BIOLOGICAL CONTROL OF INSECT PESTS IN JAPAN

A. CONTROL OF MULTIPLE PESTS OF TEA, AND SPIDER MITES IN GREENHOUSES

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ABSTRACT

In Japan, there is growing public concern about the excessive use of agricultural chemicals. Growers have become interested in the use of natural enemies in pest management programs. This paper introduces two examples of pest management using natural enemies in Japan. In the production of tea, there is the problem of controlling multiple pest species that occur simultaneously. The use of a predacious phytoseiid mite, Amblyseius womersleyi, which was resistant to synthetic pyrethroids, was found to be very effective in suppressing populations of spider mites while the pyrethroid sprays were applied which were necessary to control two sucking pests. In the second example, the release of the phytoseiid mite Phytoseiulus persimilis onto ground cover in a greenhouse where grape vines were grown was effective in suppressing the population of spider mites. This prevented their migration onto the grape vines.

BIOLOGICAL CONTROL IN JAPAN

Japan has lagged behind other developed countries in the practice of biological control. Although many experiments have been carried out, the commercial use of natural enemies has only just started. In the early 1970s, one chemical company began the commercial production of a wasp for the control of scale insects on apple, but after three years this product was discontinued. It was only five years ago that *Phytoseiulus persimilis*, a predatory mite used all over the world for the control of spider mites, was approved for commercial use in Japan. Table 1 lists the natural enemies so far registered as commercial bio-pesticides in Japan. Many of the agents are imported, and most are used for controlling pests in greenhouses made of glass or plastic.

There are several reasons why biological control has not been widely adopted by farmers in Japan. First, Japanese consumers tend to buy only agricultural products with an excellent appearance, particularly fruits. Furthermore, in order to compete with low-cost imported products, many growers are forced to focus on high-quality products. These are often used as special gifts rather than for daily consumption. Most farms are small, and growers must secure a constant yield and income. These pressures force them to spray chemicals to avoid any risk of pest injury.

Another factor that underlies their reluctance to adopt biological control is the environment. Japan in summer has a warm, humid climate, with a wide range of environmental conditions. As a result, key pests are many and varied. Thus, in order to cope with the multiple pest problems by biological control alone, it would be necessary for growers to use several natural enemies in combination. However, such a strategy is not yet ready for application.

In spite of these problems, farmers' reliance on chemicals has been declining in recent years.

Keywords: multiple-pest problem, pesticide resistance, predacious phytoseiid mites, spider mites, synthetic pyrethroid, tea pests

Table 1. Natural enemies registered as "bio-pesticides" for commercial use in Japan

Year registered	Natural enemy	Target pest	Crop
Imported			
1995-2000	*Encarsia formosa*	*Trialeurodes vaporariorum*	Tomato, cucumber, melon
1995-99	*Phytoseiulus persimilis*	*Tetranychus* spp.	Strawberry, eggplant, cucumber, grape
2000			Watermelon, green pepper, bean
1997	*Diglyphus isaea, Dacnusa sibirica*	*Liriomyza trifolii*	Tomato
1998	*Diglyphus isaea*		
1999	*Dacnusa sibirica*		
1998-2000	*Aphidius colemani*	Aphids	Strawberry, cucumber, watermelon, melon
1998-2000	*Aphidoletes aphidimyza*	Aphids	Cucumber, melon
Produced domestically			
1970	*Pseudaphycus malinus*	*Pseudococcus comstocki*	Apple
1998-99	*Amblyseius cucumeris*	*Thrips palmi*	Eggplant, cucumber, melon, green pepper
		Frankliniella occidentalis	Strawberry
1998	*Orius sauteri*	*Thrips palmi* *Frankliniella occidentalis*	Green pepper
1999	*Orius sauteri*	*Thrips palmi*	Cucumber, eggplant
2001	*Orius strigicollis*	*Thrips palmi* *Frankliniella occidentalis*	Green pepper
2001	*Encarsia formosa*	*Trialeurodes vaporariorum*	Tomato

There is a strong demand by consumers for agricultural products grown with few or no chemicals. Also, many farmers are now aware of the dangers of excessive chemicals. Many groups of farmers are trying to replace chemicals with natural enemies or organic pesticides. There has thus been a growing interest over the past few years in biological control and IPM.

In this paper, we would like to introduce two examples of the use of natural enemies in Japan. One is in tea fields, where growers are facing multiple-pest problems, and where the release of pesticide-resistant predators was effective in controlling spider mites.

The other is in a plastic greenhouse producing grapes. Predacious mites were released, not onto the vines, but onto the ground cover in the greenhouse. This suppressed spider mites living on the ground cover, thereby preventing them from invading the grape vines and multiplying on them.

IPM IN TEA FIELDS USING PREDACIOUS MITES WHICH ARE RESISTANT TO SYNTHETIC PYRETHROIDS

Table 2 shows how frequently chemicals are sprayed in tea plantations in central Japan (Takafuji *et al.* 2000). Injury from disease is not serious in tea. The main pests are two species of tea tortrix, the Kanzawa spider mite, the yellow tea thrips and the tea green leafhopper. Each year, growers spray more than 20 times. (Each spray may include more than two chemicals. In such cases, this is counted as two sprays). Spray programs of this kind have long been typical of tea plantations in central Japan.

However, there is a strong demand among consumers for tea produced without pesticides. Moreover, serious groundwater pollution as the result of excessive use of fertilizers and pesticides has become an issue in tea-growing areas. In response to these problems, some groups of tea growers have started producing tea using no chemicals at all, or only very small amounts. A

Table 2. Number of chemical sprays per year on tea in Shizuoka (central Japan)

		Species	86	87	88	89	90	91	92	93	94	95
Sucking pests	Kanzawa spider mite	*Tetranychus kanzawai*	4.2	3.5	3.8	3.5	3.8	3.8	3.6	3.6	4.6	3.4
	Tea green leafhopper	*Empoasca onukii*	3.5	4.6	4.3	4.4	5.7	6.3	4.5	4.9	5.3	3.9
	Yellow tea thrips	*Scirtothrips dorsalis*	1.7	2.5	2.5	1.6	2.0	3.3	1.7	2.8	3.5	3.1
	White peach scale	*Pseudaulaca spis pentagoma*	0.7	0.4	0.2	0.2	0.2	0.1	0.1	0.3	0.6	1.3
	Aphids		0.5	0.3	0.5	0.5	0.3	0.5	0.4	0.4	0.4	0.7
Chewing pests	Tea tortrixes	*Homona magnanima, Adoxophyes honmai*	4.7	5.3	5.2	4.6	3.9	3.2	3.9	3.8	4.2	3.6
	Tea leafroller	*Caloptilia theivora*	1.6	2.6	2.4	2.3	2.2	1.8	1.7	1.2	1.3	0.2
	Muswort looper	*Ascotis selenaria*	1.3	1.7	1.6	0.9	1.2	1.6	1.2	0.8	1.2	0.6
	Others		0.0	0.1	0.1	0.0	0.1	0.0	0.5	0.5	0.5	0.1
		Subtotal	18.2	21.0	20.6	18.0	19.4	20.6	17.6	18.3	21.6	16.9
Disease		Subtotal	4.1	6.0	6.9	6.3	6.5	8.1	6.8	7.8	6.9	4.9
		Total	22.3	27.0	27.5	24.3	25.9	28.7	24.4	26.1	28.5	21.8

* One spray application may include two different chemicals, in which case it is counted twice.

premium price is now paid for "organic" tea, and the number of organic tea growers is increasing.

In tea fields in central Japan, several insect pests and mite pests occur together. Tea growers have to control multiple pests at the same time. Mating disruption methods using sex pheromones have successfully suppressed populations of the two tea tortrixes, *Adoxophyes honmai* and *Homona magnanima.* The Kanzawa spider mite, *Tetranychus kanzawai,* is now potentially the most serious pest. In the past, it was well controlled by acaricides, or naturally suppressed by the predation of the organophosphate-resistant phytoseiid mite, *Amblyseius womersleyi.* This natural control disappeared with the introduction of synthetic pyrethroid (SP) pesticides, which are highly toxic to natural enemies, including the predacious mite.

Synthetic pyrethroids are used on tea fields to control two sucking pests, the yellow tea thrips, *Scirtothrips dorsalis* and the tea green leafhopper, *Empoasca onukii.* These sucking pests attack new buds of tea, causing serious deterioration in the quality of the leaves. No effective natural enemies are known, and most pesticides are not very effective. Thus, growers tend to rely on the SPs, which are highly effective against sucking pests.

However, the SPs are non-selective and have a long-lasting toxic effect. They kill natural enemies of *T. kanzawai,* including *A. womersleyi.* This may result in an outbreak or resurgence of the spider mite.

Mochizuki (2000) found that at a few tea plantations in central Japan, populations of *A. womersleyi* were suppressing Kanzawa spider mites even after they were sprayed with SPs (Fig. 1). A laboratory assay confirmed that these strains of *A. womersleyi* were highly tolerant of SPs, as well as of organophosphates (Table 3) (Mochizuki 1990, 1999).

However, laboratory selection for higher tolerance gave only a slight increase in resistance. Furthermore, the resistance was not stable. Susceptibility to SPs returned when the selection was stopped (Mochizuki 1997). This indicates that adequate (limited) SP spraying will be necessary to maintain the SP-resistance of these populations of *A. womersleyi,* as well as to suppress sucking pests.

Controlled field experiments (Mochizuki 2000) indicated that the release of SP-resistant strains of *A. womersleyi,* together with adequate SP spraying, effectively suppressed both *T. kanzawai* and the two sucking insect pests (Fig. 1 and Fig. 2).

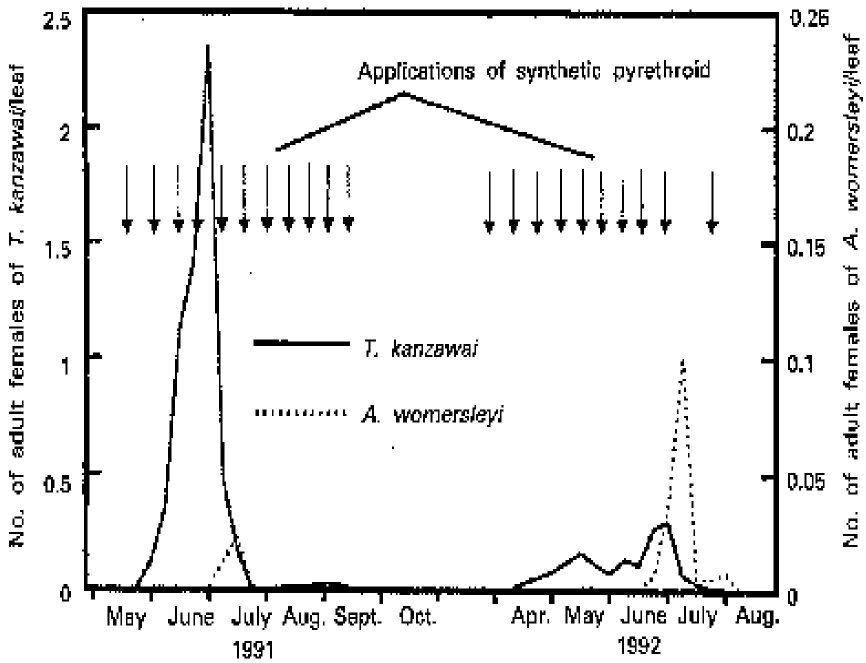

Fig. 1. Population density of *T. kanzawai* and its predator, *A. womersleyi,* in tea fields sprayed with synthetic pyrethroids (Mochizuki, 2000)

Table 3. Susceptibility of the Shizuoka populations of *A. womersleyi* to the SP pesticide permethrin (20%, W.P.)

Population	% mortality (n)
Central region	
Kanaya 1	[illegible] (73)
Kanaya 2	32.6 (40)
[illegible]	63.8 (48)
[illegible]	57.5 (40)
[illegible]	16.0 ([illegible])
[illegible]	[illegible]
Eastern region	
[illegible]	[illegible]
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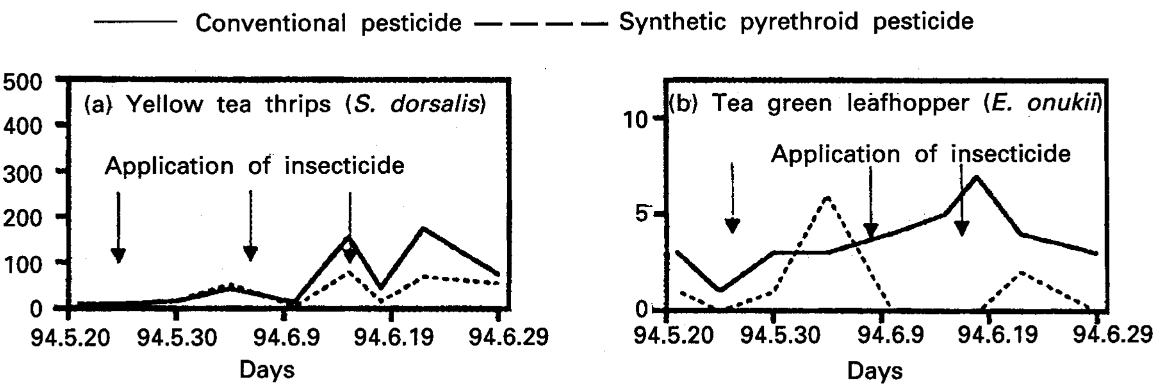

Fig. 2. Changes in the number of sucking pests captured by beating after spraying with two types of pesticide, synthetic pyrethroids ( ) and conventional ( )

There remain some problems. In order to release the SP-resistant strain of *A. womersleyi* into tea fields, it must first be mass produced. Furthermore, the resistance of *A. womersleyi* is maintained only by SP spraying, which is not desirable for the management of other natural enemies.

THE RELEASE OF THE PREDACIOUS MITE, *PHYTOSEIUS PERSIMILIS*, ONTO GROUND VEGETATION BENEATH GREENHOUSE GRAPES

There are many examples all over the world of successful control of spider mites using *Phytoseius persimilis*. Nevertheless, there are also a considerable number of unsuccessful trials, which are often not published or reported. It is important to clarify under what conditions the predators successfully suppress spider mites. Unsucessful spider mite control using *P. persimilis* may be the result of several factors. Fig. 3 shows how a combination of temperature and relative humidity affects the activity of *P. persimilis.* It is evident that the activity of the predators is severely hindered by a high temperature, particularly if this is combined with low humidity.

The physical structure of the host plant also affects whether the predator will become established. It is widely recognized that *P. persimilis* is unlikely to settle on tall host plants, such as woody plants.

Thus, although *P. persimilis* is certainly one of the most successful predators, the conditions under which it is effective are limited. For example, many greenhouses in Japan are small, and inside temperatures often exceed 35˚C in summer. This is likely to reduce the activity of the predators. The dislike of *P. persimilis* for tall hosts means that this predator cannot be used to control spider mites on tall fruit trees such as pear and peach.

Spider mites in deciduous fruit tree orchards in Japan usually overwinter on ground vegetation. In the spring, they first increase their populations on the vegetation, and then move onto fruit trees.

Although *P. persimilis* does not do well on tall fruit trees, if we introduce the predator onto groundcover, it may eliminate spider mites before they migrate onto fruit trees. Takahashi *et al.* (1998) released *P. persimilis* onto grass growing in a vinyl house planted in grape (1,000 m^2) in an attempt to control spider mites. Two releases of *P. persimilis* (a total of 8,000), one in late May and one in early June, reduced the spider-mite population on the ground cover almost to extinction by early July. Throughout July (the most important season for fruit growth), without spraying any chemicals, the spider-mite density was held at 10% of that found in the control grape orchard where no predators had been released (Fig. 4). A similar release of predators onto ground cover would also be feasible in orchards of other fruits such as pear and persimmon.

Thus, the release of *P. persimilis* onto ground cover is effective in preventing spider mites from migrating onto fruit trees, if the predator is released at the appropriate time. Our experiments showed that if the release was too late, the spider mites migrated onto trees in large numbers before the predators became abundant. If the release was too early, the predators failed to become established because of the low density of prey.

Control was unsuccessful in one year, when there was an unexpected outbreak of the stinkbug, *Halyomorpha misa.* This invaded the greenhouse in large numbers. Chemical spraying was unavoidable, and killed all the *P. persimilis.* Another problem was that although the number of *T. kanzawai* was

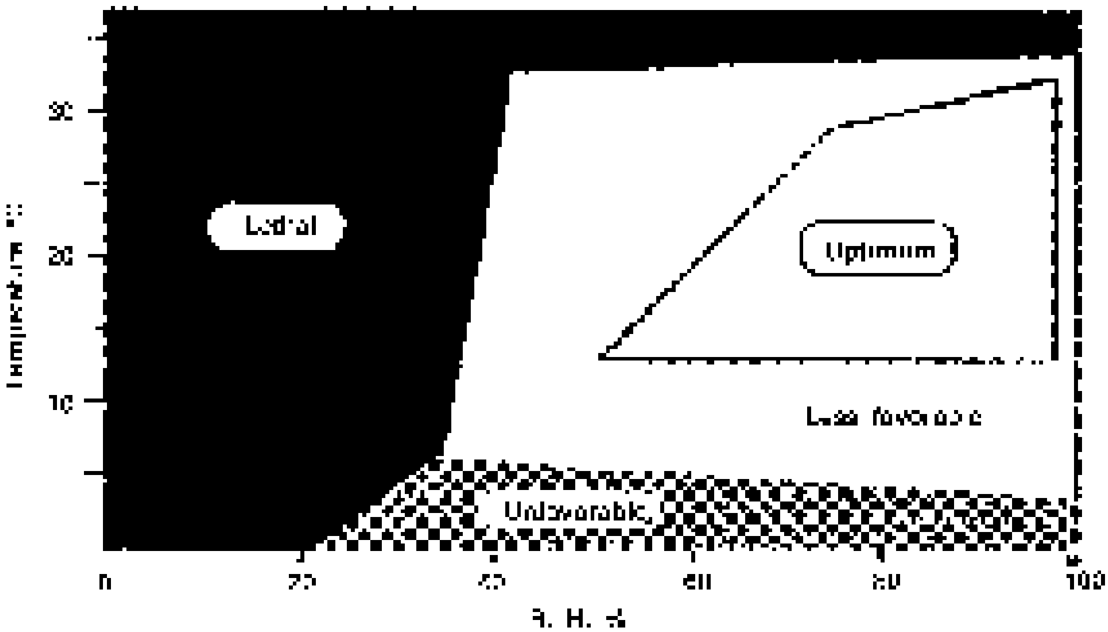

Fig. 3. Activity of *P. persimilis* in relation to temperature and relative humidity

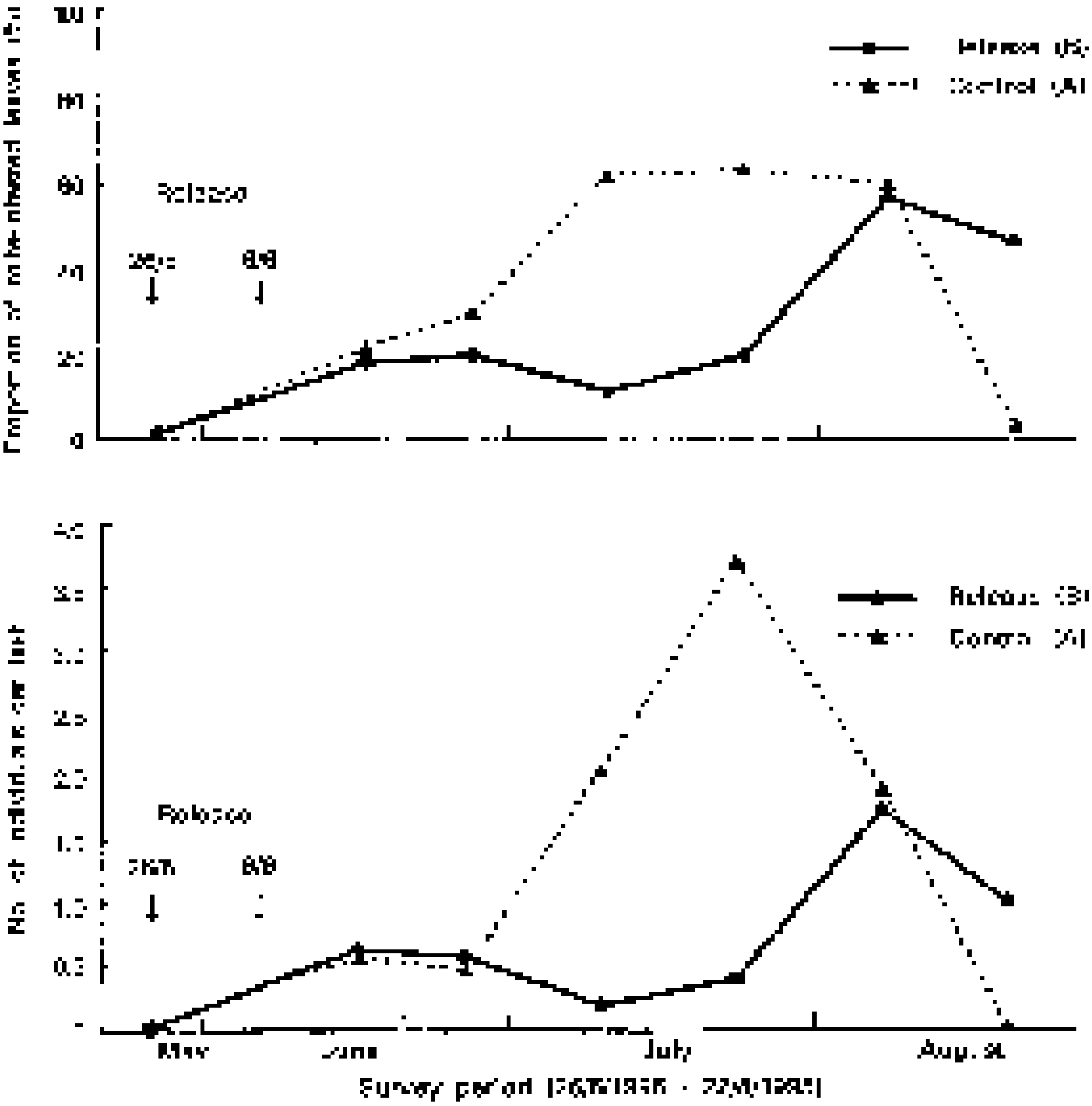

Fig. 4. Proportion of mite-infested leaves (above) and the average number of adult females of *T. kanzawai* per leaf (below) in two grape orchards (one in which *P. persimilis* had been released and the control)

kept to low levels by release of the predator, there was an outbreak of eriophyid mites on some grape leaves over the summer. We think that perhaps releasing *Amblyseius sojaensis* onto the vines will give effective control of these mites.

Possibility that *P. persimilis* will become established in Japan

We assessed the damage to the ecosystem that may result from the introduction of *P. persimilis.* This species has already been released several times in Japan. However, there is no evidence that it has become established.

Fig. 5 compares the climatic conditions of three parts of Japan with those in areas where *P. persimilis* originated, and those where it has been introduced and become established. Its current distribution in Australia, New Zealand and California may be due to intentional or unintentional introduction.

In areas where the predator originated, such as Casablanca in Morocco and Lima in Peru, the seasonal range of both temperature and humidity is

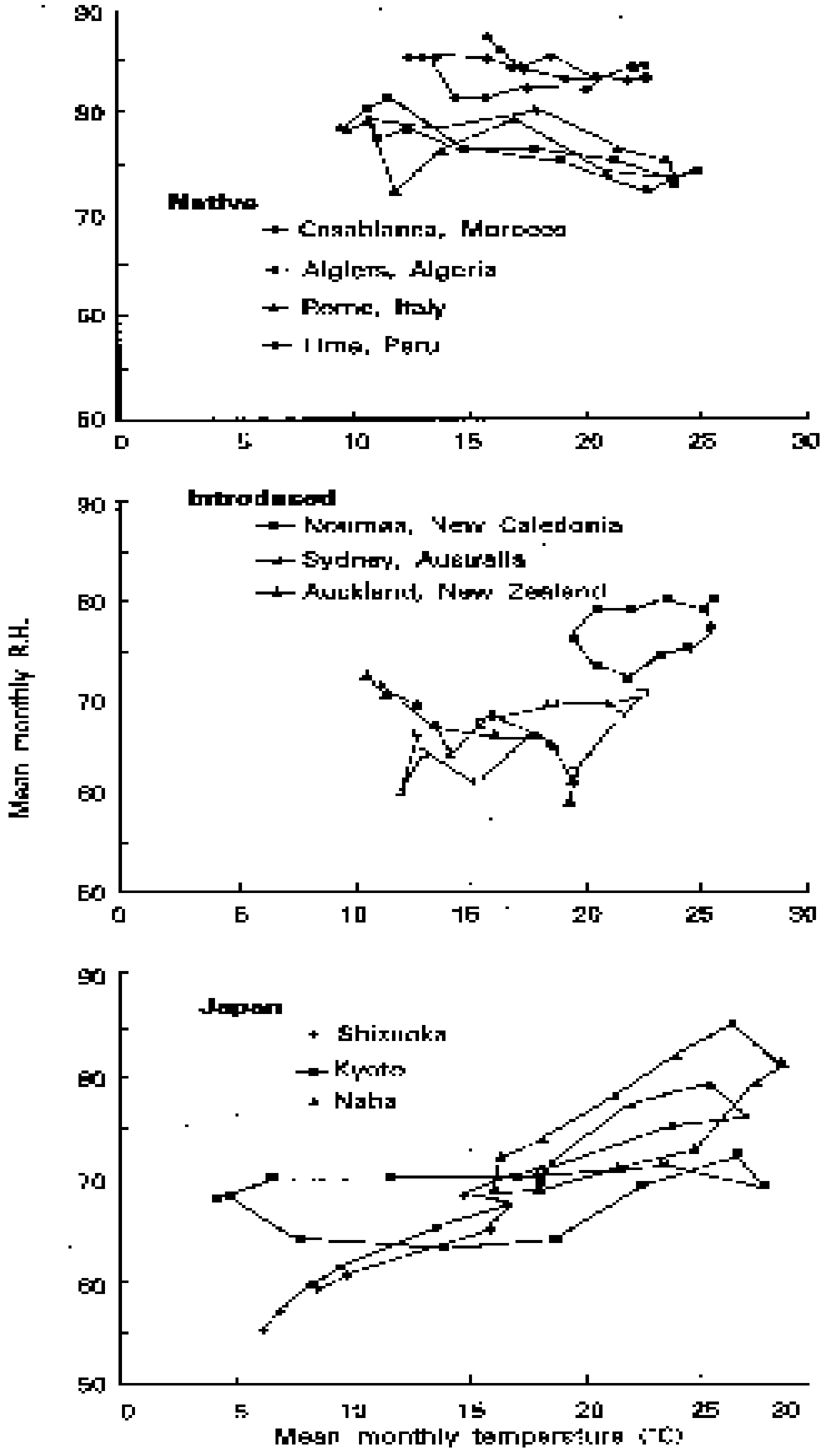

Fig. 5. Comparison of the climatic conditions in three areas of Japan, with those in areas where *P. persimilis* originated or where it was introduced and became established. The graphs show seasonal fluctuations in temperature and relative humidity.

very limited. Winters are mild and fairly humid. Areas where the predators have become established have similar climatic conditions, although their climate is drier.

In contrast, both temperature and humidity fluctuate greatly and the winters are very dry in Kyoto and Shizuoka, both in Honshu. The town of Naha in Okinawa has a climate similar to the areas where the predators are distributed, but its summer is much hotter. It would appear that the establishment of *P. persimilis* in Japan is not likely, mainly because of the cold, dry winters.

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