Spray-resistant mites to the rescue

Two tiny animals discovered by chance — one in the United States of America, the other in New Zealand — are saving Australian apple-growers many thousands of dollars in chemical sprays. The animals are predatory mites.

They destroy two species of spider mite that are common pests of apple and other deciduous fruit trees in temperate regions. But this is not just another example of biological control, for these predators are rare strains that can tolerate many of the chemical sprays used in orchards against a variety of insects and fungi.

It was sprays that turned the spider mites into serious pests; in 'pre-chemical' days, these mites never reached plague numbers. The pest mites' resistance to many chemicals has presented a difficult — and costly — challenge to their control, but now similar tolerance on the part of some of the pests' predators has come to the aid of fruit-growers. Under their shared umbrella of resistance to sprays, the two groups of mites (predators and leaf-suckers) are resuming their age-old relationship.

The pest species, the two-spotted mite and the European red mite, thrust their mouth-parts (chelicerae) into leaf cells and suck out the contents. What they lack in size (a fully grown mite measures only half a millimetre) they more than make up for in numbers, and a badly infested leaf loses its healthy green colour, turning yellowish, then bronze, and finally falling prematurely.

Both species of spider mite have short generations (down to 10–14 days in warm weather) and, if they are left to multiply freely, they can defoliate a tree completely by Christmas. That season's fruit will turn out small and discoloured, and mite damage to flower buds will badly affect the following year's yield, too.

Export fruit from affected trees may run into quarantine problems. And to make matters worse, orchard workers often develop skin rashes if mites go unchecked.

The more common of the pests, the two-spotted mite (*Tetranychus urticae*), attacks various fruit trees, including apple, pear, plum, peach, and nectarine, as well as cotton, certain glasshouse crops, roses, and many other plants. The European red mite (*Panonychus ulmi*) only affects apple, peach, and pear orchards, and is restricted to cooler districts: Tasmania and the highlands of New South Wales and southern Queensland.

One or other species seriously troubles about 40 000 ha of apples and pears and 16 000 ha of peaches. Although the area of deciduous orchards, particularly apples, has declined in recent years and is expected to go on doing so, the density at which trees are planted is rising sufficiently to more or less maintain the number of trees — and therefore the size of the mite problem.

Before spray-resistant predators became available for biological control, Australian orchardists were spending some $3 m a year on chemical mite-killers (acaricides). Many growers adopt an 'insurance' policy, attempting to prevent mites reaching pest numbers by spraying three times: once early in the season, again just before Christmas, and finally shortly

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A European red mite being attacked by a spray-resistant predatory mite, *Typhlodromus pyri* (the paler animal).

Eggs and adult females of two-spotted mite on a leaf.

Huge numbers of winter eggs of European red mite form pink patches on the trunk of a fruit tree.

before harvest. Another approach involves spraying only when the mites become conspicuous; this usually occurs in late November or early December, when two sprays are needed about a fortnight apart, with a third often necessary before the fruit are harvested.

Each application costs about $50 a ha, roughly four-fifths of that being the cost of the chemical, with the rest going on tractor fuel and labour.

Of course, commercial orchards are prone to a wide variety of other pests and disease organisms, notably codling moth and the fungus causing apple scab. Unfortunately, the chemicals used against these have no effect on spider mites. Moreover, mite populations rapidly develop resistance to acaricides, so the effective life of a new chemical often lasts only 4 or 5 years. This, combined with the increasing difficulty of finding chemicals that do kill mites, is pushing ever higher the cost of developing new acaricides, and therefore the price the grower must pay for every litre of spray.

Complex food web

On unsprayed trees the pest mites take their place in quite a complex food web, as prey of a variety of predatory mites and insects. Spraying wipes out all the insect members of the leaf community, and usually the predatory mites as well, but a few strains of predatory mite resistant to orchard insecticides have turned up in some parts of the world. As long ago as 1969 Dr Stan Hoyt detected an insecticide-resistant strain of a predatory mite on apple trees in the State of Washington in the United States of America.

At about the same time, in 1968, Dr Les Readshaw of the CSIRO Division of Entomology set out to find a way of combating spider mites in Australia. His approach reflected his strong interest in the natural regulation of animal numbers: he examined unsprayed (neglected) orchards to find out how spider mite numbers were kept down in natural communities, and compared his observations with what he found in sprayed orchards. This study formed part of a large co-operative research program involving all State Departments of Agriculture.

At the time his study began, ecologists were interested in two main hypotheses to account for the large numbers of spider mites on commercial trees. Both were based on the fact that the mites had not been pests before World War II — in other words, until modern insecticides were introduced.

On the healthy leaves (left), two-spotted mite has been controlled by a predatory mite. The sick leaves, showing bronzing, had been sprayed with a pyrethroid insecticide that killed the predator. Two-spotted mite is resistant to this chemical.

The resistant predator, *Typhlodromus occidentalis*, being released on an apple tree.

One hypothesis postulated a stimulatory effect: the sprays, it said, somehow improved the mites' fertility and survival. The other argued that mite numbers flourished as their predators fell victim to the chemicals. Two years of experiments in ten apple orchards in New South Wales, Victoria, Tasmania, and the Australian Capital Territory proved conclusively that insecticides created the mite problem, and ruled out the 'stimulant' hypothesis.

Dr Readshaw found that on unsprayed trees the main factor holding down the numbers of two-spotted mites in Australia was predation by small black ladybird beetles belonging to the genus *Stethorus*. But these beetles were eliminated by insecticides.

Resistant strain imported . . .

The best hope for biological control of spider mites seemed to lie with spray-resistant predatory mites. Curiously, although the pest mites were resistant to orchard insecticides, the predatory species in Australia succumbed. However, the resistant mite discovered in the United States of America by Dr Hoyt was successfully controlling the McDaniel mite, a close relative of the two-spotted mite, there, and in 1972 the Division introduced some of these resistant mites into Australia.

The immigrant — a strain of *Typhlodromus occidentalis* — proved a great success. In the Canberra orchard where the new predator was first tried out, biological control has kept the numbers of two-spotted mites so low that in the 10 years for which the experiment has been running the grower has only sprayed twice for mites, each time using the chemical at only half its usual strength. Without the predator this orchard would have been sprayed at least 30 times in that period.

By the 1975–76 season *T. occidentalis* had won its spurs in trials across southern Australia, and was being reared by the Departments of Agriculture of New South Wales and Victoria, which supplied both predatory mites and practical advice to fruit-growers who wanted to try out this new weapon. By 1982, it was at work in not less than 14 000 ha of Australian orchards.

If they are left to multiply freely, the pest mites can defoliate a tree by Christmas.

For the grower, however, it is not simply a matter of releasing the introduced predatory mite and then carrying on as before but without the acaricides. *T. occidentalis* tolerates some insecticides, but not all. DDT will kill it, and so growers must turn to another chemical for the control of apple dimpling bug (a mirid) and thrips. Fortunately, endosulfan combats both these pests without destroying the predatory mite.

***Cymbidium* orchids in a New South Wales nursery: a spray-resistant predator has controlled two-spotted mites here, too.**

Carbaryl, a chemical commonly used for thinning — that is, causing some fruit to fall so that the remainder grow to a good size — must also join the black list. However, a hormonal substitute known as NAA safeguards *T. occidentalis*. In another approach, the Victorian Department of Agriculture recently introduced a carbaryl-resistant strain of this predator from the United States.

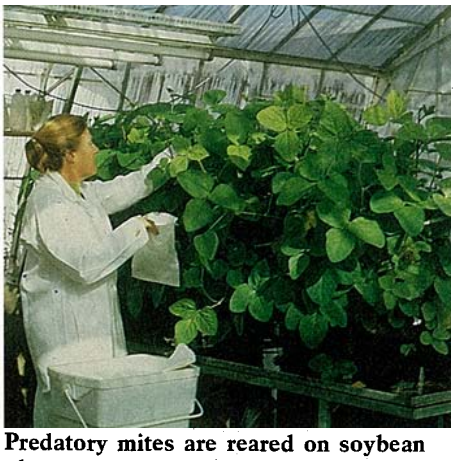
Establishing the predatory mite in an orchard, therefore, requires the grower to discard some traditional sprays and to learn some new skills. But these have not proved great difficulties and *T. occidentalis* has become popular, especially in northern Victoria, where only one spider mite — the two-spotted — occurs.

Where European red mite causes a problem, the story is more complex. *T. occidentalis* attacks both spider mites but greatly prefers the two-spotted, and in many orchards the introduction of the predatory mite led to an increase in the numbers of European red mites; growers were, of course, using no acaricides while the predator was at work.

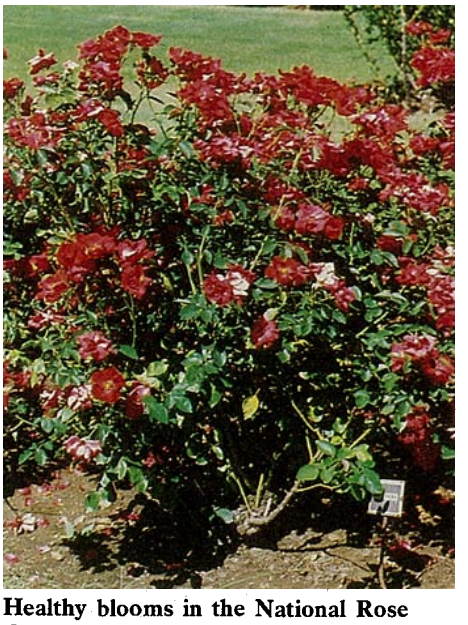
This problem looked for a while as though it would restrict the effectiveness of the program. But then came news of two further spray-resistant predatory mites, both effective against European red mite: *Amblyseius fallacis* in Michigan, U.S.A., and *Typhlodromus pyri* in New Zealand.

. . . and others

The Division imported both these resistant predators in 1977. The *Amblyseius* species failed to become established at any of its experimental sites, but *T. pyri* showed great promise right from the start. This strain tolerates much the same range of chemicals as the introduced *T. occidentalis* and is more resistant to carbaryl and perhaps also to DDT.



Predatory mites are reared on soybean plants.



Healthy blooms in the National Rose Garden, after the introduction of *T. occidentalis*.

T. pyri has now been controlling European red mite in the two trial orchards — at Batlow, N.S.W., and Ginninderra, A.C.T. — for 5 years, and has been provided to State Departments of Agriculture for more widespread testing. However, this predator is a little trickier to establish and manage than *T. occidentalis*.

For a start, *T. pyri* disperses much more slowly (both species are probably blown about in the air and on fallen leaves). In practice, growers can accelerate the spread of *T. pyri* by taking clusters of small leafy shoots in summer from well-populated trees and propping them in trees in other parts of the orchard.

Then there is the problem of knowing when to spray — a problem compounded by the fact that red-mite eggs, unlike those of the two-spotted mite, prove too tough for the predator to destroy. In the trial orchards, European red mites on some rows of trees were so well controlled that they needed no spray, but other rows, with fewer predators, needed a half-strength application.

In order to assist growers in making the crucial decisions whether to spray and, if so, when and with what, Dr Readshaw has suggested — and tested — much simpler procedures for monitoring pest and predator mite numbers than have been used elsewhere. In American and New Zealand orchards, for example, growers have used a costly procedure, counting mite samples obtained with a machine that brushes the animals off leaves. What's more, the threshold densities at which mites are considered to start posing an economic threat have been set arbitrarily.

Red-mite eggs prove too tough for the predator to destroy.

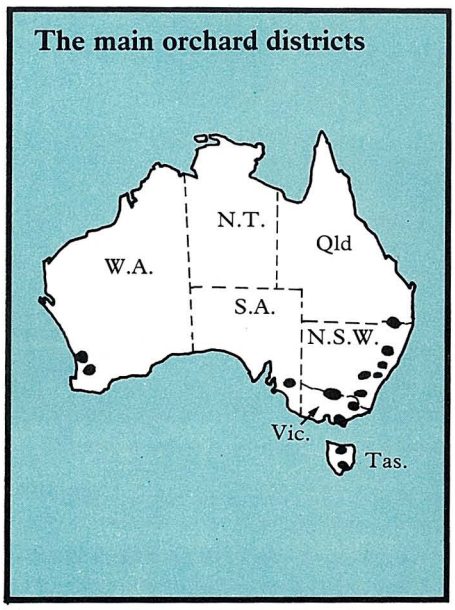
Dr Readshaw points out that the sizes of the populations of both predatory and prey mites naturally oscillate in a way that cannot easily be predicted from an initial count — nor, he adds, does the eventual damage sustained by a fruit tree follow simply from the average number of mites to be found on a leaf. The interaction between predator and prey is, in short, dynamic and complex.

Counting leaves, not mites

His system depends on the fact that pest mites generally go on increasing in number as long as the proportion of leaves occupied by active stages of the pest (that is, all stages except the egg) substantially exceeds the proportion occupied by predator mites. The grower (or horticultural adviser) simply chooses a few 'indicator' trees and takes, say, 30 leaves from each of them every 2 weeks.

Using a hand lens, or a low-power binocular microscope if one is available, the grower counts the number of leaves in each of four categories: those carrying any stage of two-spotted mite, including eggs; the same for European red mite; those with active stages of red mite; and those bearing any stage of predatory mite, including eggs. Although tiny, the different mites can, with practice, be identified using a lens.

A chart tells the grower what action, if any, to take. For example, in an orchard affected only by two-spotted mite, the grower need not spray until the proportion of leaves carrying the mite reaches about 90%, and even then only if the predatory mite occupies fewer than 45% of the leaves, in which case the chart recommends a half-strength mite spray. If there are no predators on any of the leaves, the grower should use a full-strength spray.



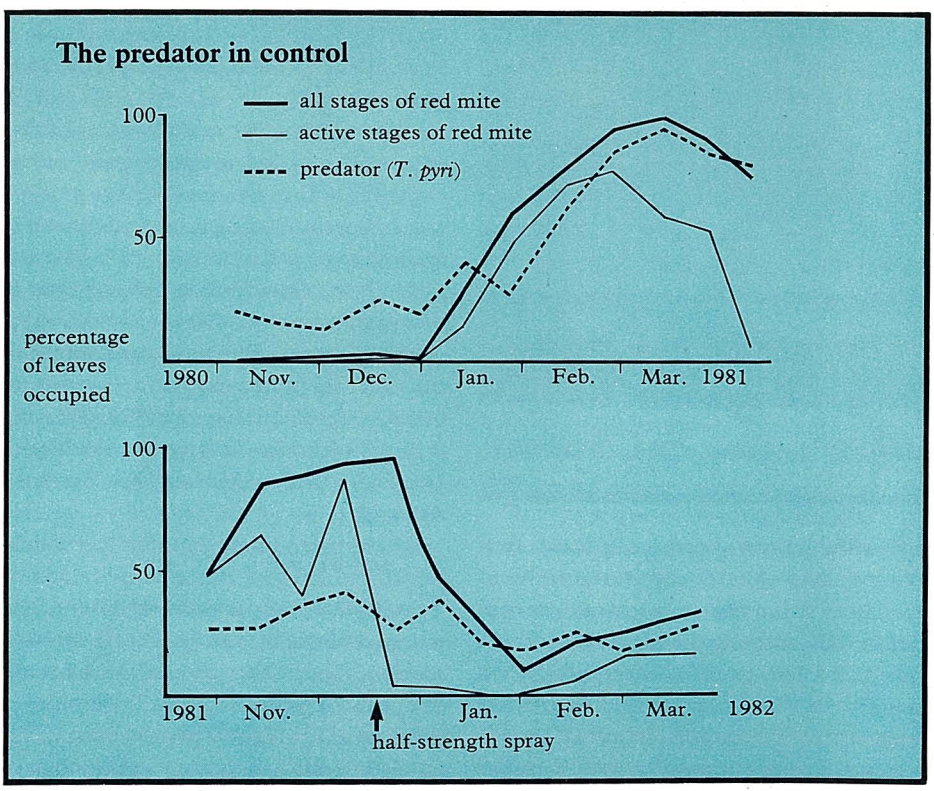
Two-spotted mite affects all orchards; European red mite is a pest only in Tasmania and the highlands of New South Wales and Queensland.

Dr Readshaw has compiled separate charts for orchards suffering from each of the pest mites, and a third chart for orchards harbouring both pests. The charts reflect the collected experience of Dr Readshaw, his assistants Mr Ken Helm and Mrs Betty Lee, of the Division, and advisers and commercial growers — experience gained both in typical commercial orchards and in experimental 'mini-orchards' maintained by CSIRO.

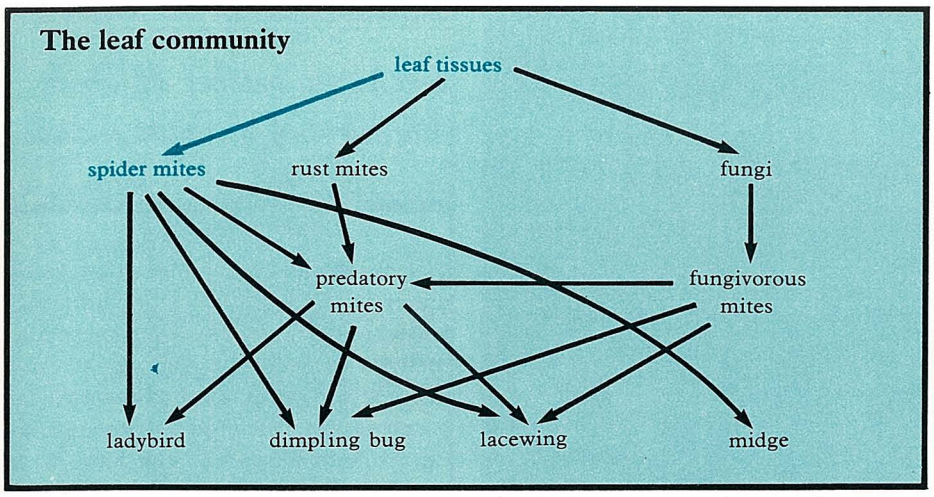
The effective life of a new chemical often lasts only 4 or 5 years.

The mini-orchards consist of pruned fruit trees growing continuously in glasshouse conditions that virtually eliminate winter. Researchers control the trees' environmental conditions, and monitor the populations of pest and predatory mites under spray programs like those used in commercial orchards. From these experiments, Dr Readshaw is beginning to understand the ecological principles underlying predator–prey interactions on fruit trees. He hopes before long to explain, for example, why the numbers of red mites and *T. pyri* fluctuate with a rhythm of 20-odd weeks, and those of two-spotted mite and its predator with a (roughly) 12-week periodicity.

But even without this theoretical work, the predatory mite program looks set to make a major economic impact in Australian orchards. A benefit–cost study of the Division, carried out jointly by the Industries Assistance Commission and CSIRO, and published in 1980, put the total benefit likely to flow from the program



In this orchard, European red mites were well controlled by *Typhlodromus pyri* in 1980–81, and only one application of half-strength spray was needed the following year.



Part of the food web on a leaf surface in an unsprayed apple orchard: pest mites are kept in check by various predators. In a commercial orchard, sprays kill all except the members of the web marked in colour – until resistant predators are introduced.

this century at more than $14 million in the money values of 1975.

Keeping the garden rosy

Where the mite sucks, there strikes the predator. If insecticide-resistant predatory mites can control pest mites on fruit trees, they should be able to repeat their success on other plants too. Already *T. occidentalis* is holding down the numbers of two-spotted mites in the National Rose Garden, in front of Parliament House, Canberra, thanks to the predator's resistance to chemicals used against aphids, thrips, powdery mildew, and other pests and diseases on the rose bushes.

A recent trial in an orchid nursery suggests that *T. occidentalis* can achieve good control of two-spotted mite on these plants, too, not only saving the expense of acaricide sprays, but also reducing the damage to blooms caused by the pest mite. Australian nurseries export orchids to many countries, including Canada, the United States of America, Japan, and various parts of Europe.

Researchers in the Division are looking into the possibility of using resistant predatory mites on other plants of economic importance, including soybean and maize.

Soybean, in fact, makes a convenient host for rearing predatory mites. Six weeks after being sown in a heated glasshouse, soybean plants can be infested with two-spotted mite, for example. A few predatory mites can be released on the plants 12 days later, and after a further fortnight the predator will have multiplied and spread to most of the soybean leaves. To introduce the predator to your crop, you just drape a soybean plant over part of the rose bush, say, or apple tree, that you wish to protect.

Handling these predatory mites requires greater care and knowledge than does straightforward biological control. While one pest is being tackled by a predator, others must be sprayed. Such 'integrated control', as it is called, demands management, founded on an awareness of the predator's different susceptibilities to different chemicals and a detailed understanding of the ecological interactions between the organisms involved. Given such knowledge and understanding, integrated control can achieve striking results. Orchard spider mites have yet to evolve a predator-resistant strain!

John Seymour

The program has been extended from fruit trees to roses and orchids.

More about the topic

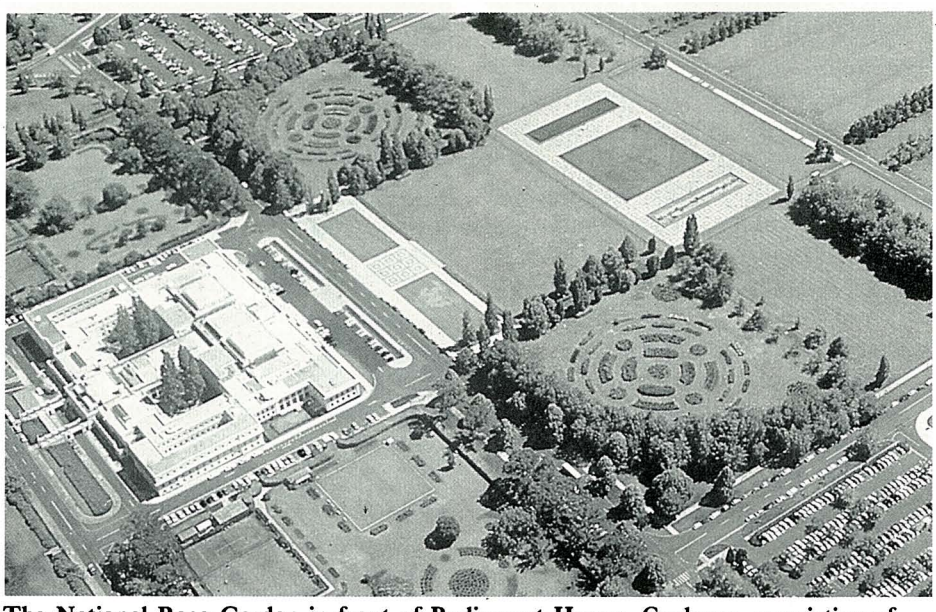
The ecology of tetranychid mites in Australian orchards. J. L. Readshaw. *Journal of Applied Ecology*, 1975, **12**, 473–95.

Biological control of orchard mites in Australia with an insecticide-resistant predator. J. L. Readshaw. *Journal of the Australian Institute of Agricultural Science*, 1975, **41**, 213–14.

Control of the two-spotted mite in a Victorian peach orchard with an introduced insecticide-resistant predatory mite *Typhlodromus occidentalis* Nesbitt (Acarina: Phytoseiidae). R. P. Field. *Australian Journal of Zoology*, 1978, **26**, 519–27.

Biological control of two-spotted mite in the National Rose Garden. M. A. Carmody, J. D. Clark, S. B. Lee, C. J. Nazer, J. C. J. Nicholls, and J. L. Readshaw. *Australian Parks and Recreation*, May 1981, 47–51.

Part of a 'mini-orchard'.



The National Rose Garden in front of Parliament House, Canberra, consisting of two sets of beds arranged in rings; two-spotted mites here are controlled by an insecticide-resistant predator.