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Phytoseiid mites (Acari: Phytoseiidae) on apple trees and in surrounding vegetation in southern Finland. Densities and species composition

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ABSTRACT

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Leaf samples were collected from sprayed ($n=29$) and unsprayed ($n=19$) apple orchards, from the surrounding vegetation ($n=58$) and from one arboretum ($n=12$), altogether from 46 plant species (1–5 samples each). The density of phytoseiid mites averaged 1.2 mites/leaf on unsprayed apple trees, but only 0.06 mites/leaf on sprayed trees. The phytoseiid density exceeded 1/leaf on *Aesculus hippocastani, Aristolochia macrophylla, Corylus avellana, Fragaria vesca, Fraxinus excelsior, Juglans cinerea, Pterocarya rhoifolia, Ribes nigrum, Rubus odoratus, Sorbus aucuparia, S. thuringiaca, Tilia×euchlora* and *Ulmus glabra*. Other common trees and bushes inhabited by phytoseiids were *Crataegus coccinea* (0.2 mites/leaf), *Prunus padus* (0.7), *Salix caprea* (0.4), and *Tilia cordata* (0.9).

Twelve species of phytoseiid mites were found, of which ten occurred on unsprayed apple trees. The most widely distributed species on apple trees were *Phytoseius macropilis* (in 79% of unsprayed samples), *Euseius finlandicus* (74%), *Paraseiulus soleiger* (53%), *Paraseiulus triporus* (37%), *Amblyseius canadensis* (26%) and *Anthoseius rhenanus* (26%). The highest densities on apple trees were found in populations of *E. finlandicus* (mean 0.7 mites/leaf), *Ph. macropilis* (0.5) and *A. canadensis* (0.5). On sprayed apple trees, *E. finlandicus, Pa. soleiger* and *Ph. macropilis* occurred most commonly, but their mean densities were under 0.1/leaf. Almost no phytoseiids were found in orchards sprayed with oxydemetonmethyl before blooming of apple.

On other plants, *E. finlandicus* occurred most commonly (on 33 plant species) and in the highest densities, followed by *Ph. macropilis* (14), *Pa. soleiger* (12), *Pa. triporus* (12) and *An. rhenanus* (7). *Seiulus aceri* and *Paraseiulus talbii* were identified as new phytoseiid species in Finland. It is concluded that deciduous trees and bushes in forest margins around orchards can serve as important reservoirs for phytoseiid mites, and that the dominant species in these plants would migrate into and colonize the orchards if the use of harmful chemicals were restricted.

INTRODUCTION

Phytoseiid mites (Acari: Phytoseiidae) are important predators of the European red spider mite *Panonychus ulmi* (Koch) (Acari: Tetranychidae) on

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unsprayed apple trees in Finland (Kropczynska and Tuovinen, 1987, 1988). Surveys conducted in apple orchards in many countries have demonstrated that phytoseiids can keep spider mite densities below economic thresholds (Dosse, 1960; Collyer, 1964; Wildbolz, 1986). The use of phytoseiids to control spider mites in orchards is also well documented (Croft and Barnes, 1971; McMurtry and van de Vrie, 1973; Hoy, 1982). In many cases, the introduced phytoseiid mites are conserved by using selective pesticides.

In Europe, the predatory mite species most commonly used in integrated pest management (IPM) programs is *Typhlodromus pyri* (Scheuten). This species occurs generally and has strains resistant to organophosphorous insecticides (OPs; Hoyt, 1972; Overmeer and van Zon, 1983). *Typhlodromus pyri* is capable of maintaining spider mite populations under economic thresholds in commercial orchards (Wildbolz, 1986). *Typhlodromus pyri* has not been found in Finland, but other phytoseiids have been detected on sprayed apple trees in very low numbers (Kropczynska and Tuovinen, 1988).

In the Nordic countries, phytoseiid mites occur on many deciduous trees and bushes (Hansen and Johnsen, 1986; Edland, 1987). These plants may serve as reservoirs for phytoseiid mites, allowing them to migrate into the orchard if harmful pesticides are not used. In Switzerland, Boller et al. (1988) studied mite samples from hedges and forests near vineyards and found *T. pyri* on some of the trees and bushes. They concluded that hedges are important reservoirs of *T. pyri* in areas where pesticides are regularly applied. Our preliminary observations of phytoseiids on different plants showed that the plant itself may have characteristics affecting phytoseiid mite populations. Therefore we conducted a more thorough study of the phytoseiids on various species of trees and bushes.

The trees most often used in windbreak hedges in Finland are alders (*Alnus* spp.) and spruce (*Picea abies*), although the natural vegetation usually supplies enough protection from strong wind. Common deciduous trees are birches (*Betula pendula* and *B. pubescens*), alders (*Alnus glutinosa* and *A. incana*), great sallow (*Salix caprea*), mountain ash (*Sorbus aucuparia*), bird cherry (*Prunus padus*) and aspen (*Populus tremula*). Bushes such as willow (*Salix* sp.), hawthorn (*Crataegus coccinea*), raspberry (*Rubus idaeus*), hazel (*Corylus avellana*) and elder (*Sambucus racemosa*) are also common near orchards. As well as the above, there are often various planted trees and bushes of foreign origin.

This study presents the results of a survey on the phytoseiid mites occurring in apple orchards and on nearby plants. The aim of the study was to evaluate the importance of surrounding vegetation as a reservoir and possible source of phytoseiid mites, especially the species that occur frequently on apple trees, and to establish if the phytoseiid mite species on apple tree show any resistance to commonly applied insecticides.

MATERIALS AND METHODS

Most of the leaf samples were collected from commercial orchards and their surroundings in southern Finland and on the Åland Islands in August and September, 1989. The standard sample size was 100 leaves, with the exception of some broadleaf samples, which consisted of 10–50 leaves (Table 1). For each sample, the leaves were taken from 10–20 sprayed apple trees in commercial orchards, from single or a few unsprayed trees in home gardens, and from several specimens of various deciduous trees or bushes near the orchards. A special survey was made in the Mustila arboretum (Elimäki, 60°44′N, 26°24′E), where many unusual plant species are grown. The number of samples other than those of apple was restricted to a maximum of five. In order to find the most suitable host plants for phytoseiid mites, samples were taken from a range of plant species.

The samples were either stored for a few days at +6–8°C or they were handled immediately. First, a subsample of 5–10 leaves was examined under a stereomicroscope to check for the presence of eriophyid mites (Acari: Eriophyidae), an important food of many phytoseiid species. The leaves were then soaked in warm soapy water (+70°C, 0.5% Taski profi soap) to remove and kill the mites on the leaves. After 24 h the samples were passed through 1-mm and 0.1 mm-mesh sieves. The phytoseiid mites were counted and collected into small tubes, and stored in 70% alcohol until preparation and identification. The mites were identified using the keys of Karg (1971, 1982, 1983) and Miedema (1987), the reference collection provided by T. Edland (1988, The Norwegian Plant Protection Institute), and the collection of Kropczynska and Tuovinen (1988).

RESULTS

The occurrence of phytoseiid mites and the presence of a common food source for phytoseiids, eriophyid mites, on apple trees and 46 other plants are presented in Table 1.

The highest phytoseiid densities were found in single samples on horse chestnut (*Aesculus hippocastani*; max. 14.4/leaf), blackcurrant (*Ribes nigrum*; 4.7), ash (*Fraxinus excelsior*; 3.8), mountain ash (3.3), hazel (3.3), Dutchman's pipe (*Aristolochia macrophylla*; 3.0), apple, unsprayed, cv. Harlamowska (2.8), purple raspberry (*Rubus odoratus*; 2.7), forest strawberry (*Fragaria vesca*; 2.4), lime (*Tilia*×*euchlora*; 2.3) and *Pterocarya rhoifolia* (2.3). Because the leaves of plants differ markedly in size, the values in Table 1 and above do not refer to the real density.

In this survey, twelve phytoseiid species were identified, ten on unsprayed apple trees, six on sprayed apple trees and eleven on various plants (Table 2). The most widely distributed phytoseiid species on unsprayed apple trees

TABLE 1

Occurrence of phytoseiid and eriophyid mites in samples[a] collected from apple orchards and nearby plants

Plant species	Samples (n)	Phytoseiids/sample	Eriophyids[b]
Deciduous trees			
Malus domestica (sprayed)	29	5.5	+ + +
M. domestica (unsprayed)	19	116.8	+
Acer platanoides	3	21.0	–
Aesculus hippocastani (15)	2	118.5	–
Alnus glutinosa	2	1.0	+ +
A. incana	1	2	+ +
Betula pendula	2	0.0	–
B. lutea M[c]	1	40	–
Fagus grandifolia M	1	8	–
Fraxinus excelsior (50)	2	98.5	+ + +
Prunus padus	3	67.3	–
P. cerasus	2	3.5	–
P. avium	2	0.0	–
Pyrus communis	1	1	–
Salix caprea	1	35	–
Sorbus aucuparia	2	170.5	+
S. aucuparia × *intermedia*	1	0	–
S. thuringiaca	1	111	–
Tilia americana M	1	27	–
T. cordata	2	88.0	–
T. euchlora M	1	228	–
Ulmus glabra	2	115.0	+
Deciduous bushes			
Amelanchier spicata M	1	2	–
Aristolochia macrophylla M (30)	1	89	–
Betula nana	1	0	+
Cornus alba	1	77	–
Corylus avellana	5	167.6	+
Crataegus coccinea	3	21.0	–
Juglans ailanthifolia M (10)	1	9	–
J. cinerea M (10)	1	15	–
J. mandschurica M (10)	1	6	–
Philadelphus sp. M	1	6	–
Pterocarya rhoifolia M (30)	1	68	–
Ribes nigrum	2	237.0	–
R. rubrum	2	11.0	–
R. uva-crispa	1	4	–
Rosa sp.	1	1	–
Rubus fruticosus	1	3	–
R. idaeus	3	5.0	+
R. odoratus (40)	1	109	–
Salix fragilis (150)	1	0	–
Salix sp.	1	1	–
Sambucus racemosa	1	0	–
Viburnum opulus	1	20	–
Herbaceous plants			
Fragaria × *ananassa*	2	1.5	–
F. vesca	1	239	–
Tussilago farfara (30)	1	9	+ +
Urtica dioica	1	0	+ + +

[a]The sample size was 100 leaves (if not, the number of leaves is indicated in brackets). [b]–, no eriophyids found; +, < 5; + +, 6–10; + + +, > 10 eriophyids/leaf. [c]M, samples from Mustila arboretum.

TABLE 2

Occurrence[a] of phytoseiid species on apple trees and the surrounding vegetation

Phytoseiid species	Apple trees		Found also on:
	Sprayed (n=29)	Unsprayed (n=19)	
Phytoseius macropilis **(Banks)**			
	4.2	46.1	*A. hippocastani, C. avellana, F. grandifolia, Fragaria×ananassa, P. avium, P. padus, R. fruticosus, R. rubrum, S. caprea, S. aucuparia, S. thuringiana, T. americana, U. glabra, V. opulus*
	17.2%	78.9%	
Euseius finlandicus **(Oudemans)**			
	8.0	73.2	*A. platanoides, A. hippocastani, A. incana, A. spicata, A. macrophylla, B. lutea, C. alba, C. avellana, C. coccinea, F. grandifolia, F. vesca, F. excelsior, J. ailanthifolia, J. cinerea, J. mandshurica, P. avium, P. padus, P. rhoifolia, P. communis, R. nigrum, R. rubrum, R. uva-crispa, R. fruticosus, R. odoratus, Salix* sp., *S. caprea, S. thuringiana, T. americana, T. cordata, Tilia×euchlora, U. glabra, V. opulus*
	41.4%	73.7%	
Amblyseius reductus **Wainstein**			
	1.0	2.3	*A. macrophylla, F. vesca, T. farfara, U. glabra*
	3.4%	5.3%	
Amblyseius canadensis **Chant & Hansell**			
	0	45.8	*C. coccinea, P. padus*
	0%	26.3%	
Seiulus aceri **(Collyer)**			
	0	0	*A. platanoides*
	0%	0%	
Paraseiulus talbii **(Athias-Henriot)**			
	0	1.0	*Fragaria×ananassa, J. ailanthifolia*
	0%	5.3%	
Paraseiulus soleiger **(Ribaga)**			
	6.2	15.6	*B. lutea, C. avellana, C. coccinea, F. grandifolia, F. excelsior, J. cinerea, J. mandshurica, P. rhoifolia, S. thuringiaca, T. cordata, Tilia×euchlora, U. glabra*
	20.7%	52.6%	
Paraseiulus triporus **(Chant & Shaul)**			
	2.0	2.4	*A. platanoides, A. hippocastani, C. avellana, F. vesca, P. avium, P. padus, P. rhoifolia, R. rubrum, R. uva-crispa, S. aucuparia, R. odoratus, U. glabra*
	3.4%	36.8%	
Anthoseius bakeri **(Garman)**			
	0	0	*R. rubrum*
	0%	0%	

Phytoseiid species	Apple trees		Found also on:
	Sprayed (n=29)	Unsprayed (n=19)	
Anthoseius rhenanus **(Oudemans)**			
	2.0	5.8	*A. glutinosa, C. coccinea, J. ailanthifolia,*
	3.4%	26.3%	*P. avium, R. nigrum, R. idaeus, S. aucuparia*
Anthoseius gilvus **(Wainstein)**			
	0	1.0	n.a.
	0%	5.3%	
Typhlodromus richteri **Karg**			
	0	1.5	*A. platanoides, S. aucuparia*
	0%	10.5%	

[a]Mean numbers of mites and percentages of samples containing the species.

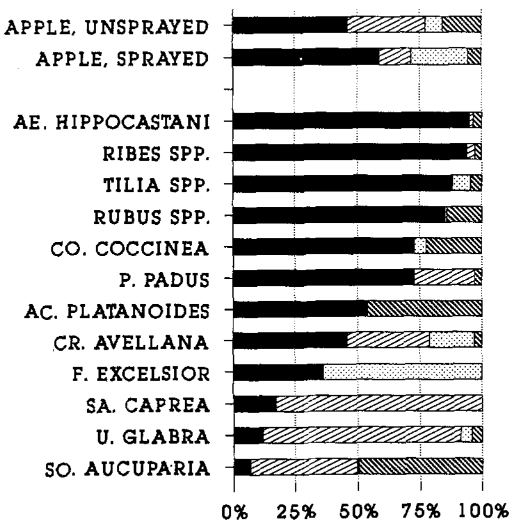

Fig. 1. The composition of phytoseiid species on unsprayed and sprayed apple trees compared with twelve deciduous trees and bushes. Sampling in August–September 1989.

were *Phytoseius macropilis* (Banks), *Euseius finlandicus* (Oudemans), *Paraseiulus soleiger* (Ribaga), *Paraseiulus triporus* (Chant & Shaul), *Amblyseius canadensis* Chant & Hansell and *Anthoseius rhenanus* (Oudemans); *E. finlandicus, Ph. macropilis, A. canadensis* and *Pa. soleiger* occurred in the highest densities. Other species occurred in only a few samples and in very low densities.

TABLE 3

Sprayings performed in 1989, and mean numbers of phytoseiids in sprayed apple orchards

Location	Pesticides and number of applications			Phytoseiids/ sample
	Fungicide[a]	Acaricide[b]	Insecticide[c]	
Pohja	dith:8	flub:1	dime:1	22.7
Virkkala	bite:5	chin:1	azin:1	12.0
Pälkäne	dith:3	chin:1	—	9.5
Paimio	dith:5	chin:2, fens:1	dime:1	2.5
Geta	bite:6	chin:1, chlo:1	azin:2	2.0
Bromarv	bite:1, dich:1 dith:9	chin:1, tolu:2	—	1.0
Pohja	bite:3, dith:5	chin:1	azin:3	1.0
Lohjansaari	dith:5, trif:4	chin:1	oxyd:1	1.0
Virkkala	bite:1, dith:1 trif:2	—	azin:1, oxyd:2	0.5
Geta	bite:2, dich:2, dith:2, trif:1	—	azin:2, dime:2, oxyd:1	0
Geta	bite:3, copp:1, dich:3, dith:2	chin:1	azin:1, dime:2	0
Godby	bite:1, dich:1 dith:6	—	azin:1, oxyd:1	0
Godby	dith:6	chin:2	azin:1, oxyd:3	0
Lohjansaari	dith:6, trif:2	chin:1	oxyd:1	0
Lohjansaari	bite:3, dith:4	dico:1	oxyd:1	0
Piikkiö	bite:6	chin:1	oxyd:1	0

[a]Fungicides: bitertanol; copperoxychlorid; dichlofluanid; dithianon; triforine.
[b]Acaricides: chinomethionate; chlorbenzilate; dicofol; fenson; flubenzimine; toluene.
[c]Insecticides: azinphosmethyl; dimethoate; oxydemetonmethyl.

The material collected for the 1985 survey was rechecked, and one correction was made to the list of phytoseiids on the apple tree: *Amblyseius cucumeris* (Oudemans) should be *A. reductus* Wainstein (Kropczynska and Tuovinen, 1988). Furthermore, one specimen of *Paraseiulus triporus*, earlier identified erroneously as *Pa. soleiger*, was identified from the same material (T. Edland, personal communication, 1988).

Paraseiulus talbii (Athios-Henriot) was found as a new species on the apple tree in Finland, and *Seiulus aceri* (Collyer) was recorded for the first time on the maple (*Acer platanoides*). The phytoseiid species found on apple trees now include *Phytoseius macropilis, Euseius finlandicus, Amblyseius reductus, A. canadensis, Paraseiulus talbii, Pa. soleiger, Pa. triporus, Anthoseius bakeri* (Garman), *An. rhenanus, An. gilvus* (Wainstein) and *Typhlodromus richteri* Karg.

Euseius finlandicus occurred on 85% of the plant species containing phytoseiids (on 33 of 46 plants). The other species with a wide host-plant selection were *Ph. macropilis* (on 14 plants), *Pa. soleiger* (on 12 plants) and *Pa.*

triporus (on 12 plants; Table 2). These four species accounted for 94.7% of all individuals ($n=2219$) in unsprayed apple leaf samples; the same species, especially *E. finlandicus* and *Ph. macropilis*, were also dominant on many common or otherwise interesting plants near orchards (Fig. 1).

The presence of eriophyid mites in leaf samples does not seem to affect the density of phytoseiids (Table 1). On the dwarf birch (*Betula nana*) and the nettle (*Urtica dioica*), eriophyid populations existed, but not a single phytoseiid mite was found. The nettles were growing near the sprayed apple trees, and had obviously been sprayed with the same chemicals. Eriophyids were rather common on *Alnus* spp., but only a few phytoseiids were found on these trees.

Six phytoseiid species were found in low densities on sprayed apple trees (Table 2). *Euseius finlandicus, Pa. soleiger* and *Ph. macropilis* were the most common species in these orchards, where several fungicidal and a few insecticidal and acaricidal sprayings had been performed (Table 3). Phytoseiids were almost entirely absent from orchards where oxydemetonmethyl had been used. In two of the orchards, no insecticidal sprayings had been made in 1989, but in the previous year, dimethoate (Pälkäne) and oxydemetonmethyl plus dimethoate (Bromarv) had been used (Table 3). In the orchards where about 10–20 phytoseiid mites/sample were found, the trees had been sprayed with bitertanol or dithianon for scab control, with acaricides once and with azinphosmethyl or dimethoate no more than once.

DISCUSSION

Although the role of phytoseiid mites as important predators of *P. ulmi* on apple trees had already been observed in the 1930s in Finland (Listo et al., 1939), the first survey to search for and identify phytoseiids was not conducted until 1985 (Kropczynska and Tuovinen, 1987, 1988). The observations made for the present study and that performed four years earlier showed that the main species compositions and the densities of phytoseiid mites are stable in a particular orchard as long as the trees have not been sprayed. Likewise, in Canada, Amano and Chant (1990) noted that populations of *E. finlandicus* and *Ph. macropilis*, the two dominant phytoseiid species in an abandoned orchard, were stable in two consecutive years.

The most common phytoseiid mite species on apple trees in Finland, *E. finlandicus* and *Ph. macropilis*, are known as predators of spider mites and eriophyid mites (Chant, 1959; Böhm, 1960; Karg, 1972). Both species also reproduce when fed only on pollen, and *E. finlandicus* reproduces also if fed only on spores and hyphae of the apple mildew *Podosphaera leucotricha* (Ell. & Ev.) (Kropczynska-Linkiewicz, 1973). These two species of phytoseiids are clearly the best adapted to the Finnish climate and to diverse habitats and food resources.

As Finnish apple orchards are small, with homogeneous blocks typically under 2 ha and very seldom over 10 ha, the significance of the surrounding vegetation as a reservoir and source of phytoseiid mites is more important than in larger uniform apple cultivations. If the harmful agents in chemical pest control are replaced with more benign pesticides, predators and parasitoids will migrate from surrounding vegetation and colonization may succeed. As phytoseiids do not walk long distances (van de Vrie, 1985), the main means of long-range dispersal is the wind. Hoy (1982) reported that the phytoseiid mite *Metaseiulus occidentalis* (Nesbitt) dispersed from one spot throughout a 32-ha almond orchard in one year. Phytoseiids can disperse via air turbulence for at least 200 m, and probably much more than that (Hoy et al., 1985). The capacity of phytoseiids for long-distance airborne dispersal seems to be so high that they might colonize small orchards within a short period.

The speed of phytoseiid migration from outside trees or bushes into an orchard depends on many factors, such as distance, prevailing wind direction, frequency of high winds, air temperature and relative humidity (Johnson and Croft, 1979; Hoy et al., 1985). The above-mentioned studies support the idea that phytoseiids may colonize small apple orchards in a few months once harmful sprayings have been stopped.

In Switzerland, a method for transferring phytoseiids from one vineyard to another has recently been introduced and implemented on a larger scale (Boller and Remund, 1986). It would also be useful to study whether artificial transfer from wild host plants would significantly accelerate the migration of phytoseiids into apple orchards.

Other generally occurring good host plants for phytoseiids besides the apple tree are blackcurrant, mountain ash, hazel, purple raspberry, bird cherry, lime (*Tilia cordata*) and elm (*Ulmus glabra*). These trees and bushes are hosts for many eriophyid mite species (Liro and Roivainen, 1951), although in this study eriophyid mites were rather scarce. Other mite groups were not considered, but with the exception of the European red spider mite on sprayed apple trees, their densities were much lower (cf. Kropczynska and Tuovinen, 1988).

Many studies report high densities of phytoseiid mites on hazel (Hansen and Johnsen, 1986; Edland, 1987; Boller et al., 1988). Although not very common in Finland, this bush can be found near many apple orchards. Another very good host plant for phytoseiids is blackberry (Boller et al., 1988), but in the present study only a few mites were found on it. *Rubus odoratus*, in contrast, was abundantly inhabited by *E. finlandicus*. Only a few phytoseiids were found on common raspberry (*R. idaeus*), but the wild raspberries should be studied more thoroughly because they are very common in forest margins.

Although samples of some plant species were taken in only a single or a few locations, the results show which plant species can support high numbers of phytoseiids. The presence of hairs on a leaf surface seems to be an important prerequisite for high phytoseiid density (cf. Overmeer and van Zon, 1984).

Prey density does not seem to have any significant effect on the presence and density of *E. finlandicus* and *Ph. macropilis*. Although only the density of eriophyid mites was estimated, the general trend was for phytoseiids also to be found on plants where only very few or no prey mites were present, at least on leaves. Obviously, these species have alternative food sources: pollen, spores and plant fluids, and possibly also the mites inhabiting branches.

Prunus padus, Sorbus aucuparia and *Salix caprea* are all common trees in forest margins and around orchards. *Euseius finlandicus* and *Ph. macropilis* were dominant on *Pr. padus*, where their densities were almost the same as on unsprayed apple trees. *Salix caprea* is an interesting tree, because it provides nourishment for honey bees in early spring, before apple blooming time. It should therefore be conserved and even used in windbreak hedges. As *So. aucuparia* is the main host of the most important apple pest in Finland, the apple fruit moth (*Argyresthia conjugella* (Zell.)), this tree should not be grown near apple orchards. *Phytoseius macropilis* was the dominant species on both *Sa. caprea* and *So. aucuparia.*

The prospects of finding strains resistant to OPs in any phytoseiid species do not look promising in the light of the present study, although 10–30 specimens of *E. finlandicus* and *Pa. soleiger* were found in some sprayed samples. However, the findings suggest that these populations may possess at least a low level of resistance to dimethoate and azinphosmethyl, and clearly show the destructive effect of pesticide spraying on predatory mites. Use of oxydemetonmethyl, one of the common insecticides, should be restricted if naturally occurring phytoseiids are to be conserved. Because the species most widely known to have developed resistance to OPs, *T. pyri*, has not been found in Finland so far, the introduction and release of this species into Finnish orchards should be studied, as should the reasons why this species does not occur in Finland.

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