTERN AUSTRALIA PERTH 1993-94 | | | SPECIES PERCENTAGES | | | |
|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *T. doreenae* | *A. dieteri* | other |
| Perth | Piesse Brook (front) WA1 (Kalamunda) | 20 | 58.5 | 16.5 | | 25 |
| | Piesse Brook (back) WA1 | 11 | 27.3 | 27.3 | | 45.4 |
| | Conti Wines WA2 (Wanneroo) | 5 | | | | 100 |
| | Evans & Tate WA3 (Midland) | 9 | | 100 | | |
| | Houghton Wines WA4 (Middle Swan) | 21 (2) | | 38.1 (100) | 61.9 | |
| | Innamincka WA5 (Lower Chittering) | 25 (9) | | 100 (78) | | (22) |
| | Sandalford WA6 (Guildford) | 1 | | 100 | | |
| **WESTERN AUSTRALIA - TABLE GRAPES 1993-94** | | | | | | |
| Region | Vineyard | Total Predator No. | *T. dossei* | *T. doreenae* | *A. elinae* | Other |
| | Waldek WA27 (Bindoon) | 3 | | 33 | | 67 |
| | Taylor WA28 (Guildford) | 17 | | 50 | 50 | |
| | Trease WA32 (Herne Hill) | 1 | | 100 | 0 | |

Pest and predator populations were small in all blocks, although predator numbers were generally greater than pest numbers. The greatest pest incidence occurred at Houghtons in February 1994 when rust mites infested 100% of sampled leaves (Fig. 47). Predators appeared to contribute to the rapid reduction in numbers which occurred by the following month. Similarly, predators appeared to regulate rust mite numbers effectively at Innamincka (Fig. 48). Mite numbers (pest and predator) were even lower in the table grape blocks with consistent (if small) numbers of predators found only at Guildford (Taylor). *T. doreenae* was recorded in all blocks except Conti Wines. In three blocks (Evans and Tate, Innamincka and Sandalford) it was the only predator found. *T. dossei* occurred in reasonable numbers in both Piesse Brook blocks. Greatest predator numbers occurred at Piesse Brook, Houghtons Wines and Innamincka in 1993/94. Numbers in 1994/95 at Houghtons and Innamincka were considerably smaller. A single specimen of *Amblyseius elinae* was recorded at Bindoon.

Spray applications in the wine grape blocks was low to moderate with fairly 'soft' materials being used e.g. mostly wettable sulphur and copper. The only synthetic fungicides used were fenarimol and triadimenol. No insecticides/miticides were used. Similar materials were used in the table grape blocks but application frequency was considerably greater and the miticide dicofol was used at Herne Hill where only a single predator was found. The relatively low numbers of rust mites may have been mostly a reflection of climatic conditions (warm-hot and dry). These conditions are not necessarily unfavourable to *T. doreenae* so it is surprising that larger numbers of this species did not occur, particularly late in the season. Perhaps, this predator has not fully established itself in this region. There is a fair degree of broad-spectrum insecticide use in other crops grown in this area which may be inhibiting population development of *T. doreenae*.

## RECOMMENDATIONS

The potential exists for very good biological control of mites on grapevines in the Swan Valley/Perth district. *T. doreenae* is clearly resident although perhaps suppressed by general pesticide use. As pesticide use is reduced in other crops, as well as grapevines, the numbers of *T. doreenae* colonising vineyards should increase. Introductions of this predator to vineyards in spring would be a useful tactic. The climate of this district probably makes it less susceptible to severe rust mite problems as occur further south in Western Australia.

(b) Margaret River

Ten vine blocks in ten vineyards (6 winegrape; Killerby-Bunbury, Amberley Estate-Busselton, Cape Clairault-Carbanup River, Evans and Tate-Cowaramup, Leeuwin Estate-Margaret River, Coodarup Wines-Augusta and 4 tablegrape; Korijedale-Harvey, Thorpe-Busselton, Ramponi-Donnybrook and Longo-Witchcliffe ) were monitored in this region during 1993/94. One site (Cape Clairault) was also monitored in 1994/95.

Pest and predatory mite population data are presented in Figures 53-62 and Table 12.

Pest and predatory mite populations were generally small in all blocks. No pest mites at all were recorded in 4 vineyards (Leeuwin Estate, Longo, Korijedale and Coodarup Wines) although predators were recorded in all of them, particularly at the end of the season. In fact, the latter 3 vineyards along with Killerby were the only sites to record reasonable numbers of predators. In some vineyards, spray pressure was high, for example, at Korijedale, the pyrethroid insecticide alphacypermethrin was applied in October and December. The occurrence of large numbers of predators at this site during February-April indicates good populations in surrounding areas allowing rapid reinvasion after insecticide use. At the Killerby vineyard, a moderate number of sprays were used, but only fungicides with generally low toxicity to predators, and predators were reasonably common from January onwards. The dominant species at Killerby was *T. dossei* with a small number of *Amblyseius elinae*. *T. dossei* was the dominant species at all sites except Ramponi, Evans and Tate and Leeuwin Estate, where numbers were too small to make a judgement, Korijedale, where *A. elinae* was dominant and Longo where *A. christinae* was dominant. The insecticides malathion and chlorpyrifos were used at Coodarup (7 applications Oct-Jan) and it is not surprising that no predators were seen until March. Like Korijedale, it was in fact surprising, that predators were detected at all, with this sort of pesticide use. Clearly, these insecticides also played a considerable role in keeping these vineyards free of pest mites. The most significant pest populations (rust mite) occurred at Cape Clairault in both seasons with mid-season outbreaks reaching 80-100% infestation. In 1993/94 carbaryl was applied to combat this in December and January, resulting in suppression of predators as well as pests. In the following season, carbaryl was NOT used to combat rust mite and predators (*T. dossei, A. elinae*) successfully controlled mites by February. In this season, the same result was achieved as in the previous one but without the economic and environmental cost of two applications of carbaryl! The only site at which predators were not found was Thorpe at Busselton. Unfortunately spray records were not available for this site, but it is likely insecticides were used. Good biological control of rust mites appeared to occur at Amberley Estate (Fig. 54) where only wettable sulphur and triademenol were used.

## RECOMMENDATIONS

It is likely that biological control of mites could be implemented successfully in this region either using the resident *T. dossei* and/or *A. elinae* or by introducing *T. doreenae*. However, spray practices need to be carefully watched with the use of broad spectrum insecticides and high use of fungicides avoided. A disease management program based on wettable sulphur and copper or limited use of inorganic fungicides would be appropriate.

**Figure 43.** **Pest and predatory mite populations at Piesse Brook (back), Perth, Western Australia during 1993/94.**

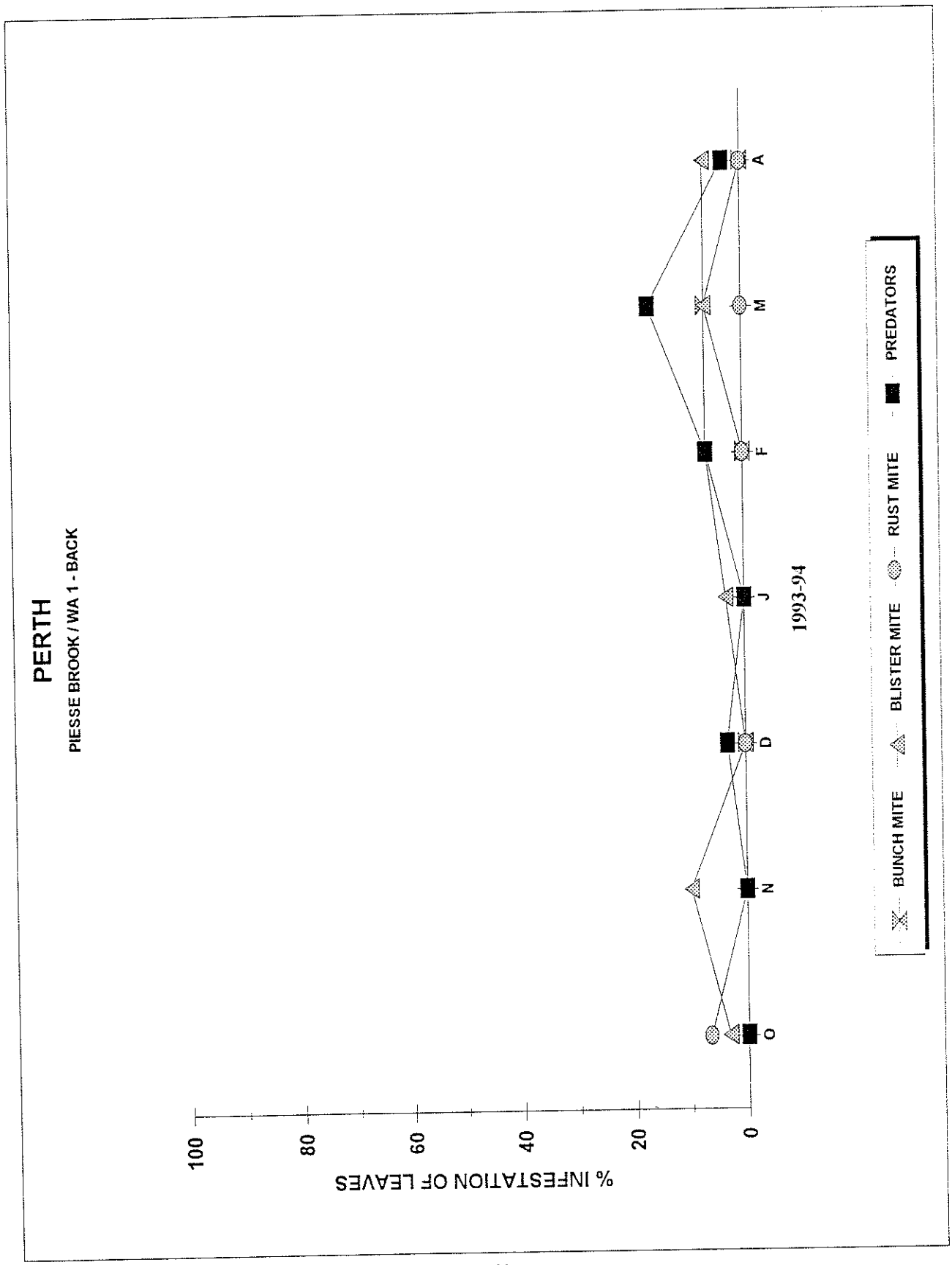


Figure 44. Pest and predatory mite populations at Piesse Brook (Front), Perth, Western Australia during 1993/94.

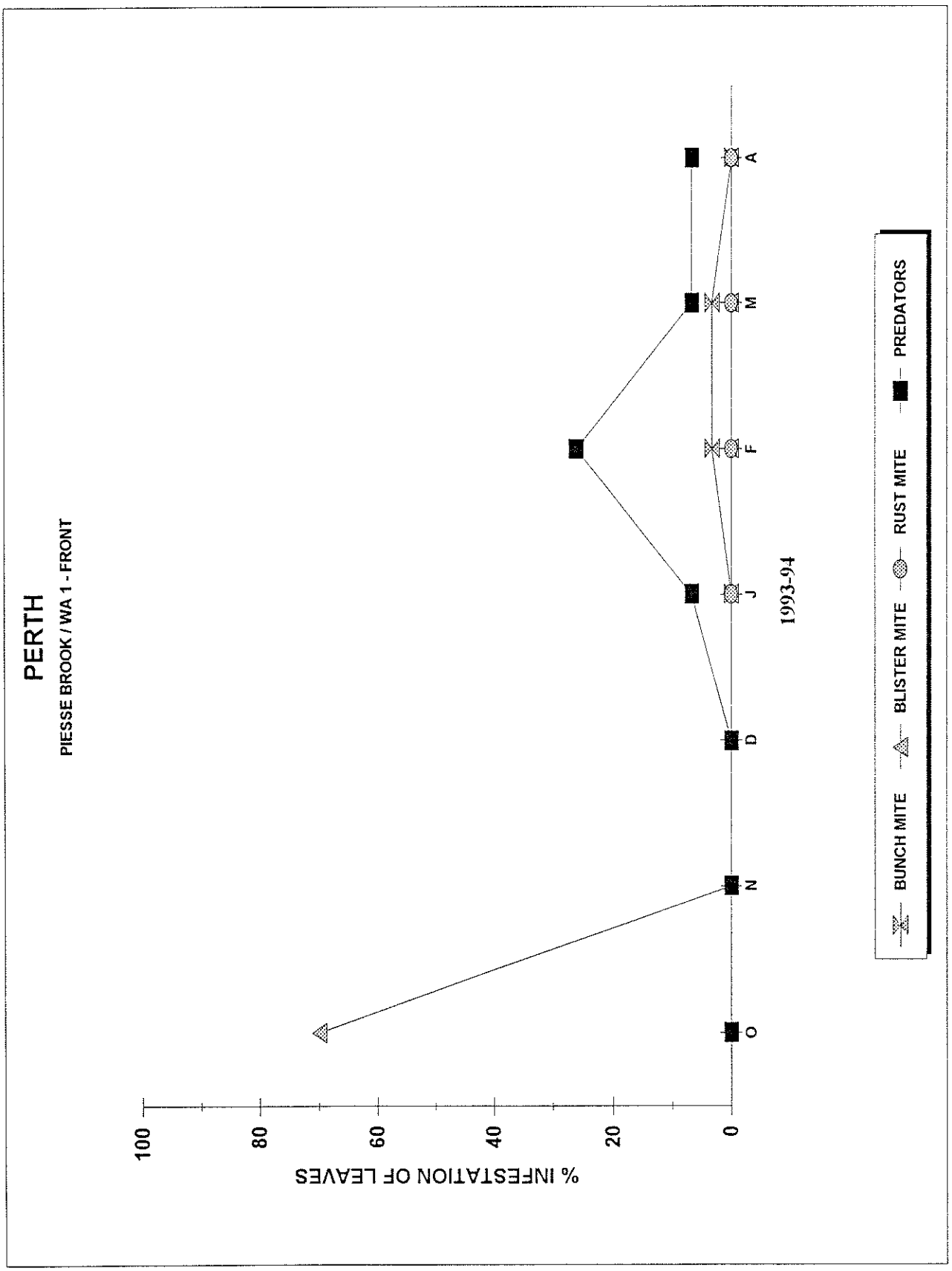


Figure 45. Pest and predatory mite populations at Conti Wines, Perth, Western Australia during 1993/94.

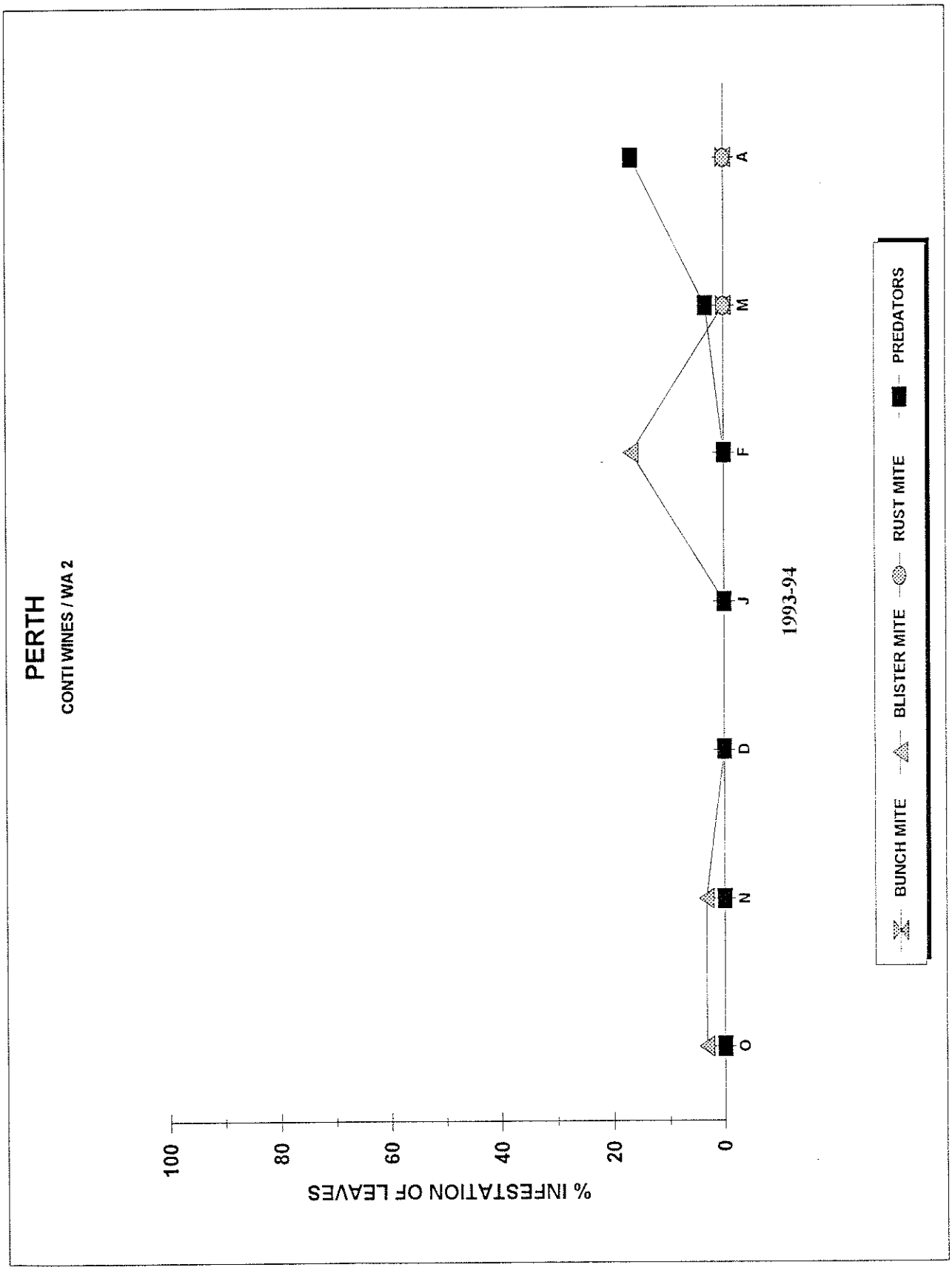


Figure 46. Pest and predatory mite populations at Evans and Tate, Perth, Western Australia during 1993/94.

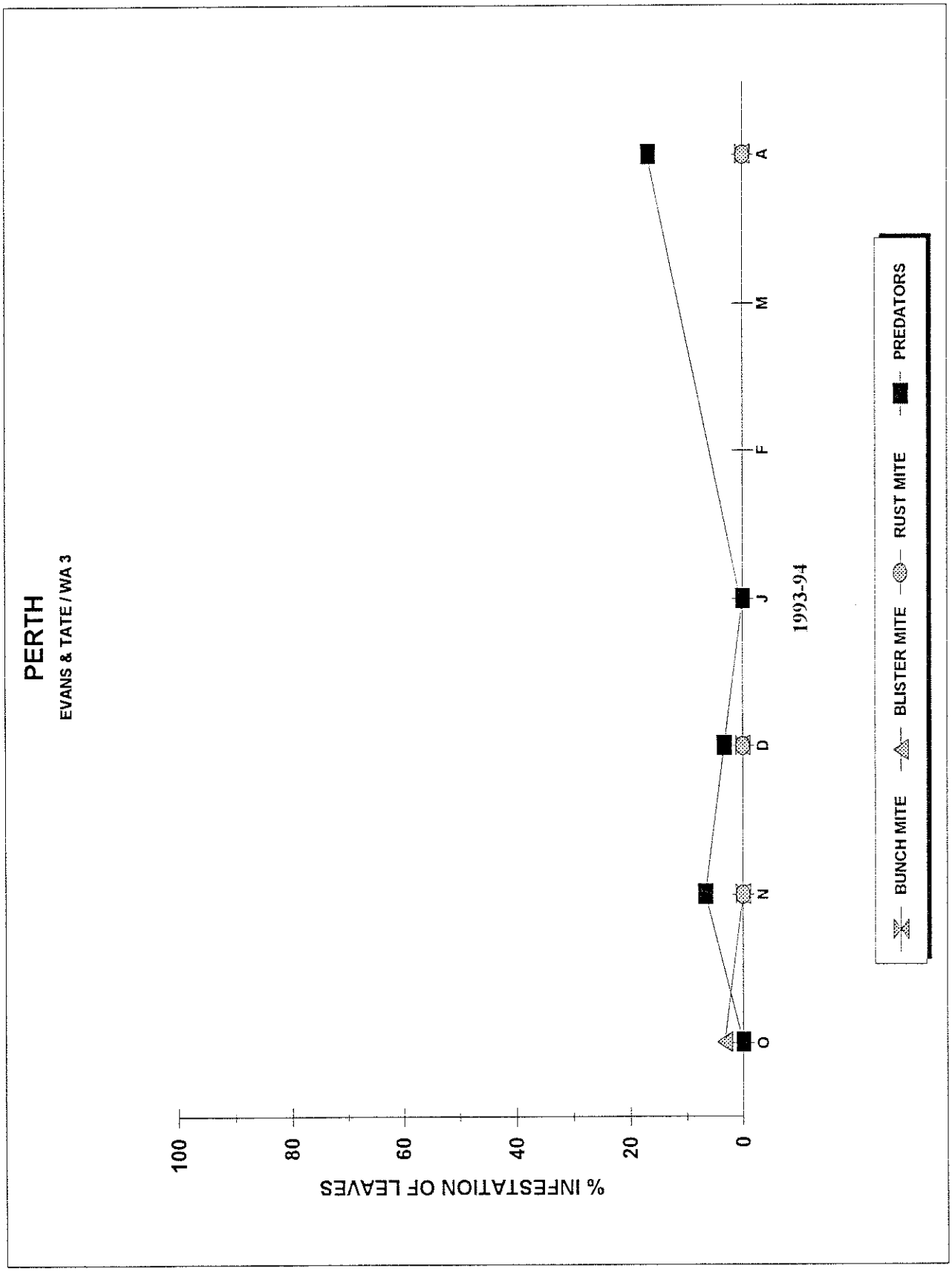


Figure 47. Pest and predatory mite populations at Houghtons, Perth, Western Australia during 1993/94.

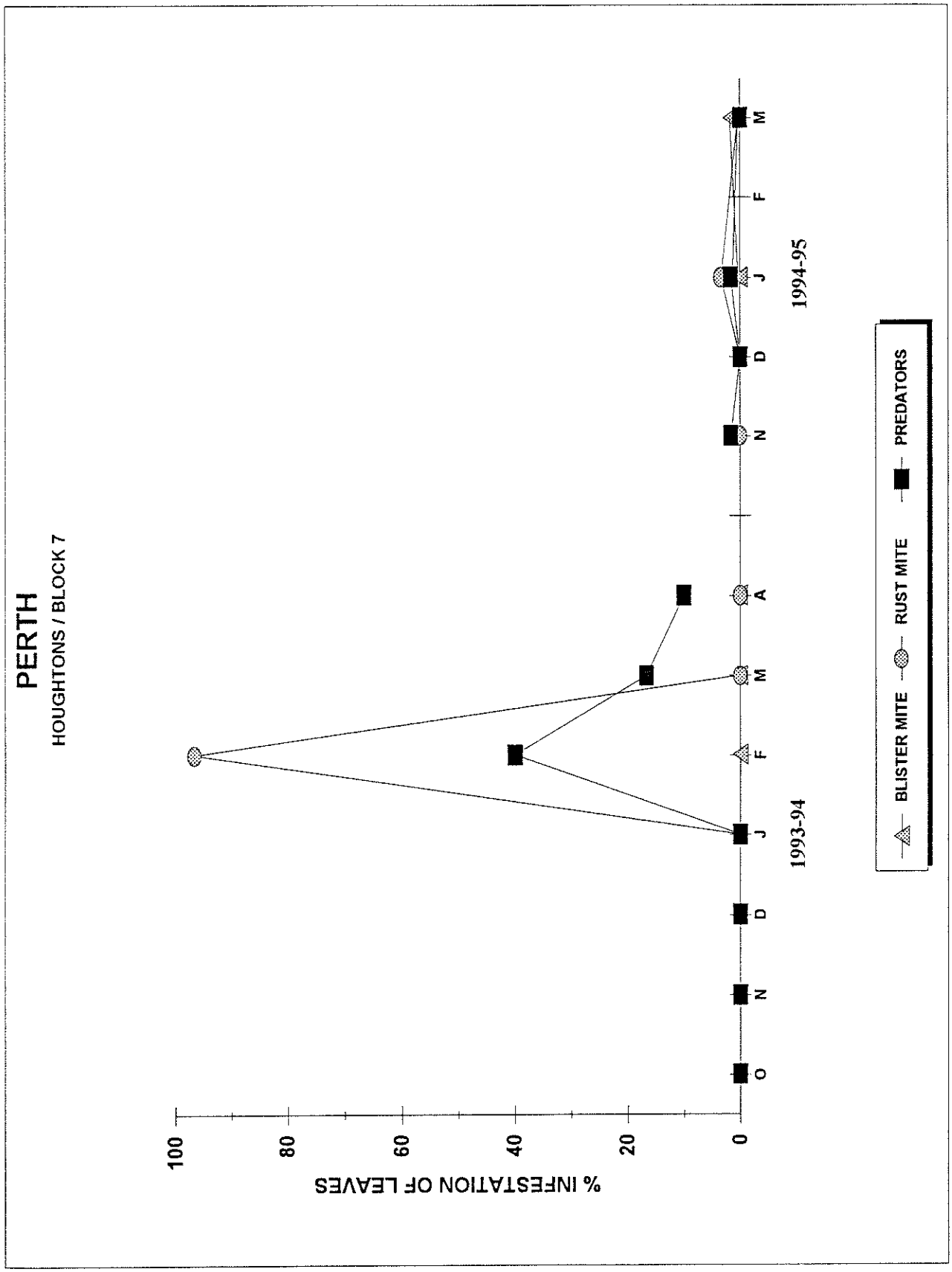


Figure 48. Pest and predatory mite populations at Innamincka, Perth, Western Australia during 1993/95.

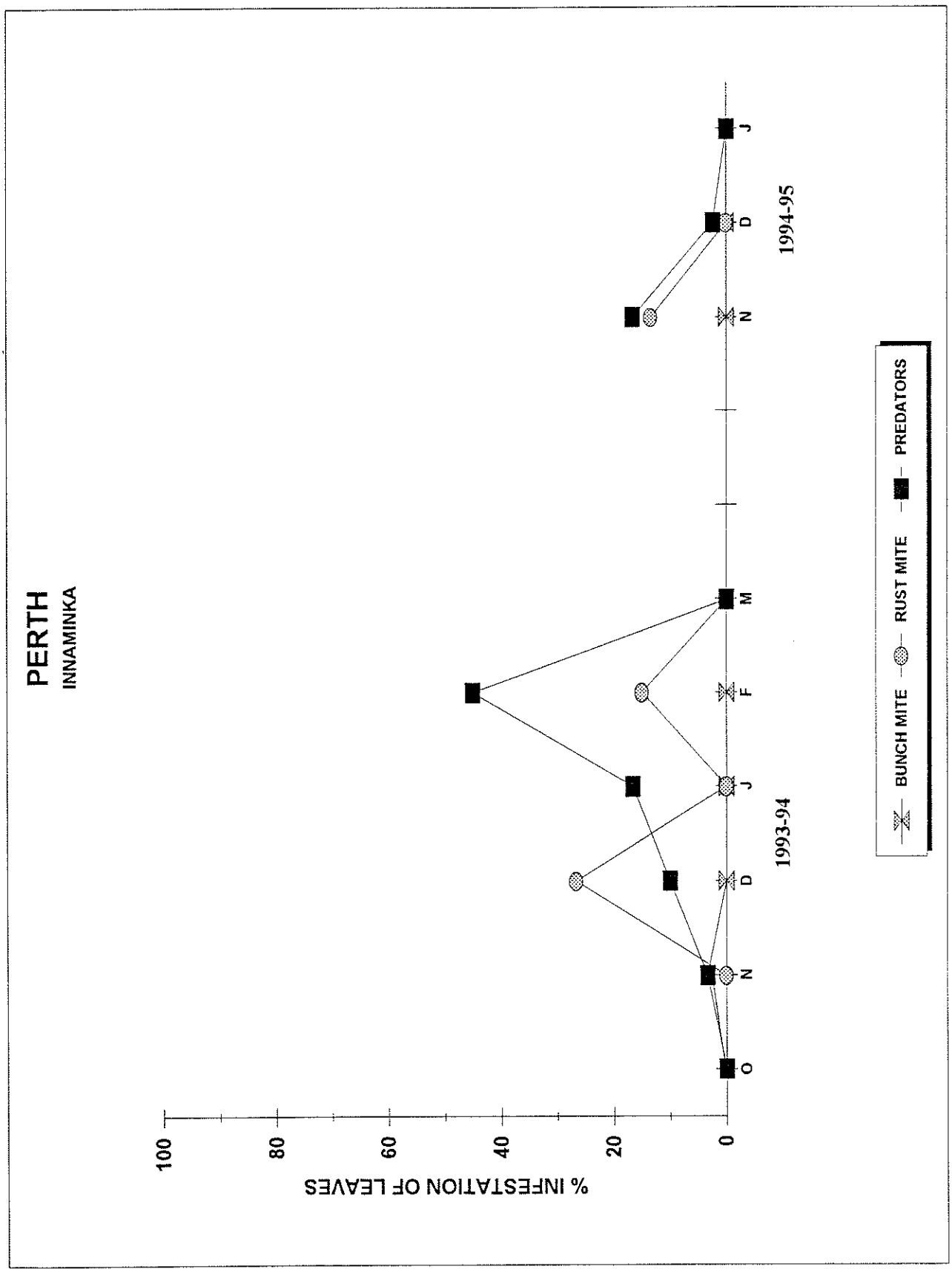


Figure 49. Pest and predatory mite populations at Sandalford, Perth, Western Australia during 1993/94.

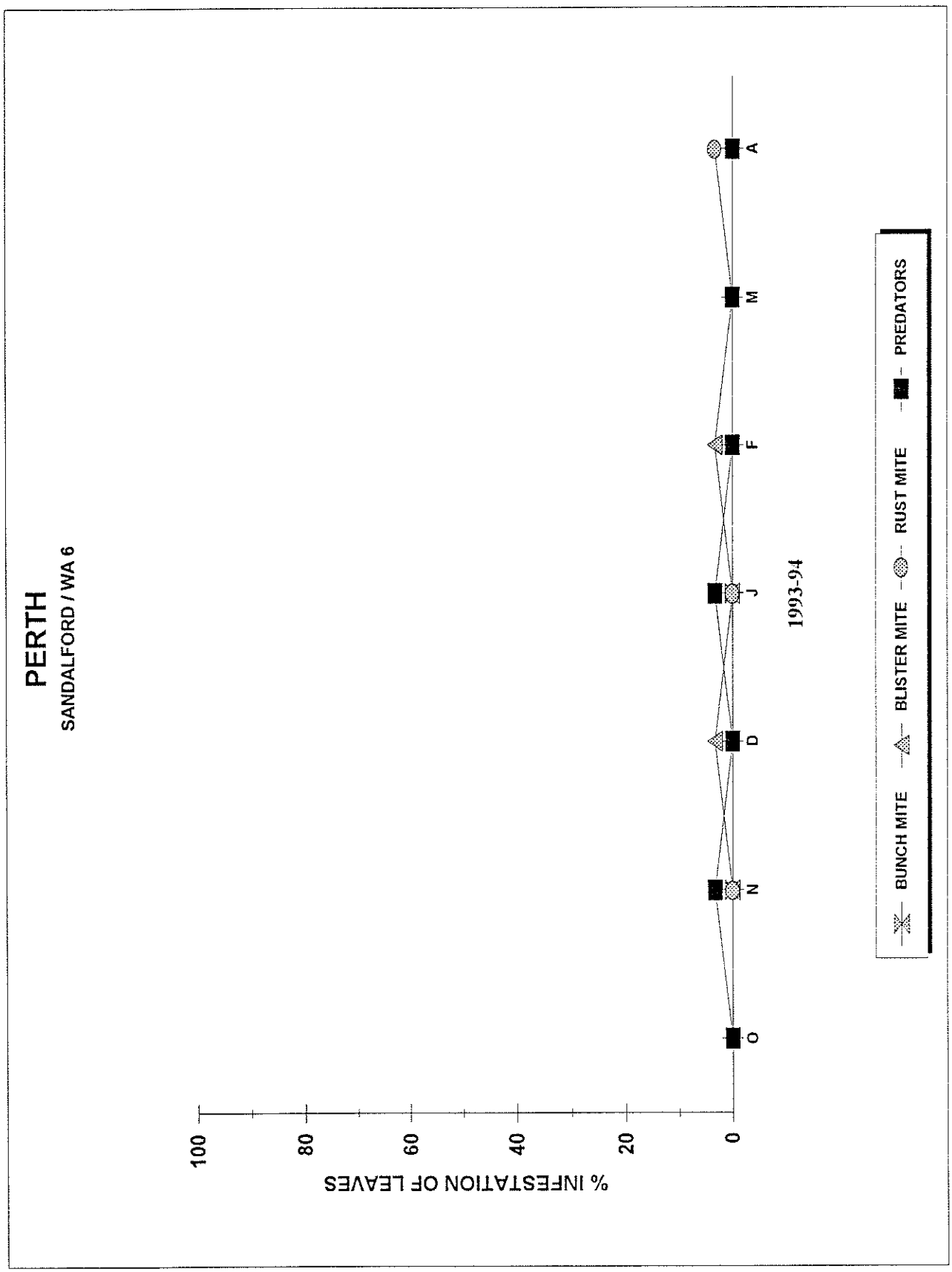


Figure 50. Predatory mite population at Trease, Herne Hill, Perth, Western Australia during 1993/94 (Table grapes)

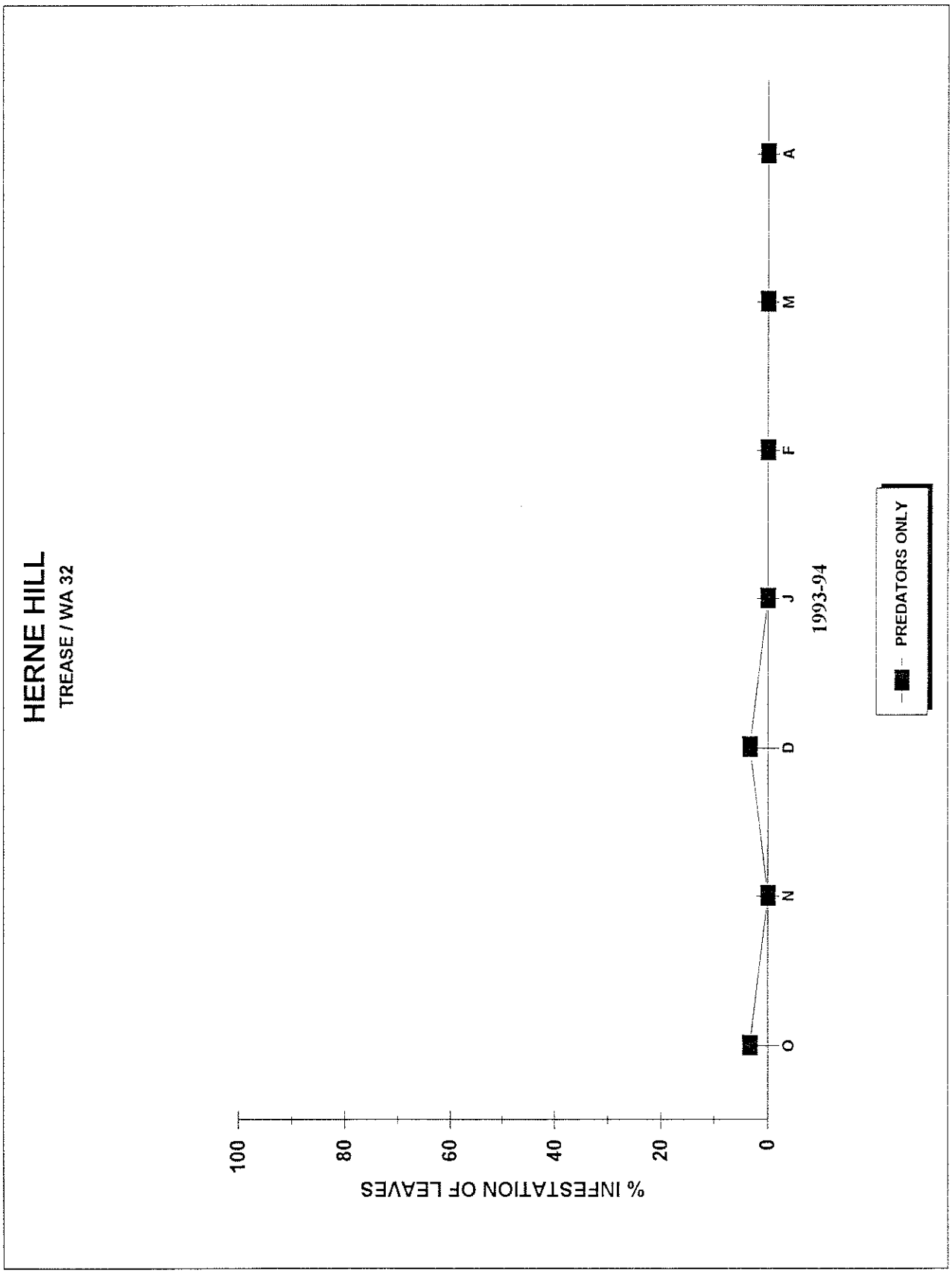


Figure 51. Predatory mite population at Bindoon, Waldek, Perth, Western Australia, (Table grapes) during 1993/94.

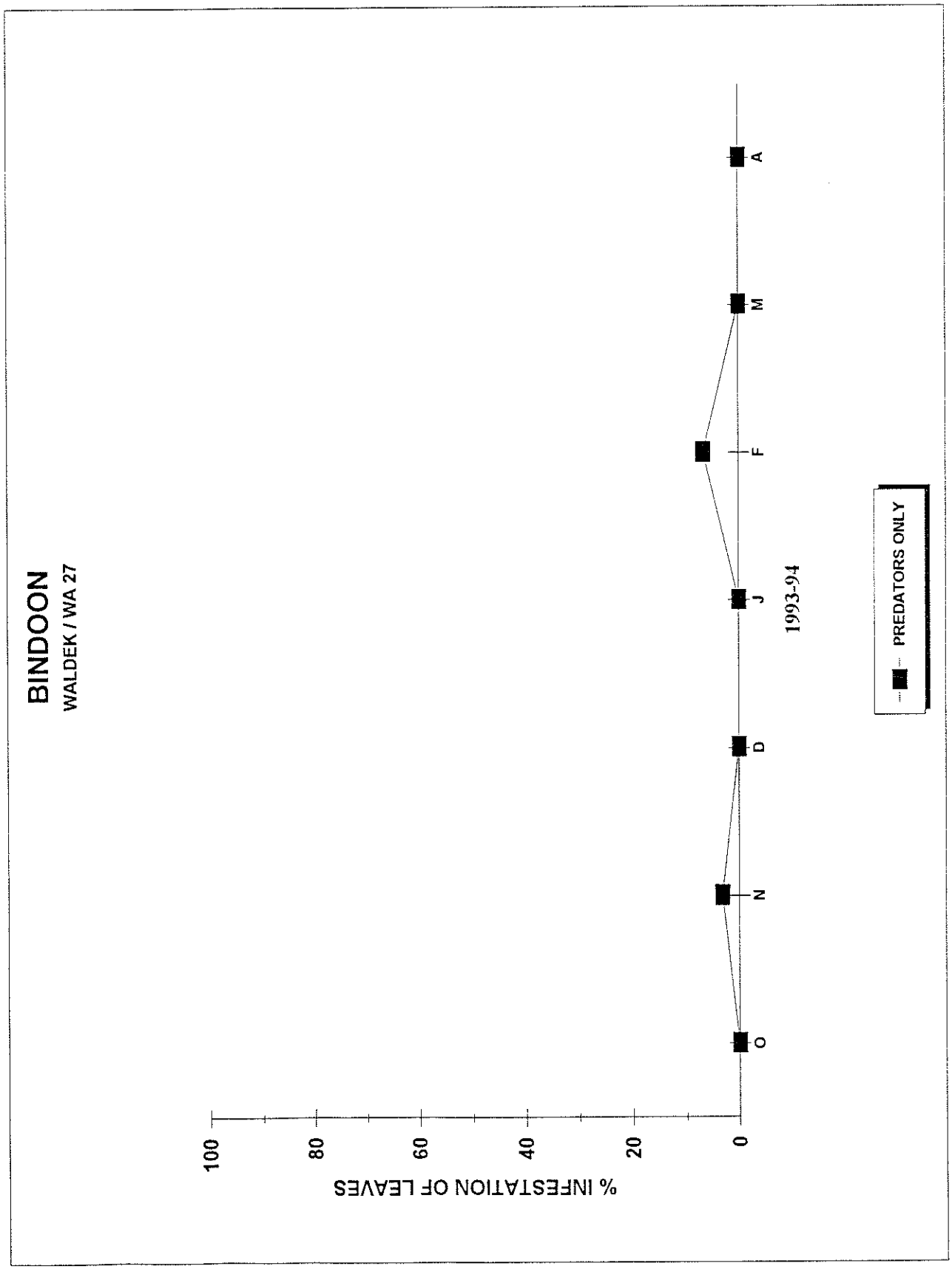


Figure 52. Pest and predatory mite populations at Taylor, Guildford, Perth, Western Australia (Table grapes) during 1993/94.

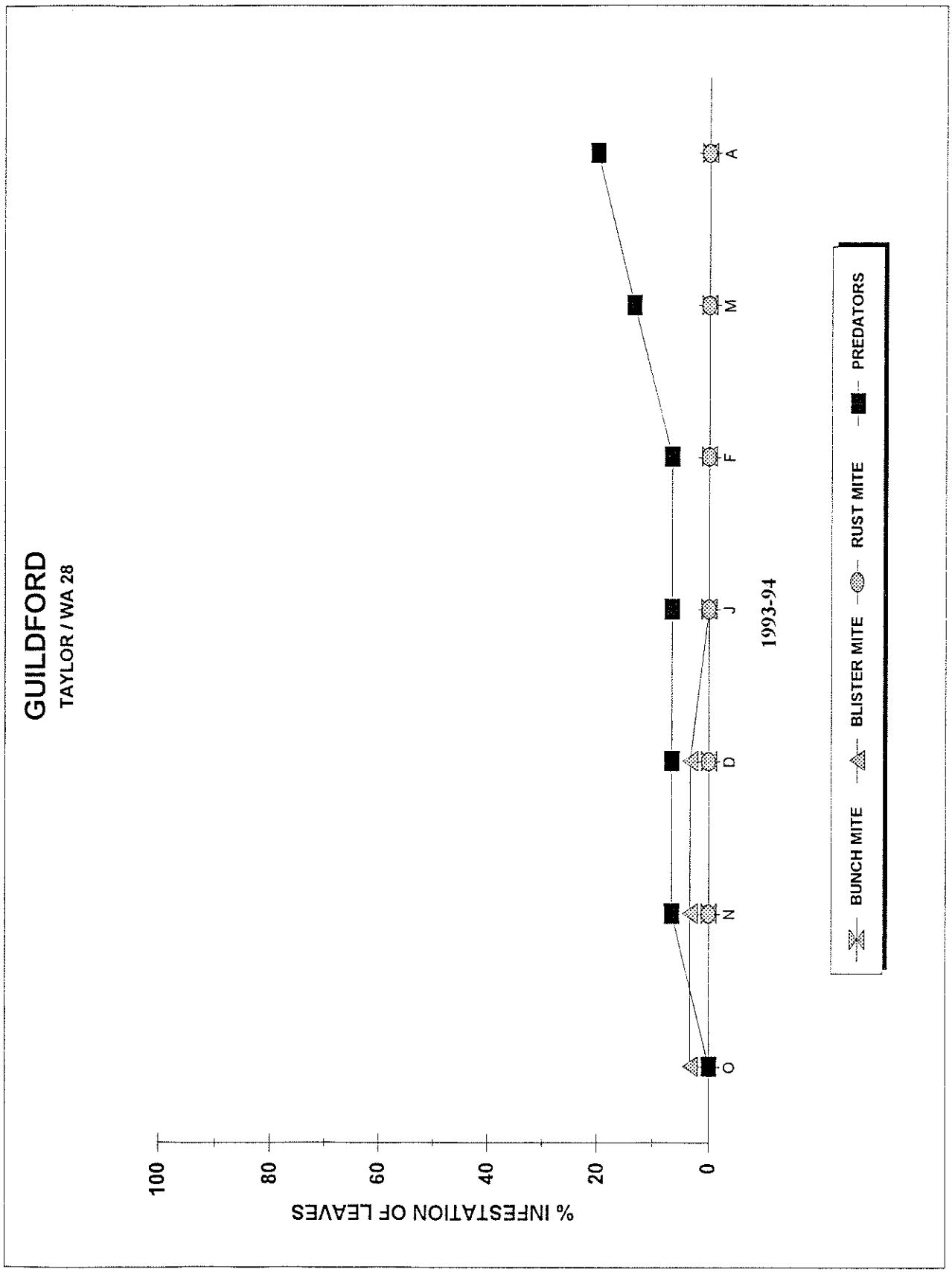


Table 12. **Predatory mite species incidence during sampling in the Margaret River region (Western Australia) during 1993/94 and 1994/95. Figures in parentheses represent 1994/95 data.**

| WESTERN AUSTRALIA MARGARET RIVER 1993/94 | | | SPECIES PERCENTAGES | | | | | |
|---|---|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *A. christinae* | *A. elinae* | *A. lentiginosus* | *A. transvaalensis* | Other |
| Margaret River | Killerby WA7 (Bunbury) | 88 | 85.2 | | 13.6 | | | 1.1 |
| | Amberley Est. WA8 (Busselton) | 35 | 94.3 | | | | | 5.7 |
| | Cape Clairault WA9 (Carbanup River) | 3(23) | 100 (34.8) | | (13) | | (52.2) | |
| | Evans & Tate WA10 (Cowaramup) | 2 | 50 | | 50 | | | |
| | Leeuwin Est. WA11 (Margaret River) | 2 | | | | 50 | | 50 |
| | Coodarup Wines WA 12 (Augusta) | 39 | 100 | | | | | |
| | Korijedale WA29 (Harvey) | 76 | | | 100 | | | |
| | Ramponi WA31 (Donnybrook) | 2 | | | | | | 100 |
| | Longo WA33 (Witchcliffe) | 56 | 18.6 | 70.6 | | 5.4 | | 5.4 |

Figure 53. Pest and predatory mite populations at Killerby vineyards, Margaret River, Western Australia during 1993/94.

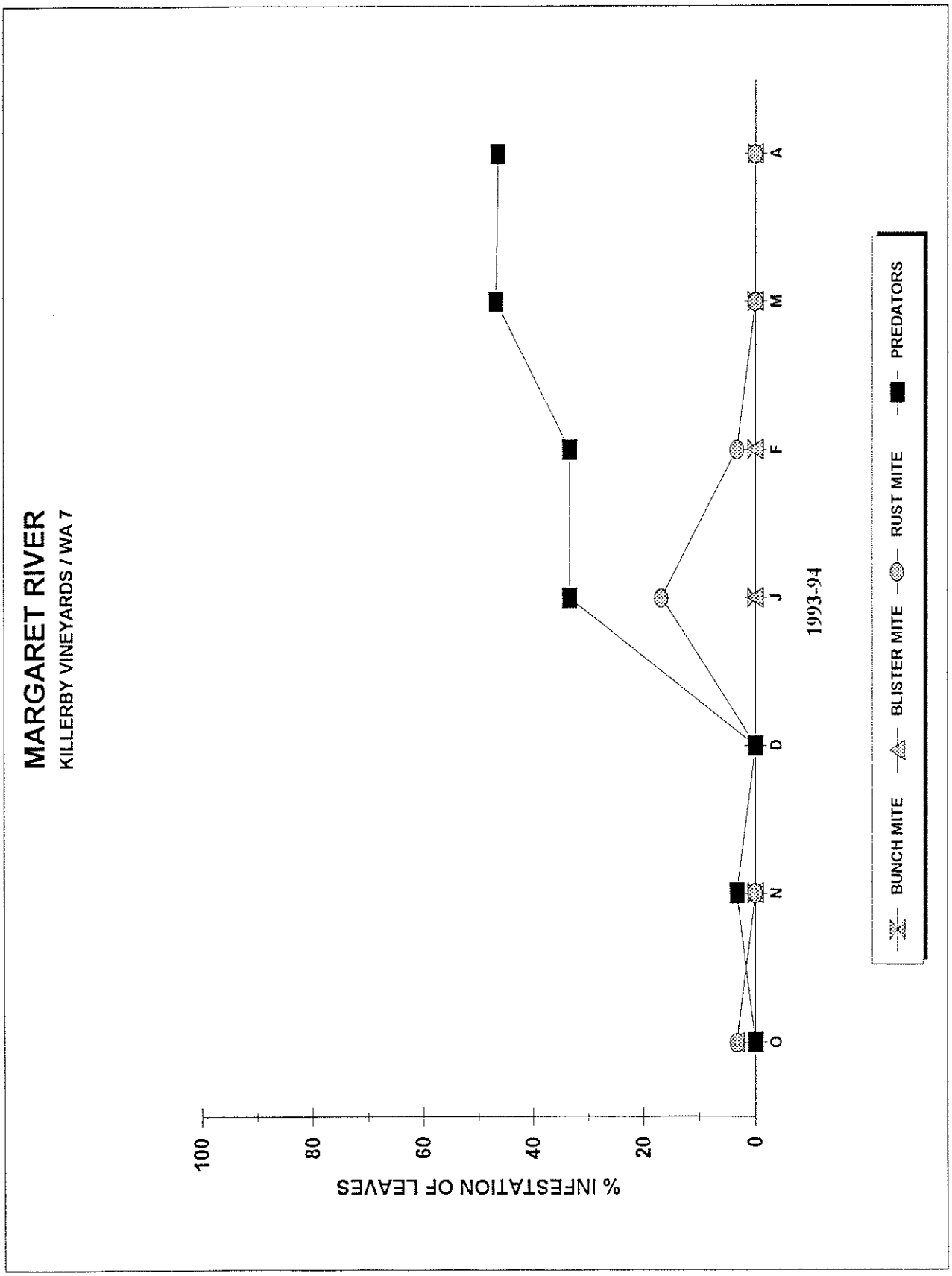


Figure 54. Pest and predatory mite populations at Amberley Estate, Margaret River, Western Australia during 1993/94.

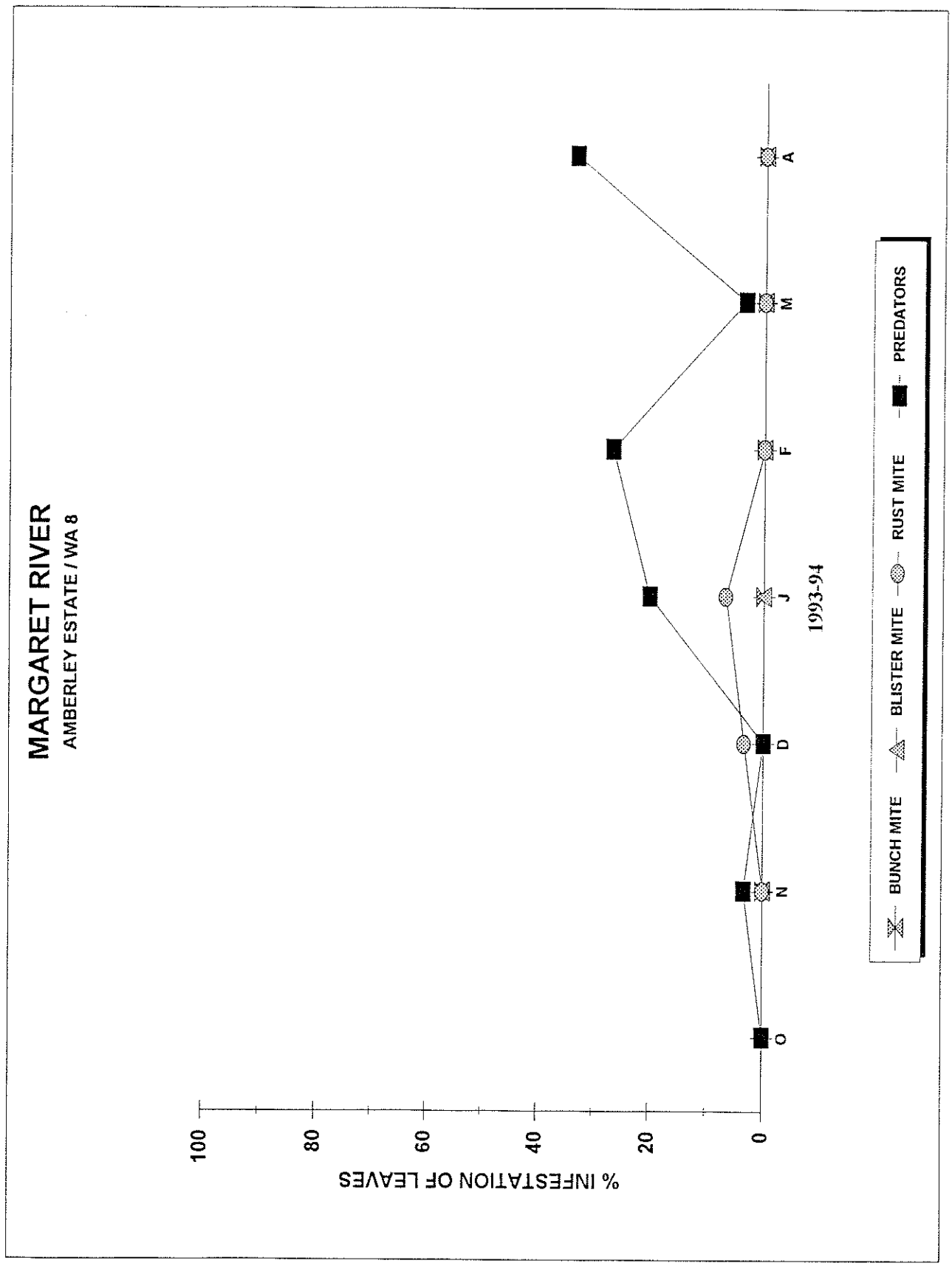


Figure 55. Pest and predatory mite populations at Cape Clairault, Margaret River, Western Australia during 1993/95.

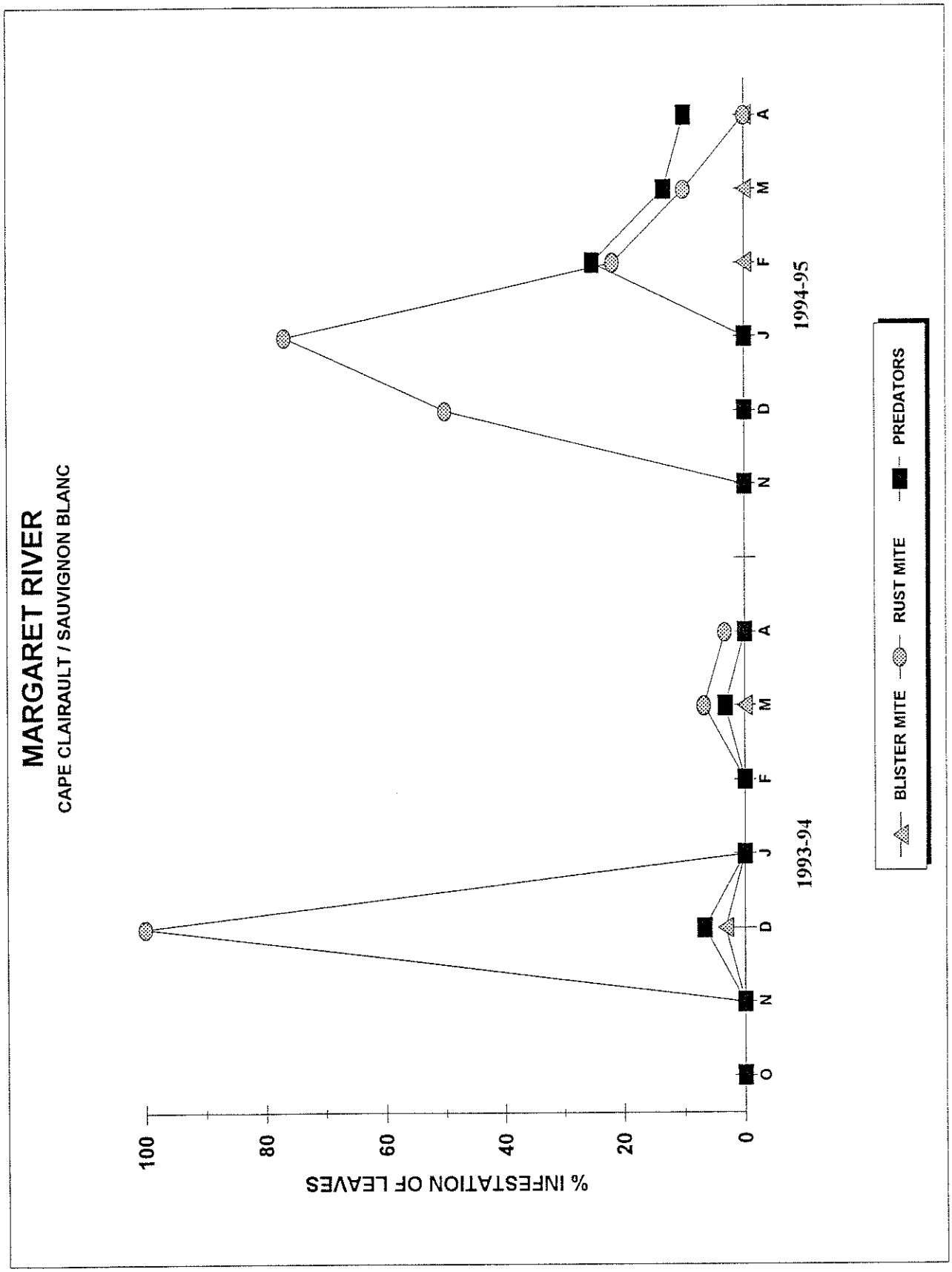


Figure 56. Pest and predatory mite populations at Evans and Tate, Margaret River, Western Australia during 1993/94.

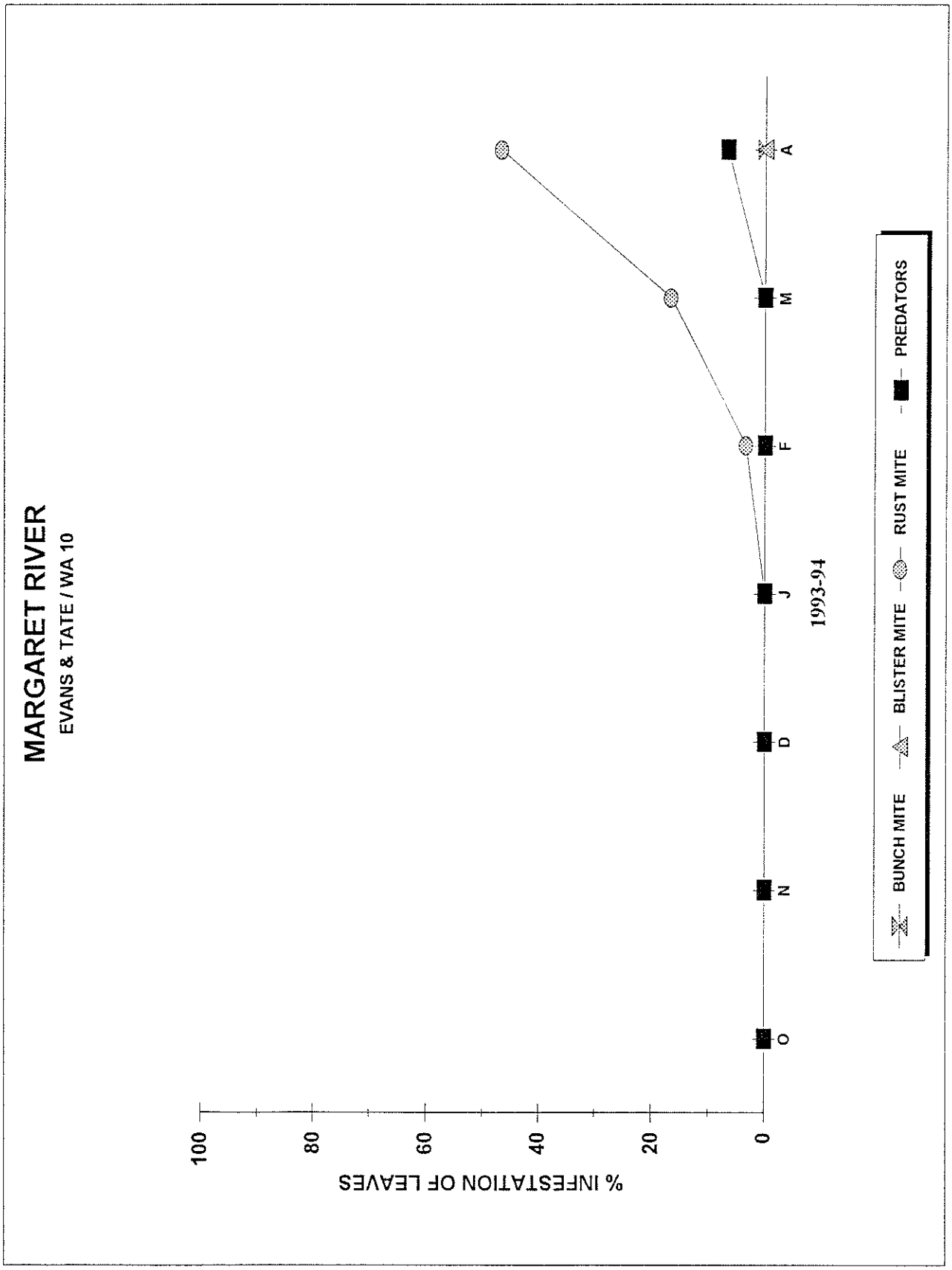


Figure 57. Predatory mite population at Leeuwin Estate, Margaret River, Western Australia, during 1993/94.

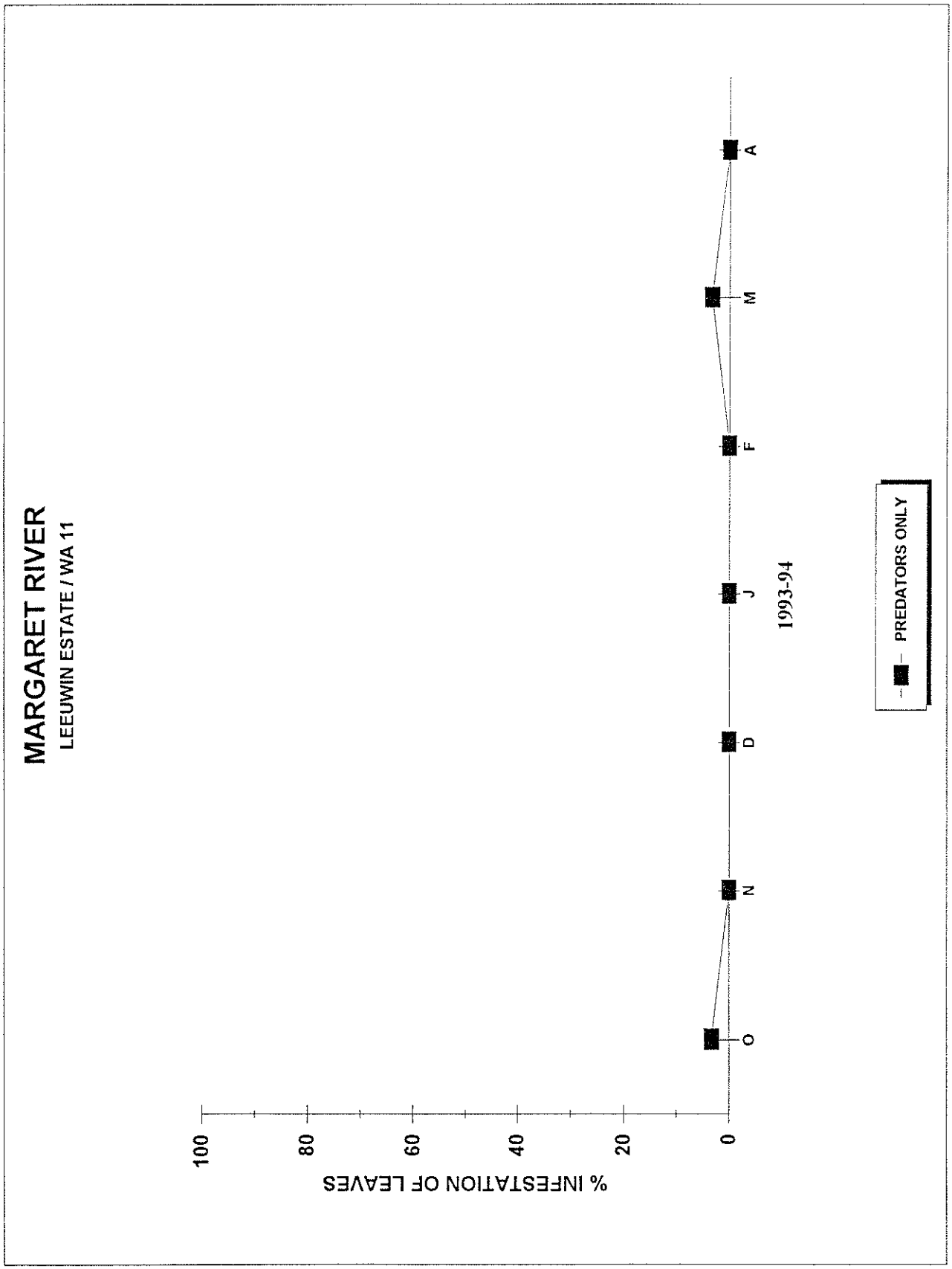


Figure 58. Predatory mite population at Coodarup Wines, Margaret River, Western Australia during 1993/94.

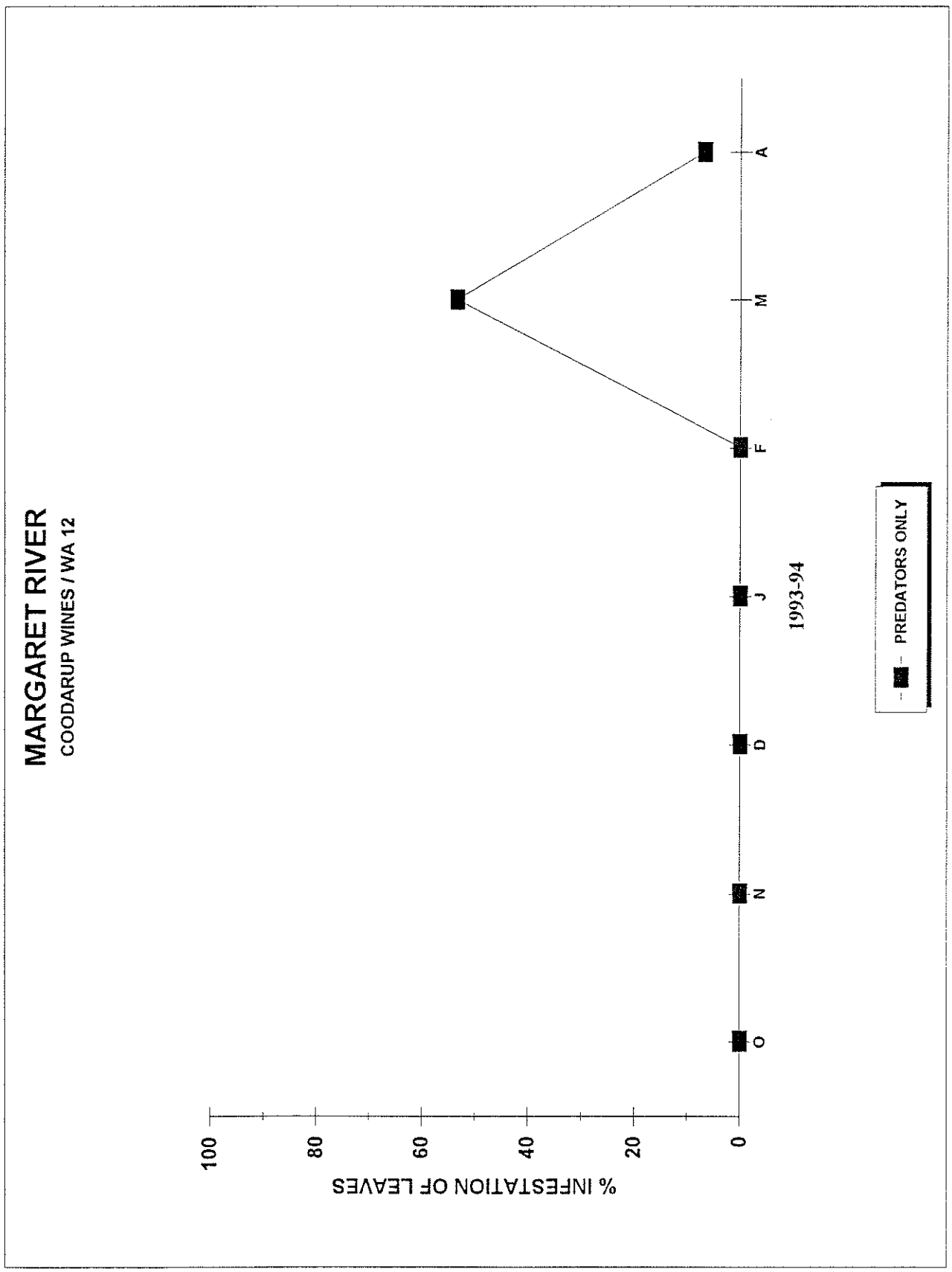


Figure 59. Predatory mite populations at Harvey, Korijedale, Margaret River, Western Australia during 1993/94 (Table grapes).

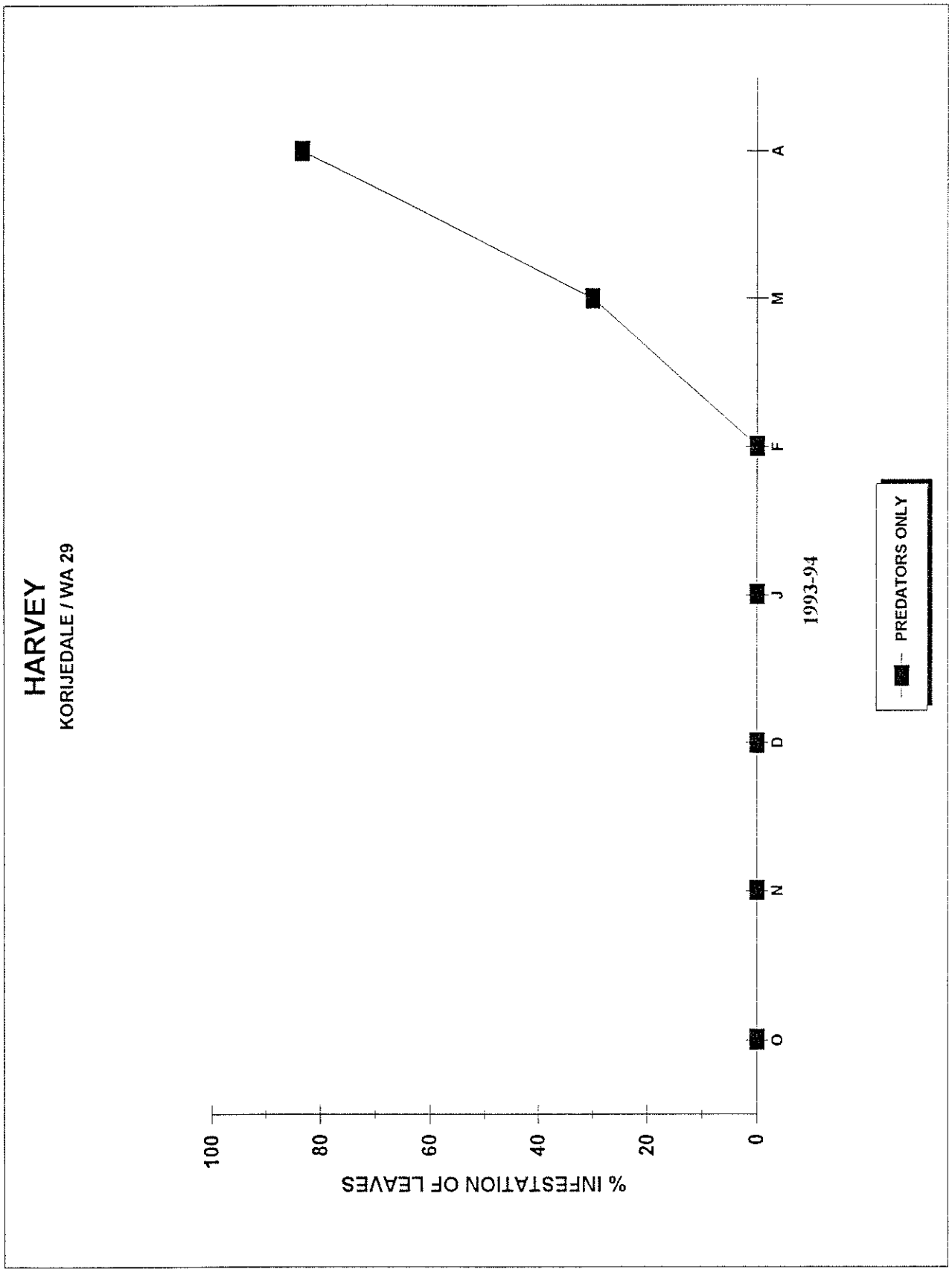


Figure 60. Pest and predatory mite populations at Ramponi, Donnybrook, Margaret River, Western Australia during 1993/94 (Table grapes).

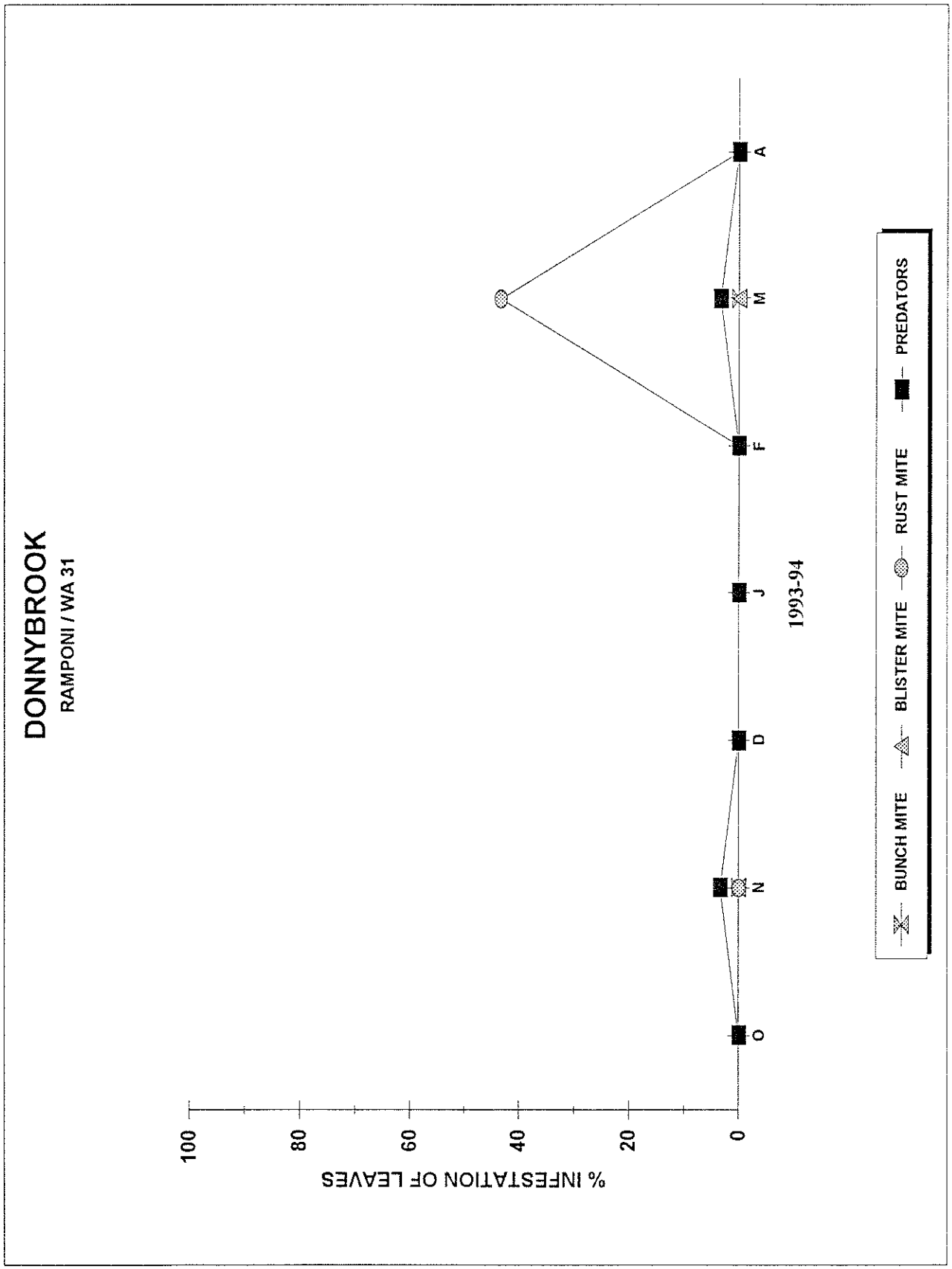


Figure 61. Rust mite population at Thorpe, Busselton, Margaret River, Western Australia during 1993/94 (Table grapes).

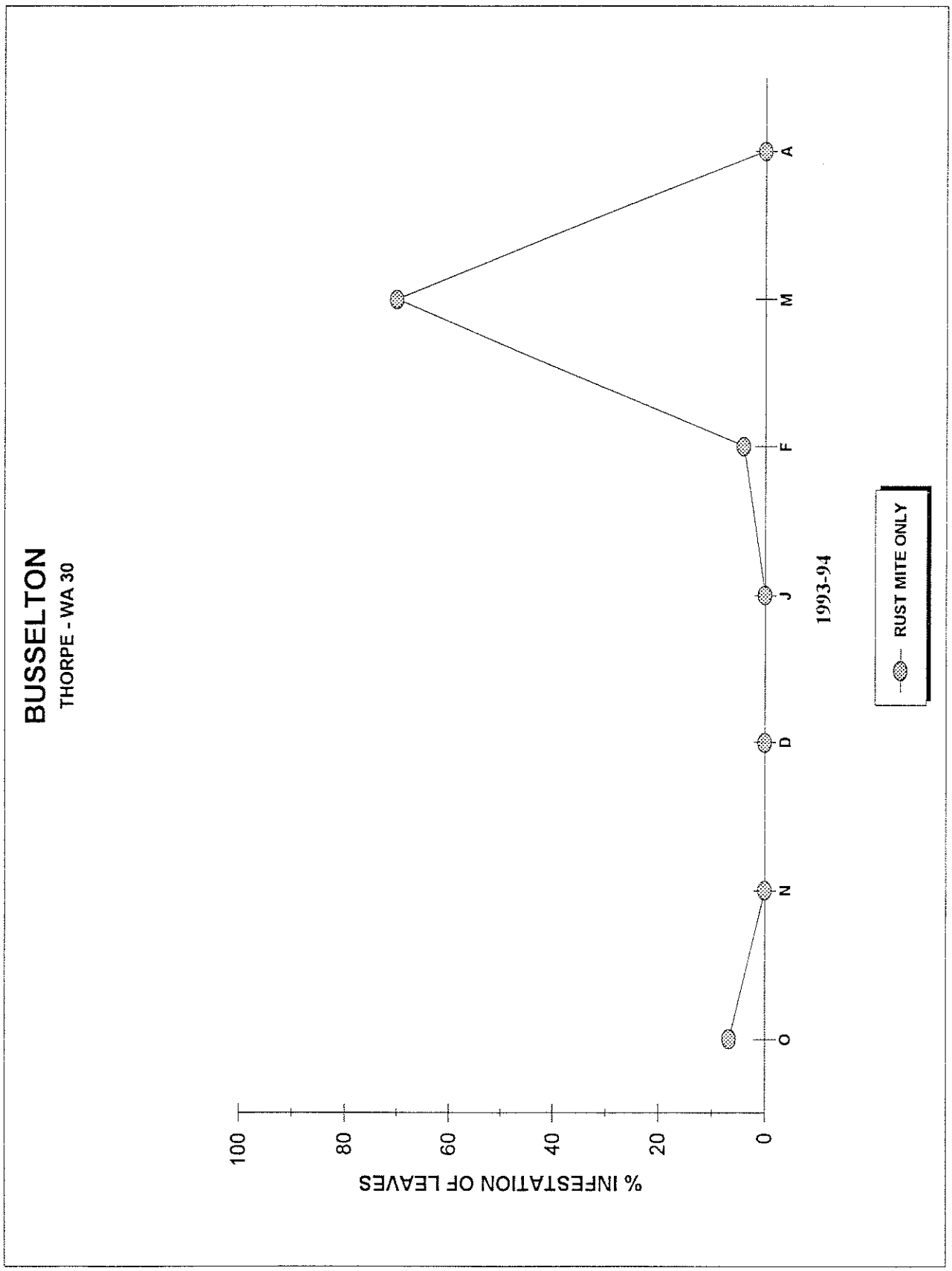
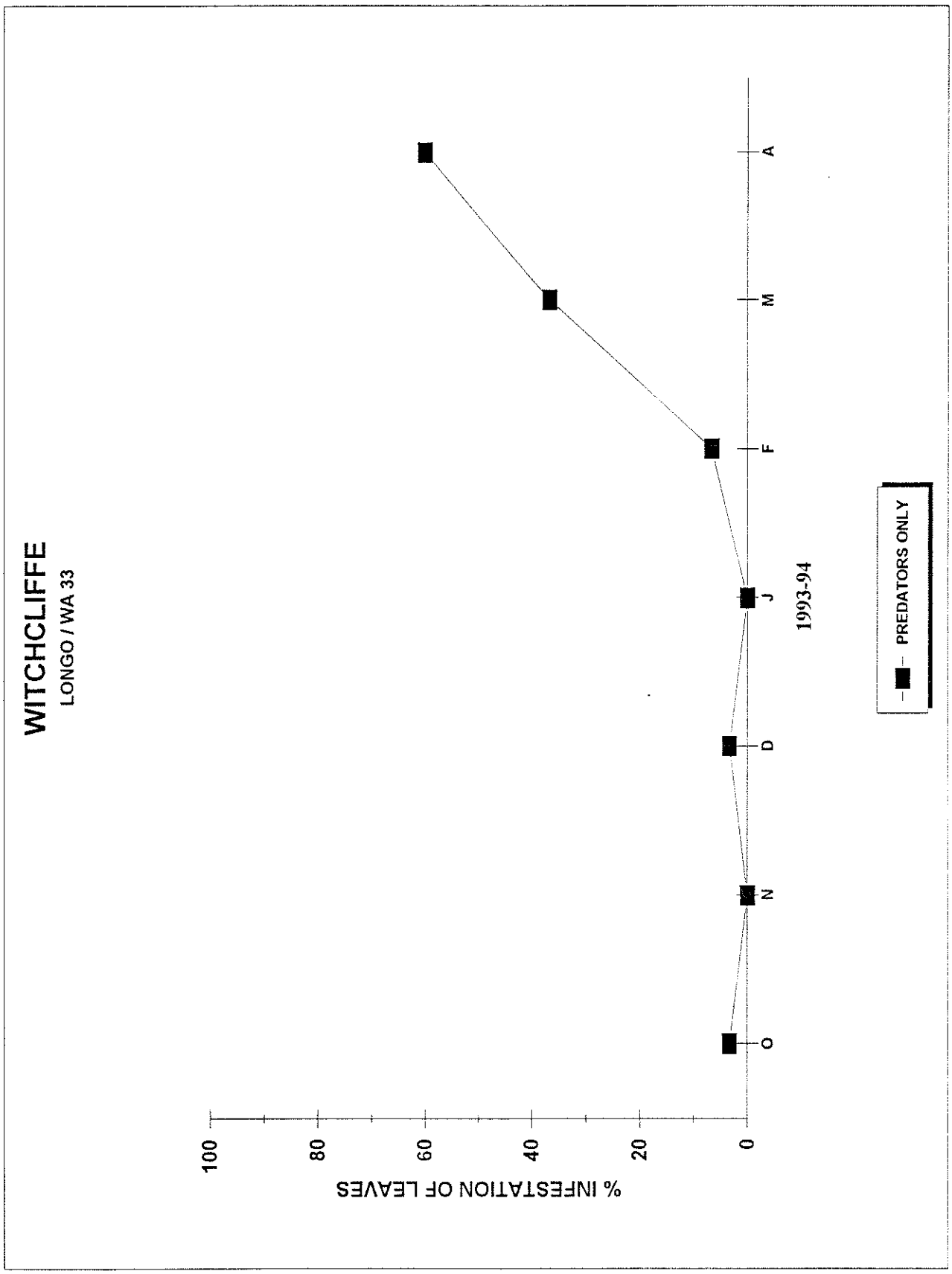


Figure 62. Predatory mite population at Longo, Witchcliffe, Margaret River, Western Australia, during 1993/94 (Table grapes).



(c) Manjimup

Eight blocks in 8 winegrape vineyards (Blackwood Crest Wines-Boyup Brook, Kinclaven Estate-Bridgetown, Constable Vineyard-Manjimup, Fonti Pool Farms-Manjimup, Mountford Wines-Pemberton, Phoenicia Vineyard-Pemberton, Smithbrook Vineyard-Manjimup, Donnelly River Wines-Pemberton) were sampled in this region during 1993/94. Blackwood Crest Wines and Donnelly river Wines were also sampled in 1994/95.

Pest and predatory mite population data are presented in Figures 63-69 and Table 13.

Generally low levels of pest and predatory mites were typical of most sites. No mites, pest or predatory were found at Fonti Pool farms. Four applications of insecticides and miticides (endosulfan, dicofol, carbaryl) were made at this vineyard during December/January which no doubt accounts for this. Greatest numbers of predators (primarily *T. dossei*) were found at Blackwood Crest, Kinclaven Estate and Donnelly River. At all these sites pest populations (rust and/or blister mites) were apparently regulated by predators (Figs. 63-64, 69). Fungicide sprays at these three sites were based on wettable sulphur, fenarimol and propiconazole although lime sulphur was used at Blackwood Crest. No insecticides were used. No predators were found at Constable, Fonti Pool, Phoenicia and Smithbrook; although spray records were not supplied it seems likely that insecticides were used in these vineyards.

**RECOMMENDATIONS**

The potential for biological control of mites in this region appears to be good. Large populations of *T. dossei* appear able to develop when chemical inputs are low and/or benign. Populations outside vineyards appear to be good and can invade rapidly. High chemical inputs appear to be the major factor suppressing predatory mite populations in this region; the use of lime sulphur and broad spectrum insecticides/miticides must be stopped. The introduction of *T. doreenae* to this region would enhance biological control potential.

**Table 13.** Predatory mite species incidence during sampling in the Manjimup region (Western Australia) during 1993/94 and 1994/95. Figures in parentheses represent 1994/95 data.

| WESTERN AUSTRALIA MANJIMUP 1993-94 | | | SPECIES PERCENTAGES | | | |
|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *A. lentiginosus* | *A. harveyi* | *A. dieteri* |
| Manjimup | Blackwood Crest WA13 | 102 (16) | 96.1 (76.9) | 3.9 | | (23.1) |
| | Kinclaven Est. WA14 | 39 | 97.4 | | 2.6 | |
| | Mountford Wines WA17 | 3 | 100 | | | |
| | Donnelly River WA20 | 31 (35) | 100 (100) | | | |

Figure 63. Predatory mite populations at Blackwood Crest, Manjimup, Western Australia, during 1993/95.

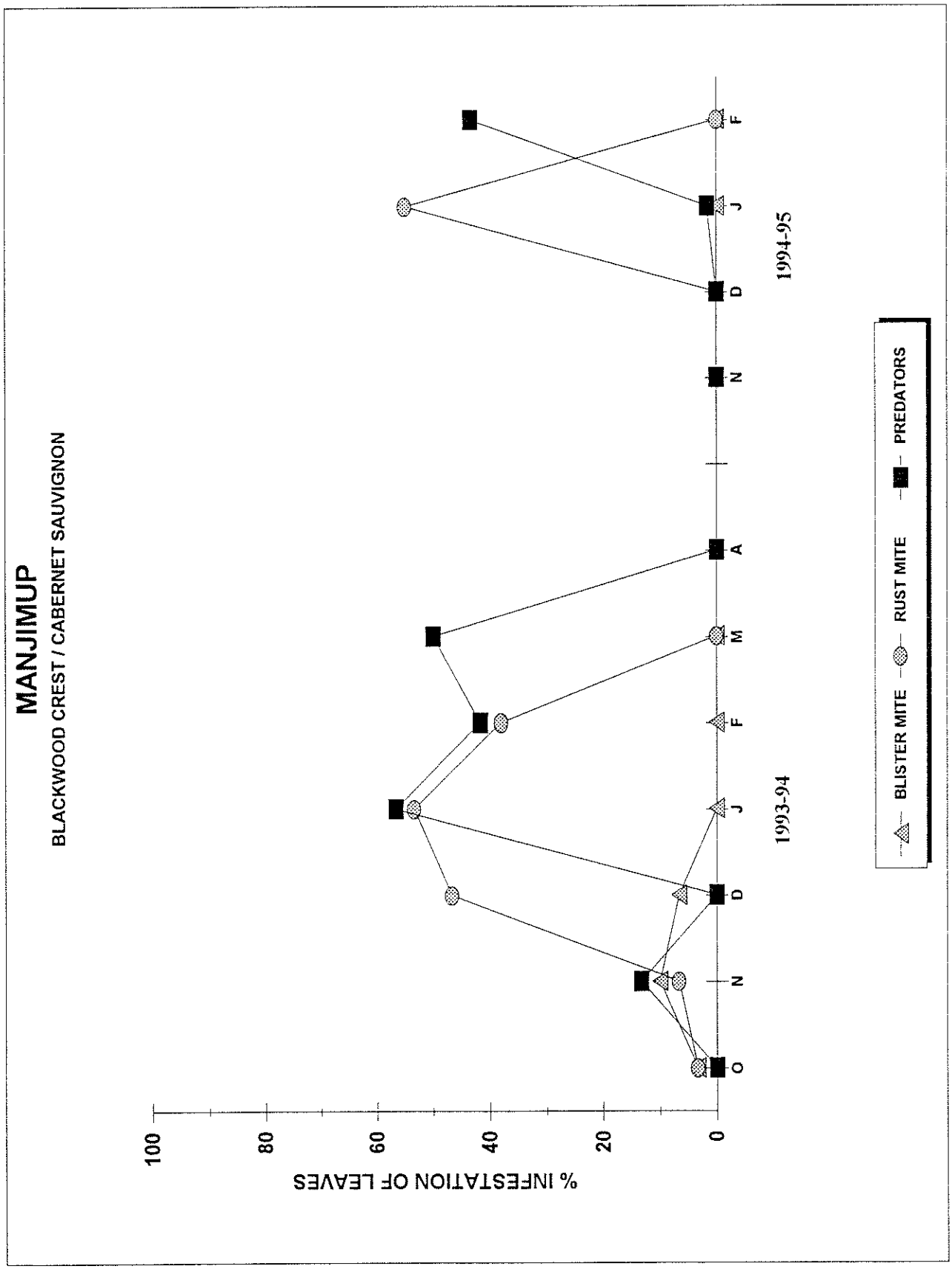


Figure 64. Pest and predatory mite populations at Kinclaven Estate, Manjimup, Western Australia during 1993/94.

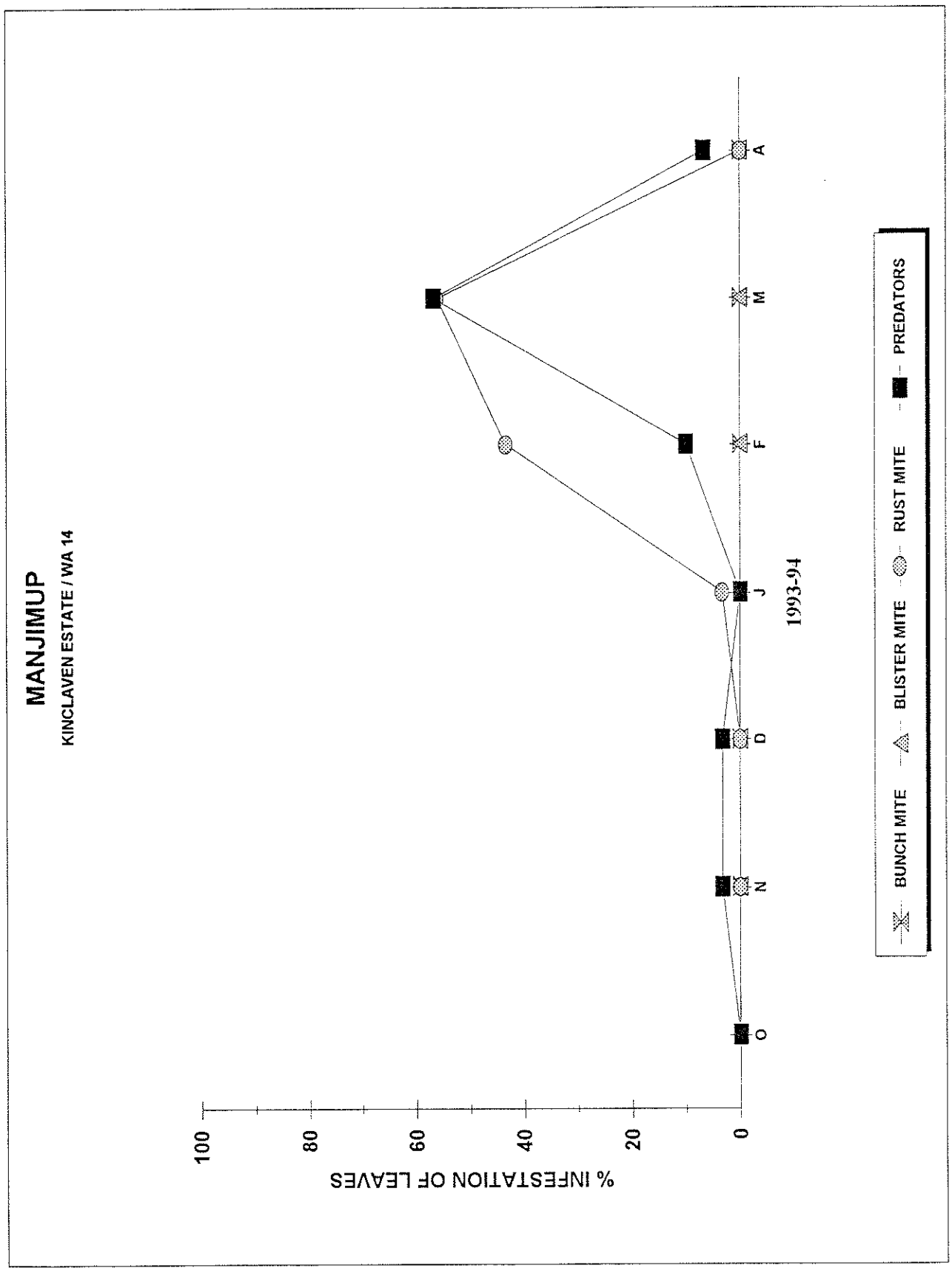


Figure 65. Pest mite populations at Constable Vineyards, Manjimup, Western Australia, during 1993/94.

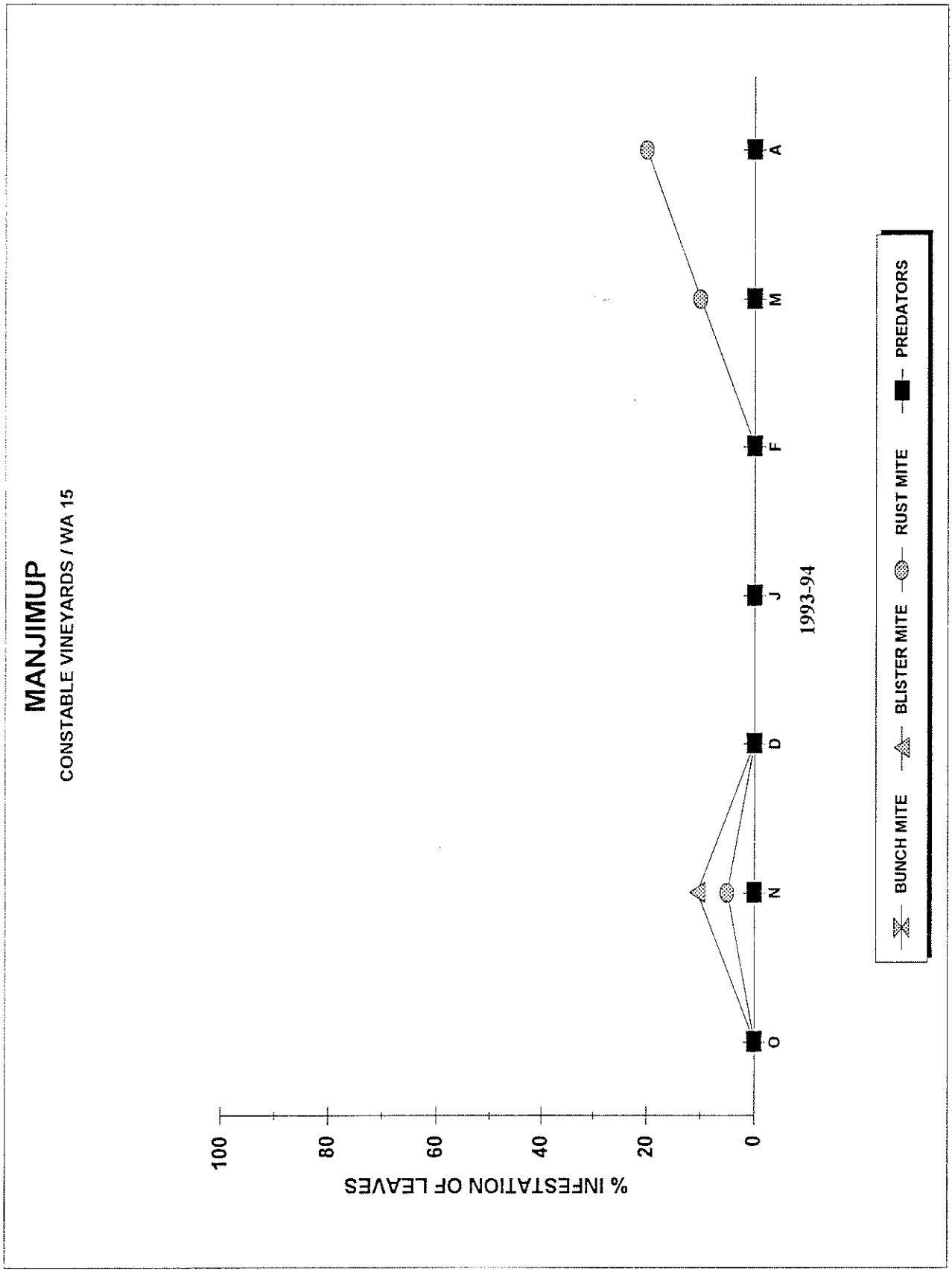


Figure 66. Pest and predatory mite populations at Mountford Wines, Manjimup, Western Australia, during 1993/94.

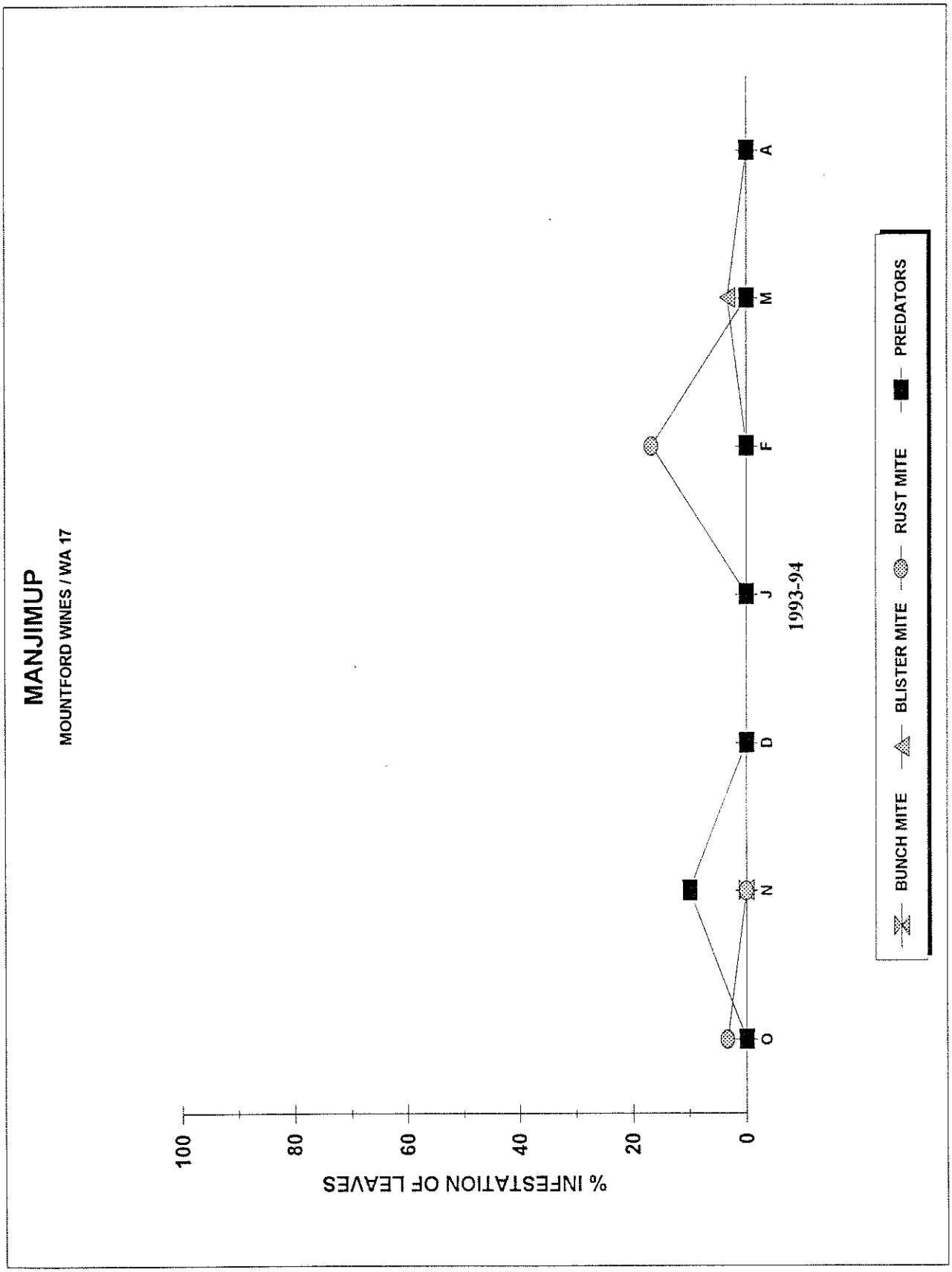


Figure 67. Blister mite population at Phoenicia Vineyard, Manjimup, Western Australia, during 1993/94.

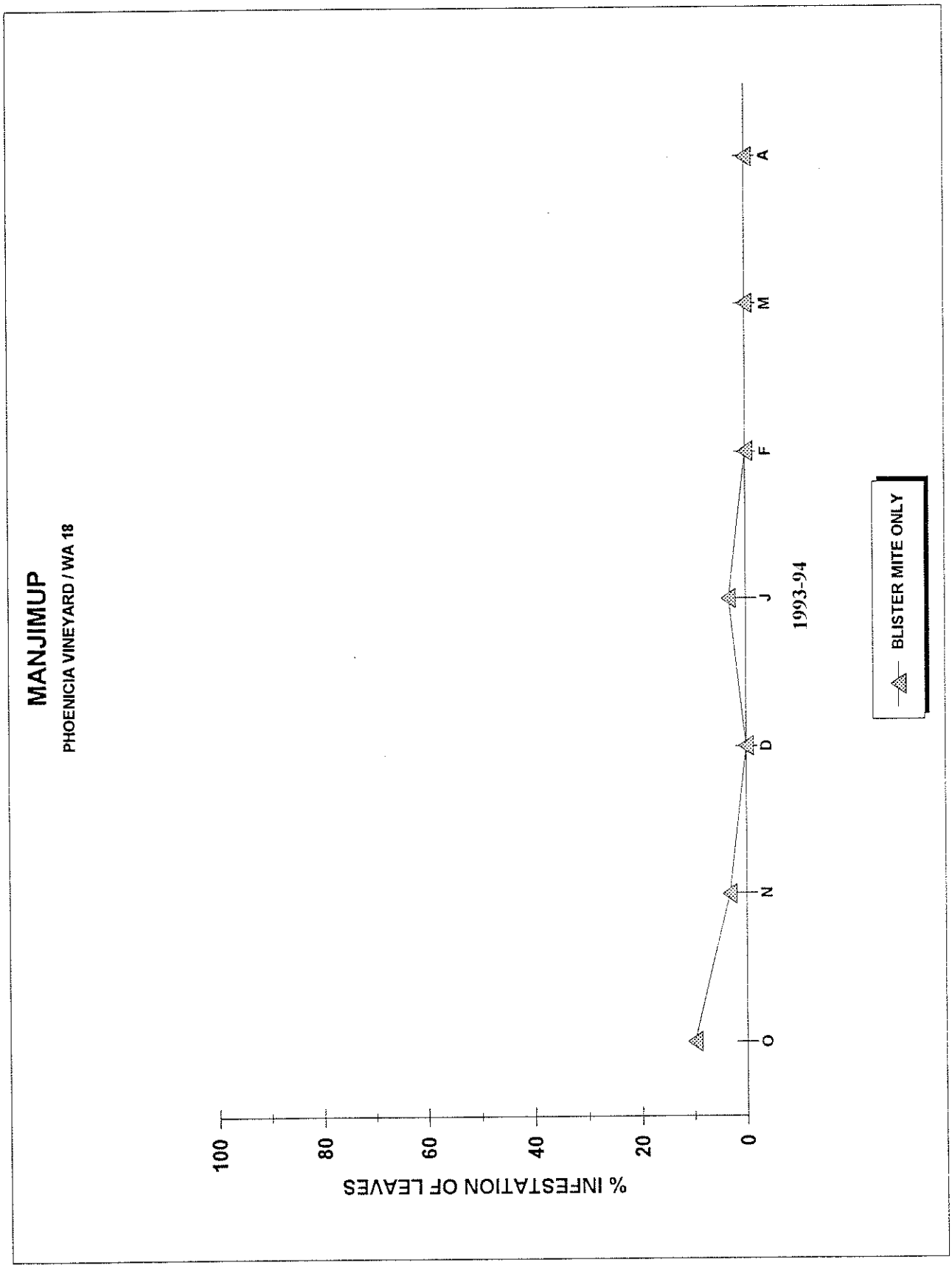


Figure 68. Rust mite population at Smithbrook, Manjimup, Western Australia, during 1993/94.

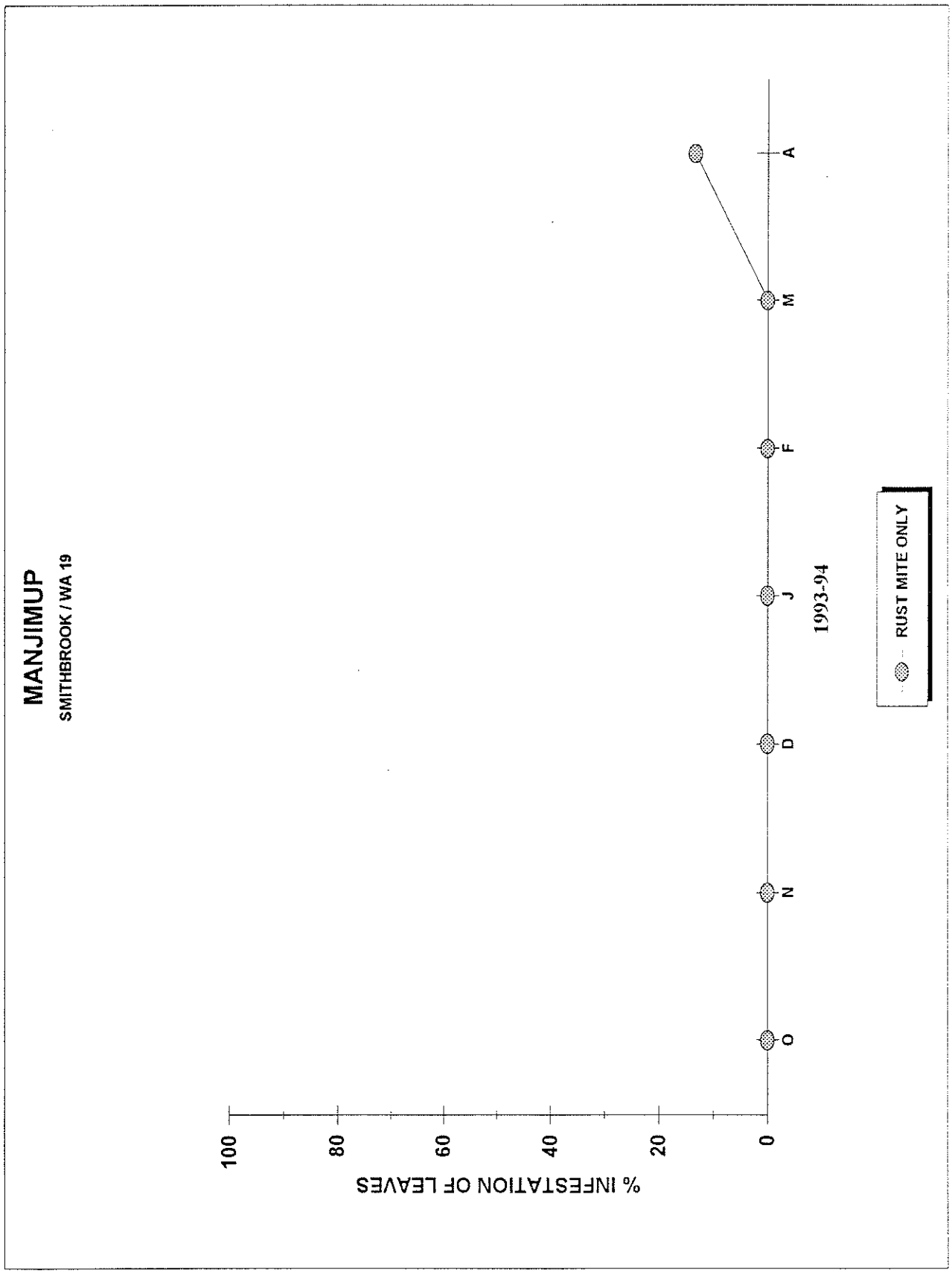
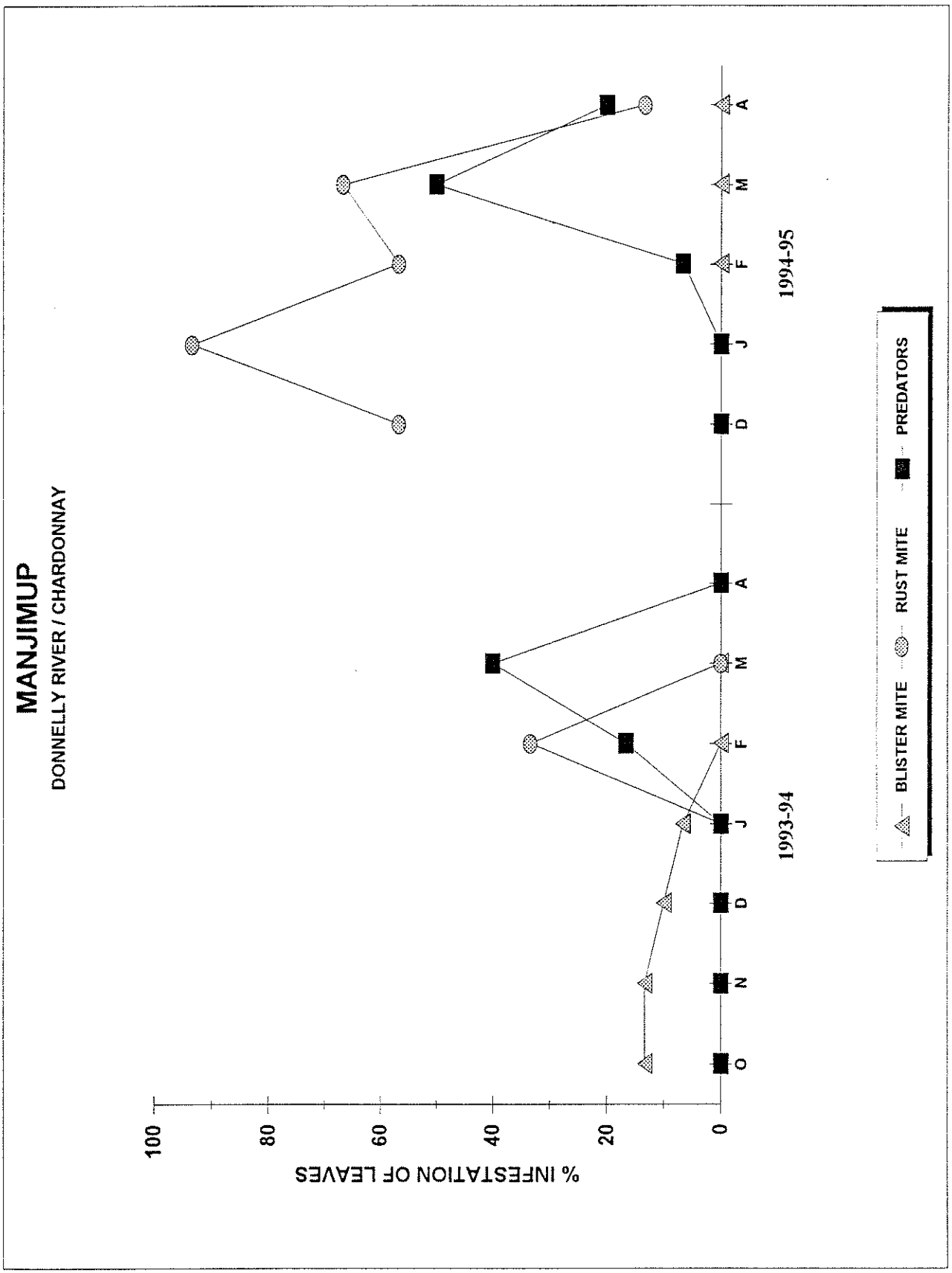


Figure 69. Pest and predatory mite populations at Donnelly River, Manjimup, Western Australia, during 1993/95.



d) Mount Barker

Six vine blocks in 6 vineyards (Frankland River Vineyard-Frankland, Landsdale Vineyard-Mount Barker, Whispering Hill Vineyard-Albany, Castle Rock Estate-Albany, Wignalls King River Wines-Albany, Karriview Wines-Denmark) were sampled in this region during 1993/94. The Wignalls King River vine block was also sampled during 1994/95.

Pest and predatory mite population data are presented in Figures 70-74 and Table 14.

Low or absent mite populations were a feature of all sites except Wignalls King River and Karriview. No mites were found at Landsdale and only very small numbers of rust mite in February at Whispering Hill and very small numbers of rust mite, blister mite and predators in April at Frankland River. The broad-spectrum insecticide malathion was used regularly at Landsdale. Castle Rock had a small population of rust mites at the end of the season shortly after alphacypermethrin (broad-spectrum pyrethroid) was applied. In contrast, large numbers of predators, almost all *T. dossei*, occurred at Wignall's King River and to a lesser extent at Karriview Wines. At both sites, *T. dossei* successfully regulated rust mite populations (Figs. 73-74). Only two applications of wettable sulphur and one of triadimenol were applied in 1993/94 at King River. A similar spray schedule was followed in 1994/95 although fenarimol was also used. At Karriview, disease control was based on copper, carbendazim, fenarimol and triadimenol.

**Table 14. Predatory mite species incidence during sampling in the Mount Barker region (Western Australia) during 1993/94 and 1994/95. Figures in parentheses represent 1994/95 data.**

| **WESTERN AUSTRALIA MT BARKER 1993/94** | | **SPECIES PERCENTAGES** | | | |
|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *A. lentiginosus* | Other |
| Mt Barker | Frankland River WA 21 | NIL | | | |
| | Landsdale WA 22 | NIL | | | |
| | Whispering Hill WA23 | NIL | | | |
| | Castle Rock WA24 | NIL | | | |
| | Wignalls King River WA25 | 184 (177) | 98.9 (100) | | 1.1 |
| | Karriview Wines WA26 | 55 | 88.5 | 2.4 | 9.1 |

Figure 70. Pest and predatory mite populations at Frankland River, Mount Barker, Western Australia, during 1993/94.

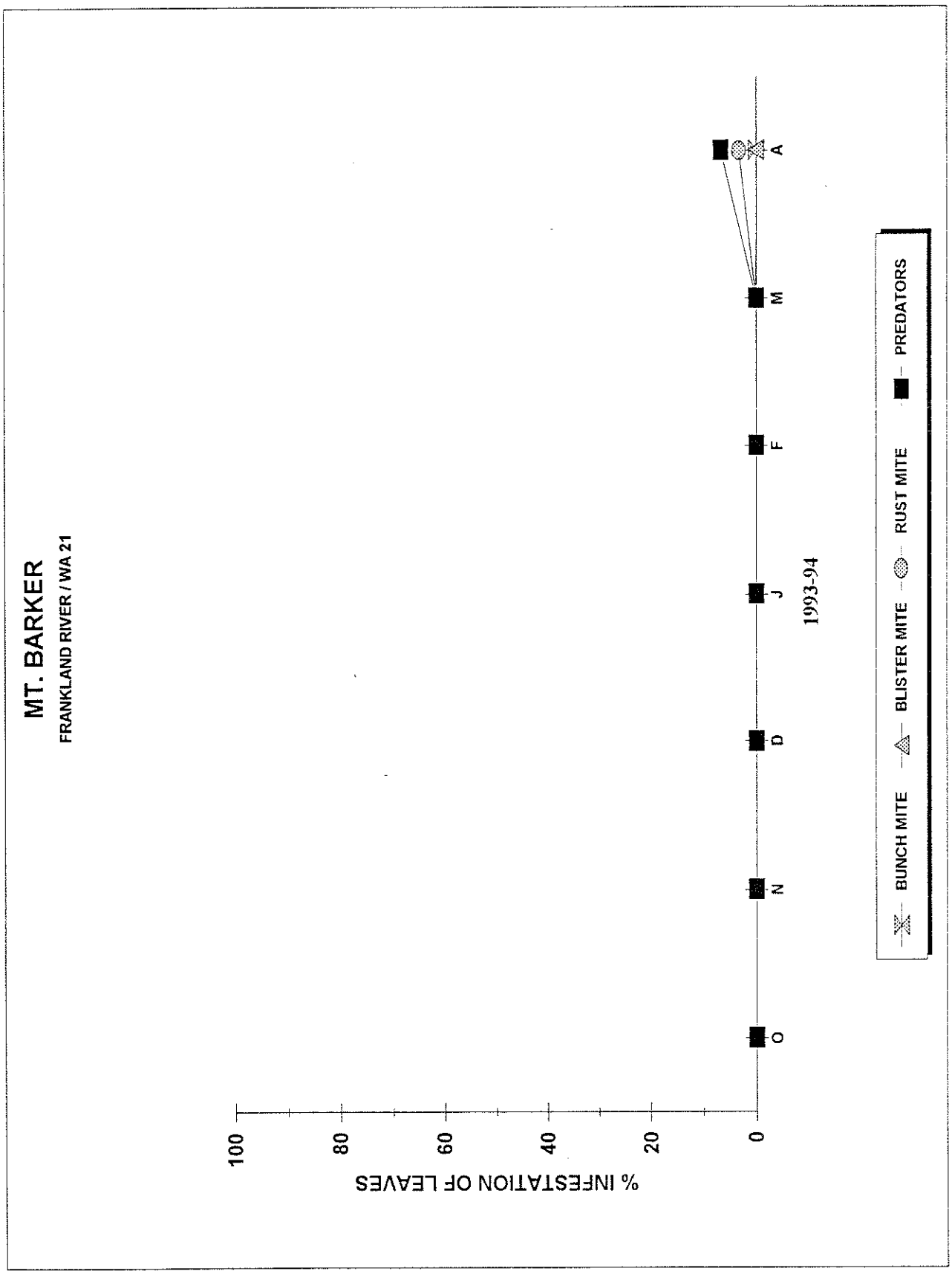


Figure 71. Rust mite population at Whispering Hill, Mount Barker, Western Australia, during 1993/94.

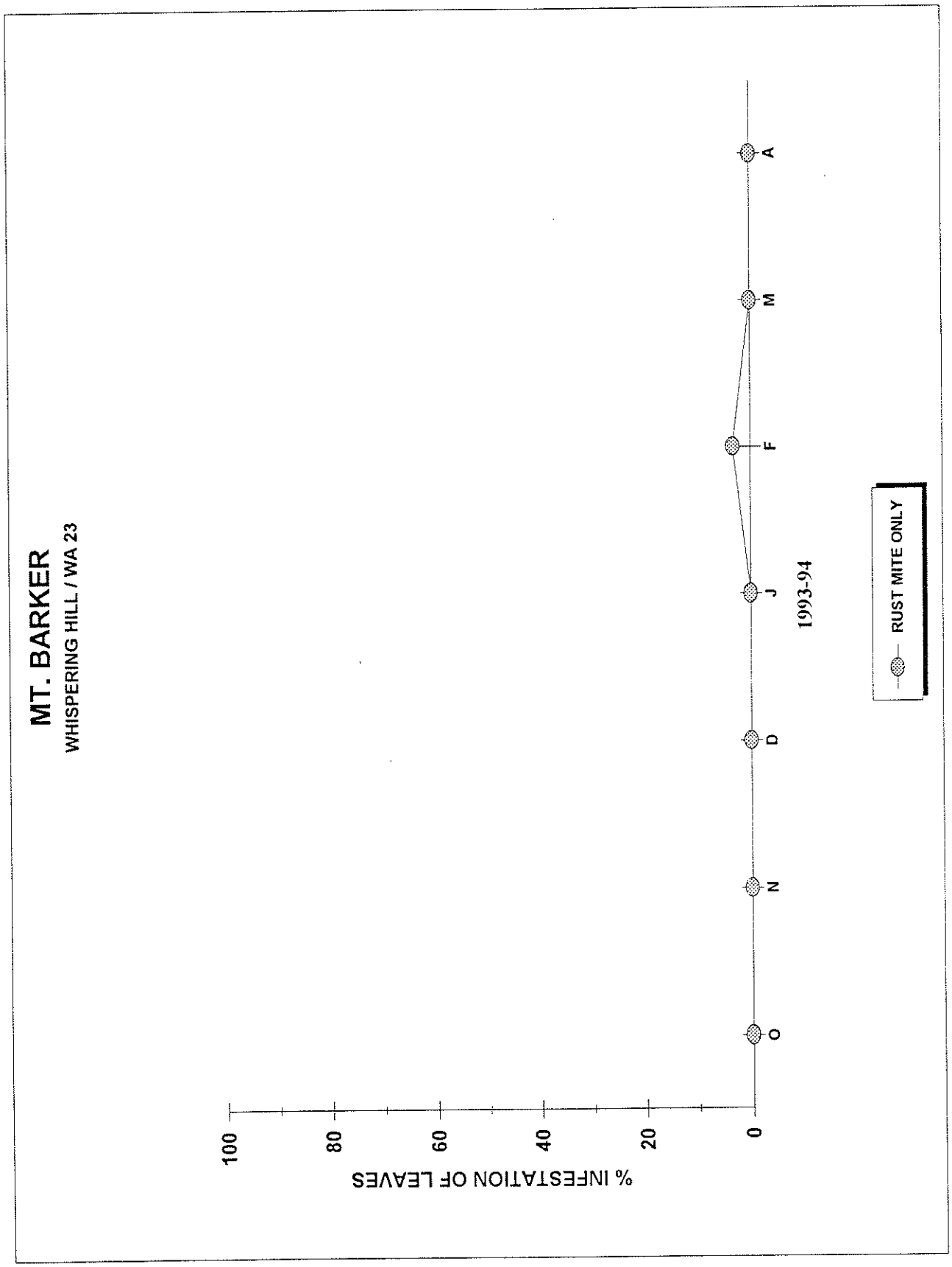


Figure 72. Rust mite population at Castle Rock, Mount Barker, Western Australia, during 1993/94.

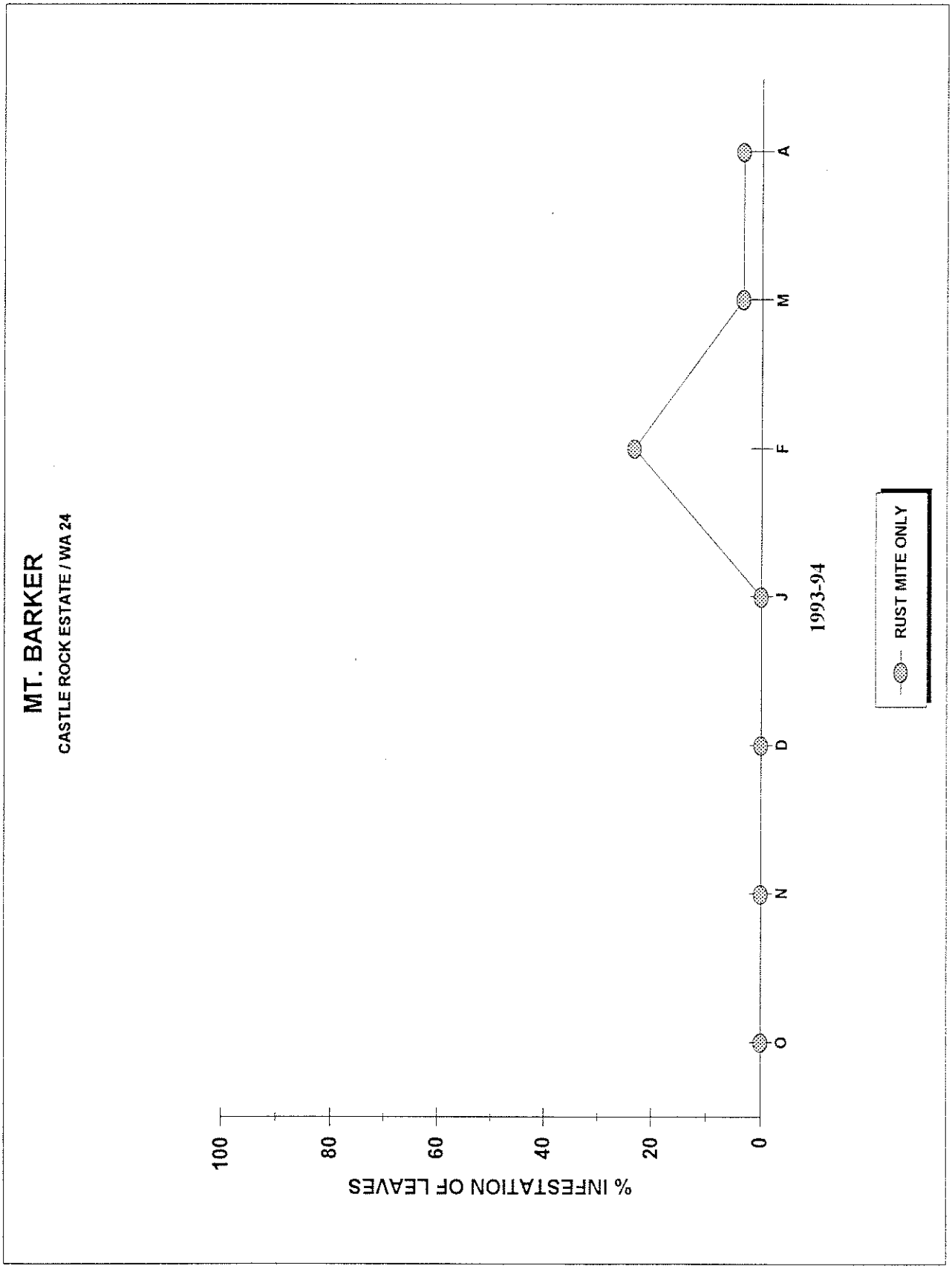


Figure 73. Pest and predatory mite populations at Wignall's King River, Mount Barker, Western Australia, during 1993/95.

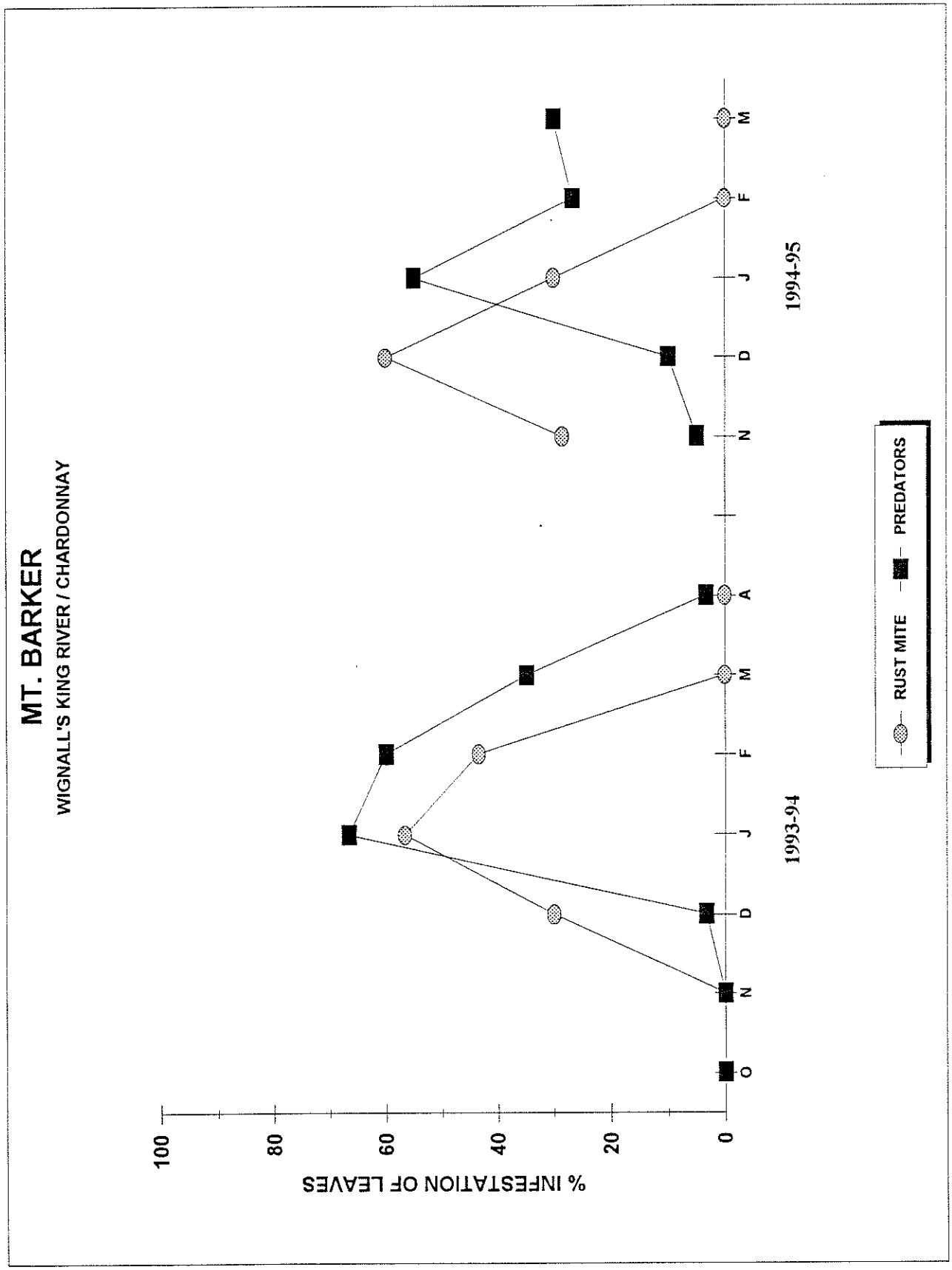
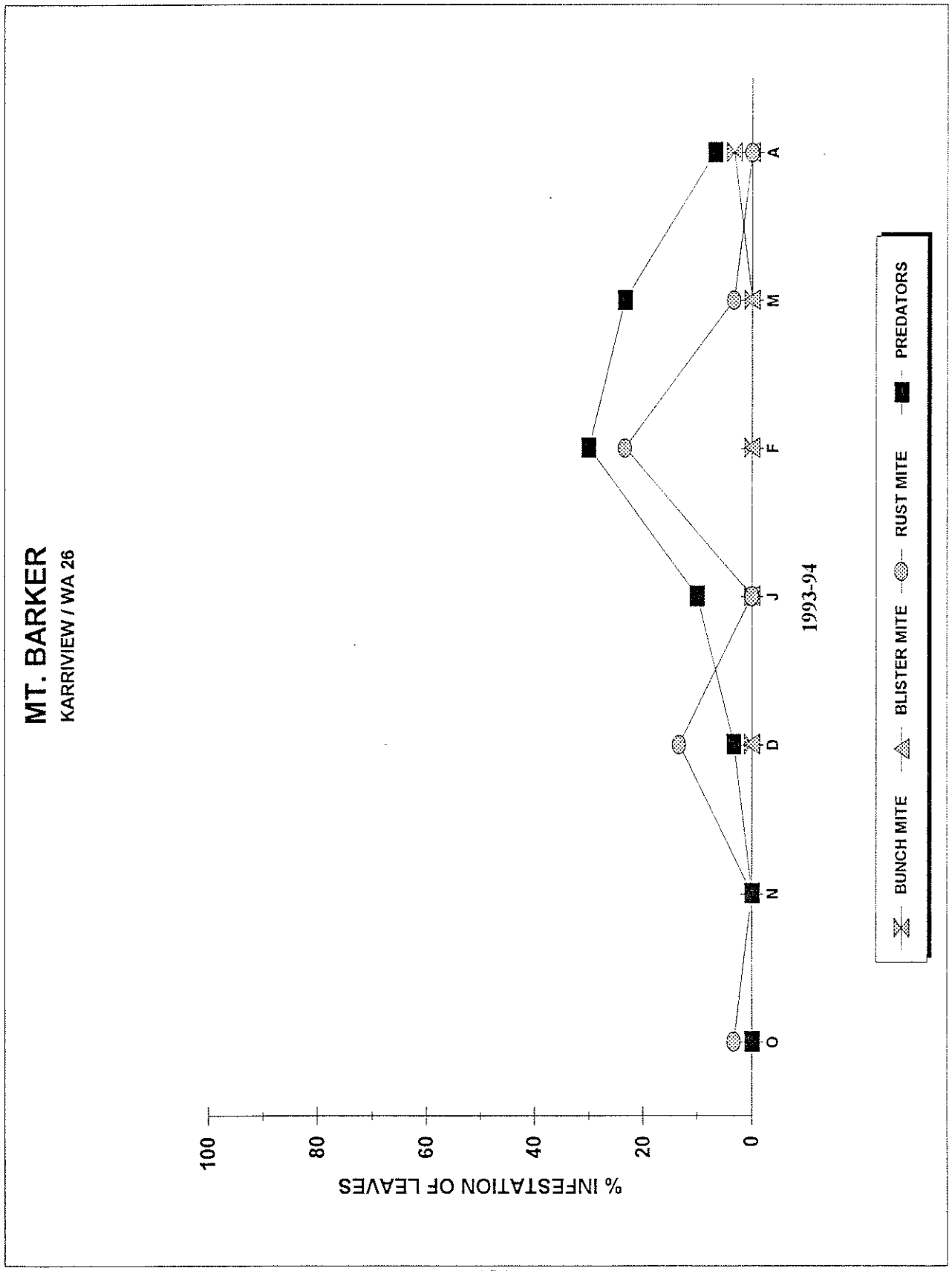


Figure 74. Pest and predatory mites at Karriview, Mount Barker, Western Australia during 1993/94.



## RECOMMENDATIONS

Like the Manjimup and Margaret River regions, Mount Barker vineyards also show good potential for biological control of mites, if they are not exposed to excessive and predator-harmful spray programs. *T. dossei* is again the dominant predator species. The introduction of *T. doreenae* to this region, like Margaret River and Manjimup, would most likely further improve biological control potential.

## WESTERN AUSTRALIA: OVERALL RECOMMENDATIONS

The Manjimup, Margaret River and Mount Barker regions share many features with respect to populations of pest and predatory mites and the potential for biological control. Spray practices are also similar with high use of fungicides and the occasional use of broad-spectrum insecticides, common. Even though some of the materials used (e.g. wettable sulphur, mancozeb) are known to be 'safe' to *T. dossei*, the major predator species in these regions, the high frequency of applications appears to have a detrimental effect, like it does with *T. doreenae*. The use of broad-spectrum insecticides prevents colonisation of vineyards by *T. dossei* and other predator species.

Biological control of mites in vineyards in the Manjimup, Margaret River and Mount Barker regions using endemic predators, primarily *T. dossei,* appears to be relatively easy to achieve if essential sprays are modified to exclude predator-harmful compounds. *T. dossei* is an effective predator of rust mite, the primary pest species in these regions. However, there is sometimes a significant lag between development of rust mite populations and development of significant predator populations, more so than in vineyards where *T. doreenae* is the primary predator. This may be due to a greater reliance of *T. dossei* for the presence of prey to enable population development. *T. doreenae* seems more able to develop populations in the absence of prey by feeding on non-mite sources like pollen and honeydew. This time lag between rust mite populations and *T. dossei* populations may on occasions allow rust mites to cause significant damage before being brought under control. The value of introducing *T. doreenae* to vineyards in these regions lies primarily in removing this 'lag phase' between predator and pest populations.

It is interesting and significant that *T. doreenae* is resident in vineyards in the Perth/Swan Valley districts of Western Australia. Its presence in Western Australia makes it politically less of a problem to introduce it to the more southerly grape growing areas. It is a little surprising that it is not more abundant in Perth/Swan Valley vineyards but possibly this is a consequence of widespread insecticide use in other crops in the region

## 8) QUEENSLAND (THE GRANITE BELT)

Six vine blocks in 6 vineyards (Robinson, Sauvignon blanc, Ballandean; Dunne, Chardonnay, Stanthorpe; Ballandean Estate, Cabernet sauvignon, Ballandean; Rumbalara, Semillon, Fletcher; Oag, Shiraz, Glen Aplin; Jacobsen, Shiraz, Ballandean) were sampled during 1993/94. The Oag, Robinson and Rumbalara blocks were also sampled during the 1994/95 and 1995/96 seasons.

Pest and predatory mite population data are presented in Figures 75-83 and Table 15.

Most sites had significant populations of pest and predatory mites. In the 1993/94 season predators were common at all sites except Ballandean Estate where only a single predator was recovered. There were major differences in predator species composition between sites. Whilst *T. dossei* was the only predator recorded at Rumbalara during the first two seasons, its dominance at other sites was not as great. *A. lentiginosus* was also common in four of the vineyards (Dunne, Oag, Jacobsen, Robinson). *Typhlodromus pyri* was dominant at a single site (Dunne) whilst *Typhlodromus occidentalis* was common at Oag during the first 2 seasons. This was unusual in that these two species usually occur in association with spider mite species, not eriophyids like rust and blister mite. *T. doreenae* was recorded in small numbers at Rumbalara in 1995/96.

Blister and rust mites occurred at most sites but were usually brought under control by the predators by mid-season. At Rumbalara very large numbers of predators occurred in 1993/94 controlling rust, blister and bunch mites by March. More rapid control (by January) occurred in 1994/95 and 1995/96. Progressively smaller populations of both pest and predatory mites occurred during the 3 year period. This was likely to have been the progressive result of adopting biological control as a mite management strategy from 1993/94 onwards. As evidenced elsewhere, large populations of *T. dossei* seem unable to exist without a good prey source. Therefore as pest numbers decline so do predator numbers, in contrast to the situation with *T. doreenae.* No insecticides were used at Rumbalara during 1993-96 and disease control was based on mancozeb, benomyl, propiconazole and procymidone, all materials likely to be reasonably harmless to *T. dossei.* Similar situations occurred at the other 2 sites monitored during the entire 3 year period (Robinson, Oag), although a reduction in overall numbers of pests and predators only occurred at Oag in 1995/96. Again., insecticides were not used in these vineyards and disease control was based on generally predator-friendly materials.

### RECOMMENDATIONS

Good potential for biological mite control exists in this region. The predatory mite fauna is rich although the relatively large number of species occurring in reasonable numbers suggest some disruption to the ecosystem. Insecticides are used fairly frequently in other crops, often adjacent to vineyards. The data from the three vineyards monitored for the three seasons suggests that the careful low-input use of chemicals can result in progressively good biological control of mites.

Once again, introduction of the less prey-specific predator, *T. doreenae,* would appear to be a useful strategy and it is encouraging that at least a small population of this species was detected at one site.

**Table 15. Predatory mite species incidence during sampling in the Granite Belt region (Queensland) during 1993/96.**

| QUEENSLAND 1993-94 | | | SPECIES PERCENTAGES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Region | Vineyard | Total Predator No. | *T. dossei* | *T. pyri* | *T. transvaalensis* | *T. occidentalis* | *A. lentiginosus* | *A. noosae* | *P. fotheringhamiae* | *T. doreenae* | Other |
| Granite Belt | Balleandean Est | 1 | 100 | | | | | | | | |
| | Rumbalara | 411 | 100 | | | | | | | | |
| | Dunne | 282 | 0.4 | 68.4 | | | 29.1 | | | | 2.1 |
| | Oag | 145 | 33.7 | | | 37 | 26.6 | | | | |
| | Jacobsen | 179 | 65 | | | | 34 | 1 | | | |
| | Robinson | 280 | 61.2 | | | | 26.7 | 7.8 | 4.3 | | |
| **1994/95** | | | | | | | | | | | |
| | Rumbalara | 107 | 100 | | | | | | | | |
| | Oag | 83 | 38.9 | 28.9 | | 22 | 9 | | | 1.2 | |
| | Robinson | 56 | 100 | | | | | | | | |
| **1995/96** | | | | | | | | | | | |
| | Rumbalara | 6 | 33.3 | | | | | | | 66.7 | |
| | Oag | 27 | 88.9 | | 11.1 | | | | | | |
| | Robinson | 99 | 91.9 | | | 8.1 | | | | | |

Figure 75. Pest and predatory mite populations at Ballandean Estate, Granite Belt, Queensland during 1993/94.

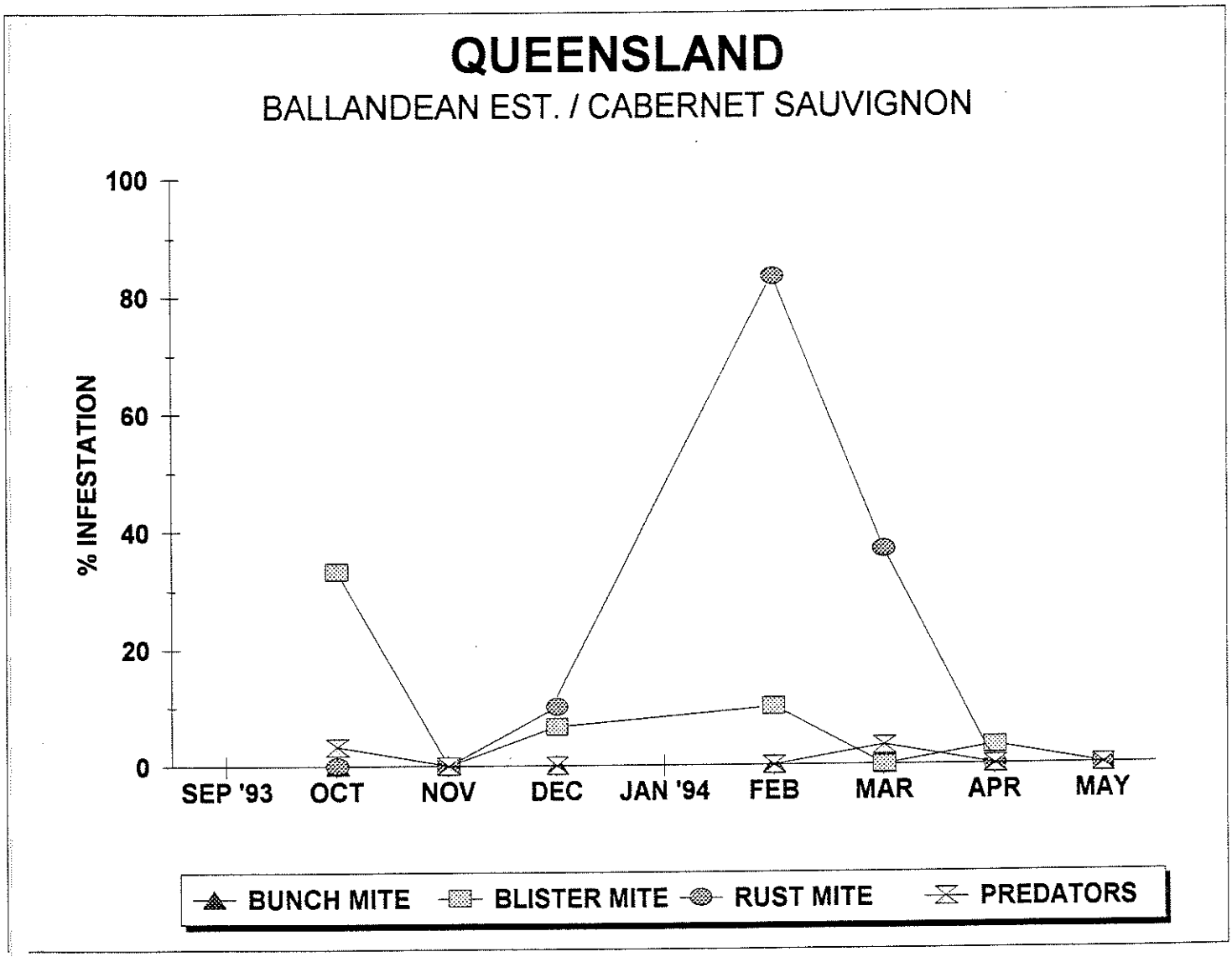


Figure 76. Pest and predatory mite populations at Dunne, Granite Belt, Queensland, during 1993/94.

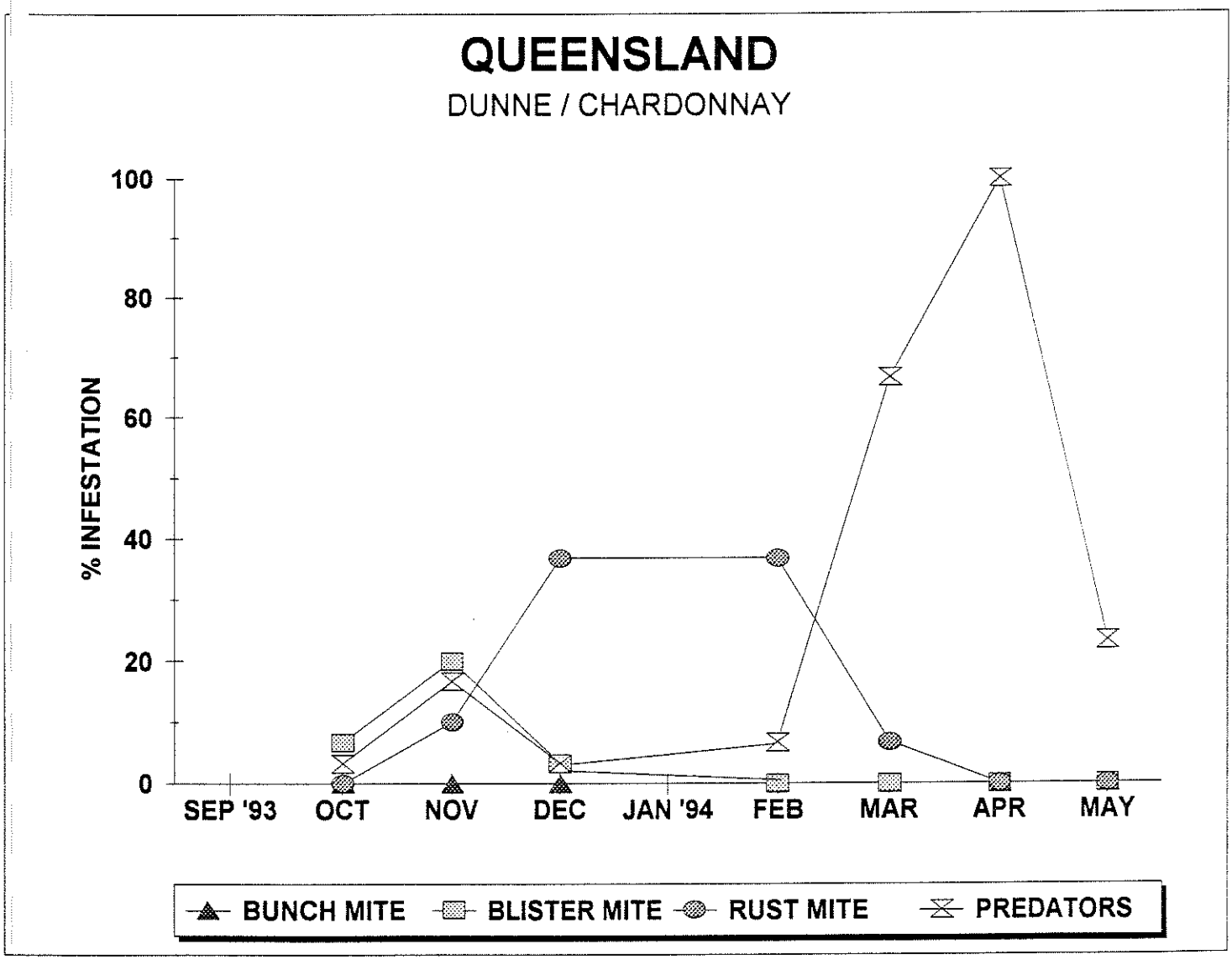


Figure 77. Pest and predatory mite populations at Jacobsen, Granite Belt, Queensland, during 1993/94.

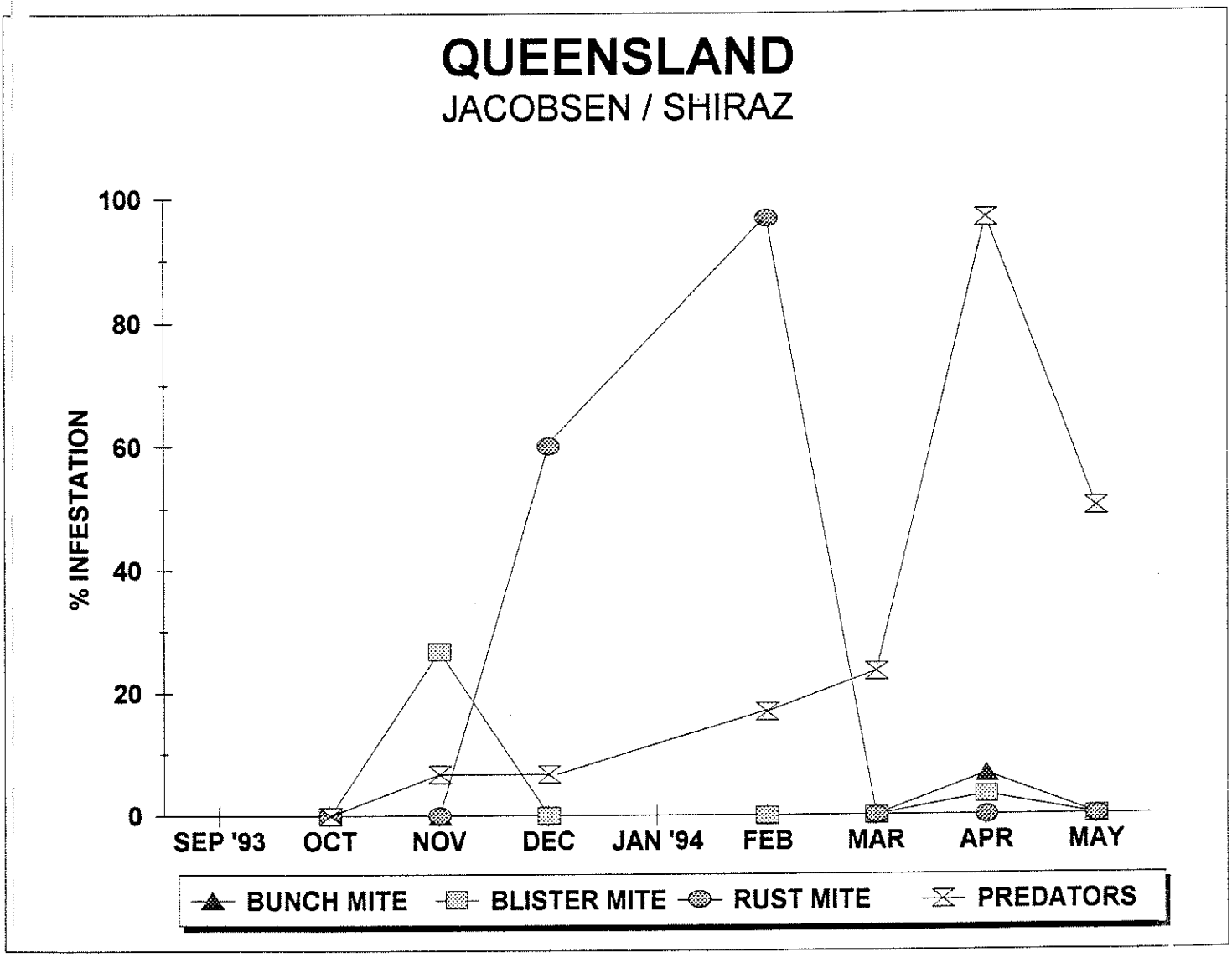


Figure 78. Pest and predatory mite populations at Robinson, Granite Belt, Queensland, during 1993/96.

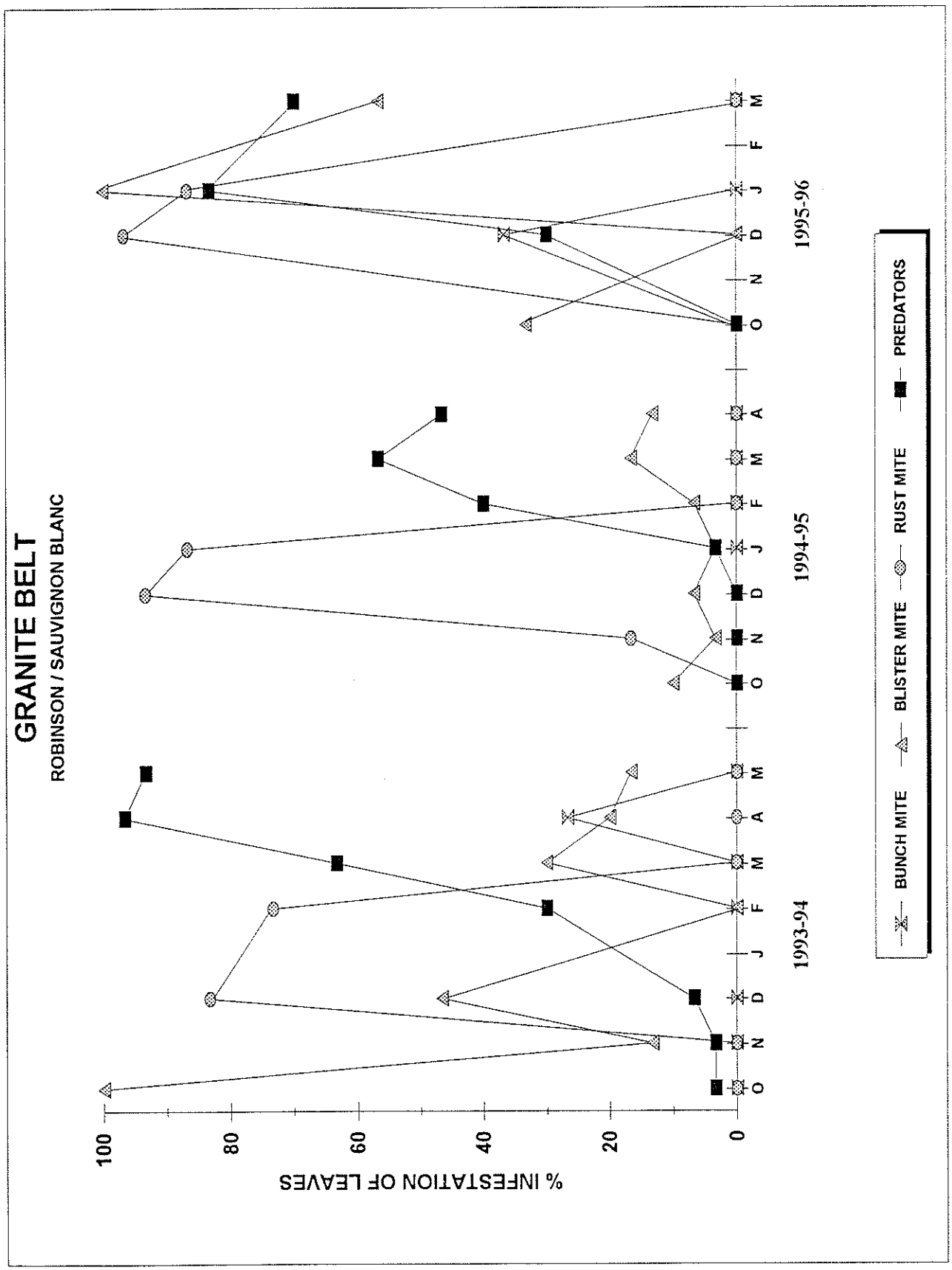


Figure 79. Pest and predatory mite populations at Oag, Granite Belt, Queensland, during 1993-96.

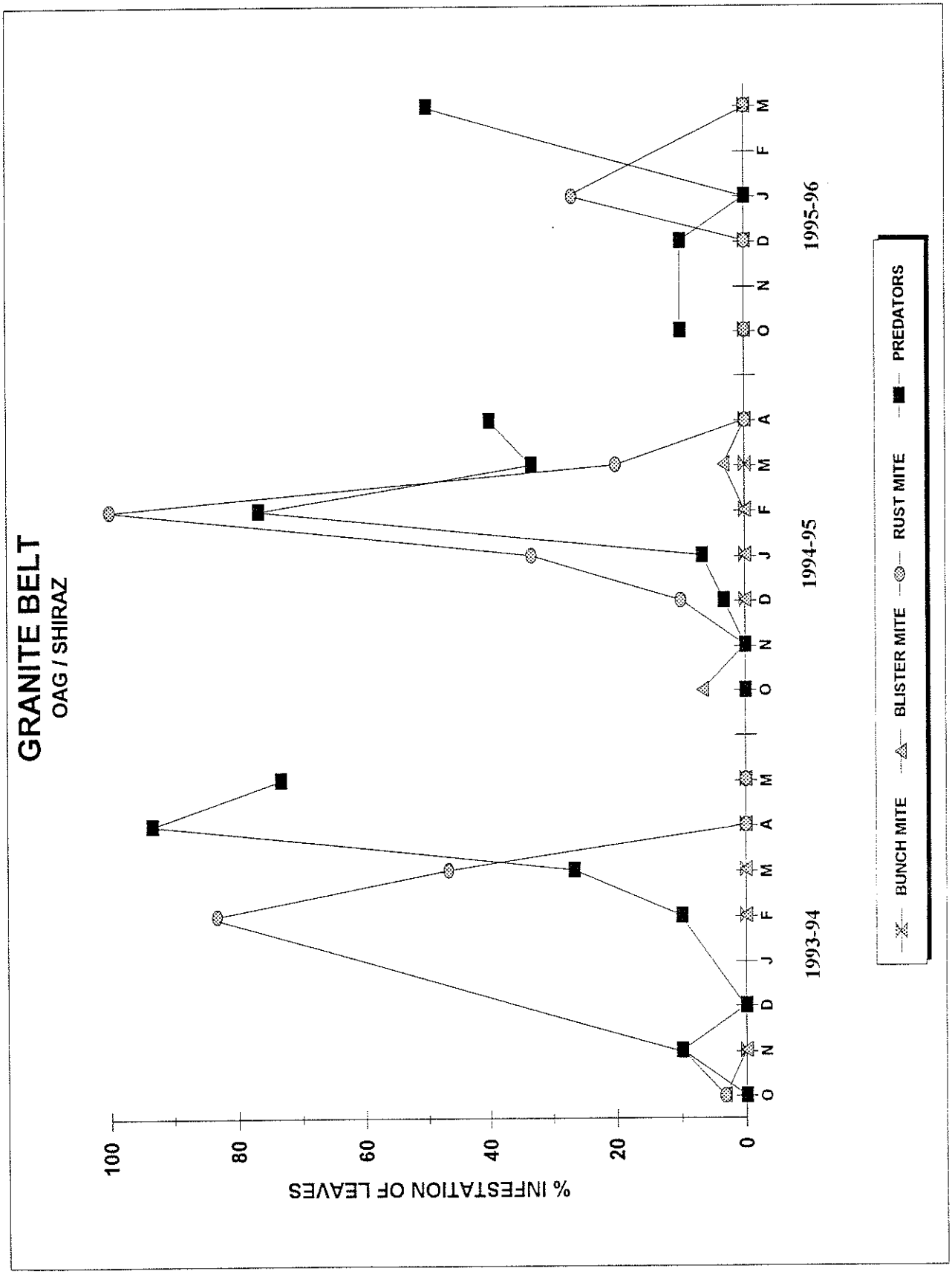


Figure 80. Pest and predatory mite populations at Rumbalara, Granite Belt, Queensland, during 1993/96.

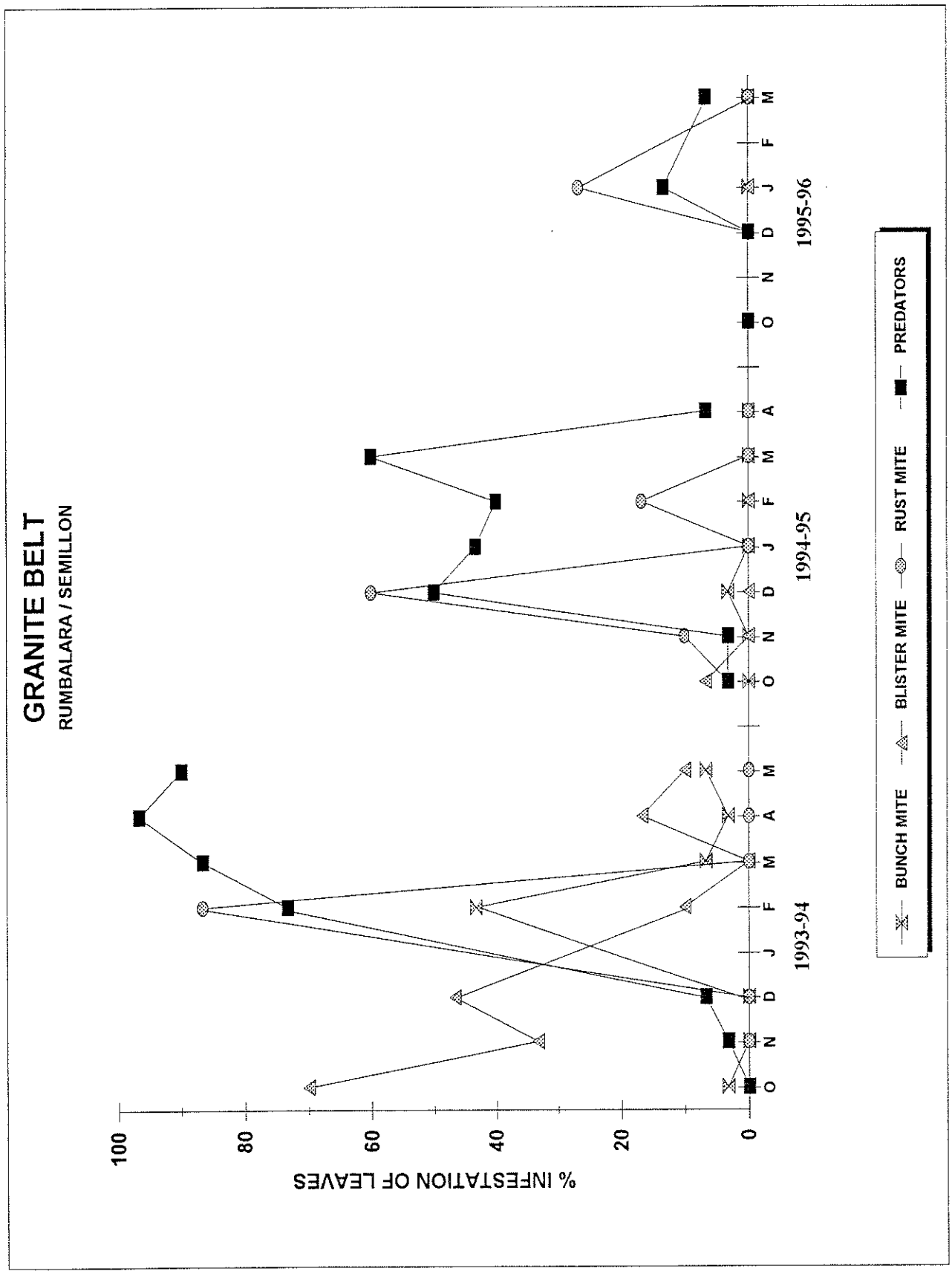


Figure 81. Predator species percentages at Robinson, Granite Belt, Queensland during 1994/95.

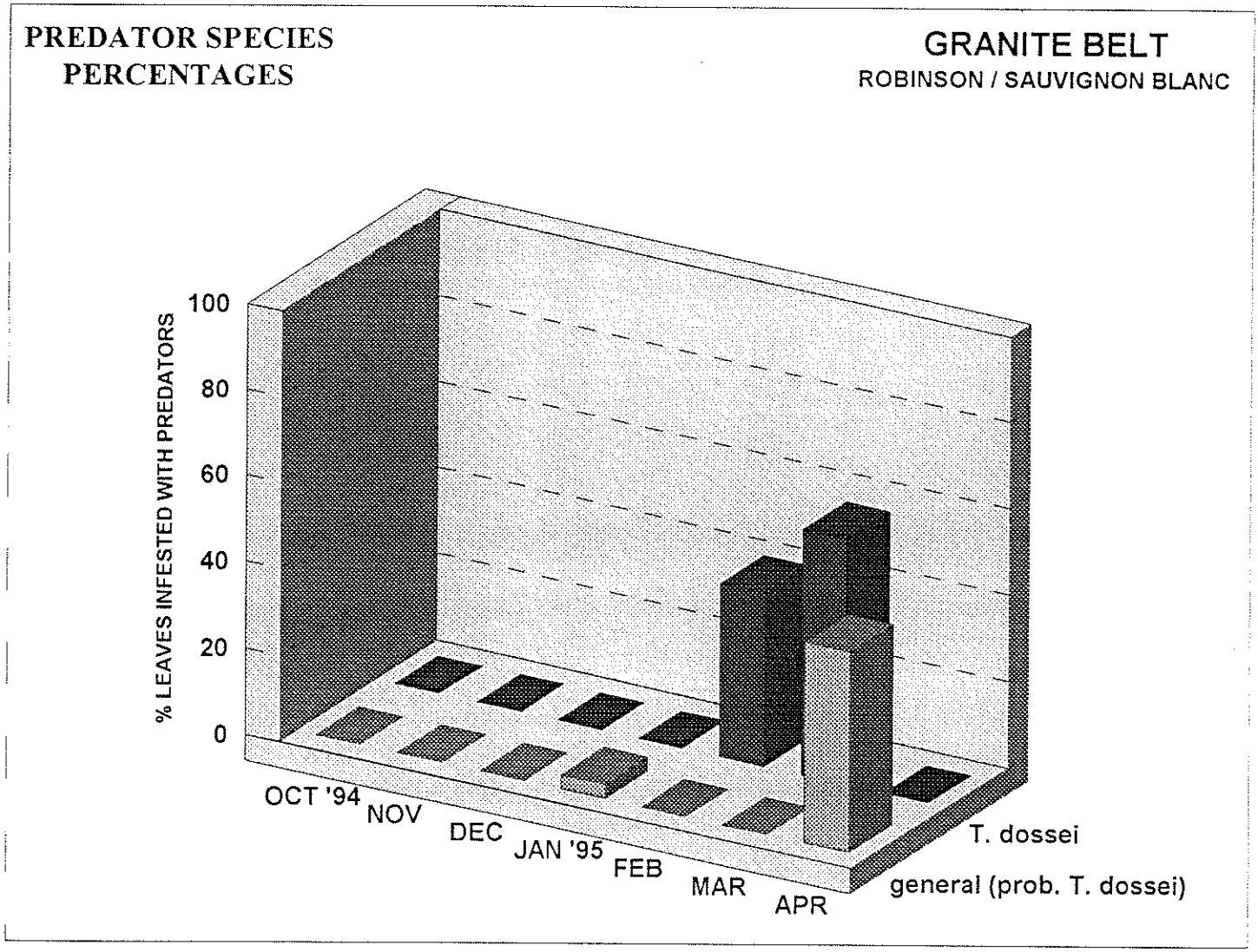


Figure 82. Predator species percentages at Oag, Granite Belt, Queensland, during 1994/95.

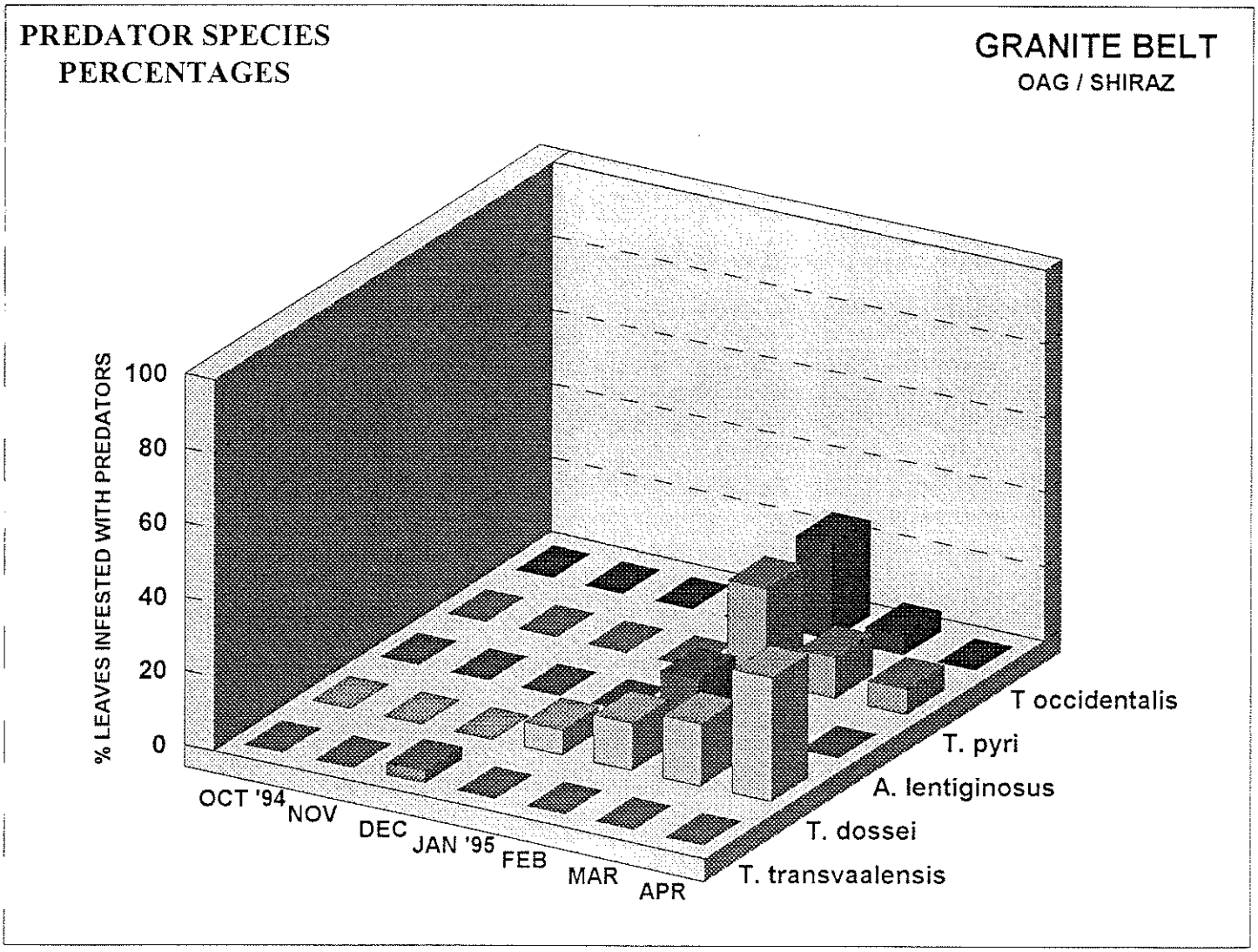
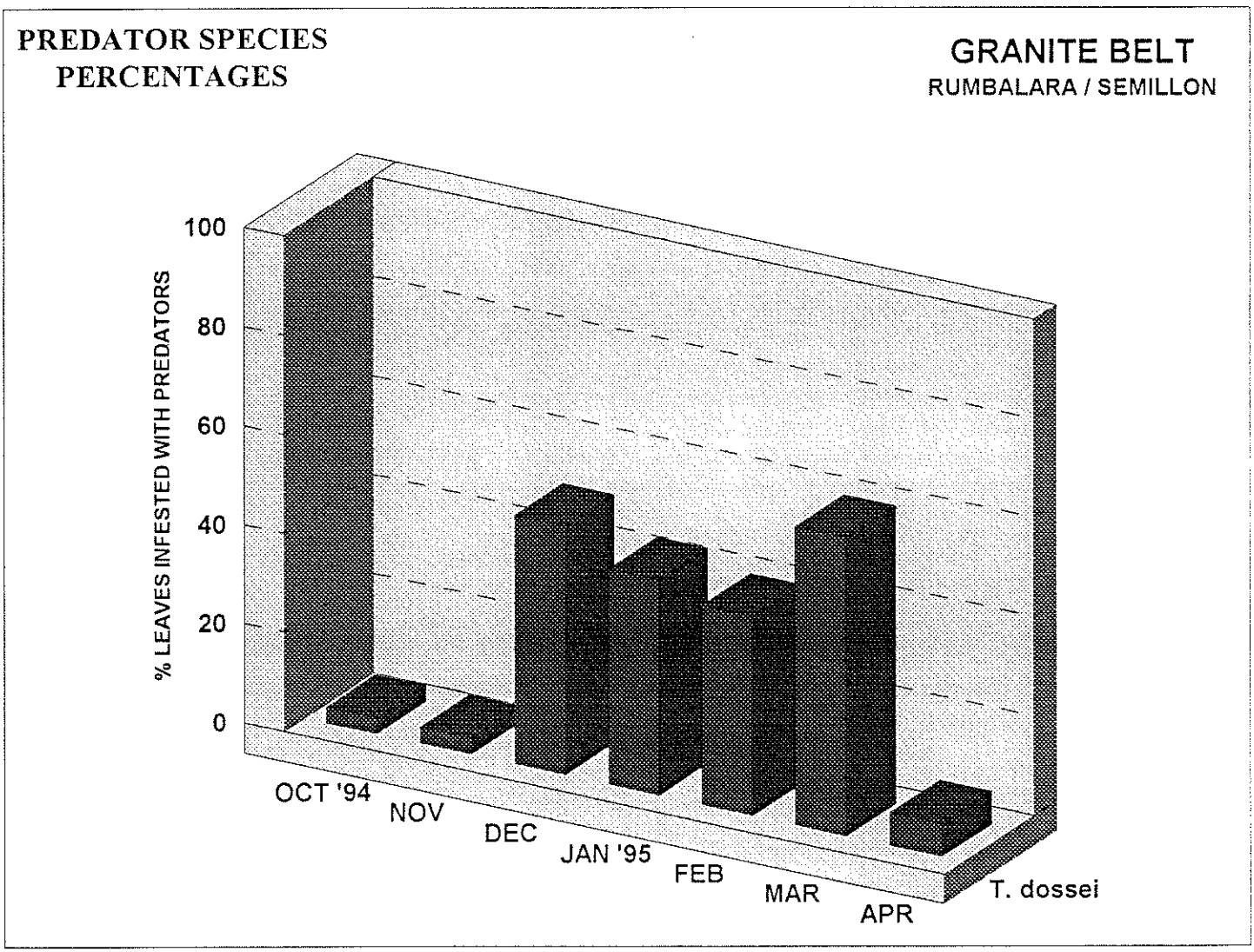


Figure 83. Predator species percentages at Rumbalara, Granite Belt, Queensland, during 1994/95.



## C. "SNAPSHOT" SAMPLING OF MITES AND PREDATORS IN OTHER VITICULTURAL REGIONS

Late in the 1995/96 season single samples of 30 leaves were obtained from 6 vineyards in regions or areas of New South Wales which had not previously been studied for mite populations.

A late season (March) sample was considered to provide the best opportunity to detect predatory mite populations which usually reach a peak near this time.

The sites were 1) Inneslake, Port Macquarie 2) Cassegrain, Port Macquarie 3) Mountilford, Ilford 4) Sondile, Rylstone 5) The Silos Winery, Nowra and 6) Cubbaroo Cellars, Wee Waa.

Data on mite and predator infestation of leaves at these sites in March 1996 are presented in Figures 84-89.

The two Port Macquarie vineyards had small populations of both pests and predators (Figs. 81-82). Interestingly, different predator species occurred at each site, perhaps indicating disturbed ecosystems. *Typhlodromus brisbanensis* was the commonest predator at Inneslake while *A. lentiginosus* was commonest at Cassegrain. Spray programs were fairly 'soft' at both vineyards during the growing season although lime sulphur was used early in the season at Cassegrain. The Ilford and Rylstone vineyards are both situated on the outskirts of the Mudgee region and would be expected to share similar features with Mudgee with respect to mite and predator populations. Both sites had good predator populations in March 1996 with *T. doreenae* dominant at Ilford and *P. fotheringhamiae* dominant at Rylstone (Figs. 86-87). Pest mite numbers were low at Ilford but blister mite numbers were significant at Rylstone, indicating, perhaps, *P. fotheringhamiae* is less effective at controlling this species than *T. doreenae*. Only wettable sulphur, copper oxychloride and phosphorus acid were used at Ilford. No spray records were available from the Rylstone vineyard. Very few mites were found at the Nowra vineyard; south of Sydney. No pests, only a few individuals of an undescribed predator species and *Amblyseius deleoni* (Fig. 88). A feature of this site was regular spraying with methomyl, a relatively short-lived insecticide, but still a chemical likely to interfere with predator survival. Cubbaroo Cellars at Wee Waa is in far north western New South Wales and subject to a very hot, dry climate. This vineyard had a substantial population of bunch mite and nothing else. No sprays were used and the harsh climate may be partly responsible for the absence of predators.

## CONCLUSIONS

"Snapshot" sampling provides only an indication of pest and predatory mite populations. Predatory mite populations are generally at their largest in March and sampling at this time should indicate maximum population levels. The coastal sites (Port Macquarie, Nowra) do not show any great evidence of good biological control of mites. Coastal vineyards are generally disturbed ecosystems with higher pest and disease pressure necessitating greater

use of chemicals. The Tableland sites (Ilford, Rylstone) appear similar in mite and predator populations to the previously described Mudgee sites. Good biological control of mites appears to be a general condition for vineyards on the Dividing Range. Newly established vineyards in far western or northern inland areas like Wee Waa may suffer from a paucity of predatory mites on the surrounding natural vegetation. Occasional samples from a vineyard at Alice Springs in the Northern Territory also showed an absence of predatory mites.

Figure 84. Pest and predatory mite species incidence at Inneslake, Port Macquarie, NSW in March 1996.

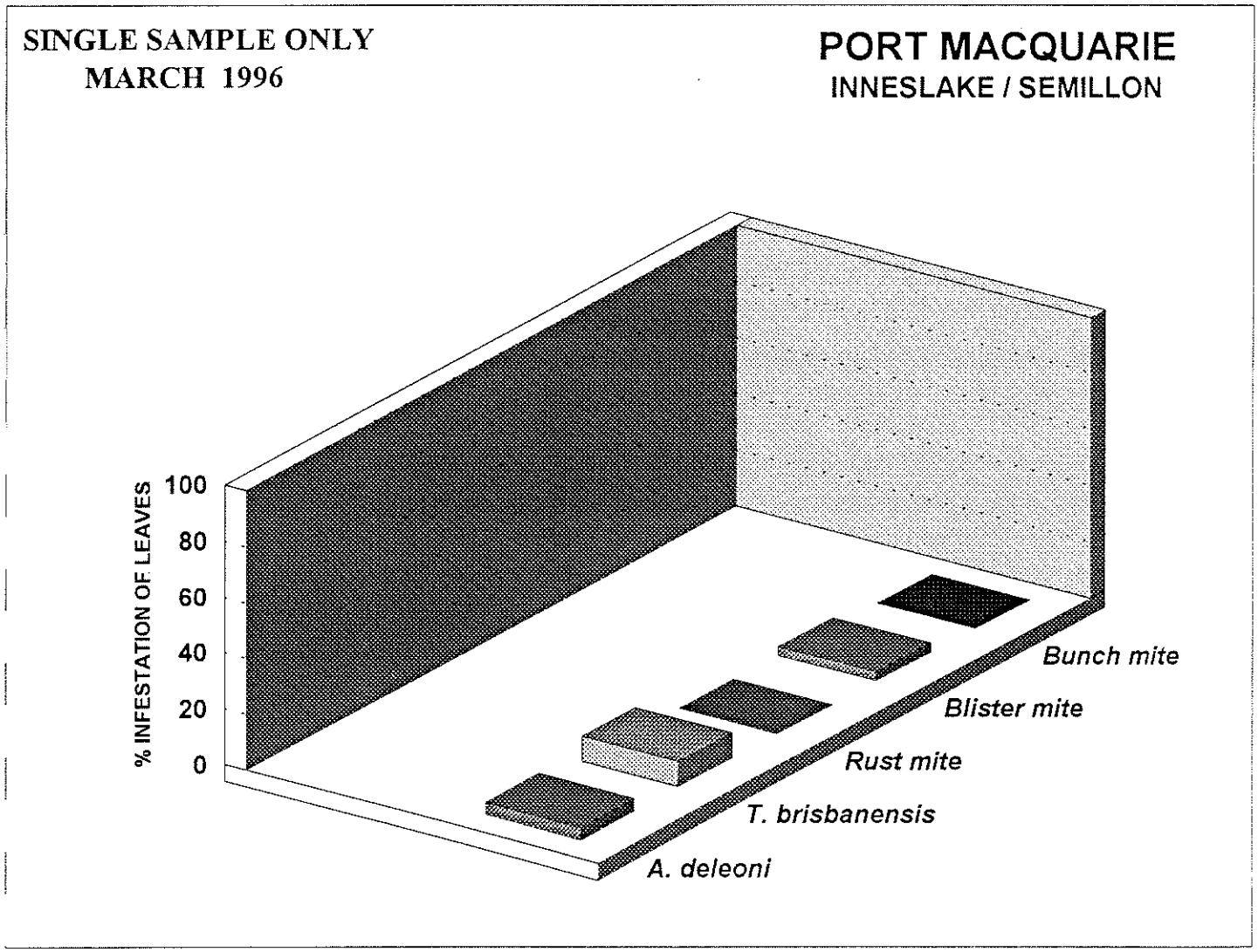


Figure 85. Pest and predatory mite species incidence at Cassegrain, Port Macquarie, NSW in March 1996.

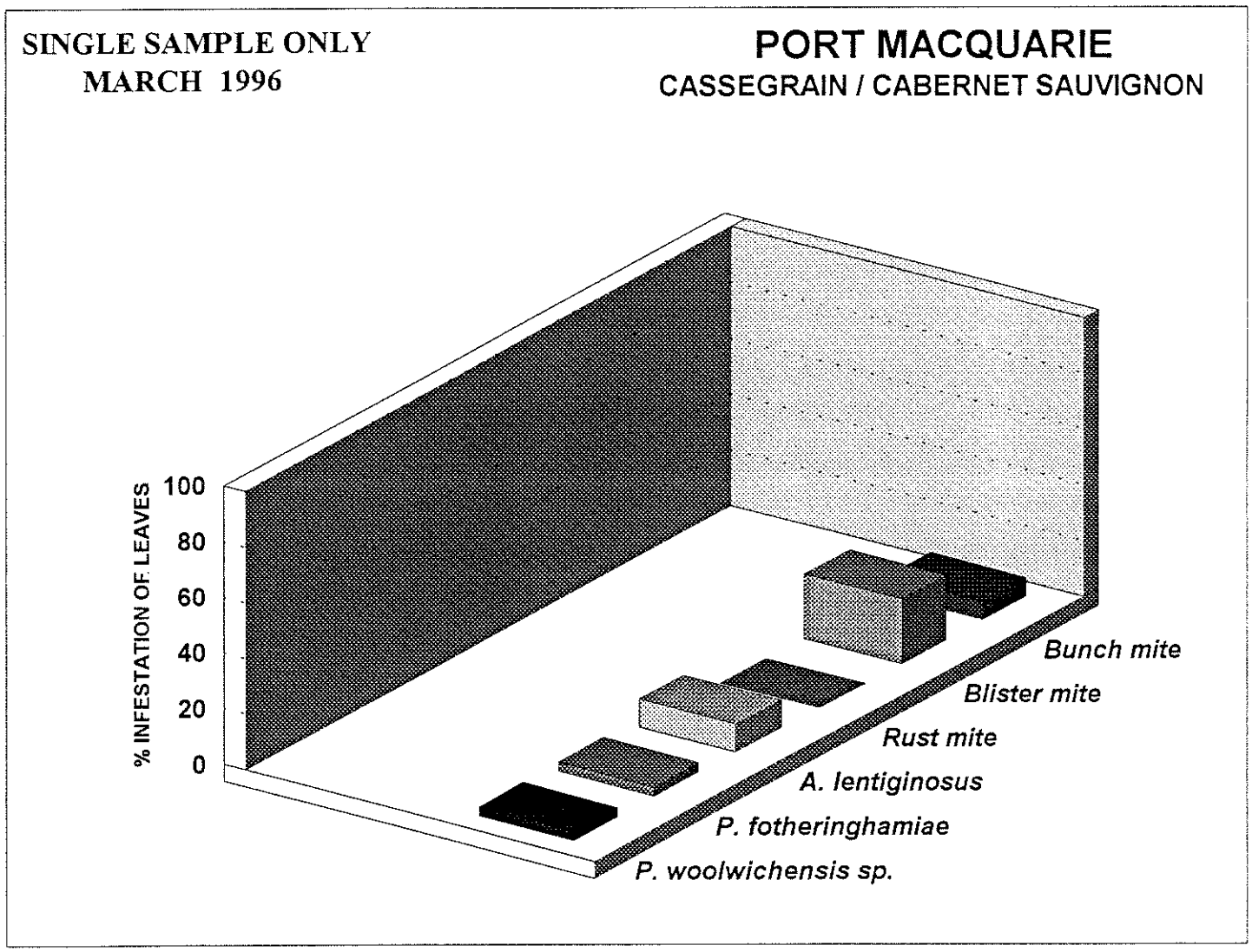


Figure 86. Pests and predatory mite species incidence at Mountilford, Ilford, NSW, in March 1996.

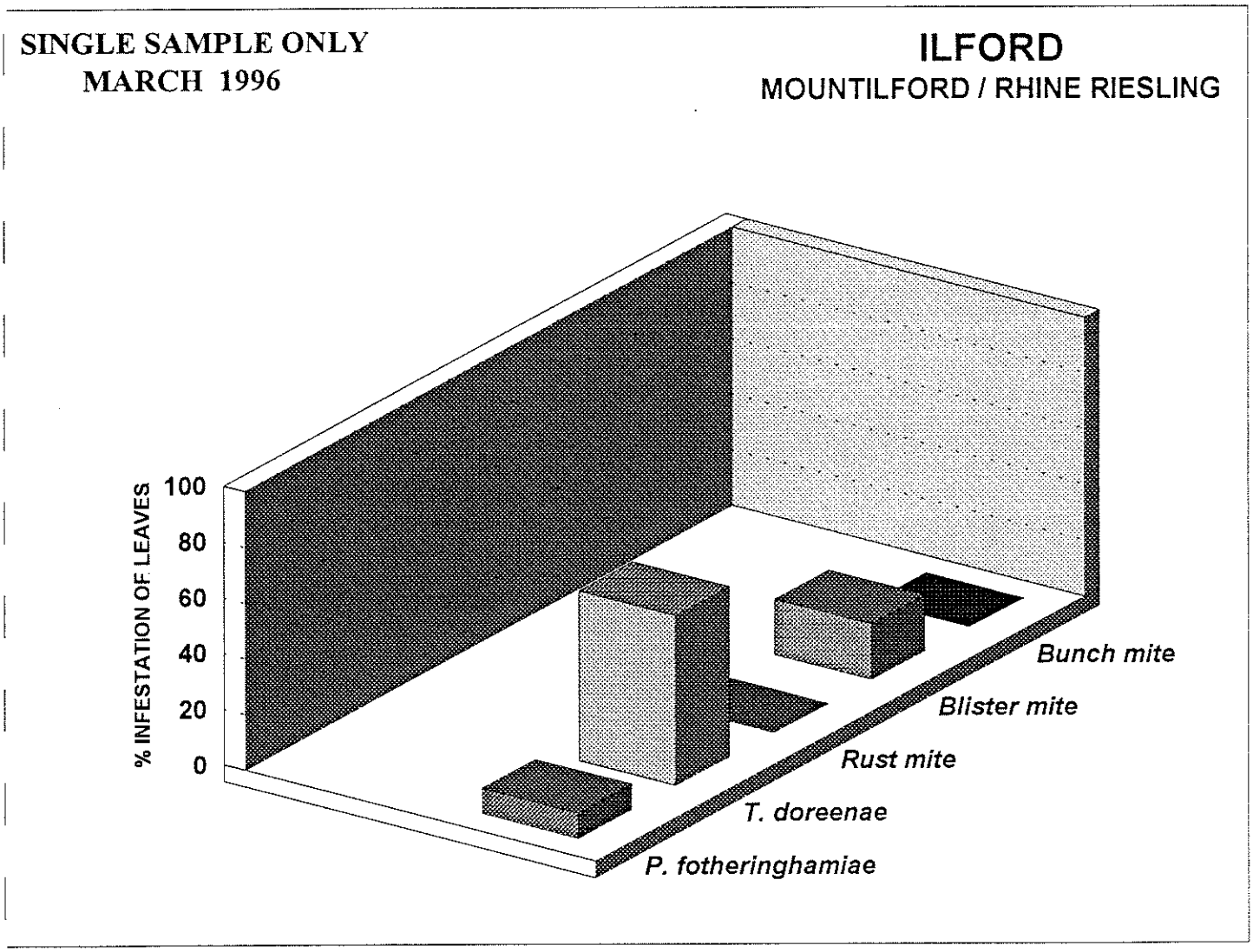


Figure 87. Pest and predatory mite species incidence at Sondile, Rylstone, NSW in March 1996.

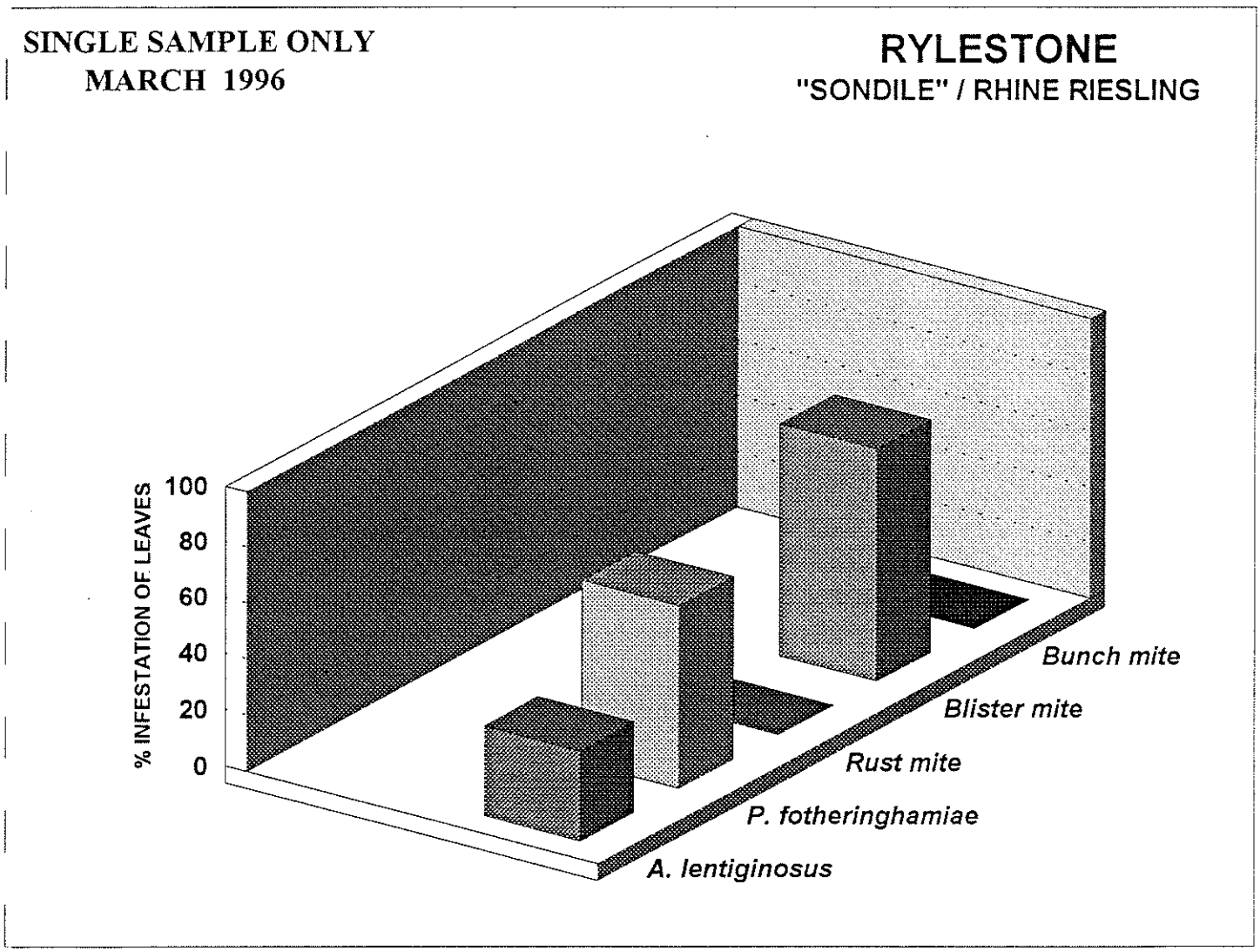


Figure 88. Pest and predatory mite species incidence at the Silos Winery, Nowra, NSW in March 1996.

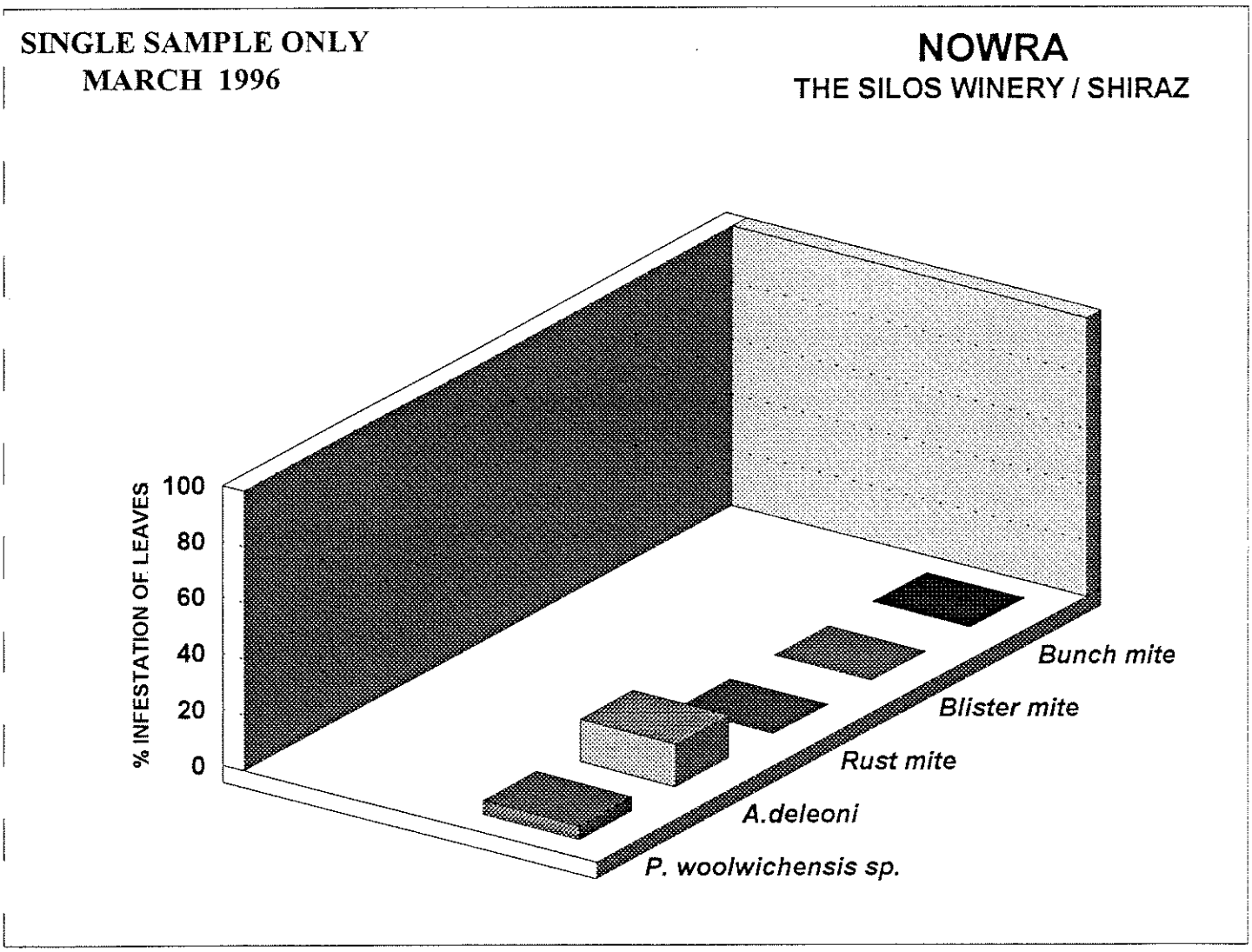
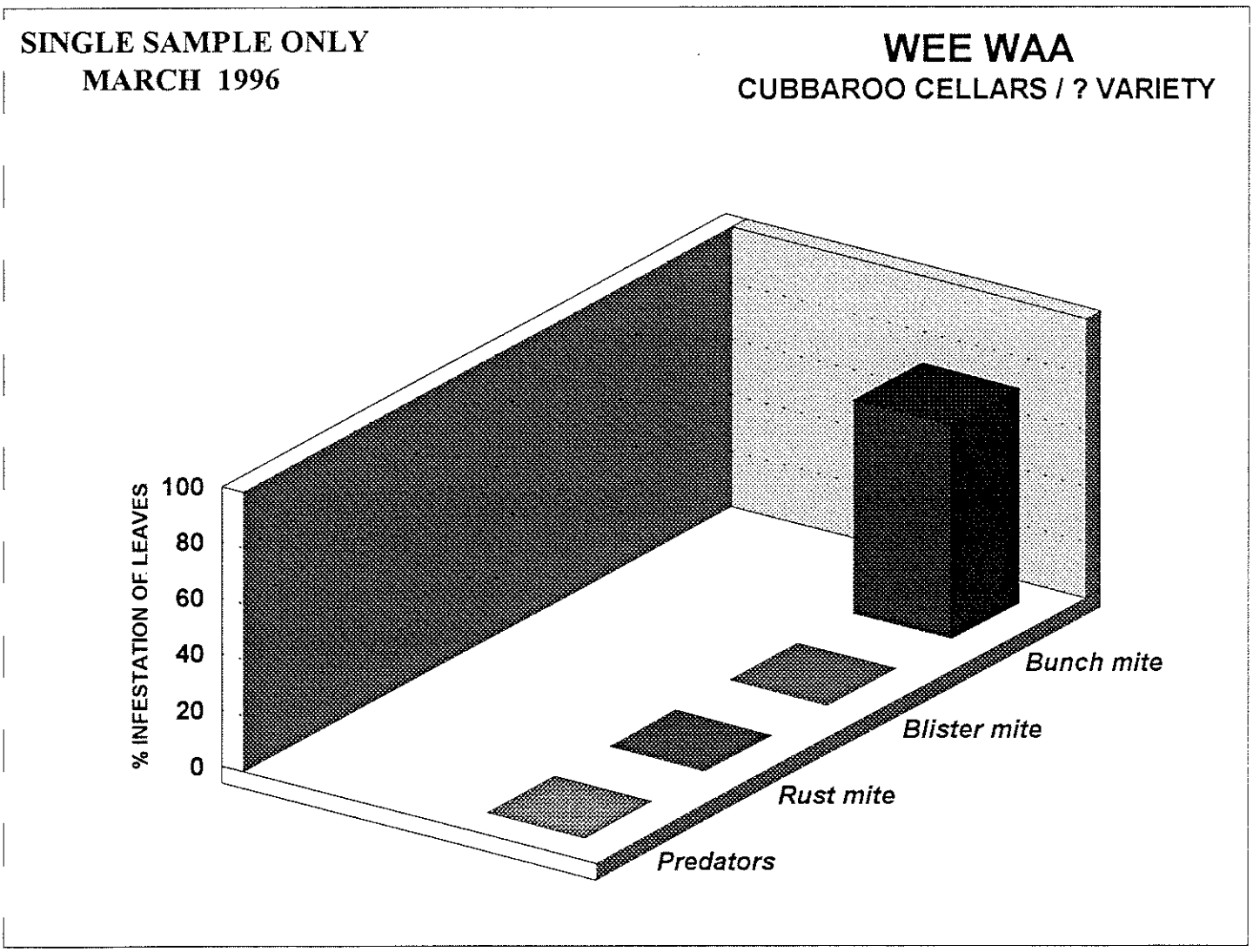


Figure 89. Bunch mite incidence at Cubbaroo Cellars, Wee Waa, NSW in March 1996.



## D. MASS REARING AND INTRODUCTION OF *TYPHLODROMUS DOREENAE* TO MURRUMBIDGEE IRRIGATION AREA VINEYARDS

REARING

Preliminary mass rearing systems were developed for *Typhlodromus doreenae* and *Amblyseius victoriensis* in the two earlier projects (DAN4GW, DAN 92/3). The arena/pollen mass rearing system developed for *T. doreenae* was upsized and used for large scale production of this species for inoculative introduction to vineyards.

Early experiments looked at the possibility of increasing arena size from the approximately 18 X 14 cm tiles used previously to units about 10 times this size. However, problems were experienced primarily in the maintenance of sufficient relative humidity levels on these arenas away from the edges. Once relative humidity falls below 80-90% eggs of most phytoseiid predators dehydrate and fail to hatch. Consequently, an 'upsized' arena system had to be based on the use of a large number of 'normal' sized arenas.

A constant temperature room (approximately 3 X 2 metres) was used for rearing and was maintained at around 26°C. Shelving was used to accommodate 25-30 arenas in plastic boxes as described in DAN 92/3. Arenas were laid on plastic absorbent foam lying in water. Each plastic box had a fine gauze lid which helped maintain high humidity on the arena. Overall humidity in the room was increased by placing a number of water filled trays on the floor. Cotton wool was used on the arenas to provide shelter and egglaying sites for the predators. Cumbungi pollen was used as the food source and was sprinkled liberally on the arenas twice or three times a week. Predator colonies were initiated from wild collected *T. doreenae* from South Australian (Riverland) and New South Wales (Orange) vineyards. Two or three plastic box colonies of predators were established initially then sub-divided to ultimately create up to 30 separate colonies.

### VINEYARD RELEASE SITES

Releases were made at 21 vineyard sites in seven different regions (Upper Hunter, Murrumbidgee Irrigation Area, Sunraysia, Granite Belt, Margaret River, Mount Barker and Yarra Valley). However, problems in the production of predators meant that only the releases at MIA sites actually contained good numbers of *T. doreenae*.

Shortly after production of predators at a high level commenced, the entire culture became contaminated with another predator species, *Typhlodromus transvaalensis*. This species rapidly displaced *T. doreenae* from the arena colonies and created a situation where all releases save those in the MIA, were dominated by *T. transvaalensis*. This species is a naturally occurring predator in Australia and has actually been detected in vineyards during this study (see Section A). However, nothing is known about its biology/ecology and preferred prey. Clearly, the mass rearing environment of plastic box arenas and cumbungi pollen suits this predator more than *T. doreenae*, allowing it to dominate. This experience graphically demonstrates the importance of maintaining strict protocols to ensure contamination of predatory mite cultures does not occur. It also highlights the need to

routinely check the identity of the predators being reared. *T. transvaalensis* and *T. doreenae* are extremely similar morphologically and cannot be separated without microscopic preparation. Thus, in this study contamination of the cultures was not detected until after most releases were made.

## MURRUMBIDGEE IRRIGATION AREA RELEASE SITES

Six vineyard blocks were selected for introduction of *T. doreenae* in November 1994, 3 at Griffith and 3 at Leeton. All had been examined in previous seasons and *T. doreenae* was absent. Vignerons at all sites agreed to adopt spray programs that would not interfere with the establishment and survival of *T. doreenae*. No insecticides were used (except *Bacillus thuringiensis*) and only fungicides known to be safe to *T. doreenae* were applied, with preference given to wettable sulphur and copper.

Site Details:

1) McWilliams Wines, Hanwood, Griffith. Chardonnay block. Introduced: 15 November 1994
2) Riverina Wines, Ballingal Estate, Griffith. Chardonnay block. Introduced: 15 November 1994
3) Murphy, Yenda, Griffith. Chardonnay block. Introduced: 15 November 1994
4) Oag, Yanco, Leeton. Semillon block. Introduced: 10 November 1994
5) Toorak Wines, Leeton. Chardonnay block. Introduced: 9 November 1994
6) Lilly Pilly Estate, Leeton. Cabernet Sauvignon block. Introduced: 9 November 1994

Release strategy:
A release sub-block was selected within each release block. Sub-blocks were 10 rows containing 400-1000 vines. Thirty to forty 'deposit sites' (where predator-infested material was deposited) were evenly distributed within the sub-block (ie 3-4 deposit sites in each row).
Predator-infested material consisted of cotton wool taken from arenas. One day prior to release, all arenas to be used in the release were provided with extra cotton wool which soon became predator-infested. On the day of release, large eskies containing arenas resting on damp foam were taken to the vineyard. Cotton wool infested with predators was 'inserted' into the vine canopy at each deposit site, ensuring anchorage on bark, twigs or leaves. Predators dispersed from the cotton wool onto the vine foliage usually within hours. Hot, windy days were avoided as release days; all releases took place under sunny, mild-warm (18-25°C) conditions to enhance predator survival and maximise dispersal. An estimated 20,000 predators were introduced at each site. A randomly collected sample of 30 leaves was collected from each site prior to predator release and examined in the laboratory for pest and predatory mites.

Post-release monitoring:
Samples of 30 leaves collected randomly from the sub-block at each site were taken in January, March and April 1995 (2, 4 and 5 months after predator release). During the 1995/96 season samples were collected monthly from October to April (except for

February). All leaves were examined in the laboratory under a stereomicroscope for pest and predatory mites.

**PREDATOR ESTABLISHMENT**

Data on establishment of *T. doreenae* at the 6 sites together with data on pest mite and other predatory mite populations are presented in Figures 90-110.

1) McWilliams Wines
No evidence of establishment of *T. doreenae* occurred until October 1995 (Fig. 90). Low numbers were recorded during October-December then large numbers were present from January until the end of the season. Other phytoseiids (primarily *A. victoriensis* and *A. helmi*) occurred in low numbers during both seasons (Fig. 91).

2) Riverina Wines
*T. doreenae* failed to establish at this site. *A. victoriensis* was the only predator recorded. Two broad-spectrum insecticides, azinphos-methyl and methomyl, were applied in November 1995 and probably account for the non-establishment of *T. doreenae*.

3) Murphy
A single individual of *T. doreenae* was collected in March 1995. Samples on all other dates failed to identify further individuals. The spray records for this site are not available and the use of chemicals harmful to *T. doreenae* may have occurred at some point. Good numbers of *A. victoriensis* and *A. helmi* occurred at this site and provided good biological control (Fig. 97).

4) Oag
First evidence of establishment of *T. doreenae* occurred in February 1995. It was subsequently found in all months sampled except October 1995. The small population which had developed by the end of the first season was insufficient to regulate a significant bunch mite population. However, the substantially larger population of *T. doreenae* during the 1995/96 season maintained all pest mite species below damaging levels (Fig. 99).Other phytoseiids (*A. victoriensis, T. occidentalis, T. transvaalensis*) were relatively uncommon in comparison to the newly established *T. doreenae* in 1995/96 (Fig. 102). The reasonably sized predator population in 1994/95 (dominated by *A. victoriensis*) was unsuccessful in controlling bunch mites, confirming that this predator is not a good control agent for this grapevine mite species.

5) Toorak Wines
Good establishment of *T. doreenae* occurred within 2 months of release, and apparently led to control of a burgeoning rust mite population (Fig. 103). Other predators (primarily *A. victoriensis*) were relatively uncommon at this time (Fig. 104). Good numbers of *T. doreenae* were also recorded in the following season, although there was an apparent mid-season decline.

Figure 90. Populations of *T. doreenae* and pest mites at McWilliams, Griffith during 1994-96 following introduction of *T. doreenae* in November 1994.

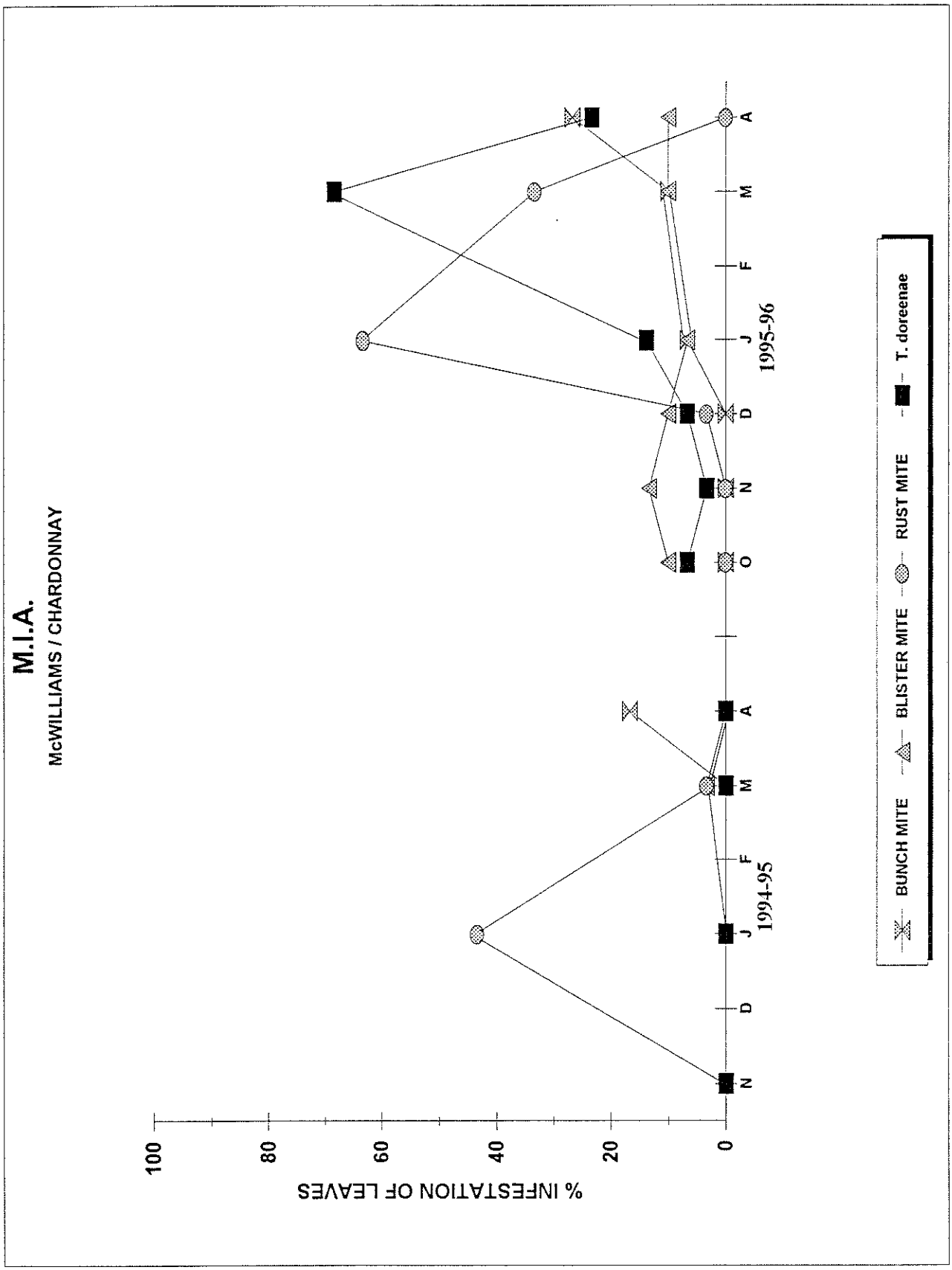


Figure 91. Populations of pest mites and phytoseiids other than *T. doreenae* at McWilliams, Griffith during 1994-96.

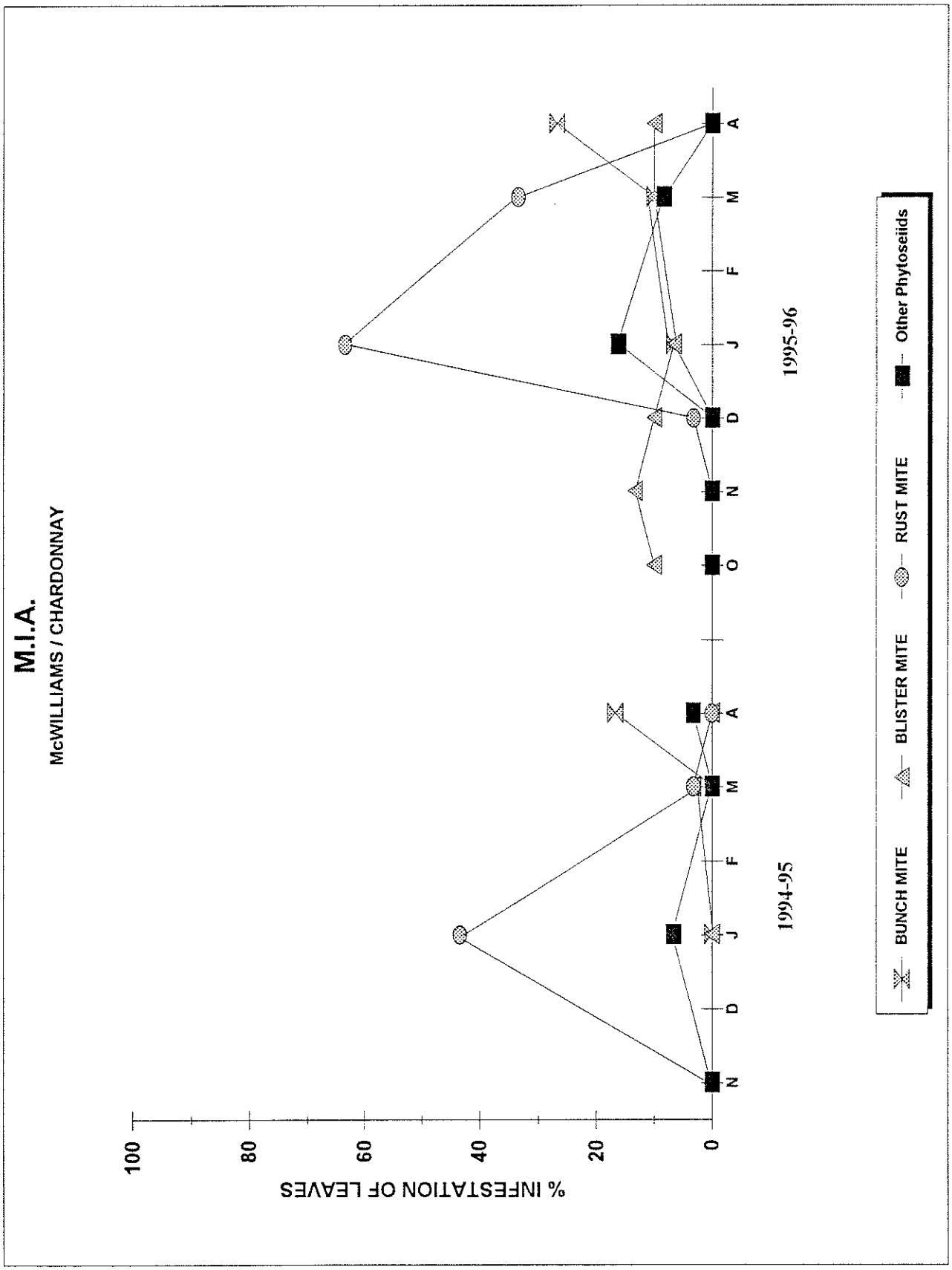


Figure 92. Pest and predatory mite populations (all predator species) at McWilliams, Griffith, during 1994-96.

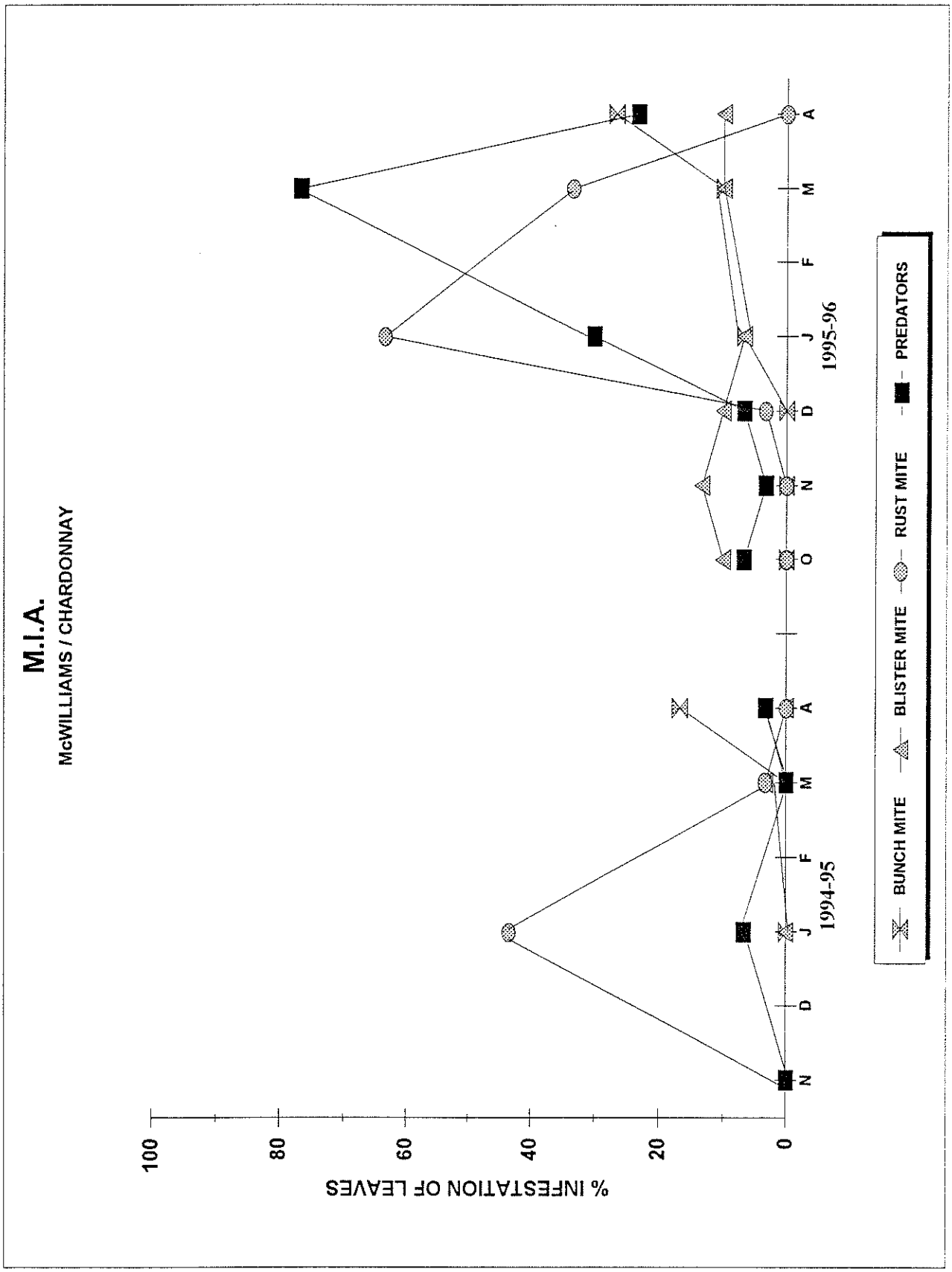


Figure 93. Predator species percentages at McWilliams, Griffith during 1994-96.

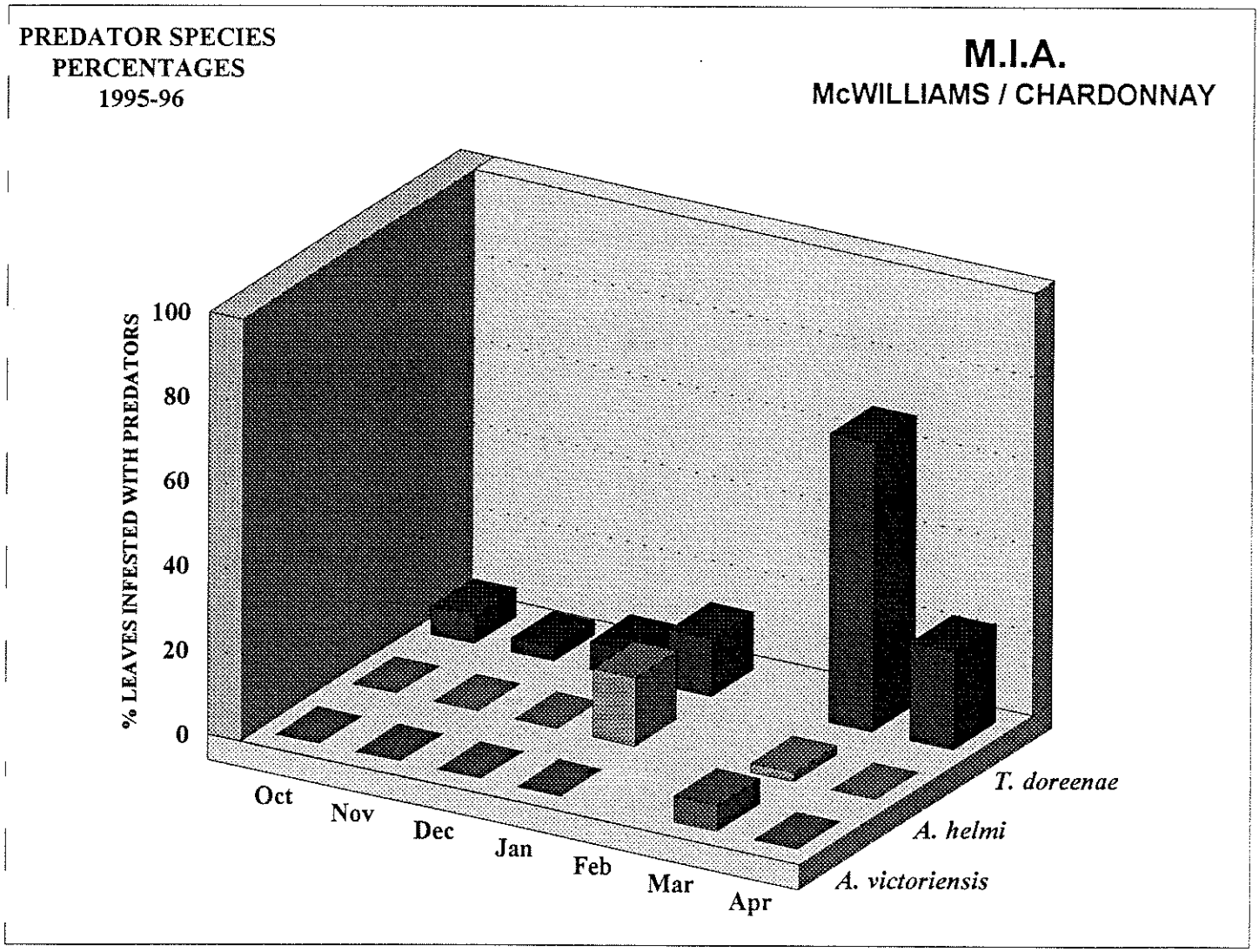


Figure 94. Pest and predatory mite populations at Riverina Wines, Griffith, during 1994-96.

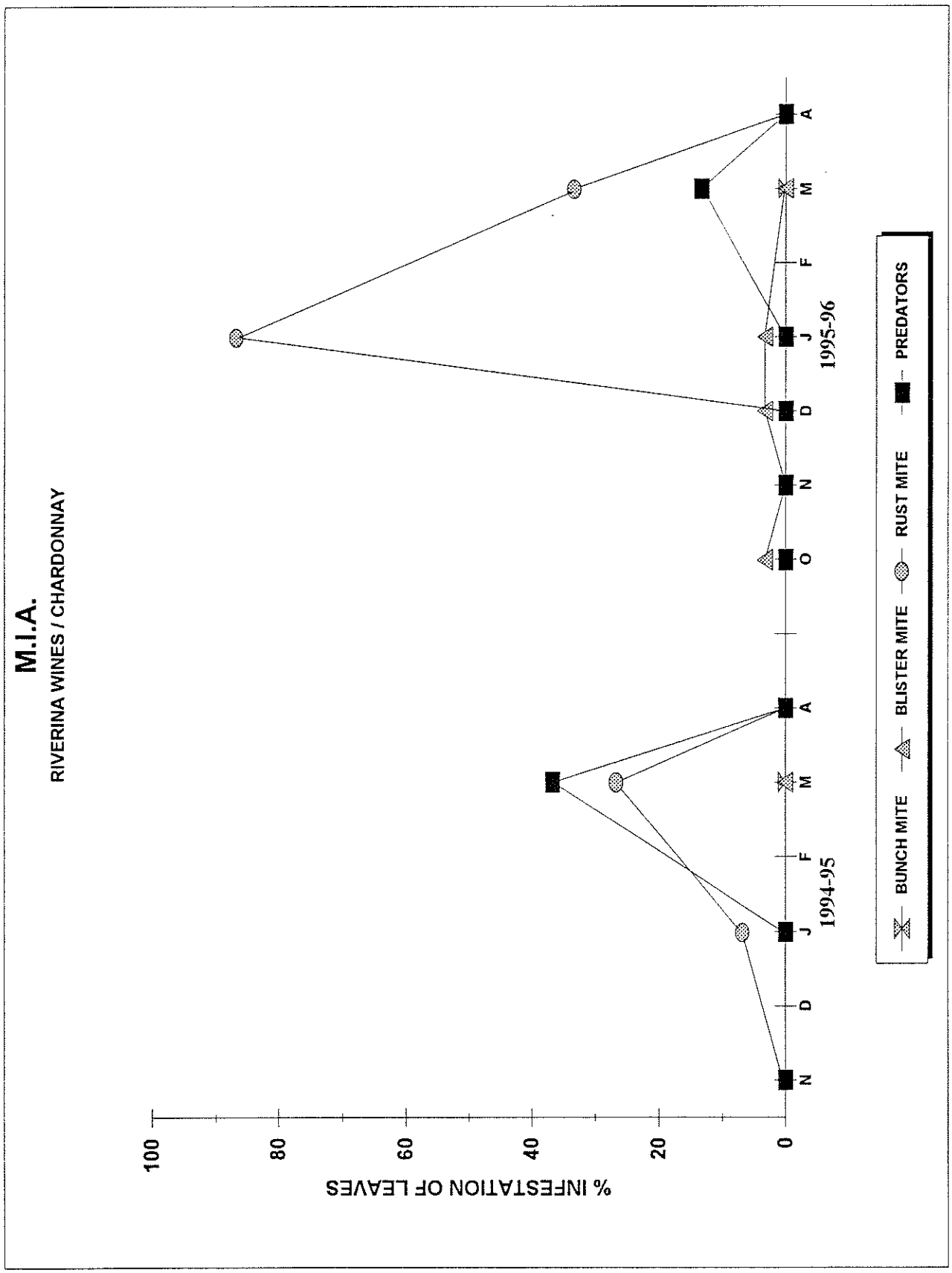


Figure 95. Predator species percentages at Riverina Wines, Griffith, during 1995/96.

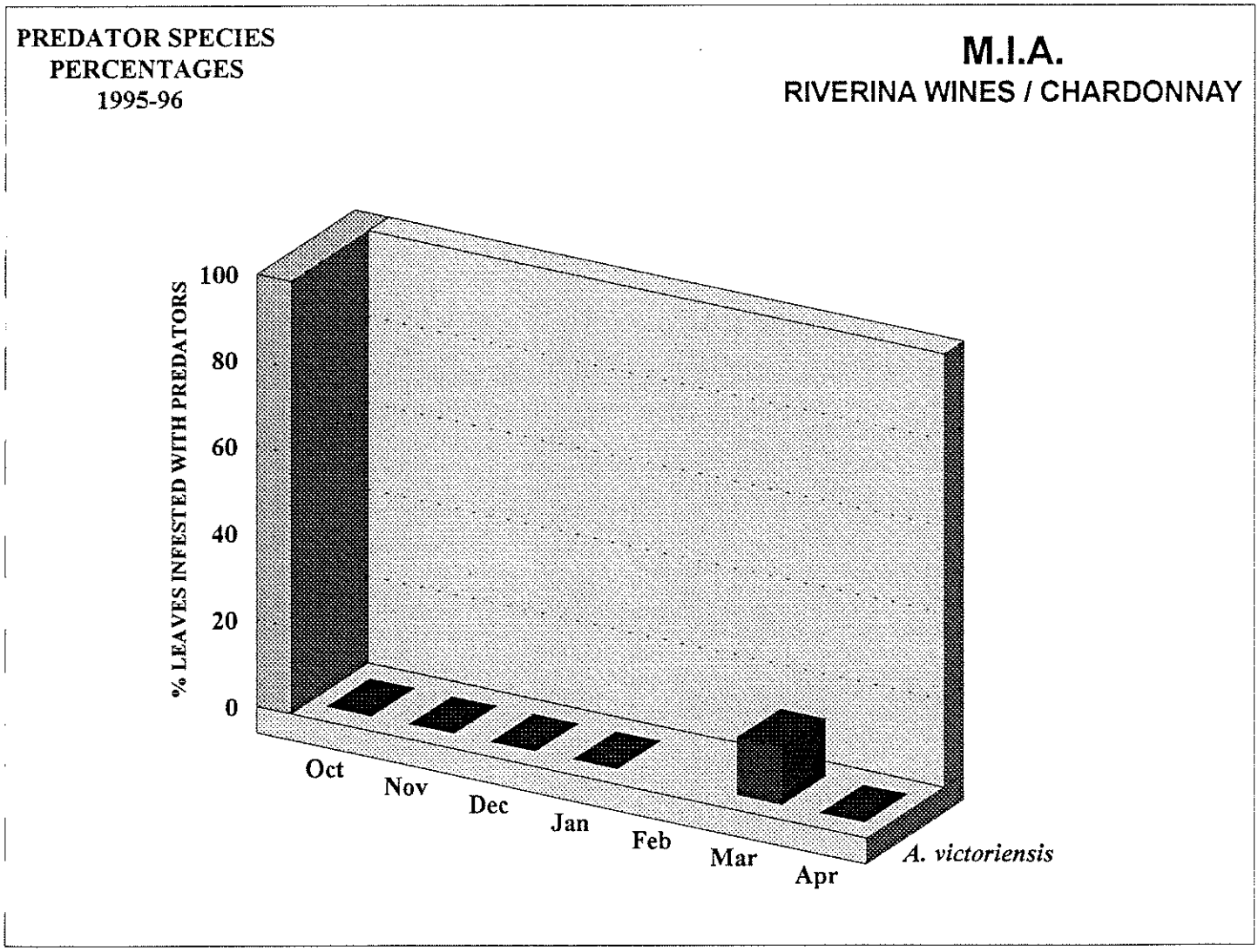


Figure 96. Populations of *T. doreenae* and pest mites at Murphy, Griffith, during 1994-96, following introduction of *T. doreenae* in November 1994.

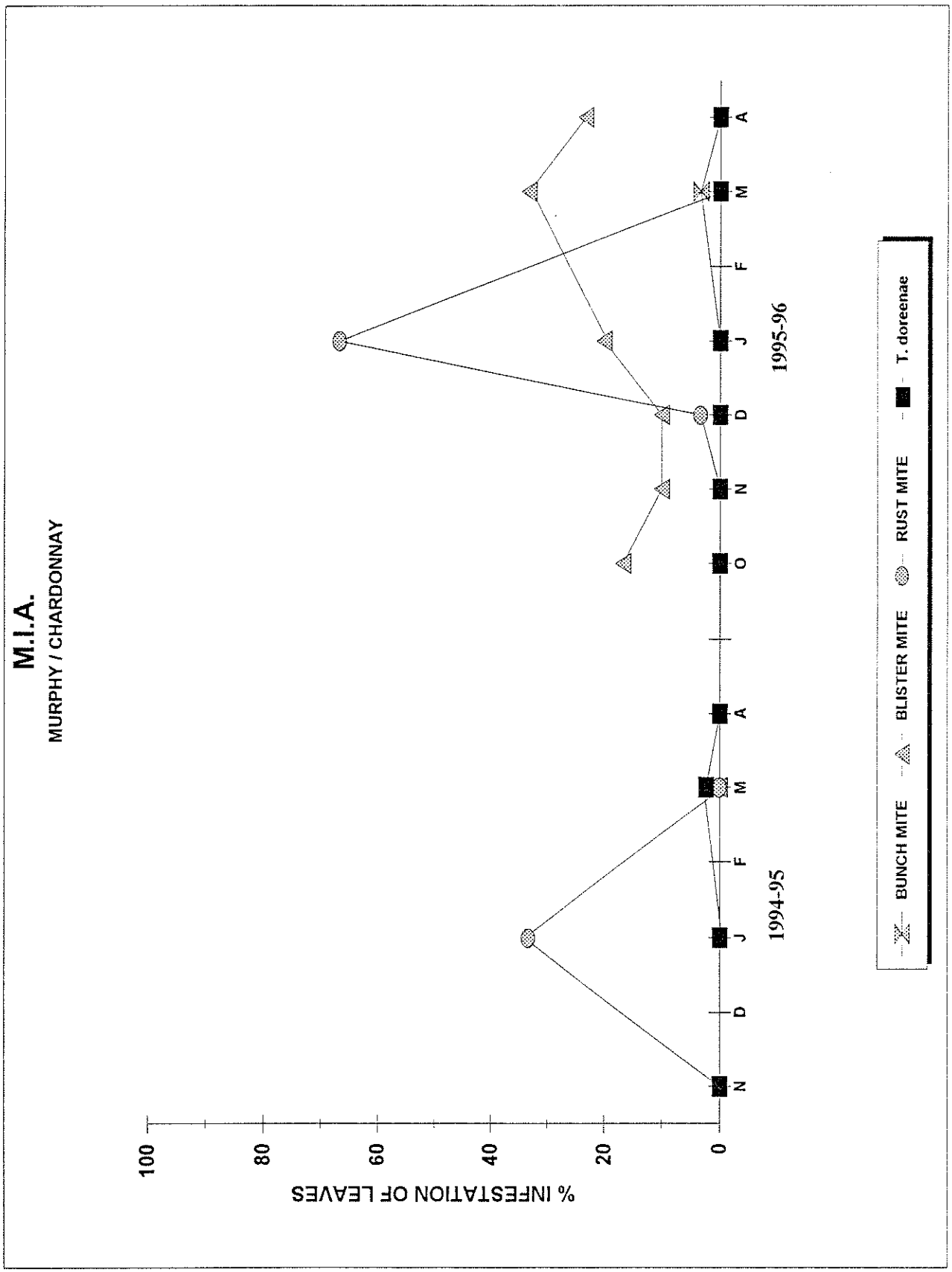


Figure 97. Populations of pest mites and phytoseiids other than *T. doreenae* at Murphy, Griffith, during 1994-96.

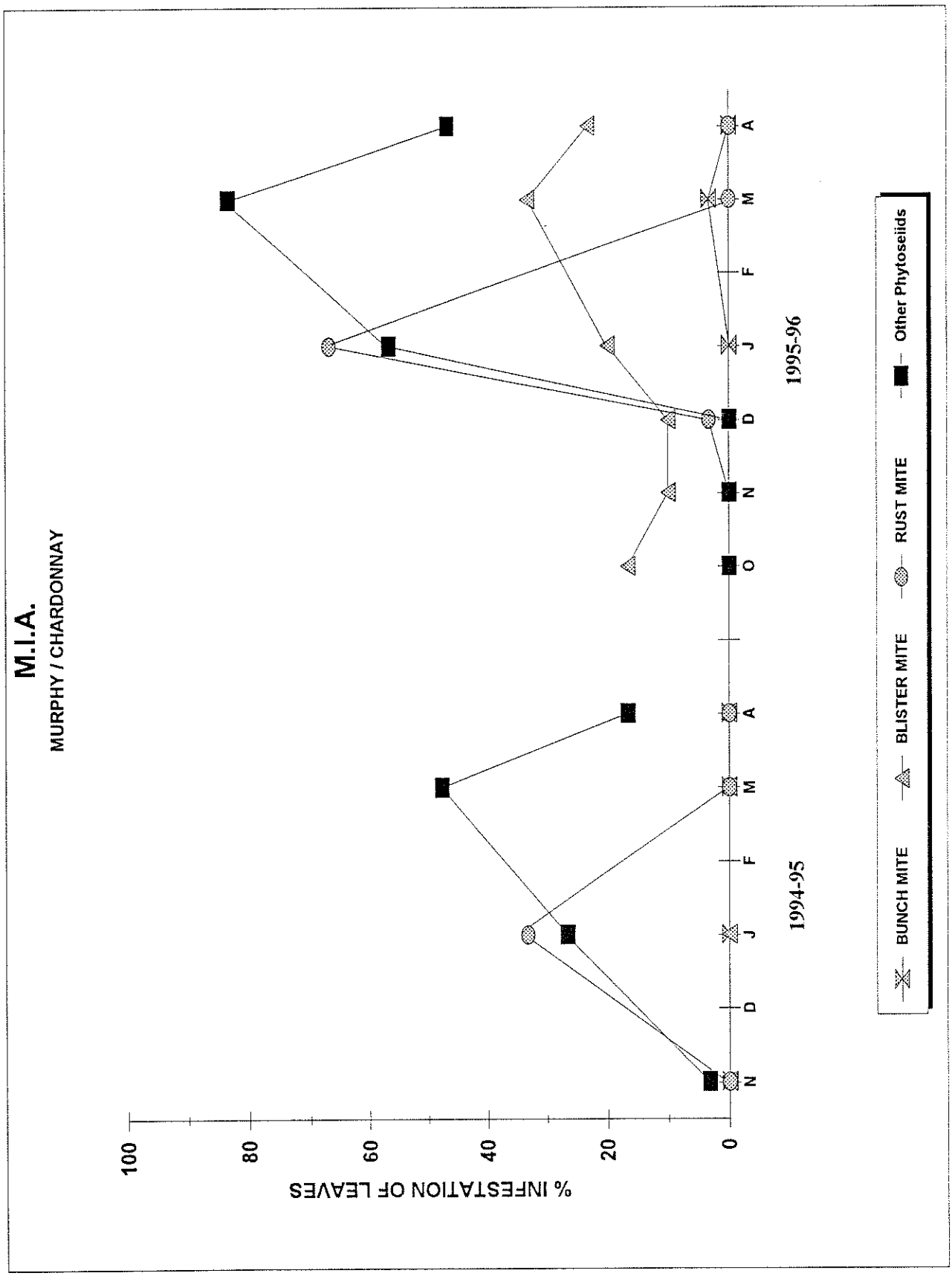


Figure 98. Predator species percentages at Murphy, Griffith during 1995/96.

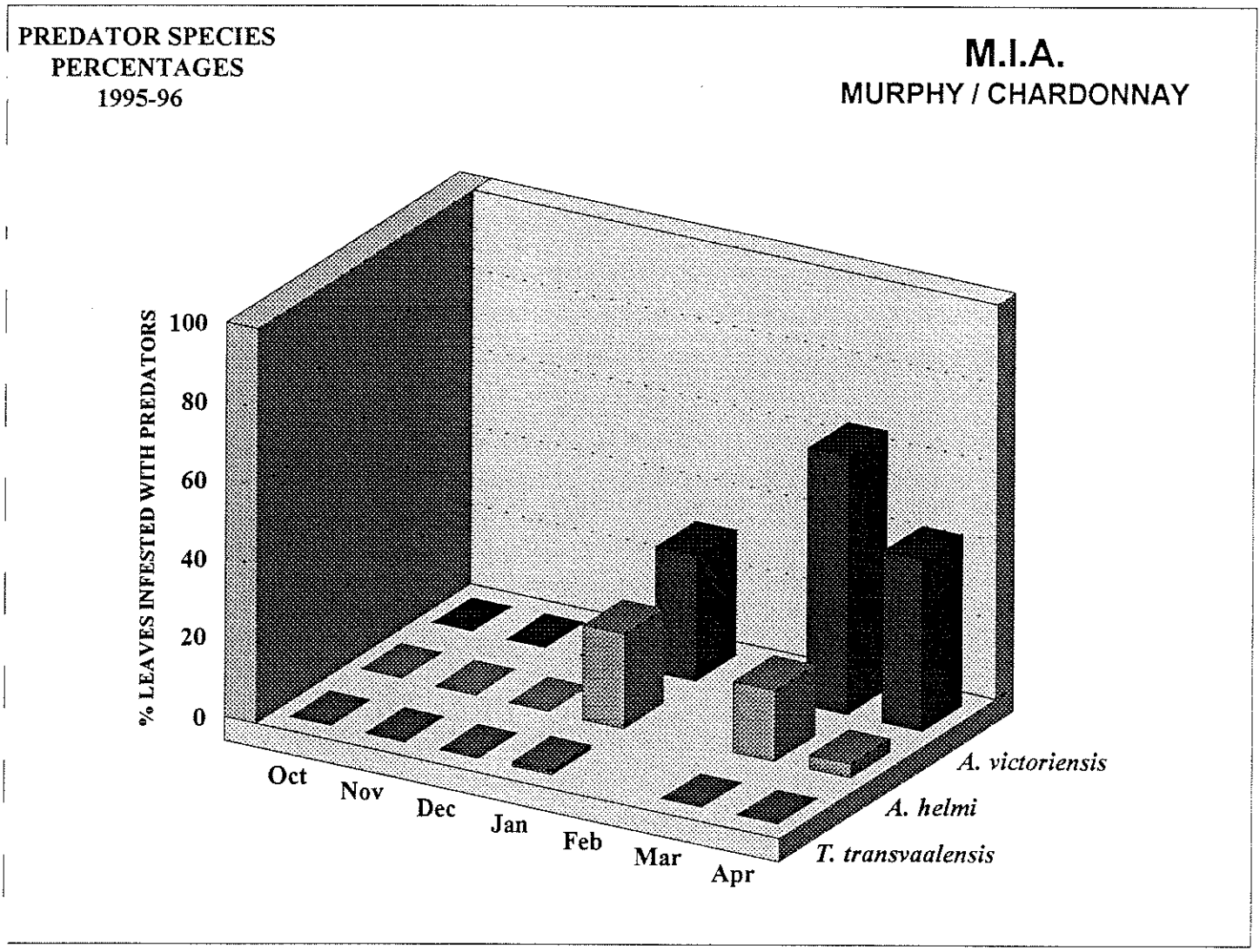


Figure 99. Populations of *T. doreenae* and pest mites at Oag, Leeton, during 1994/96, following introduction of *T. doreenae* in November 1994.

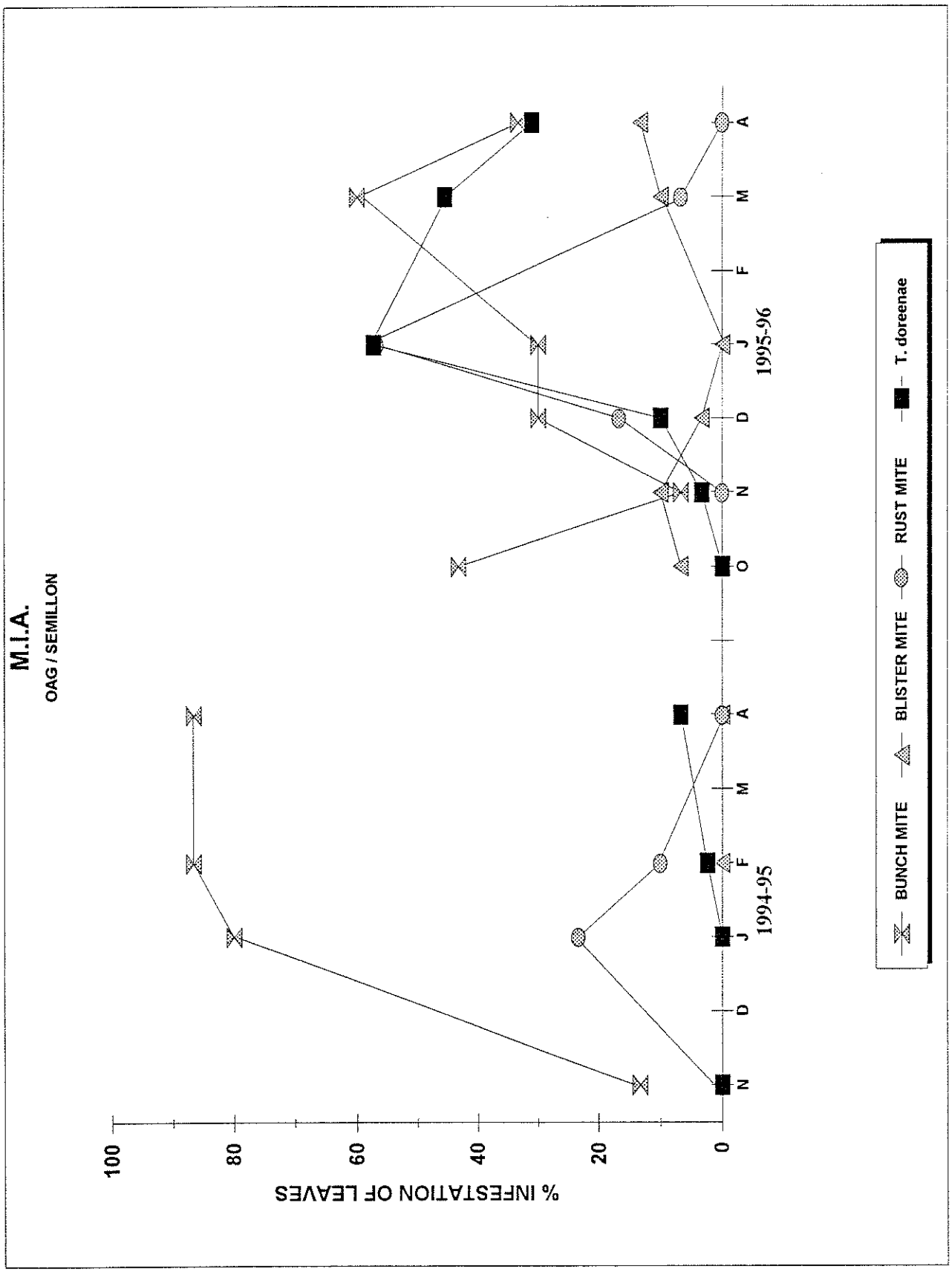


Figure 100. Populations of pest mites and phytoseiids other than *T. doreenae*, at Oag, Leeton, during 1994-96.

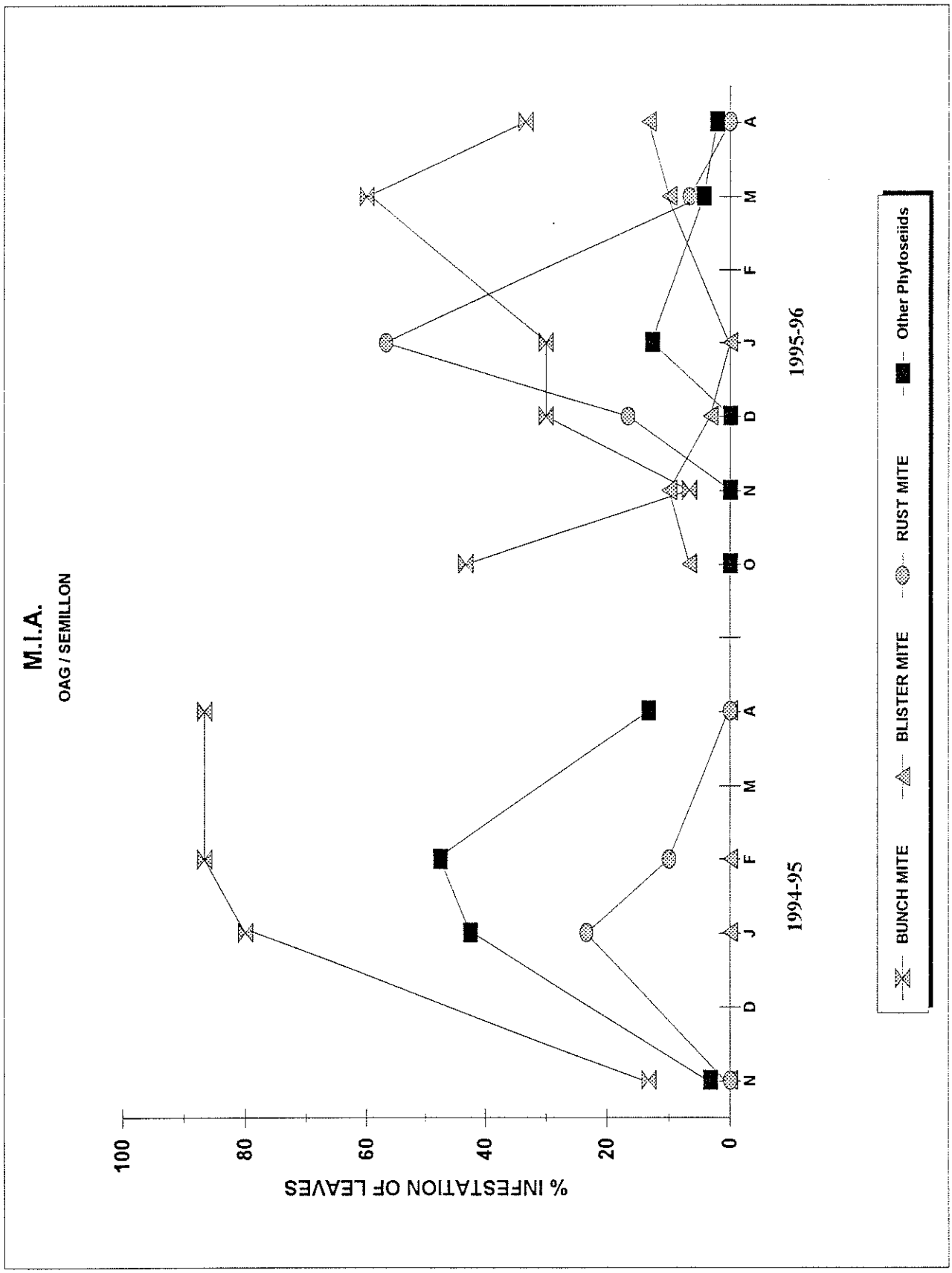


Figure 101. Pest and predatory mite populations at Oag, Leeton, during 1994-96.

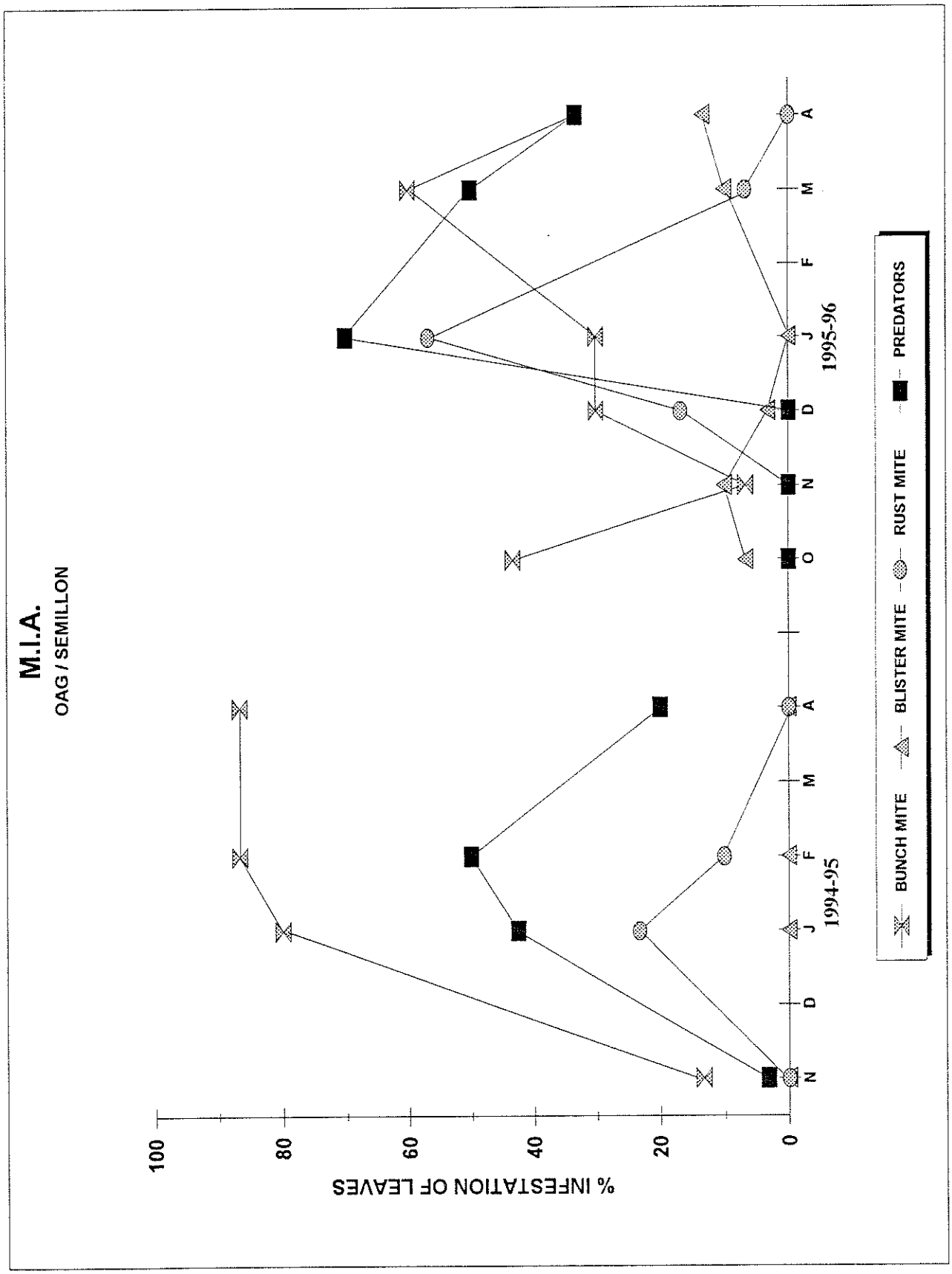


Figure 102. Predator species percentages at Oag, Leeton, during 1995/96.

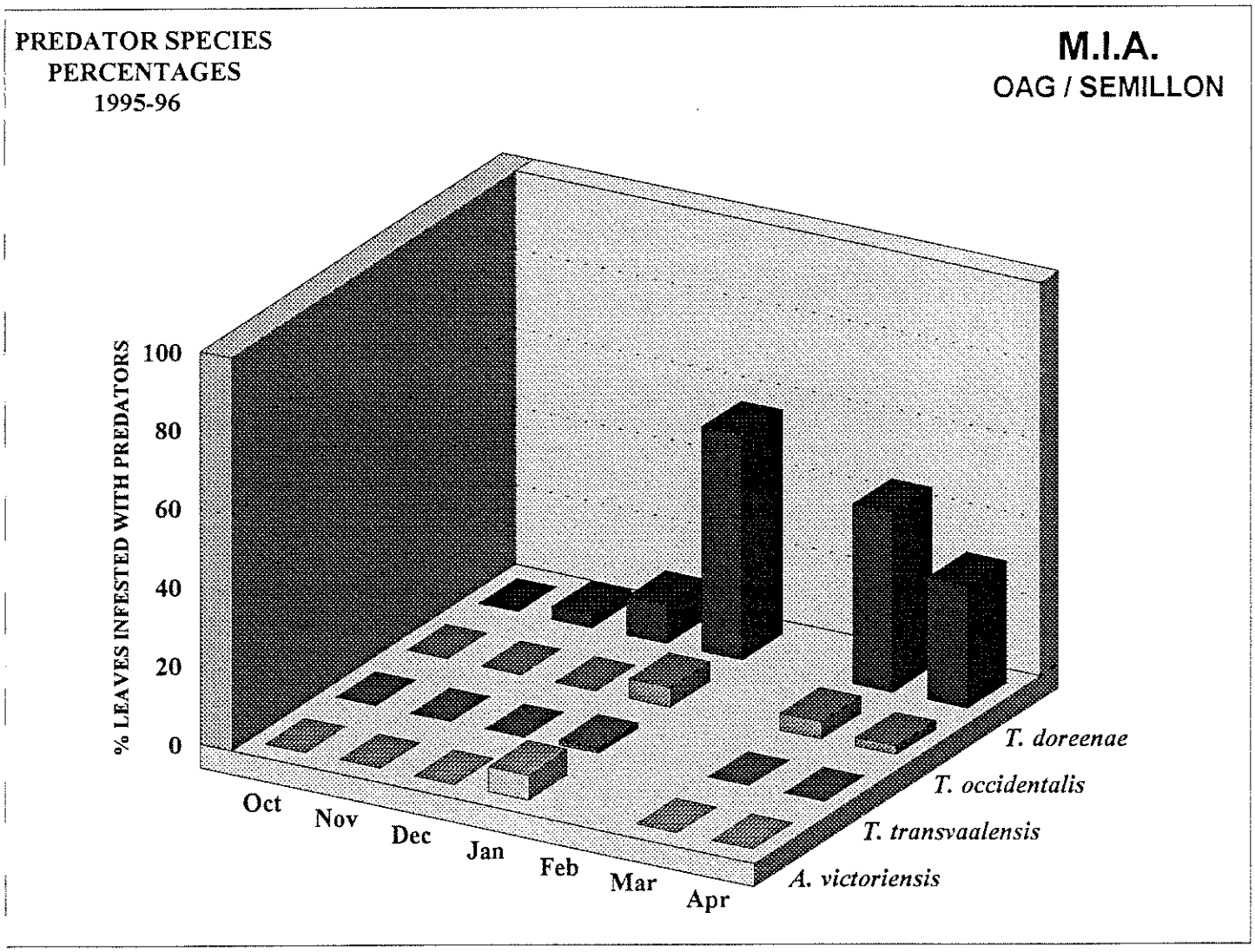


Figure 103. Populations of *T. doreenae* and pest mites at Toorak Wines, Leeton, during 1994-96, following introduction of *T. doreenae* in November 1994.

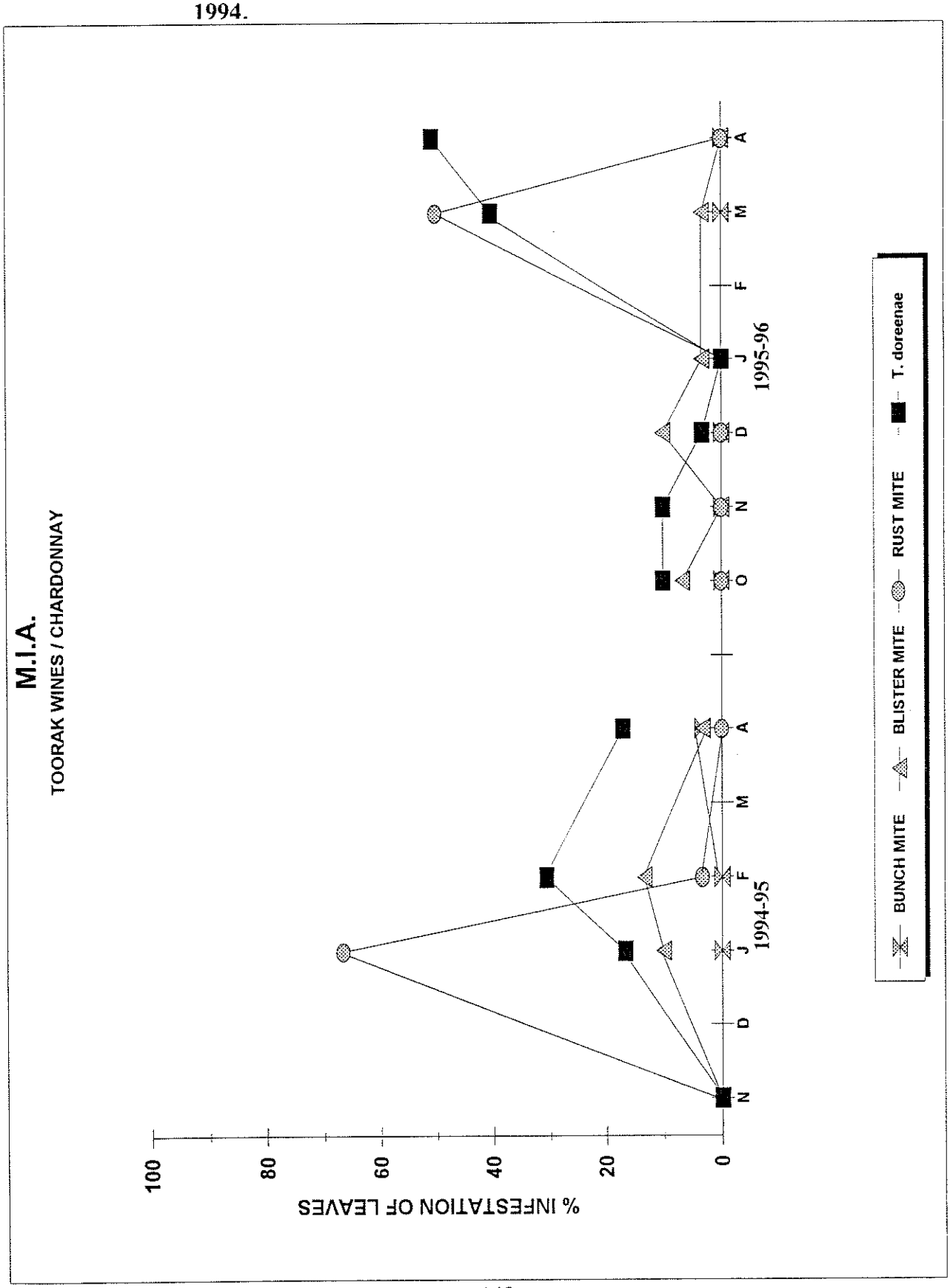


Figure 104. Populations of pest mites and phytoseiids other than *T. doreenae* at Toorak Wines, Leeton, during 1994-96.

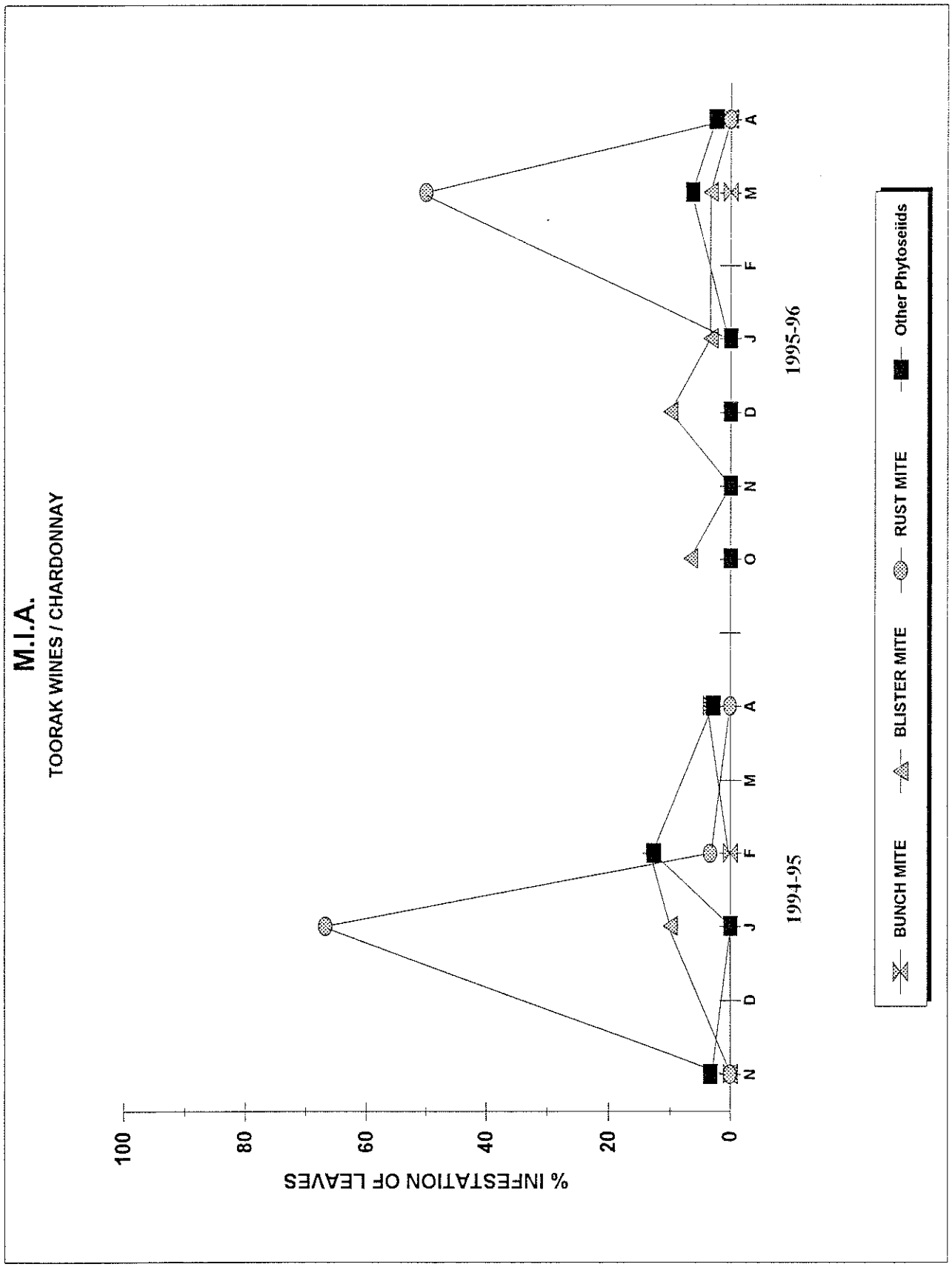


Figure 105. Pest and predatory mite populations at Toorak Wines, Leeton during 1994-96.

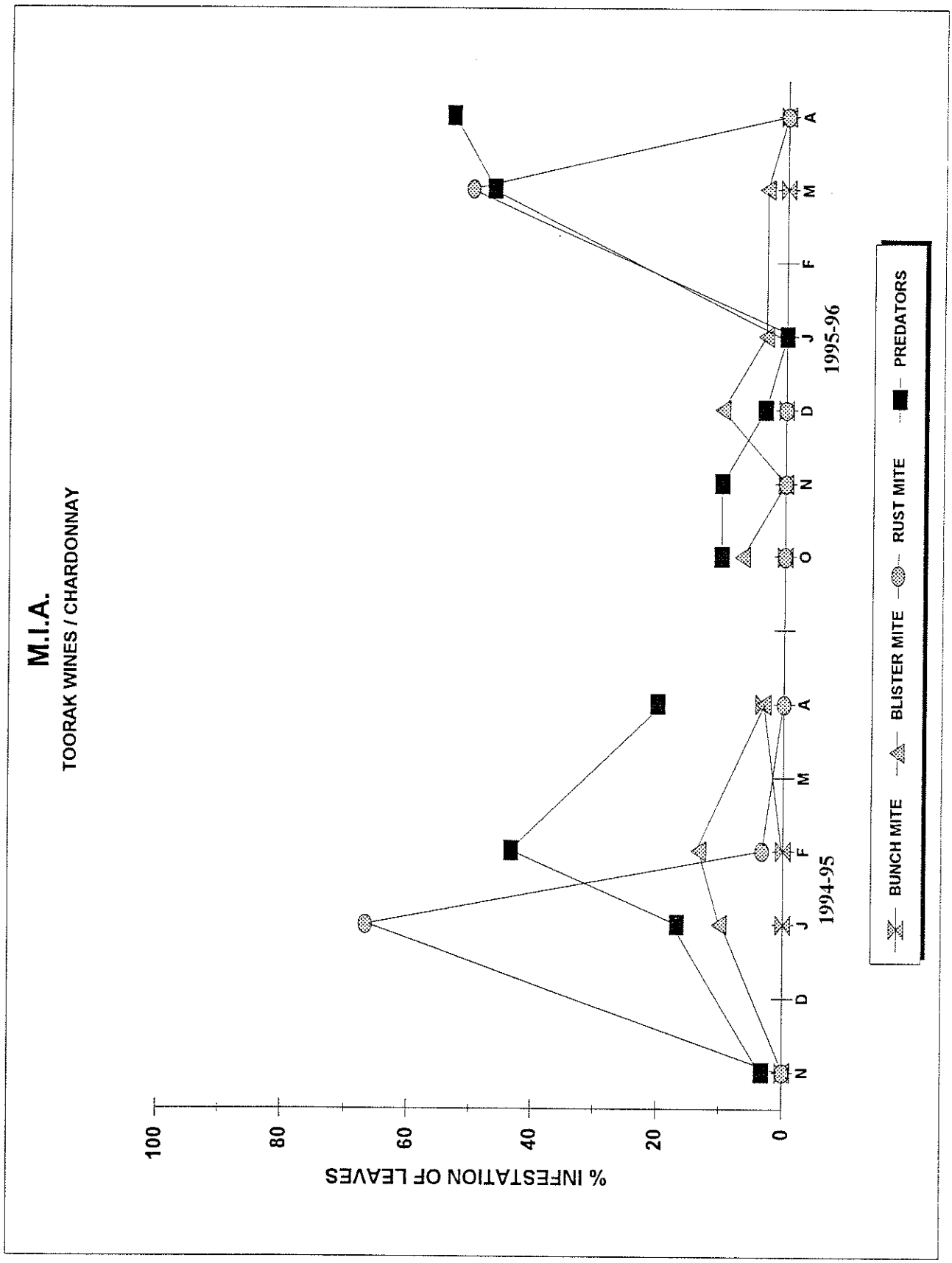


Figure 106. Predator species percentages at Toorak Wines, Leeton during 1995/96.

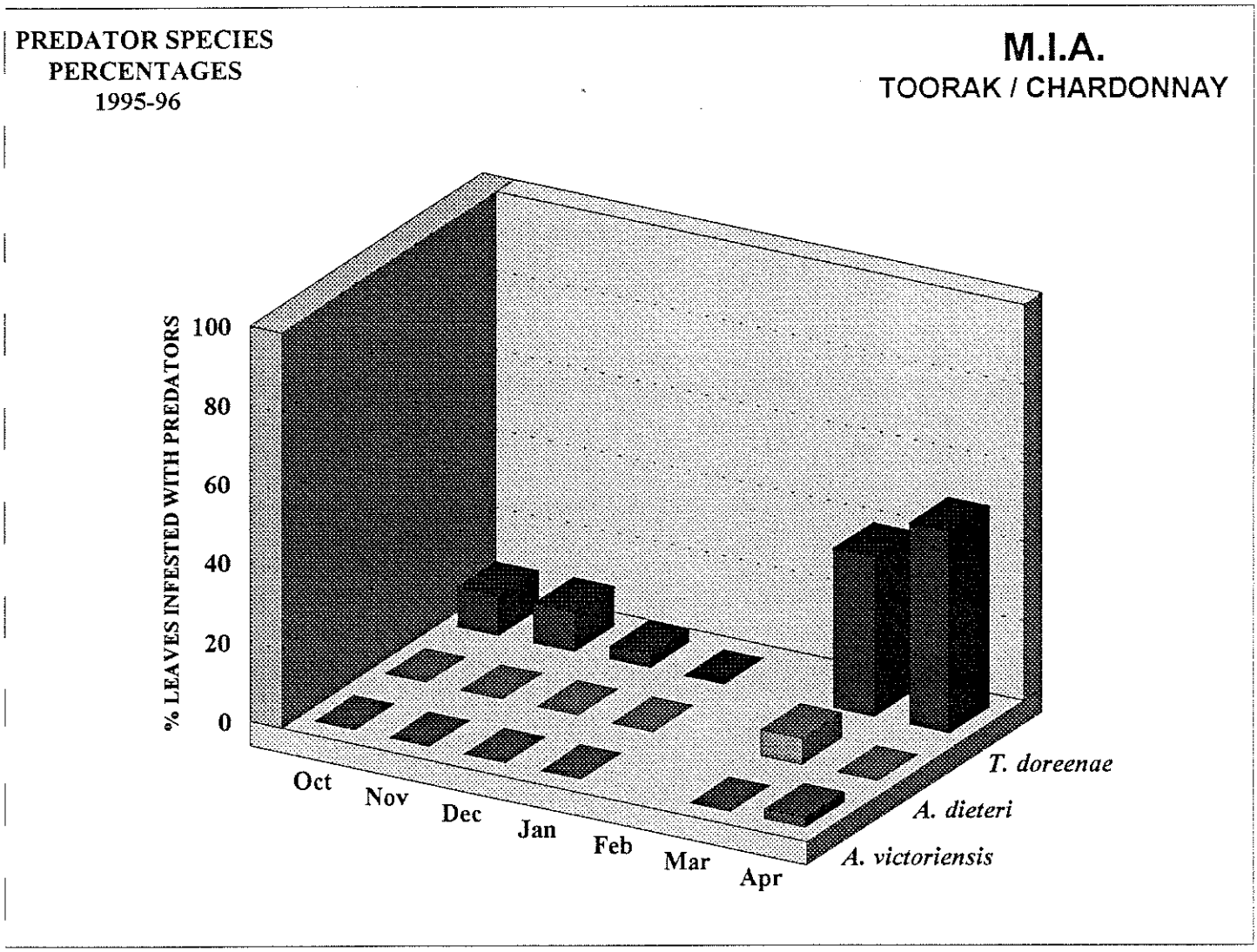


Figure 107. Populations of *T. doreenae* and pest mites at Lillypilly Winery, Leeton during 1994-96, following introduction of *T. doreenae* in November 1994.

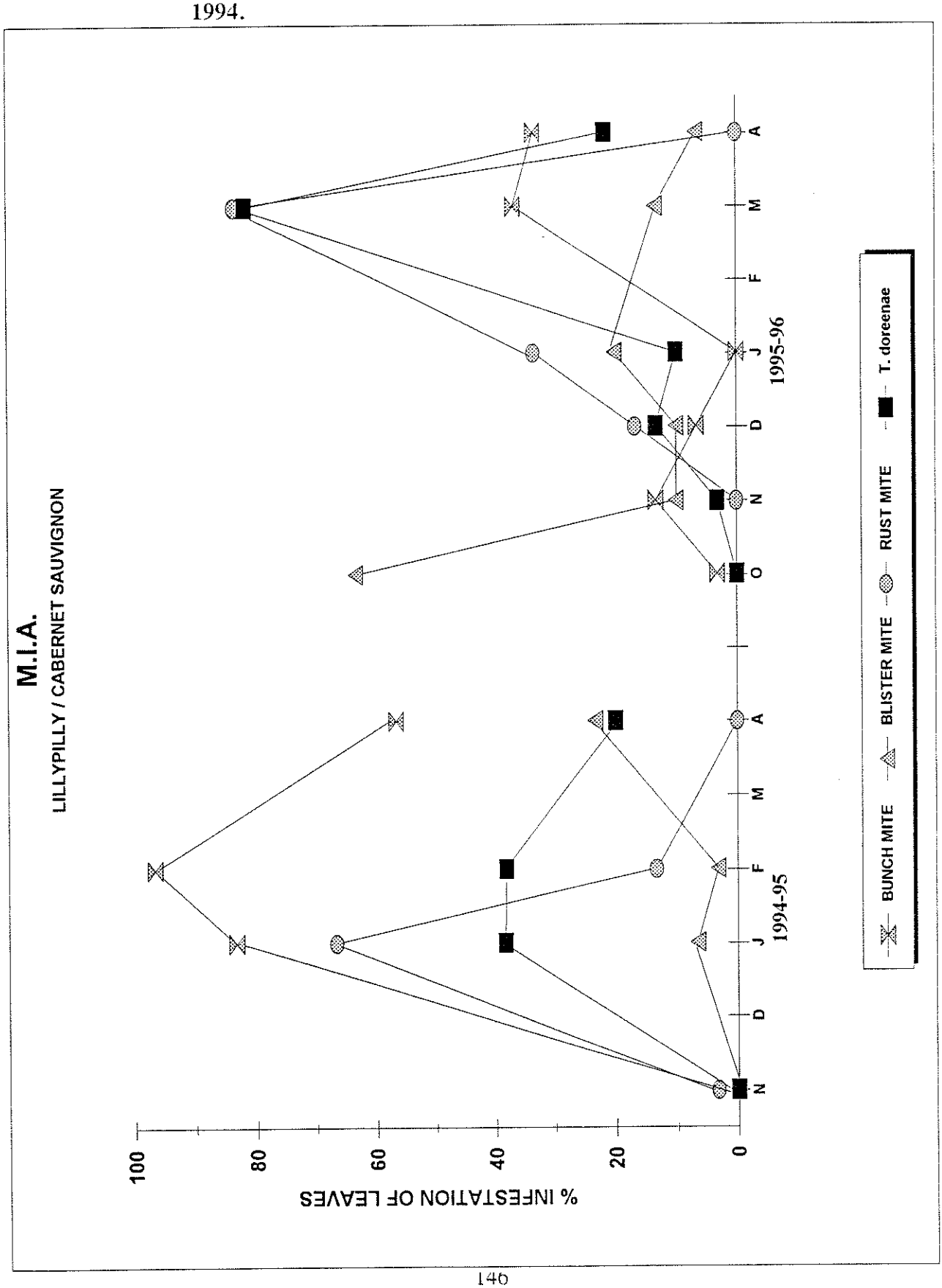


Figure 108. Populations of pest mites and phytoseiids other than *T. doreenae* at Lillypilly Winery, Leeton during 1994-96.

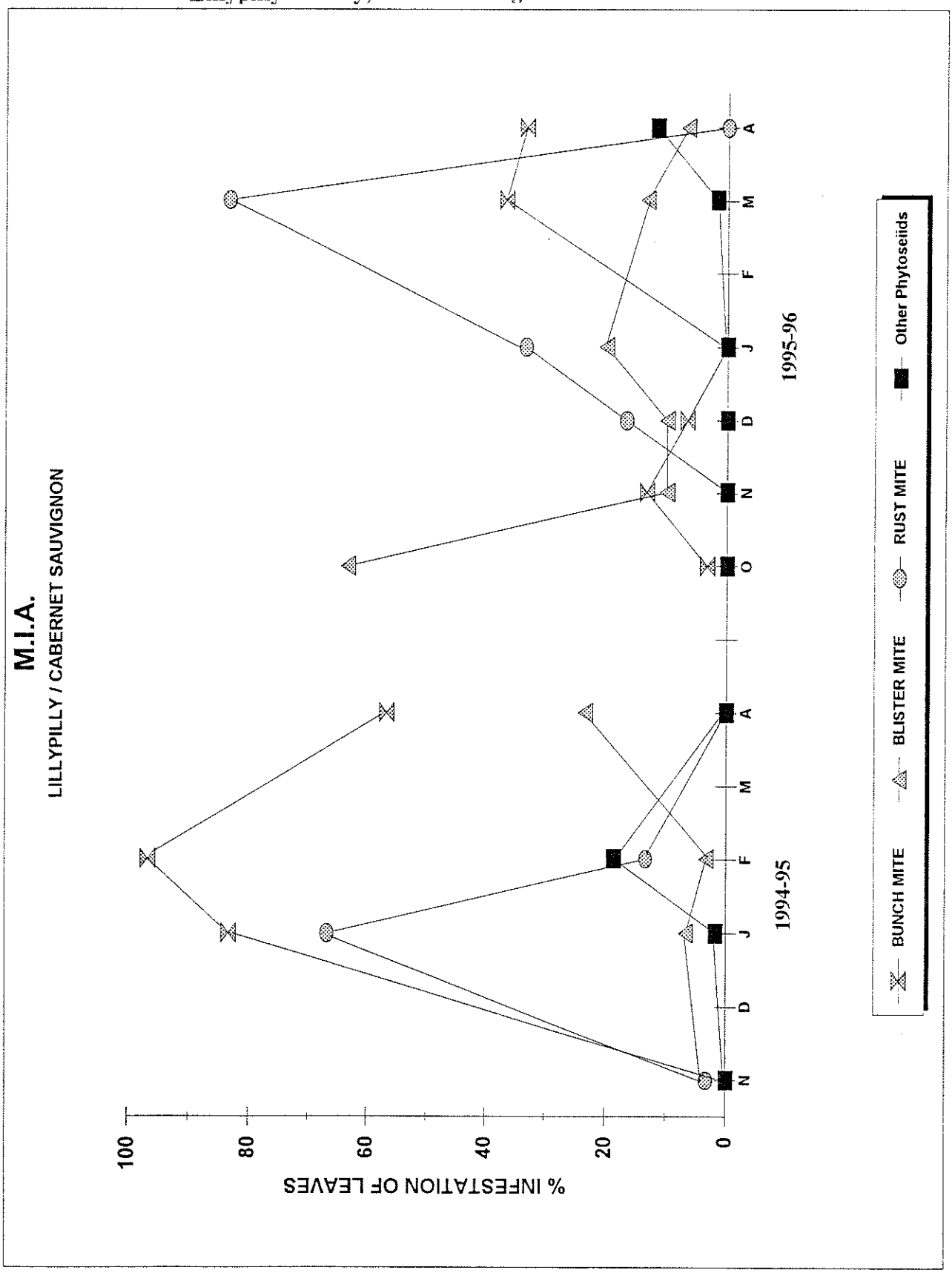


Figure 109. Pest and predatory mite populations at Lillypilly Winery, Leeton during 1994-96.

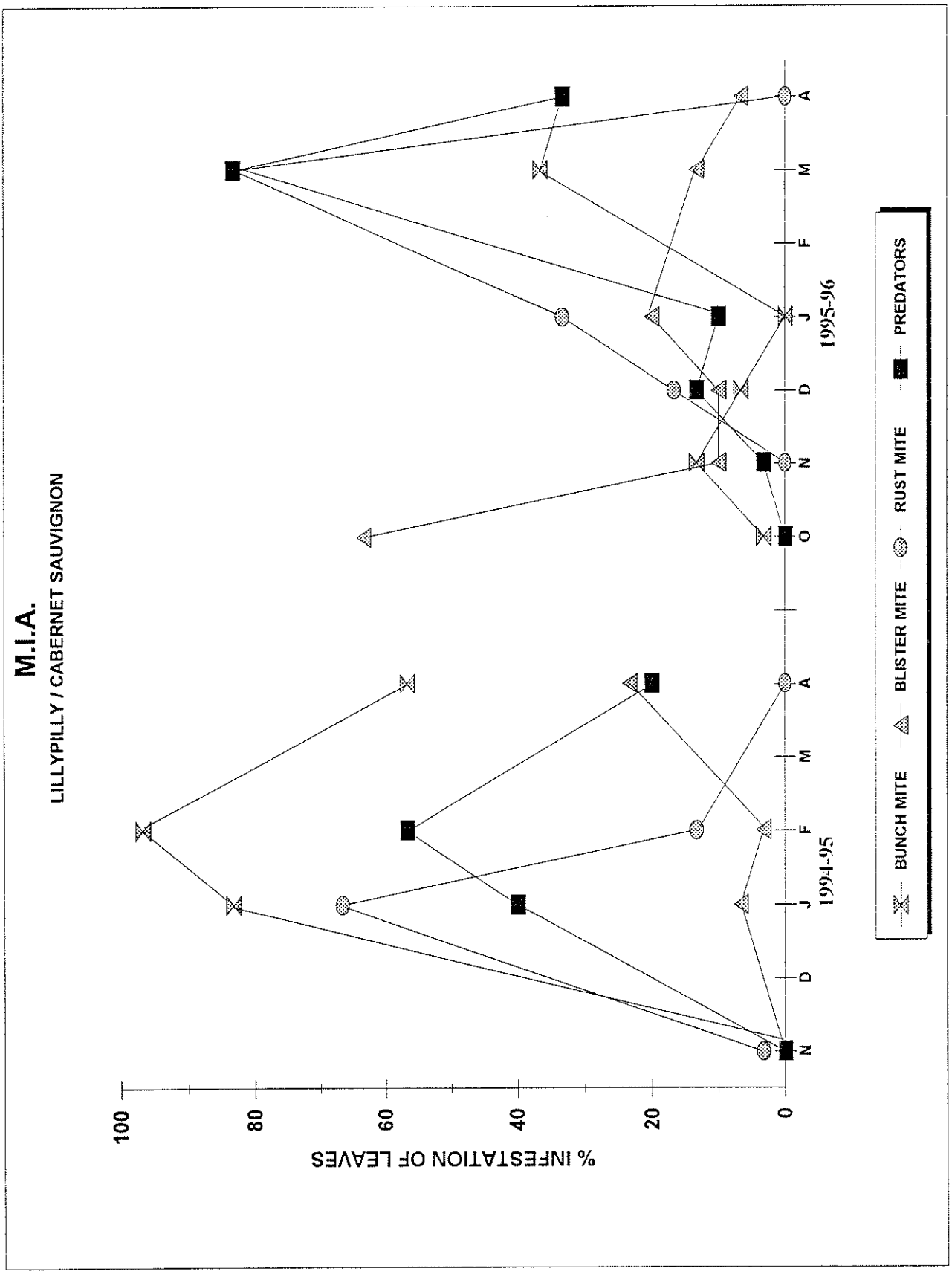
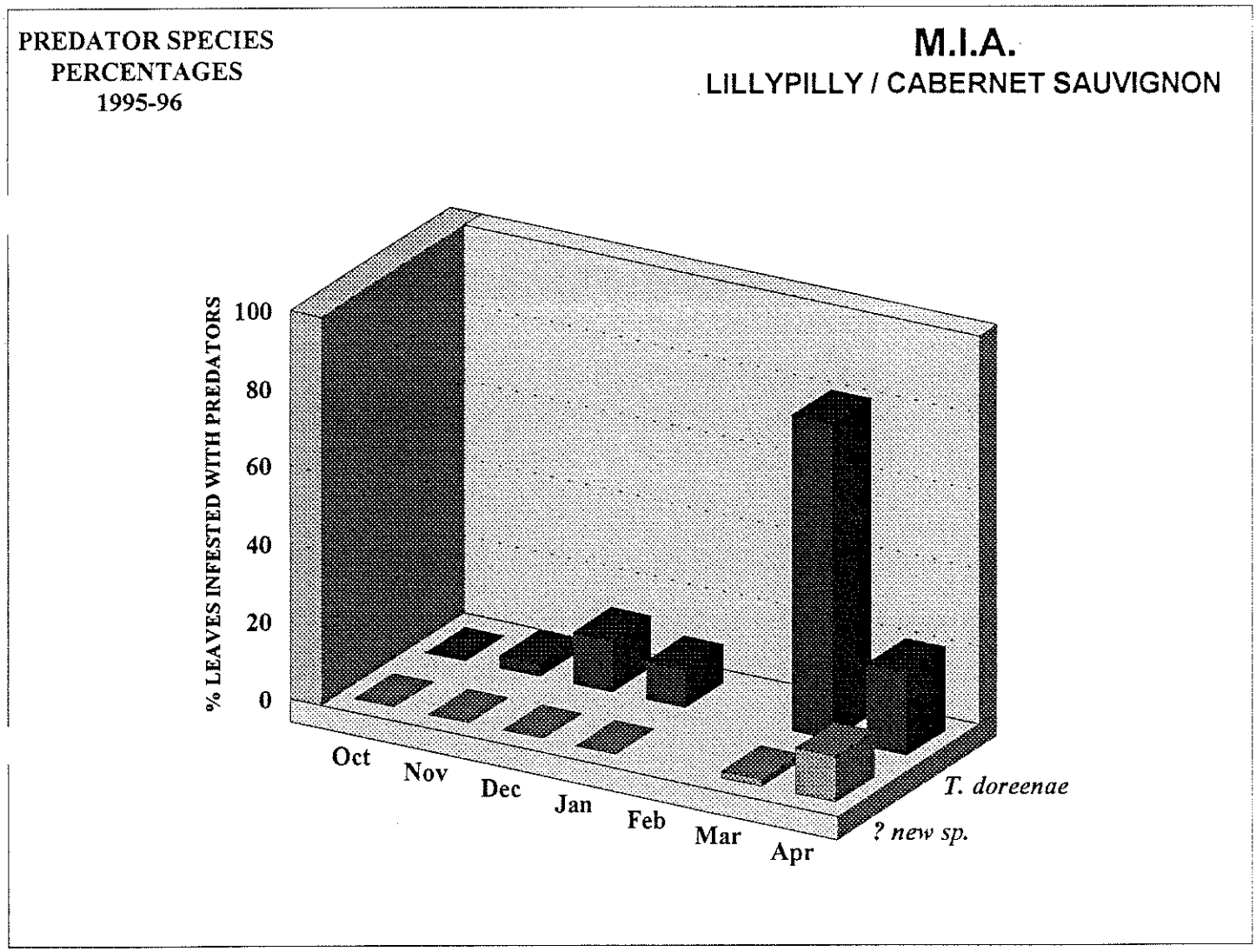


Figure 110. Predator species percentages at Lillypilly Winery, Leeton during 1995/96.



6) Lillypilly Estate
Establishment of *T. doreenae* at this site was rapid like the previous site. Good numbers were present in the block during January to April of the first season, apparently contributing to control of bunch and rust mites (Fig. 107). A large population was present in the second season too, providing good control of all pest mite species. Very few other phytoseiids were present at this site; a few *A. victoriensis* in 1994/95 and a few individuals of an undescribed species in April 1996 (Fig. 110).

## CONCLUSIONS

Rapid and good establishment of introduced *T. doreenae* occurred at 4 of the 6 sites. Failure to establish at the other 2 sites may be linked to the use of insecticides. In some cases large populations developed within 2 months (Toorak Wines, Lillypilly Estate) and in all cases large populations were present by the end of the second season.

These results demonstrate that *T. doreenae* can be successfully introduced into vineyard blocks with a single introduction of an estimated 20,000 individuals. In fact, successful establishment can occur with considerably fewer individuals. In DAN4GW, I reported successful establishment of *T. doreenae* in a vineyard using only an estimated 1280 individuals. *T. doreenae* was still present in this block during the 1995/96 season, five years after its introduction.

Information on the dispersal of *T. doreenae* from release blocks is lacking, but if this species possesses the dispersal abilities documented for other phytoseiids, then its natural expansion across MIA vineyards can be expected during coming seasons. The development of low-input chemical practices which is now prevalent in MIA viticulture should assist in the widespread establishment of *T. doreenae* across the MIA.

Dispersal can be further assisted by growers obtaining grape leaf material from *T. doreenae* colonised vineyards and distributing it in vineyards yet to be colonised. This is best done after harvest when *T. doreenae* numbers are usually maximal. In March 1994 a seminar/workshop was held on the value of *T. doreenae* in biological mite control in viticulture at the Griffith Centre for Irrigated Agriculture. The approximately 30 local viticulturists who attended were each given a sample of grape leaves containing *T. doreenae* for introduction to their own vineyards. Such events should be held during the next few seasons to hasten widespread establishment of *T. doreenae* in the MIA.

## E. EFFECT OF BENOMYL ON EGG PRODUCTION IN *AMBLYSEIUS VICTORIENSIS* AND *TYPHLODROMUS DOREENAE*

### Introduction

*Amblyseius victoriensis* and *Typhlodromus doreenae* are important predatory mites in stone fruit, grapes and citrus in southeastern Australia, contributing to biological control of a number of pest mite species (James 1990, James and Whitney 1993a, Smith and Papacek 1991). Information on the compatibility of these predators with pesticides is vital for their effective exploitation in mite management. James and Rayner (1995) presented data on the toxicity of thirty pesticides to *A. victoriensis* and *T. doreenae*, derived from laboratory bioassays.

Whilst toxicity is clearly the most obvious and important impact of pesticides on predatory mites, sub-lethal effects should not be overlooked. For example, the benzimidazolecarbamate fungicide, benomyl, has been reported to reduce the fecundity of at least two predatory mite species, *Amblyseius fallacis* (Garman) (Nakashima and Croft 1974, Hislop and Prokopy 1981) and *Typhlodromus occidentalis* Nesbitt (Hoy and Standow 1981, Roush and Plapp 1982). Benomyl is not toxic to *A. victoriensis* and *T. doreenae* (James and Rayner 1995), although James (1989) showed that it significantly reduced populations of *A. victoriensis* in an orchard trial.

Data are presented from a laboratory study on the effect of benomyl on egg production in *A. victoriensis* and *T. doreenae*.

### Materials and Methods

Predators used in these tests were taken from mulberry leaves collected in a garden at Leeton in southern New South Wales (*A. victoriensis*) or from grape leaves collected from a vineyard (Bloodwood Estate) at Orange in the Central West of New South Wales (*T. doreenae*). Adult female predators were removed from the leaves and placed singly on 10 grape leaf discs (38 mm diameter), 5 of which were pre-treated with an aqueous suspension of benomyl (0.02 % a.i.) and dried. The other 5 were treated with water. Discs were sprayed with 2 ml of liquid using a Potter Precision Spray Tower with a spray pressure of 50 kpa which delivered 1.6 mg/liquid/cm . Discs were placed on saturated cotton wool in trays and each disc was supplied with a small amount of *Typha orientalis* Presl. pollen (James and Whitney, 1993b) for food and a fragment of broken cover slip for shelter. The predators were held for 7 days at 25°C, 60-70% rh and examined daily for oviposition. Eggs were counted and removed. The test was replicated 4 times for each species. Data were analysed using t tests and % reduction in fecundity (RF%) was calculated by: RF% = [1 - (number of eggs on treated discs/number of eggs on control discs)] x 100.

### Results and Discussion

Egg production by *A. victoriensis* was significantly lower (0.05-0.3 eggs/♀/day) on benomyl-treated discs than on untreated discs (1.0-1.97 eggs/♀/day) ($P < 0.001$) (Table

16). RF% in all tests was 91% or greater. Egg production by *T. doreenae* was not significantly different on benomyl-treated or untreated discs in 3 tests (0.66-0.86 eggs/♀/day) ($P > 0.05$) (Table 17). In the fourth test significantly more eggs were produced by females on the benomyl-treated, than on the untreated discs ($P < 0.01$) (Table 17).

The almost total inhibition of egg production in *A. victoriensis* by benomyl residues is similar to that described for *A. fallacis* and *T. occidentalis* (Hislop and Prokopy 1981, Roush and Plapp 1982). Given the apparent low toxicity of benomyl to adult *A. victoriensis* (James and Rayner 1995), female sterility is likely to have been the cause of the significant suppression of *A. victoriensis* populations on benomyl-treated trees, reported by James (1989). An unreplicated laboratory test (100% hatch in 50 eggs sprayed with 0.2% benomyl) indicated that benomyl does not have an ovicidal effect on *A. victoriensis*, as was reported for *A. fallacis* (Nakashima and Croft 1974).

Although only a few species of phytoseiid have been examined, *T. doreenae* is the first to show no effect of benomyl on fecundity. Roush and Plapp (1982) showed that the carbaryl-resistant strain of *T. occidentalis* is also cross-resistant against benomyl-induced sterility, however, there was still a 30% reduction in fecundity. The strain of *T. doreenae* (from South Australia) examined by James and Rayner (1995) also showed tolerance to carbaryl and it is possible that benomyl and carbaryl tolerance in this species is another example of carbamate resistance in a phytoseiid. However carbaryl and benomyl have not been used in the vineyard where *T. doreenae* was obtained for this study or in any other vineyard in the Orange district (Stephen Doyle, Bloodwood Estate, pers. comm.). A study of tolerance levels to carbaryl and benomyl in strains of *T. doreenae* from different viticultural areas related to the use of these pesticides, would clarify the resistance status of *T. doreenae*.

In the light of these results, benomyl can no longer be recommended as a safe fungicide for use with *A. victoriensis* in biological control programs for mites in stone fruit (James 1989,1990) or grapes (James and Whitney 1993a, James and Rayner 1995). However, benomyl remains a safe fungicide for use in mite biological control programs on grapes which are based on *T. doreenae* (James and Whitney 1995).

Table 16. Egg production by *A. victoriensis* on benomyl-treated and untreated leaf discs over 7 days. Data derived from 5 females in each treatment in each replicate. In each test, means followed by different letter are significantly different ($P < 0.001$, t test).

| Test | Mean (±SE) No. eggs/♀/d | | Total No. eggs | | % reduction in fecundity |
|---|---|---|---|---|---|
| | Benomyl | Control | Benomyl | Control | |
| 1 | $0.30 \pm 0.05^a$ | $1.97 \pm 0.20^b$ | 6 | 69 | 91.3 |
| 2 | $0.06 \pm 0.04^a$ | $1.90 \pm 0.10^b$ | 2 | 68 | 97.0 |
| 3 | $0.05 \pm 0.05^a$ | $1.79 \pm 0.20^b$ | 2 | 59 | 97.0 |
| 4 | $0.10 \pm 0.08^a$ | $1.00 \pm 0.20^b$ | 4 | 44 | 91.0 |
| All | $0.10 \pm 0.03^a$ | $1.67 \pm 0.10^b$ | 14 | 240 | 94.0 |

Table 17. Egg production by *T. doreenae* on benomyl-treated and untreated leaf discs over 7 days. Data derived from 5 females in each treatment in each replicate. In each test, means followed by same letter are not significantly different ($P > 0.05$, t test).

| Test | Mean (±SE) No. eggs/♀/d | | Total No. eggs | |
|---|---|---|---|---|
| | Benomyl | Control | Benomyl | Control |
| 1 | $0.86 \pm 0.10^a$ | $0.77 \pm 0.20^a$ | 30 | 27 |
| 2 | $1.36 \pm 0.10^a$ | $0.77 \pm 0.10^b$ | 50 | 27 |
| 3 | $0.70 \pm 0.20^a$ | $0.70 \pm 0.20^a$ | 27 | 26 |
| 4 | $0.66 \pm 0.10^a$ | $0.67 \pm 0.10^a$ | 24 | 24 |
| All | $0.94 \pm 0.08^a$ | $0.71 \pm 0.08^a$ | 131 | 104 |

## F. TOXICITY OF THE NEW INSECTICIDE TEBUFENOZIDE TO *AMBLYSEIUS VICTORIENSIS* AND *TYPHLODROMUS DOREENAE*

Recent research has shown biological control using endemic predatory mites is a practical and effective strategy for controlling bunch, blister and rust mites in Australian vineyards (James and Whitney, 1990, 1993a, 1994; James et al., 1995). The main impediment to effective use of these predators is the use of toxic pesticides to control other pests and diseases. James and Rayner (1995) tested thirty pesticides used commonly in viticulture for their toxicity to the two most important predatory mites, *Amblyseius victoriensis* and *Typhlodromus doreenae* and rated them as 'safe' or 'harmful'. It is important that new pesticides intended for use in viticulture are also screened for toxicity to predatory mites so that biological management of grapevine mites can be preserved. Tebufenozide (Mimic®) is a new insecticide which will be registered for control of light brown apple moth in vineyards.

### MATERIALS AND METHODS

Predatory mites used in this study were obtained from a vineyard in Orange, NSW (*T. doreenae*) and a backyard Fig tree in Leeton, NSW (*A. victoriensis*). Testing was conducted during January-March 1996 and generally followed the procedures described in James and Rayner (1995).

*Toxicity of Tebufenozide*

Predators were removed from collected leaves by excising tiny leaf 'platforms' containing a predator and placing it on a grape leaf disc (38 mm diameter). The platforms were removed after predators moved onto the leaf disc. This method of predator transferral removed the risk of injury from direct manipulation. The leaf discs were laid on saturated cotton wool (to prevent predators walking off discs) in plastic trays. Ten to fifteen adult predators were placed on each disc and two discs were prepared for each concentration of pesticide tested. A further two-three discs were prepared and used as controls. For each pesticide, tests were conducted using the recommended field rate and 10 x this rate. Discs were sprayed with aqueous suspensions of the pesticides using a Potter Precision Spray Tower. The spraying pressure was 50 kPa and 2 ml of liquid was used for each concentration giving a deposit of 1.6 mg of liquid per square centimetre. Each test was replicated three or four times. Thirty one to 60 individuals per concentration were used and controls, sprayed with water only, were included in each replicate. After spraying, the discs were placed back onto the saturated cotton wool. Discs were supplied with food (cumbungi pollen [James and Whitney, 1993b]) and shelter (small piece of broken glass cover slip) for the predators and held at 25±1°C, 60-70% rh, under a 15 hour photophase. Mortality was assessed after 48 hours by gently prodding each predator with a fine bristle. Predators were considered dead if unable to show coordinated movement. Individuals which became entangled in the wet cotton wool were excluded from the analysis. All data were corrected for control mortality (Abbott, 1925) and tests discarded if this mortality exceeded 10%.

*Effect of Tebufenozide on developmental survival*
The effect of Tebufenozide on survival during development of *A. victoriensis* and *T. doreenae* was examined by spraying egg cohorts of each predator with the recommended field rate (.006% a.i.) and monitoring subsequent juvenile development to adulthood. Spray was applied as described above and three cohorts of 25 eggs each were used for each predator. A single cohort (25 eggs) was used as a water-only control for each predator. Individual eggs were excised from grape (*T. doreenae*) and Fig (*A. victoriensis*) leaves and cohorts placed on ca. 8 x 4 cm arenas cut from grape leaves. Arenas were laid on saturated cotton wool. Eggs used in these tests were all <48 h old as indicated by absence of embryonic development. After spraying, arenas were held at 25±1°C and examined daily. A count of number of individuals achieving adulthood in each cohort was made after 10 days.

*Effect of Tebufenozide on fecundity*
The effect of Tebufenozide on fecundity of *A. victoriensis* and *T. doreenae* was examined by retaining females used in toxicity tests for a further 96 hours (after 48 hour mortality assessment) and recording daily egg production.

RESULTS

*Toxicity of Tebufenozide*
Data from toxicity bioassays are summarised in Table 18. Tebufenozide at the field rate caused no mortality to *A. victoriensis* and *T. doreenae*. Tebufenozide at 10 x field rate was very slightly toxic to *A. victoriensis* but non-toxic to *T. doreenae*.

*Effect of Tebufenozide on developmental survival*
Survival of *A. victoriensis* and *T. doreenae* during development from egg to adult was not affected by exposure of eggs to tebufenozide (Table 19).

*Effect of Tebufenozide on fecundity*
Exposure of adult females to tebufenozide did not significantly affect egg production by *A. victoriensis* and *T. doreenae* (Table 20).

**Table 18 Percentage mortality of adult *A. victoriensis* and *T doreenae* sprayed with field rate (FR) and 10 times the field rate concentration of Tebufenozide**

| Pesticide (FR % a.i.) | *A. victoriensis* | | *T. doreenae* | |
|---|---|---|---|---|
| | FR | 10 x FR | FR | 10 x FR |
| Tebufenozide (.006%) | 0 | 0 | 0 | 1.8 |

**Table 19** **Percentage survival to adulthood of egg cohorts of *A. victoriensis* and *T. doreenae* sprayed with Tebufenozide (0.006%) or water only (control).**

| Cohort (25 eggs) | *A. victoriensis* | | *T. doreenae* | |
|---|---|---|---|---|
| | tebufenozide | Control | tebufenozide | Control |
| 1 | 80 | 75 | 48 | 48 |
| 2 | 70 | 70 | 55 | 50 |
| 3 | 85 | 80 | 50 | 50 |
| Mean | 78.3 | 75 | 50 | 49.3 |

**Table 20** **Egg production (Mean ±SE eggs/♀/day) by *A. victoriensis* and *T. doreenae* following exposure to tebufenozide.**

| Rate | *A. victoriensis* | *T. doreenae* |
|---|---|---|
| FR | 1.1 ± 0.2 | 1.1 ± 0.3 |
| 10 x FR | 1.1 ± 0.3 | 1.1 ± 0.3 |
| Control | 0.8 ± 0.1 | 0.9 ± 0.1 |

*No Significant difference in egg production by each species whether exposed to tebufenozide or not ($P < 0.05$, t test)

DISCUSSION

Tebufenozide is a moult-accelerating compound which imitates the insect moulting hormone, 20-hydroxyecdysone and initiates a premature lethal moult in targeted Lepidopteran larvae. It is non-toxic to most beneficial insects and mites that have been tested. The predatory mites, *A. victoriensis* and *T. doreenae* can now be added to this list. Tebufenozide also has no effect on egg-adult development or fecundity of these predators. The use of tebufenozide against light brown apple moth in grapevines can therefore be considered compatible with biological mite management.

# G. TOXICITY OF SOME PESTICIDES TO *TYPHLODROMUS DOSSEI*

## INTRODUCTION

During this study, it became apparent that *Typhlodromus dossei* is an important predator of grapevine mites in a number of viticultural regions, particularly the cooler areas of Western Australia, Tasmania, southern Victoria and the Granite belt in Queensland (see section B). Little is known about the biology and ecology or susceptibility to pesticides of this species.

*T. dossei* was described by Schicha (1978) and Schicha (1987) recorded it from grapevines or other hosts in all states except South Australia and Western Australia. In this study it was recorded from grapevines in all states (see section A). Schicha (1987) also recorded that this species has been observed feeding on eriophyid (rust) mites, but little is known of its prey preferences. In this study *T. dossei* was invariably found in association with rust or blister mites, upon which it was feeding.

The obvious importance of *T. dossei* as a predator on rust and blister mites in some viticultural areas, requires we collect similar information on its pesticide susceptibility, as is already known for *T. doreenae* and *A. victoriensis*. Consequently, information is presented here on the toxicity of a small number of pesticides (eight fungicides, one insecticide) used on grapevines, against *T. dossei*. Some of these materials are new products which have only recently appeared in the marketplace. Evaluation of their toxicity against *T. dossei* formed part of their performance profile prior to registration.

## MATERIALS AND METHODS

*Typhlodromus dossei* was obtained for pesticide bioassays from a vineyard in Geelong, southern Victoria in March 1995 and March 1996. Leaves were collected from the vineyard, packed in plastic bags in an esky and transported to Yanco within a day of collection. Prior to use in bioassays, leaves and predators were stored at 5-10°C for up to 10 days.

Adult female predators were removed from grape leaves and placed on bean leaf discs (38 mm diameter), laid on saturated cotton wool in plastic or metal trays. Manipulation of the predators was conducted using a moistened fine camel hair brush. Five to twenty predators were placed on each disc and one or two discs were prepared for each concentration of pesticide tested. A further one or two discs were used as controls which were sprayed with water only. Discs were sprayed with aqueous suspensions of the pesticide being tested using a Potter Precision Spray Tower. The spraying pressure was 50 kPa and 2 mL of liquid was used for each concentration giving a deposit of 1.6 mg of liquid per square centimetre. Each test was replicated three times (except for zineb, dithianon and propiconazole which were only tested once due to lack of available predators) and data for each concentration were derived from 11-37 individuals. After spraying, the discs were placed back onto the saturated cotton wool. Discs were supplied with food (cumbungi pollen) and shelter (small pieces of broken glass cover slip) for the predators and held at 25±1°C, 60-70% rh, under a 15 hour photophase. Mortality was assessed after 48 hours by gently prodding each predator with a fine bristle. Predators were considered dead if unable to show coordinated movement.

Individuals which became entangled in the wet cotton wool were excluded from the analysis. All data were corrected for control mortality and tests discarded if mortality exceeded 10%. All pesticides were tested at field and 10 times field rate concentrations (% a.i.). Mancozeb, wettable sulphur and KBR2738 were also tested at 100 times field rates.

## RESULTS AND DISCUSSION

Bioassay results are shown in Table 21. Six of the eight fungicides (dithianon, propiconazole, wettable sulphur, systhane, fluquinconazole, KBR 2738) and the insecticide, imidacloprid, caused no mortality to *T. dossei* at field and 10 times rates. Mancozeb caused minimal mortality (<5%) at both concentrations and zineb was harmless at the field rate but caused 20% mortality at 10 times the rate. Total mortality occurred at 100 times the field rate with mancozeb and wettable sulphur, but only low mortality with KBR2738.

These results indicate that *T. dossei* may be as tolerant to viticultural pesticides as *T. doreenae* is. Certainly, the lack of mortality caused by wettable sulphur and the minimal mortality from mancozeb are extremely positive signs. These materials are amongst the most frequently used fungicides in the regions where *T. dossei* is common.

Imidacloprid is a new insecticide which is being developed for use against a wide range of insect pests and it is likely it will be used in vineyards at some stage. Its apparent safety to *T. dossei* is very encouraging. Recent data for *T. doreenae* and *A. victoriensis* indicate this insecticide also has no deleterious effect against these predators. In fact, James (1997) showed imidacloprid actually enhances egg production by *A. victoriensis*, making it potentially a very useful and biological control-compatible compound.

Testing of a larger range of viticultural pesticides against *T. dossei* is desirable.

**Table 21 Percentage mortality of adult female *T. dossei* sprayed with field rate (FR) and 10 times the field rate concentrations of eight fungicides and one insecticide.**

| Pesticide (FR %a.i.) | FR | 10 x FR | 100 x FR |
|---|---|---|---|
| **Fungicides** | | | |
| Zineb | 0 | 20 | - |
| Dithianon | 0 | 0 | - |
| Propiconazole | 0 | 0 | - |
| Mancozeb | 3.6 | 4.5 | 100 |
| Wettable Sulphur | 0 | 0 | 100 |
| Systhane | 0 | 0 | - |
| KBR2738 (Bayer) | 0 | 0 | 5 |
| Fluquinconazole | 0 | 0 | - |
| **Insecticide** | | | |
| Imidacloprid | 0 | 0 | - |

# H. DEVELOPMENT OF COMMERCIAL MASS REARING TECHNIQUES FOR PREDATORY VINEYARD MITES
## TRAVEL REPORT (THE NETHERLANDS/UK 30/6/95-18/7/95)

## SUMMARY

A number of research institutions in the Netherlands and United Kingdom were visited and discussions held with appropriate staff concerning mass rearing of phytoseiid mites and other biological control agents. Fundamental and detailed information on a number of rearing systems, some of which have been exploited commercially, was obtained and should provide the basis for research on developing a similar system for the Australian phytoseiids, *Typhlodromus doreenae* and *Amblyseius victoriensis*. Of particular importance was information gained on a 'volume' rearing system based on bran and flour mites. This system is considered to be the most appropriate for cost-effective commercialisation. Development of a volume culturing system for *T. doreenae*, in particular, should enhance the prospects of commercialisation of this important predator. The commercial availability of predatory mites (*T. doreenae, A. victoriensis*) is important for long term sustainability of biological mite control in Australian viticulture.

## OBJECTIVES OF VISIT

To visit research acarologists and commercial suppliers of predatory (phytoseiid) mites in the Netherlands and United Kingdom to gain information on commercial mass rearing technologies. Optimal exploitation of biological control of grapevine mites, which has been developed by Dr James, requires commercial availability of the principal biological control agent, *Typhlodromus doreenae* (DOREEN). Although laboratory-based mass rearing techniques have been developed for *T. doreenae*, these are not considered suitable for commercialisation. "Volume rearing systems" which have been developed for certain phytoseiid species in Europe are considered to have great potential as the basis of a commercial rearing system for *T. doreenae* in Australia, and were the focus of this study tour.

## BACKGROUND

Dr James has been funded by the Grape and Wine Research and Development Corporation since 1989 to investigate the potential, develop and implement biological control of grapevine mites in Australian viticulture. This research has been highly successful and it is expected that biological control will become the industry standard for mite management within a few years. Basic biological and ecological research on vineyard mites throughout Australia showed that biological control of vine mite pests through indigenous natural enemies, was largely suppressed by the use of certain chemicals. Modification of pesticide usage and enhancement of predator populations is usually all that is required to establish natural regulation of vineyard mite pests.

The phytoseiid predator, *Typhlodromus doreenae* (DOREEN),is recognised as the most important component of the natural enemy complex regulating vine mite pests. A program of mass-production and introduction of this predator to viticultural regions in which it does

not occur, is described in Section D. It is important that *T. doreenae* be available commercially so growers can have access to this important predator. Once established *T. doreenae* should persist in a vineyard indefinitely, however, occasions will undoubtedly arise when it becomes necessary to supplement populations. Commercial availability of *T. doreenae* will enable this to occur.

Current mass-rearing of *T. doreenae* is based on a layer technique which is an inefficient producer of predators when space is limited. In addition, a considerable amount of routine culture maintenance is required to keep layer cultures at optimal production levels. Volume culturing of phytoseiids offers significant economy of space and greatly reduced maintenance inputs.

## VISITS TO ORGANISATIONS/AREAS

(i) The Hague, Netherlands. XIII International Plant Protection Congress, 2-5 July.
Dr James attended this congress and presented a paper entitled "Biological Control of Mites in Australian Viticulture:State of the Art". He also presented a poster: "Biological Control of Mites in Australian Viticulture: Implementation and Sustainability.

University of Amsterdam, Dept. of Pure and Applied Ecology, 6 July. Dr James visited this world-renowned centre for phytoseiid research and participated in discussions with experts on phytoseiid rearing (Dr M Sabelis, Dr L P S Van der Geest, Dr W Helle).

Glasshouse Crops Research Institute, Naaldwijk, 7 July. Dr James visited this institution to consult with Dr P Ramakers, the architect of volume rearing systems for phytoseiids.

(ii) United Kingdom: Rothamsted Experimental Station, Harpenden, 10 July.
Discussion with Biological Control scientists with reference to phytoseiid rearing and delivery systems.

International Institute of Biological Control, Silwood Park, Ascot, 11 July.
Discussion with Biological Control scientists .

Bunting Biological Control Ltd, Middlesex and other commercial suppliers of phytoseiid mites, 12 July.
Discussions re mass rearing and delivery systems.

## REPORT

*Introduction*

Research on and commercialisation of mass rearing of predatory phytoseiid mites has been developed further in The Netherlands and the United Kingdom than anywhere else in the world. This has resulted primarily from the considerable development of glasshouse crops in this region with subsequent plant-feeding mite problems. Red spider mites (*Tetranychus* spp.) are a pest of nearly all horticultural crops grown under glass and outdoors. Similarly, thrips, including western flower thrips, are important glasshouse pests. Mites and thrips can both be controlled biologically, using predatory phytoseiids.

*Phytoseiulus persimilis* or the chilean predatory mite, is produced by all suppliers of biological control agents in The Netherlands and the UK. This predatory mite feeds on eggs, nymphs and adults of a number of species of red spider mite. It is supplied by one company in shaker bottles containing vermiculite under the trade name SPIDEX (Koppert Biological Systems). Another phytoseiid, *Typhlodromus occidentalis,* is also produced by this company for spider mite control. Delivery of predators to glasshouse crops using shaker bottles is a clear improvement on the more time consuming method of distributing predator-infested bean leaves to a crop, as practised by Australian suppliers of *P. persimilis* and *T. occidentalis*.

*Amblyseius cucumeris* is another predatory mite produced commercially in The Netherlands and the United Kingdom, but this one is used as a control agent for thrips. It too, is provided in shaker bottles (THRIPEX) and also as a 'breeding system' in sachets. *Amblyseius degenerans* is also produced for thrips control. This species can reproduce at lower humidities than *A. cucumeris* and has the ability to survive on pollen.

Commercial production of biological control agents including predatory mites first began in The Netherlands and the United Kingdom in the late 1960's and early 1970's. Consequently, there have been considerable advances in the technology associated with the production and delivery of the various beneficial organisms marketed. It is these advances in the mass production and delivery of predatory phytoseiid mites which were the focus of my study tour to The Netherlands and United Kingdom in July 1995.

Unfortunately, along with the substantial commercial development of production and delivery of beneficial organisms, has come an aura of 'secrecy' and reluctance by the industry to divulge information. In part, this is understandable given the number of emerging producers and the competitiveness of the market. However, it presents a significant barrier to development and adoption of similar practices in Australia and elsewhere in the world. All of the commercial suppliers I contacted, were unable to provide details or show in full the processes involved in commercial rearing of phytoseiid mites.

Fortunately, some indication of the processes and techniques involved in commercial production of phytoseiids, was gleaned by consultation and discussions with government and other institution researchers. In some cases, the researchers I consulted were the

'architects' of basic systems developed many years ago, adopted and presumably modified, by industry today.

*Glasshouse Crops Research Institute, Naaldwijk*

A day was spent at this institution in the company of Pierre Ramakers, who is considered to be a foremost expert in glasshouse crop entomology and was the first person to develop a 'volume' rearing technique for phytoseiids.

In the late 1970's Dr Ramaker experimented with various techniques of culturing phytoseiids (primarily *Amblyseius mckenziei* and *Amblyseius cucumeris*) using bran as a substrate and flour mites (*Acarus farris*) as a food source. These early experiments resulted in development of a 'volume' rearing technique that is now the basis of most commercial phytoseiid rearing systems.

Very large numbers of *A. mackenziei* and *A. cucumeris* can be produced in a relatively small area using bran and flour mites. Bran was chosen as the primary food/substrate because it is easily penetratable by both flour mites and phytoseiids, allowing the development of volume instead of layer cultures. Prior to this all phytoseiid rearing was conducted either on living plants with phytophagous mites (e.g. dwarf beans infested with twospotted spider mite) or as an 'arena' culture with pollen or phytophagous mites as food. On an experimental, laboratory scale, predators are produced in open glass vials, containing about 200ml of wheat bran. each vial is placed inside a somewhat larger glass vial with a loose lid, containing a saturated salt solution for humidity and isolation. The bran is heated before use at about 50°C overnight to eliminate insects and mites. The heat treatment is not meant to suppress fungi because mycelium is a food source for the flour mites.

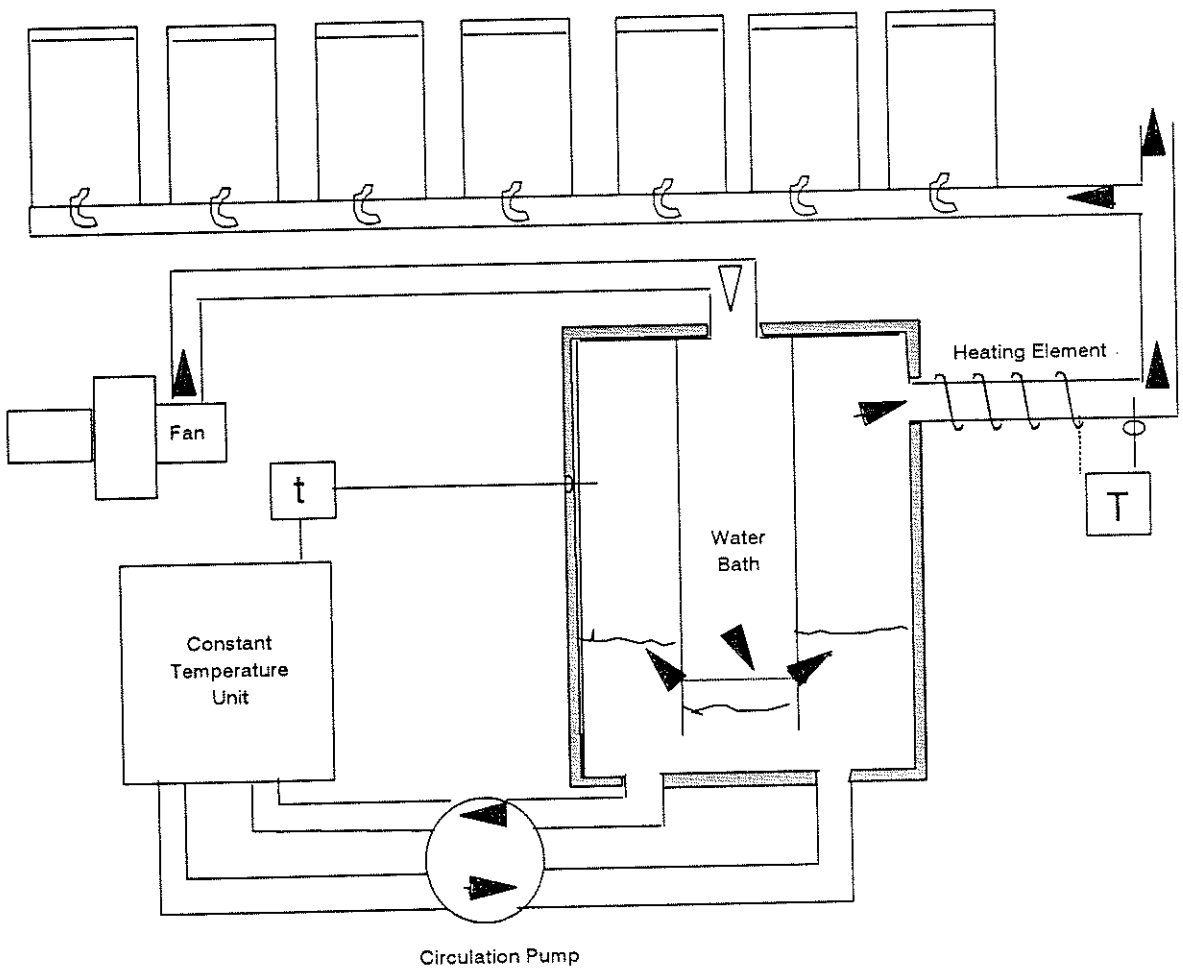
The density of mites in such cultures is shown in Table 1 which shows the results of an experiment to find the optimal moment for predator introduction to obtain the highest possible number of predators. Eggs are excluded in the listed figures. Numbers of mites were established by rinsing samples of bran with tap water through two sieves with mesh width 400 and 63 mu, respectively, and counting the number of mites on the 63 mu sieve. In the control plot D no predators were introduced which allowed the flour mites to reach their maximum density of about 1.5 million per litre. From this number and the ratio *Acarus/Amblyseius* in the other plots, it is estimated that the maximum number of predators which can be produced in this way, is 120 per litre.

**Table 22** **Number of storage mites, *Acarus farris*, and predatory mites, *Amblyseius mckenziei*, per ml of wheat bran at 25°C and 92% RH.**

| | A | B | C | D |
|---|---|---|---|---|
| Storage mites at start | 100 | 100 | 100 | 100 |
| maximum | 200 | 500 | 1100 | 1500 |
| period (weeks) | 1½ | 2 | 3 | 4 |
| Predator introduction after | 4 days | 10 days | 17 days | - |
| Predators at start | 3 | 3 | 3 | - |
| maximum | 20 | 40 | 90 | - |
| Total period (weeks) | 2 | 3 | 5 | - |

Dr Ramakers also described mass rearing of predators on a larger, more 'industrial' scale. The production system (Figure 1) is situated in a well insulated room with constant temperature, where ninety six 25 litre plastic buckets containing wheat bran are placed vertically on shelves. The wheat bran is ventilated by an air stream, whose temperature and humidity is controlled. The air is provided by a side channel blower which presses it through an airconditioning plant via a PVC pipe distribution system out to the buckets, into which it is injected and dispersed. The in and outlets of the buckets are covered with miteproof nylon mesh. The principle of the airconditioning is that the air bubbles through a temperature-controlled water bath in a 130 litre PVC barrel. Here the air obtains a relative humidity close to 100% at the temperature t defined as the dew point temperature for the desired state of the air as to relative humidity (rh) and temperature (T) when introduced into the production containers. The desired temperature T is obtained by leading air from the water through a thermostatically controlled electric heating element placed in the outlet pipe of the humidifier. The values used are t = 22°C, at T = 23°C and 92% rh. As the system works with high relative humidity (>80%), it is essential to keep the surrounding room temperature equal to or slightly higher than that of the air in the system (T), so as to avoid local condensing and subsequent fungus growth. On the other hand, a too high room temperature will increase T and thus lower relative humidity in the buckets to a degree which may prove fatal to the mites. It is equally important that the airflow is not subjected to any considerable pressure drops on the way from the humidifier to the bucket outlets, e.g. by flowing through small valves, filters and narrow tubes with too high air resistance, as this will cause a decrease in relative humidity. An advantage of this system is that the use of salt solutions for humidity control is avoided, eliminating the problem of clogging of pipes with salt crystals and reducing the health hazards to the people involved. For production, very coarse wheat bran is moistened with 10% water and heated. Dry yeast (250 g/25L) is added to improve the production rate of flour mites. The bran is infested with flour mites which are allowed to reproduce in the system for 21 days. Predatory mites are added and the bran is distributed to growers three weeks later.

Figure 111 Production system for mass rearing the predatory mite, *Amblyseius mckenziei*



The systems described above represent the basis of commercial rearing systems for *Amblyseius* spp. in Western Europe. Dr Ramakers believes the large companies involved in commercial production (e.g. Kopperts, Brinkley and Ciba-Bunting) have all added modifications/improvements to the fundamental design, according to the species being produced. The main species in which NSW Agriculture and the Australian viticultural industry is interested in seeing mass-reared commercially, is *Typhlodromus doreenae*. Although not in the same genus as the other phytoseiids being produced commercially using the volume technique, our research has shown it will feed on certain kinds of flour mite and should therefore be amenable to this technique. *Amblyseius victoriensis*, the other phytoseiid important to Australian viticulture, will not readily feed on flour mites but can be maintained on a pollen diet. It is possible that a volume rearing system incorporating a substrate like vermiculite plus pollen, could be successfully developed for *A. victoriensis*.

*Natural Pest Control Ltd, Bognor Regis, UK*

Half a day was spent at Natural Pest Control Ltd at Bognor Regis in southern England, and my visit was hosted by the proprietor of the business, Ivan Worrall. This is a long established but small 'cottage industry' type of business, which has similarities to the small biological control agent suppliers in Australia. Mr Worrall has no desire to increase the size of his business and has resisted opportunities for commercial takeovers. Natural Pest Control Ltd has about 300 clients, mostly glasshouse-based in the local district. Three predatory mites, *P. persimilis, T. pyri* and *A. cucumeris* are produced along with other beneficials including the parasitic wasp, *Encarsia* and the predatory beetle, *Cryptolaemus*.

Although more free with his information than other commercial producers I spoke to during my tour, Mr Worrall was still reluctant to show me the fine details of his successful volume rearing system for *Amblyseius cucumeris*. He used to use a simple system of bran in 10L buckets (half-filled) plus flour mites. There was no attempt to rigorously control temperature, humidity and airflow. All rearing was conducted in a partially temperature-controlled glasshouse. He has now developed an improved method using 20-30L containers with vermiculite. Mr Worrall declined to name the food source for the flour mites, but clearly something like yeast, wheatgerm or pollen must be added to the vermiculite. Due to the lack of rigour in cleanliness etc, Mr Worrall experiences frequent 'contamination' problems with his phytoseiid cultures. At the time of my visit, one of his small bucket cultures was heavily contaminated with another species of phytoseiid. Mr Worrall has demonstrated that volume rearing of phytoseiids can be done on a small and uncontrolled scale at least for a short period of time. Continuous rearing on a large scale clearly requires greater rigour in rearing conditions and hygiene.

*Ciba-Bunting Ltd, Colchester, UK*

Ciba-Bunting Ltd is probably the largest supplier of beneficial insects and mites in the UK. I was able to have discussions with Clive Stinson, Head of Production, but these were in general terms only. The company was unwilling to discuss specific issues concerning mass

rearing of phytoseiids using the volume technique. Dr Stinson provided me with a brief tour of their production facility but this only covered the production of insects for which there are no secrets!

Ciba-Bunting is a rapidly expanding company and has a large share of the market. It produces a range of beneficial insects and mites, including the phytoseiids, *P. persimilis* and *A. cucumeris*, the parasitic wasps, *Encarsia, Aphidius* and *Diglyphus* and bumble bees for glasshouse crop pollination.

*Other Commercial Suppliers of Beneficial Insects and Mites*

Representatives of a number of other commercial suppliers of beneficial insects and mites in The Netherlands and the UK were also approached for information on mass rearing of phytoseiids. These included Brinkman BV and Entocare Ltd. None were in any way forthcoming concerning details of production processes.

*Other Research Institutions*

A number of research institutions in The Netherlands and UK were visited and discussions held with researchers involved in biological control, phytoseiids and Integrated Pest Management.

**University of Amsterdam:** The Section of Population Biology within the Institute of Systematics and Population Biology at this university, contains a number of scientists who are world-renowned for their research on phytoseiid biology and ecology. I was fortunate enough to have discussions with the Head of the Section, Professor Maurice Sabelis who is currently the most experienced phytoseiid scientist in the world. A deep understanding of fundamental biological and ecological principles relating to phytoseiids is essential to maximum exploitation of these organisms in biological control. An important scientific and collaborative link between Professor Sabelis and NSW Agriculture has now been established and should serve our research well in the future.

**Imperial College at Silwood Park, Ascot, Berkshire, UK**
A day was spent at this institution in the company of a number of distinguished scientists involved in biological control and integrated pest management. Although not directly involved in phytoseiid rearing, most of the scientists were involved in ecological research aimed at understanding pest and predator interactions. These studies are of great importance to development and implementation of practical biological control programs.

**Institute of Arable Crops Research, Rothamsted Experimental Station, Harpenden, Harts, UK**
Rothamsted has a worldwide reputation for outstanding entomological research and it was extremely valuable to be able to spend two days there visiting most of the departments and meeting the scientific staff. Important contacts were made with scientists involved in

biological control, integrated pest management and development of pheromones as insect management tools. I was also able to present a well-attended seminar on my research on biological control.

*Attendance and participation in the XIII International Plant Protection Congress*

I attended the XIII International Plant Protection Congress held in The Hague, during 2-5 July 1995. This was the latest in a series of International plant Protection Congresses which have been held since 1947. The congress had the theme of 'Sustainable Crop Protection for all'.

I presented a paper (Biological control of mites in Australian Viticulture: State of the Art) and also a poster (Biological control of mites in Australian viticulture: Implementation and sustainability). Both presentations engendered a good deal of comment.

*Conclusions and recommendations*

The objective of this study tour was to gain information on the development and commercial exploitation of mass rearing systems for predatory phytoseiid mites. Research conducted by NSW Agriculture at Yanco since 1989 has shown biological control using native phytoseiids to be a practical management option for mites in Australian viticulture. Although in some regions, phytoseiids occur commonly enough to provide reliable control every year, there are some regions where vineyards would benefit from predator introductions either annually or bi-annually. In addition, it would be useful for vignerons to have predators available commercially so that introductions can be made if emergency or inadvertent chemical use destroyed natural populations. Therefore it would be of great benefit to the viticultural industry and sustainability of biological mite control if the major predator species, primarily *T. doreenae* and *A. victoriensis* were available commercially.

Laboratory based techniques for mass rearing *T. doreenae* and *A. victoriensis* have already been developed at Yanco using layer culturing on arenas and plant cultures (James, 1993) Neither technique is considered suitable for economic and effective commercial exploitation, due to the inherent demands on space and labour resources. The 'ideal' way for rearing these predators would involve 'volume cultures' which maximise production per unit area and minimise costs.

It is clear that the volume rearing system developed commercially for *A. cucumeris* in The Netherlands and UK has the potential to form the basis of a similar rearing system for *T. doreenae*. *T. doreenae* is known to feed on flour mite species (e.g. *Tyrophagus putrescentiae*). A system based on bran or vermiculite using *T. putrescentiae* as the food source for *T. doreenae* should be investigated. The information obtained from Pierre Ramakers on the techniques and procedures used in the laboratory-scale volume production of *A. cucumeris*, should facilitate these investigations.

It is recommended that a volume culturing technique for mass rearing *T. doreenae*, based on the examples available in Western Europe, should be researched as soon as possible. A

cost-effective and reliable production system for this important predator would contribute greatly to sustainability of biological management of mites in Australian viticulture.

## GENERAL DISCUSSION

The research presented here, although generated during the term of the current project 1993-96, should be considered in conjunction with the final reports for the two earlier GWRDC funded projects (Biological control of grapevine mites DAN4GW 95 pp. and Biological control of mites in inland viticulture DAN 92/3 89 pp.). Together they provide a substantial volume of data and information on biological control of grapevine mites in Australian viticulture.

Biological control of grapevine mites using endemic predatory mites is achievable in nearly all of Australia's viticultural regions. It is more readily achieved in certain regions because of climate (warm-hot and dry), adoption of minimum pesticide input strategies and higher abundance of the single most important predator species, *T. doreenae*. These regions include the Riverland, Barossa and Clare Valleys of inland South Australia and Central Tableland areas of inland New South Wales like Canberra and Mudgee. Regions in which *T. doreenae* is absent or not the dominant predator species, may require more effort in spray minimisation and monitoring, to achieve biological control. Most of these regions are cooler, moister areas in which greater use of fungicides is often necessary for disease control. The predatory mite fauna in these regions tends to be dominated by *T. dossei*, which in itself appears to be a less efficient predator of grapevine mites than *T. doreenae*. There is some evidence of a 'time lag' between build up of blister and rust mite populations before *T. dossei* exerts control. This may be due to faster development of the pests under cool conditions or reflect an inability of *T. dossei* to survive on a diet of pollen alone, thus preventing significant predator population development until pests are present. The ability of *T. doreenae* and *A. victoriensis* to establish large populations in the absence of mite prey is a crucial factor in their success as effective regulators of grapevine mite populations. It also precludes the need for regular monitoring; once populations of these predators are established, early season in a vineyard, they will persist and increase in numbers, unless harmful chemicals are used.

The Murrumbidgee Irrigation Area (MIA) and Sunraysia are two of the largest viticultural areas and have a hot, dry climate that should be very suited to biological control of mites. However, the earlier studies reported in DAN4GW showed that the MIA, in particular, had a small and ineffective predatory mite fauna. Sunraysia had larger populations of predators but *T. doreenae* was not recorded in either region and biological control of mites was variable in Sunraysia and virtually non-existent in the MIA. It was concluded that the poor predatory mite fauna in both regions, including the absence of *T. doreenae*, was related to greater use of predator-harmful pesticides in these areas, both on grapes and nearby irrigated crops. Research reported earlier and in this report has shown that *T. doreenae* can be readily established in MIA vineyards and develop large populations within a season. Adoption of minimum pesticide input strategies in these vineyards should ensure persistence and dispersal of *T. doreenae*. *T. doreenae* should now be introduced into Sunraysia and its dispersal encouraged there and in the MIA by transferring predator-infested leaves after harvest to uncolonised vineyards. Such dispersal was encouraged in the MIA in March 1996 when a field day was conducted and participants were provided with a sample of *T. doreenae*-infested leaves to distribute in their own

vineyards.

Availability of *T. doreenae* commercially would clearly hasten the introduction of this species to the MIA, Sunraysia and other areas where it does not occur. Results from this study indicate that ALL viticultural regions in Australia would benefit from innoculative releases of *T. doreenae*. Even regions which currently experience relatively good biological control provided by *T. dossei* would benefit by establishment of *T. doreenae,* overcoming some of the deficiencies of the former species. It is also likely that an annual spring innoculation of *T. doreenae* to vineyards which already harbour the species would enhance population development and biological control. In some instances, natural populations of *T. doreenae* take some time during spring to build up, presumably because of significant overwintering mortality. Annual or bi-annual spring releases of *T. doreenae* would clearly help ensure sustainability of the system.

Despite collection of overseas information on mass rearing of predatory mites and some preliminary studies on various ways of mass producing *T. doreenae* (e.g. James 1993), a definitive method for commercial production of this species still awaits discovery. It appears that a volume rearing system based on bran, mould mites and perhaps pollen, should be possible for *T. doreenae.* Such a system would likely be acceptable to commercial producers of predatory mites in Australia.

The impact of viticultural pesticides on predatory mites is clearly a critical factor in the efficacy and sustainability of biological mite control on grapevines. Information generated in this and the earlier studies shows that *T. doreenae* is reasonably robust in this regard. This predator will tolerate most fungicides when they are used sparingly. However, repeated use of synthetic fungicides does appear to have a significant suppressive effect on *T. doreenae* populations. This may be due to sub-lethal impacts on predator longevity, fecundity and other aspects of biology. In other words, although fungicides are generally not toxic to *T. doreenae* they may disadvantage the predator in other ways which are cumulative. *T. dossei* appears to have similar tolerances to *T. doreenae* but far fewer pesticides have been tested against this species and more caution is required. Both species require further studies on sub-lethal impacts of pesticides on their biological efficacy, so that greater discrimination may be exercised in choice of fungicides. *A. victoriensis* is the only other predator species examined for its susceptibility to viticultural pesticides, and is generally far less tolerant than the other two species.

The most important limiting factor to establishment and persistence of *T. doreenae* and other predatory mites in vineyards, is the use of broad-spectrum insecticides or miticides like chlorpyrifos, malathion, carbaryl and dicofol. In regions in which these compounds are used regularly to control light brown apple moth and/or mites, predatory mites are virtually absent. The widespread use of these materials in a region on a regular basis over a number of years (e.g. Coonawarra, Yarra Valley) exacerbates the problem, and makes adoption of biological control difficult to achieve rapidly, even if these chemicals are not used. A single vineyard within one of these regions that decides to stop spraying these chemicals and rely on biocontrol for mites, is unlikely to be invaded by predatory mites very rapidly, given the spraying going on around the vineyard. To be successful the entire region needs

adopt the new strategy. In many regions vignerons use various formulations of the predator-friendly bacteria *Bacillus thuringiensis* to control light brown apple moth. Whilst control of the moth by this compound can be acceptable in warm-hot regions in which it is less of a problem, a lack of grower confidence in its reliability is a problem. Increasingly, growers in all regions are looking towards more effective and reliable control of light brown apple moth, which at the moment can only be provided by broad spectrum insecticides. This trend, if it continues, will adversely effect the extent and efficacy of biological mite control across the industry. In addition, ecosystem disruption will extend beyond simply killing the predatory mites responsible for controlling bunch, blister and rust mites; it will destroy the entire beneficial arthropod fauna of grapevines, and twospotted mite, *Tetranychus urticae*, will become the major mite pest of grapevines as it is in the highly disturbed vineyard ecosystems of Europe and North America.

Fortunately, there is some hope that the above scenario will not eventuate, with the imminent release of a new, non-disruptive insecticide for light brown apple moth on grapevines. Tebufenozide (Mimic®) is an insect growth regulator which while highly effective on larvae of light brown apple moth, is harmless to most non-Lepidopteran arthropods including *T. doreenae* and *A. victoriensis*. Industry wide use of this compound to control light brown apple moth should greatly improve management of this pest whilst preserving stability of the vineyard ecosystem and biological control of mites. The release and widespread adoption of this compound in preference to chlorpyrifos is probably critical to continued sustainability of biological mite control in grapevines.

In November 1994 the 10 minute video "Wine, women and Vineyard Mite Control" was released by the Communications Unit of NSW Agriculture. This production was filmed at Yanco and on location in various vineyards and gives an overview of the biological mite control system in grapevines. It is also a practical guide to ways of establishing biological control in any vineyard and contains stickers showing safe and harmful chemicals to *T. doreenae* and *A. victoriensis*.

The video has so far proved very popular with viticulturists, advisers and students. A number of copies have also gone to research institutions and advisers in North America, Europe and South Africa.

In conclusion, this research has been an excellent example of how basic studies on a virtually unknown component of the fauna of a horticultural crop can lead to applied and practical pest management which substantially reduces pesticide inputs and increases industry profitability and viability. The basic studies in this research (surveying and identifying the phytoseiid fauna of grapevines in Australia, understanding phytoseiid biology/ecology) were a truly specialised science. The ability to accurately identify phytoseiid species had to be learnt and the success of this program is in no small way attributable to the skills and endeavour of Jenny Whitney in becoming a taxonomic authority on phytoseiids during the course of this project. The time span during which this research developed from knowing nothing about mite ecology on grapevines to creation of practical mite management strategies based on biological control, was remarkably swift and cost effective. From a total industry outlay of around $250,000 in funds for this 7 year

program, there are potential savings to the industry of around $4M per annum in estimated cost savings in pesticide use alone. Monetary values in terms of enhanced export appeal (reduced pesticide usage), reduced residues in the environment and marketed produce, are less definable, but no doubt considerable.

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The majority of technical support provided to this program came from Jenny Whitney. Jenny was the original Technical Officer (Scientific) employed at the beginning of the program in 1989. Her enthusiasm, dedication and considerable expertise during 1989-92 enabled accumulation of the database on pest mite/phytoseiid incidence, distribution, abundance, from which all subsequent biological studies, management applications and strategies were derived.

During this period, Jenny developed substantial taxonomic skills in the identification of phytoseiid species, which were essential to conduct of the program. In the early stages she was fortunate enough to learn from Dr Eberhard Schicha who was Australia's foremost authority on Phytoseiidae before he retired from NSW Agriculture in 1992. Dr Schicha's monograph, "Phytoseiidae of Australia and surrounding areas" was of crucial importance to this research.

Danuta Knihinicki, formerly of the Biological and Chemical Research Institute at Rydalmere and now at Orange Agricultural Centre, also provided valuable advice on phytoseiid identifications throughout the program.

During 1992/93 the program suffered reduced funding and Jenny was unable to be employed.

Fortunately, we gained the services of Margaret Rayner who provided excellent technical support for this period, allowing the program to continue, albeit at a reduced level.

With re-establishment of full funding during 1993-96, Jenny returned to the program and again was a critical factor in the ultimate success of the research as detailed in this report.

I would like to publicly congratulate Jenny and Margaret for their critical roles in the success of this program. It truly would not have been possible without their commitment, dedication and expertise. I would also like to thank various other technical support staff based at Yanco Agricultural Institute who also assisted in various aspects of the research. These include Merv Graham, Anne Hickey (nee Taylor), Beverley Vogele, Richard Faulder and a number of casual staff.

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