DIVERSITY OF PHYTOSEIID MITES IN UNCULTIVATED AREAS ADJACENT TO VINEYARDS: A CASE STUDY IN THE SOUTH OF FRANCE

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PHYTOSEIIDAE
UNCULTIVATED AREAS
FAUNISTIC SURVEY
TYPHLODROMUS PHIALATUS
TYPHLOFROMUS EXHILARATUS
VINEYARDS

SUMMARY: The diversity of phytoseiid mite communities was experimentally investigated on uncultivated and cultivated lands. Ninety four plants were sampled three times a year over five years (1999-2003) and traps were filtered once a week over the same five-year period, from April to September. Thirty-seven phytoseiid mite species were found, five for the first time ever in France. Seventy-six of the 94 plants sampled bore phytoseiid mites. The most abundant species were, by order of density: *Typhlodromus* (*Typhlodromus*) *phialatus*, *Kampimodromus aberrans* and *Typhlodromus* (*Anthoseius*) *recki*. The plants mostly highly colonised by phytoseiid mites were: *Celtis australis*, *Quercus ilex*, *Rubus* sp., *Q. coccifera*, and *Ulmus* sp. The diversity of phytoseiid mites in uncultivated areas seems to be linked to plant diversity.

INTRODUCTION

Phytoseiid mites are the most widespread predatory mites in agrosystems today. These predators are of great interest for integrated pest management since some of the species are effective for controlling phytophagous mite populations (mainly Tetranychidae and Eriophyidae) (KREITER & BRIAN, 1986; MCMURTRY & CROFT, 1997), leading to reduced pesticide applications (KREITER & SENTENAC, 1995).

Many studies have shown relationships between these predators and the leaf structure (pilosity, domatia) and pollen availability on their host plants, which both influence their development (*i.e.*, survival, fecundity) (DUSO, 1992; WALTER & O'DOWD, 1992; VAN RIJN & TANIGOSHI, 1999; KREITER *et al.*, 2002a). Others have shown the abundance of phytoseiid mites in uncultivated areas in the vicinity of crops such as vineyards (BOLLER *et al.*, 1988; TSOLAKIS *et al.*, 1997; KREITER *et al.*, 2000; TIXIER *et al.*, 2000b, DUSO *et al.*, 2004), and some of them have emphasized possible exchanges between these areas (HOY *et al.*, 1985; TIXIER *et al.*, 1998, 2000a, b).

Management of mite biodiversity in uncultivated areas adjacent to areas where crops are grown could emphasize biological control of phytophagous mites, limiting the drawbacks of artificial introduction. However, in order to improve this management, more information is needed concerning the occurrence of predatory mites in uncultivated areas and the factors affecting the structure of communities and, especially, the presence, abundance and diversity of these mites.

A study has already been carried out in a vineyard in southern France (TIXIER *et al.*, 2000b) but the local climatic and soil conditions and, thus, the vegetation

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type, were different from those in the present survey. The aim of the present paper is to determine the phytoseiid mite diversity in uncultivated areas adjacent to vineyards in another site also located in the south of France, in order to compare this diversity with previous results and to provide more data in order to improve our knowledge about phytoseiid mite occurrence in the South of France, especially in areas adjacent to crops.

Material and methods

The experimental site

Uncultivated areas of the experimental site are located in Restinclières (15 km north of Montpellier, France) and border an experimental vine plot of 0.45 ha, planted with Syrah and Grenache cultivars in 1997 on reclaimed fallow land. The orientation of rows within the grapevine plot is orthogonal to the direction of dominant winds (north-west and north-east). The soil is a rendzine, calcareous, stony, dry and the climatic conditions are typical of the subhumid Mediterranean climate.

Sampling

The plants of the uncultivated areas surrounding the north, the west and the south of the vine plot (maximum distant: 1 km) were sampled three times a year (May, July, August) over five consecutive years (1999-2003). At least 50 leaves per plant at each sampling date were collected. The leaves were brought back to the laboratory in a freezer. Phytoseiid mites were removed from leaves using Berlese-Tullgren funnels (Kreiter *et al.*, 2000) or the checking-washing-filtering method (Boller, 1984).

Traps

Twelve traps were placed in the vine plot in order to characterize the arrival of phytoseiid mites on the crop. These traps consisted of plastic funnels (∅ 31 cm), filled with water, with a small grid opening made of a small piece of plastic sieve for preventing loss of mites due to excess water during rains. The traps were placed one meter above the vegetation on glued sticks (Tixier *et al.*, 1998, 2000b). Funnel contents were filtered weekly through 100 μm sieves and all mites were counted, mounted and identified.

Mounting, identification and counting of mites

All of the mites were counted under a binocular microscope at 40x magnification, mounted in Hoyer's medium on slides and identified using a phase and interferential contrast microscope, according to the taxonomic keys of the generic revisions of Chant & McMurtry (1994) for Typhlodrominae and Phytoseiinae, those of Chant & McMurtry (2003a, b) for Ambyseiinae *Neoseiulini* and *Kampimodromini,* and the generic acceptance as defined by the catalogue of Moraes *et al.* (2004) for all other genera of Amblyseiinae. The slides are kept in the mite collection of the Department and computerised in the corresponding database.

Data analysis

The percentage of each phytoseiid species per host plant was calculated from the number of individuals collected (Table I). Dominant species are those that occurred on more than 50% of the plants collected. In the same way, dominant species are those representing more than 50% of the densities observed on all host plants. In order to compare specific diversity and its temporal evolution over five years in Restinclières, the Shannon index (H') and an equitability index (E) were used (Biodiversity Professional, 1998). Values of H' varied from 0 (only one species) to $\log_2$ (S), where S was the number of species. When high densities occurred for only one species, E=0, and when all the species were equally abundant, E=1 (Barbault, 1992).

Results and discussion

The Phytoseiidae found in uncultivated areas:

Thirty-one phytoseiid species were collected (Table 1). A high number of phytoseiid species (70%) was found on some plants such as *Celtis australis* and *Quercus ilex* (nine species)*, Rubus* sp. (seven species), and *Q. coccifera*, *Ulmus* sp. and *Viburnum tinus* (six species). These plants are known to be favourable host plants (Barret & Kreiter, 1993; Tixier, 1998; Kreiter *et al.*, 1999; Moraes *et al.*, 2004).

No phytoseiid mites were found on *Abies* sp., *Bromus* sp., *Chlora perfoliata* L., *Cistus monspeliensis* L., *Festuca* sp., *Gledichia* sp., *Hedera helix* L., *Iberis pinnata* L., *Jasminum fruticans* L., *Ligustrum vulgare* L., *Melilotus officinalis* L., *Prunus dulicis* Miller, *Rhamnus alaternus* L., *Robinia pseudacacia* L., *Saponaria ocymoides* L., *Smilax aspera* L., *Sonchus arvensis* L., *Torilis* sp. or *Zelcova* sp.

Among the 31 species of phytoseiid mites collected, four were new to French fauna (Kreiter *et al.*, 2002b).

Phytoseius echinus Wainstein & Arutunjan was reported in Armenia in 1970 on *Fragaria* sp., and found in Russia, Moldavia and Georgia on different host plants: *Malus* sp., *Prunus* sp., *Prunus avium*, *Pyrus* sp. and *Viburnum* sp. (Moraes *et al.*, 2004). In Restinclières, it was found on five plants: *Malus domestica*, *Prunus* sp., *Thymus vulgaris*, *Ulmus* sp. and *V. tinus*.

Typhlodromus (*Typhlodromus*) *ernesti* Ragusa & Swirski was reported in Italy in 1978 on *Taxus baccata* L. It was collected in Germany, Switzerland, Norway and Canada on different plants, such as *Quercus* sp., *Juniperus communis* L., *Pinus sylvestris* L. and *Sorbus aucuparia* L. (Moraes *et al.*, 2004). This species was collected in 1999 on *Juniperus oxycedrus*, *Q. ilex* and *Ulmus* sp.

Paraseiulus triporus Chant & Yoshida-Shaul was reported in Italy in 1982 on an unidentified plant. This species has been encountered in Portugal on *Juglans regia* and *M. domestica,* in the USA (California) on *Prunus domestica* L. and *Rubus* sp., and in Russia and Germany on many plants such as *Prunus cerasifera* L., *Rubus* sp., *Viburnum* sp., *Cydonya* sp., *Malus* sp., *Pyrus* sp., *Clematis* sp., *Ulmus* sp. and *R. pseudacacia* (Moraes *et al.*, 2004). In Restinclières, this species was collected on *Sophora japonica* in 2001.

Typhlodromus (*Anthoseius*) *ilicis* Athias-Henriot was reported in Algeria in 1960 on *Q. ilex*. This species was found three times, in 1999, 2002 and 2003, on three host plants: *Clematis flamula*, *Q. coccifera* and *Q. ilex.*

All other species collected in the sampled areas were already known in France. Only one specific mite-plant association was discovered in the case of *Typhloseiella isotricha* Athias-Henriot that was exclusively found on *Inula viscosa*. This previously observed association (Tixier *et al.*, 2000b; Moraes *et al.*, 2004) suggests close mite-plant relationships.

Some species were frequently observed (79% of individuals collected), such as *Typhlodromus* (*Anthoseius*) *recki* Wainstein, *T.* (*A.*) *cryptus* Athias-Henriot, *T.* (*T.*) *exhilaratus* Ragusa*, T.* (*T.*) *baccetti* Lombardini, *T.* (*T.*) *phialatus* Athias-Henriot and *Kampimodromus aberrans* (Oudemans).

T. (*A.*) *recki* was observed on 28 plants and the highest densities (53% of individuals collected) occurred on *Sorbus domestica*, *Ulmus* sp. and *Q. ilex*. Densities of this species were very low on the other host plants (Table 1). This species has already been collected on vines, fruits, ornamental plants and weeds (Kreiter *et al.*, 2000; Moraes *et al.*, 2004). Even if this species has been reported in many surveys in Europe, its biology is still poorly known.

T. (*T.*) *exhilaratus* was collected from 2000 to 2003 on 13 plants. This species, described from *Rosmarinus officinalis* in Italy (Ragusa, 1979), and found in vineyards in the south of France (Tixier *et al.*, 2000a), can survive and develop in low relative humidities and high temperatures (more than 50% of the eggs hatched at 55% RH & 25°C) (Liguori & Guidi, 1995).

T. (*T.*) *baccettii* was reported in Italy, Australia and France on *Buxus* sp., *Pinus* sp., *Fraxinus* sp., *Pirus communis* and *Malus* sp. This species was found in Restinclières on nine plant species and particularly on *Cornus sanguinea* (53%).

T. (*A.*) *cryptus* has already been reported in Italy, Spain and Chile (Moraes *et al.*, 2004). In France, it has been found on vines and in surrounding uncultivated areas (Kreiter *et al.*, 2000; Tixier *et al.*, 2000b). In this survey, this species was collected on nine plants but at very low densities (one individual per plant).

T. (*T.*) *phialatus* was the main species occurring in the uncultivated areas sampled and its proportion increased over the five years. This species was found on more than 60% of the plants and 62% of the individuals were found on *V. tinus, C. sanguinea, Q. coccifera, Q. ilex, Pinus halepensis* and *Rubia peregrina* (more discussion on the occurrence of this species can be found below).

TABLE 1. Phytoseiid mite occurrences on sampled plants in uncultivated areas in Restinclières (Hérault, France) from 1999 to 2003.

Plant species	Phytoseiid species (No. of individuals per plant)																														
	Ambyseius andersoni (Chant)	*Euseius finlandicus* (Oudemans)	*Euseius stipulatus* (Athias-Henriot)	*Kampimodromus aberrans* (Oudemans)	*Neoseiulus aurescens* (Athias-Henriot)	*Neoseiulus bicaudus* (Wainstein)	*Neoseiulus californicus* (McGregor)	*Neoseiulus cucumeris* (Oudemans)	*Neoseiulus graminis* (Chant)	*Neoseiulella tiliarum* (Oudemans)	*Paraseiulus triporus* (Chant & Yoshida-Shaul)	*Paraseiulus soleiger* (Ribaga)	*Phytoseiulus persimilis* Athias-Henriot	*Phytoseius echinus* Wainstein & Arutunjan	*Phytoseius juvenis* Wainstein & Arutunjan	*Phytoseius plumifer* (Canestrini & Fanzago)	*Proprioseiopsis messor* (Wainstein)	*Typhlodromus (Anthoseius) cryptus* (Athias-Henriot)	*Typhlodromus (Anthoseius) ilicis* (Athias-Henriot)	*Typhlodromus (Anthoseius) recki* (Wainstein)	*Typhlodromus (Anthoseius) rhenanoides* (Athias-Henriot)	*Typhlodromus (Anthoseius) rhenanus* (Oudemans)	*Typhlodromus (Typhlodromus) athiasae* Porath & Swirski	*Typhlodromus (Typhlodromus) ernesti* Ragusa & Swirski	*Typhlodromus (Typhlodromus) baccettii* Lombardini	*Typhlodromus (Typhlodromus) exhilaratus* Ragusa	*Typhlodromus (Typhlodromus) phialatus* Athias-Henriot	*Typhlodromus (Typhlodromus) pyri* Scheuten	*Typhloseiella isotricha* (Athias-Henriot)	*Typhloseiulus carmonae* (Chant & Yochida-Shaul)	*Typhloseiulus eleonorae* Ragusa	No. of phytoseiid species per plant
Acer sp.			1																								1					2
Acer monspessulanum L.																				1							1					2
Agrimonia eupatoria L.																				3							1					2
Alnus sp																											1					1
Arbutus unedo L.																											1					1
Asparagus officinalis L.																											3					1
Buxus sempervirens L.																											1					1
Carlina vulgaris L.																				1												1
Carpinus sp.																											1					1
Celtis australis L.			1	53									1			2		1		1		2				1	3					9
Clematis flamula L.																			6													1
Clematis vitalba L.	2	1																									5					3
Conyza sumatrensis (Retz)	1	1																		1		1					3			1		6
Cornus sp.																											2					1
Cornus sanguinea L.				1																		1			9		24				6	5
Corylus sp.				3																1							1					3
Crataegus sp.																				1												1
Cupressus sp.																		1		1							1					3
Cytisus sp.																											1					1
Daphne gnidium L.				1																							4					2
Dorycnium suffruticusum Viller																				1						2	6					3
Echium vulgare L.																											1					1
Erica multiflora L.																											1					1
Euphorbia pepilis L.																									1							1
Euphorbia serrata L.																											1					1
Fraxinus sp.				7														1		1							1					4
Fraxinus excelsior L.																	1				1					7	7					4
Fraxinus ornus L.																		1		1												2
Galium sp.								1																								1
Genista scorpius (L.)																									1	1	6					3
Helianthemum vulgare Gaertner																											1					1
Inula viscosa (L.)																				1							1		74			3

Juglans nigra L.																				1											1
Juglans regia L.																				1											1
Juniperus sp.																										2					1
Juniperus oxycedrus L.				6								3												2			5				4
Laurus sp.				1																1											2
Lavandula spica L.																				2							5				2
Liriodendrons sp.				1																	1						1				3
Lonicera sp.				3																2		2					2				4
Lonicera caprifolium L.				1																1							9				3
Malus domestica Borkh	1			1										1				1		1							1				6
Malva sylvestris L.				2														1		3							1				4
Morus sp.												1															1				2
Olea europea L.																											1				1
Ostrya carpinifolia Scopoli																												1			1
Phyllirea sp.																											2				1
Phyllirea angustifolia L.																						7					6				2
Phyllirea media L.				1																							2				2
Pinus brutia (Ten.)																				1						1					2
Pinus halepensis Miller																					1					1	17				3
Pirus communis L.					1																						1				2
Pistacia lentiscus L.																									1	1	3				3
Plantago lanceolata L.									1									1		2							1				4
Poterium sanguisorba L.																										1					1
Prunus sp.					2									1											1						3
Prunus avium (L.)			1	1																1							1				4
Prunus dulcis Miller																											1				1
Prunus persica (L.)																											1				1
Prunus spinosa L.							1																								1
Prunus mahaleb L.					3					1																	1				3
Quercus coccifera L.									1			1						1	2						1		17				6
Quercus ilex L.				1														1	1	6			1	1			18	1		1	9
Quercus pubescens Willdenow				11																											1
Rosa canina L.																											3				1
Rosmarinus officinalis L.																				1							4				2
Rubia peregrina L.																											17				1
Rubus sp.	1						2								1	1					1					1	3				7
Ruscus aculeatus L.				1																											1
Sophora japonica L.			1			1					1															1					4
Sorbus domestica L.		1		1																23					1	7	4				6
Syringa sp.				1																											1
Thymus vulgaris L.				2										1											1		6				4
Tilia sp.			1	8																1	1					1					5
Ulmus sp.				1						1				4						7				1			5				6
Viburnum tinus L.				1										1							1				1	3	168				6
No. of host plants	4	3	5	23	3	1	2	1	2	2	1	3	1	5	1	2	1	9	3	28	6	5	1	3	9	13	57	2	1	2	1	

K. aberrans was found on 23 plants but high densities (78%) were only found on *C. australis*, *Q. pubescens*, *Tilia* sp., *Fraxinus* sp. and *J. oxycedrus*. This species occurred in vineyards in several countries: France, Spain, Italy, Switzerland and Portugal (Moraes *et al.*, 2004), and is known to reduce population densities of some species of Tetranychidae and Eriophyidae (Ivancich-Gambaro, 1987; Kreiter *et* *al*., 2000). This species can also feed on pollen (Daftari, 1979). *K. aberrans* is essentially found in vineyards in the South of France, perhaps because it is adapted to hot and dry climatic conditions and to agricultural practices (Tsolakis *et al*., 1997; Kreiter *et al*., 2000; Tixier e*t al*., 2000b).

Other species [*i.e, Amblyseius andersoni* (Chant), *Neoseiulus aurescens* (Athias-Henriot), *N. californicus* (McGregor), *N. cucumeris* (Oudemans), *N. graminis* (Chant)] were found more sporadically (Table 1). These species have been found in France and in other countries of Europe on several crops such as soybean, citrus, orchards and on weeds (Kreiter & Brian, 1986; Kreiter *et al*., 2000; Tixier *et al*., 2000b; Moraes *et al*., 2004).

According to the classification proposed by McMurtry & Croft (1997), the species found in this survey belong mainly to the type-3 category, corresponding to generalist polyphagous predators. These type of predators could colonise minimally perturbed environments with low levels of prey (Kreiter & Sentenac, 1995; Tixier *et al*., 2000b).

The number of phytoseiid mite species found in uncultivated areas was high (21 species) in 1999, and then decreased to six species in 2003. The maximal value of the Shannon index and equitability were found in 1999 and then decreased (Table II). This decrease could be due to the sporadic presence of several species belonging to various genera, such as *Amblyseius*, *Euseius*, *Neoseiulus*, *Paraseiulus* and *Phytoseius*, which were found only for one or two dates and in very low densities, and also to the proportion of *T.* (*T.*) *phialatus,* which increased from 1999 to 2003, to become the dominant species in the uncultivated areas sampled. This species was reported in Algeria (Athias-Henriot,1960), is known to feed on *Panonychus citri* (McGregor), *Tetranychus urticae* Koch and pollen, and has a great economic impact in Spain (Ferragut *et al*., 1987).

The number of species encountered in this survey (31) was higher than in the previous one (14). However, the number of plant species sampled was also higher in the present study (94 instead of 34 for the previous location). This result seems to confirm the hypothesis of the enhancement of faunistic diversity and, in this case, phytoseiid mite diversity in relation to plant diversification (Rieux *et al*., 1999).

Even if a high number of species was reported in the two surveys, we found that a different single species was dominant in each case. The dominant species was *T.* (*T.*) *phialatus* in the present study and *K. aberrans* in the previous one. These two species are commonly found in vineyards in the south of France, and *T.* (*T.*) *phialatus* in vineyards and orchards in northeastern Spain (Ferragut *et al.*, 1987; Tixier *et al*., 1998; Kreiter *et al*., 2000). The dominance of one species in the two locations surveyed suggests the considerable impact of selective factors in areas adjacent to cultivated areas. Agricultural practices, especially pesticide drifts, certainly affect the diversity of phytoseiid mites able to develop in these areas. Furthermore, pesticide drifts would also affect food (prey, fungi) availability and diversity in these zones (Tsolakis *et al*., 1997).

T. (*T.*) *phialatus* is quite rare in France but is widespread in Spanish vineyards. In southern France, *K. aberrans* is the species most commonly encountered (Kreiter *et al*., 2000). Several factors could explain the dominance of *T.* (*T.*) *phialatus* in the present study instead of *K. aberrans*. The soil, the micro-climatic conditions and, consequently, the type and the dynamics of plant communities are different in the two sites surveyed. The area studied in Restinclières was just recently cultivated on reclaimed fallow land on superficial, calcareous, stony and dry soil. The surrounding vegetation is in a dynamic process and is mainly composed of *P. halepensis*, *Q. ilex*, *Q. coccifera* and *V. tinus*, resulting in drier conditions than at the previous site (deep alluvious soils, old vineyards) where plant species encountered in the surrounding vegetation were in a more stable phase. These included *Q. pubescens*, *Rubus* sp. and *C. australis*. These climatic and soil conditions leading to different plant composition and community dynamics could explain the dominance of *T.* (*T.*) *phialatus* in Restinclières instead of *K. aberrans,* on the basis of relationships between plants and phytoseiid mites (Kreiter *et al*., 2002a). On the one hand, some of the plant species common to Restinclières, such as *Pinus* sp. and *R. officinalis,* are known to be hosts for *T.* (*T.*) *phialatus* (Moraes *et al*., 2004). On the other hand, since the main plant species found in Restinclières are glabrous, they are not suitable for *K. aberrans,* especially because of their leaf characteristics (Kreiter *et al*., 2002a).

TABLE 2. Shannon index, equitability index and number of phytoseiid mites found in funnels and in uncultivated areas in Restinclières (Hérault, France) from 1999 to 2003.

Phytoseiid species	Uncultivated areas					Funnels				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
Amblyseius andersoni (Chant)	5									
A. obtusus (Koch)									2	
A. rusticana (Athias-Henriot)						1				
Euseius finlandicus (Oudemans)		3								
E. stipulatus (Athias-Henriot)		5					1			
Kampimodromus aberrans (Oudemans)	2	47	20	34	6		7	1		
Neoseiulus aurescens (Athias-Henriot)	6					2		1		
N. barkeri (Hughes)						2		1		
N. bicaudus (Wainstein)	1									1
N. californicus (McGregor)	1	2								
N. cucumeris (Oudemans)	1							1		
N. graminis (Chant)			1	1						
Neoseiulella tiliarum (Oudemans)	2									
Paraseiulus triporus (Chant & Yoshida-Shaul)			1						1	
P. soleiger (Ribaga)		5								
Phytoseiulus persimilis Athias-Henriot	1									
P. echinus Wainstein & Arutunjan	8									
P. juvenis Wainstein & Arutunjan	1									
P. plumifer (Canestrini & Fanzago)	3									
Proprioseiopsis messor (Wainstein)	1									
P. okanagensis (Chant)							1			
Typhlodromus (*Anthoseius*) *bakeri* (Garman)										1
T. (A.) cryptus (Athias-Henriot)		5		4		6			1	
T. (A.) ilicis (Athias-Henriot)	4			3	2					
T. (A.) intercalaris (Livshitz & Kuznetsov)						2				
T. (A.) recki (Wainstein)	18	14	3	14	19	1	2		2	
T. (A.) rhenanoides (Athias-Henriot)	6									
T. (A.) rhenanus (Oudemans)	2	3	4	1	3			3		
T. (Typhlodromus) athiasae Porath & Swirski	1						1			
T. (T.) ernesti Ragusa & Swirski	4									
T. (T.) baccettii Lombardini	4	4	9						1	
T. (T.) exhilaratus Ragusa		4	5	5	14			1	1	
T. (T.) phialatus Athias-Henriot	42	53	67	83	143	2	5	2	4	
T. (T.) pyri Scheuten		1	1						1	
Typhloseiella isotricha (Athias-Henriot)	24	38	11	1		1				
Typhloseiulus carmonae (Chant & Yoshida-Shaul)		2					2			
T. eleonorae Ragusa			4	2						
Total number of species	21	14	11	10	6	8	7	7	8	2
Shannon index	0.83	0 .7	0.5	0.45	0 .36	0.8	0.7	0.7	0.7	0.3
Equitability index	0.6	0.6	0.48	0.45	0.46	0.9	0.85	0.84	0.83	1

Finally, in laboratory experiments, Ferragut *et al.* (1987) have shown that *T.* (*T.*) *phialatus* can survive and develop at high temperatures (32°C) but no hatching was found at RH ú 50%. The mortality rate of *K. aberrans* eggs is 30% at 65% RH, and greater than 55% at RH=50% (Schausberger, 1998). Moreover, Malison (1994) showed that the development of *K. aberrans* is affected by water-stressed (lack of water) vine plants. On the basis of this study, it could be assumed that dry local climatic conditions could be unfavourable for *K. aberrans* (Tsolakis *et al.*, 1997).

Phytoseiidae in funnels:

Sixty-one individuals belonging to 22 species were captured in funnels from 1999 to 2003. This mite sample expressed low densities but a high degree of diversity.

T. (*T.*) *phialatus* was the most abundant species trapped, followed by *K. aberrans*, *T.* (*A.*) *cryptus* and *T.* (*A.*) *recki*. This result confirms previous data showing the aerial dispersal of phytoseiid mites (Tixier *et al.*, 1998, 2000b) and population exchanges between uncultivated areas and neighbouring vineyards. However, the number of trapped mites is low compared to previous data (Tixier *et al.*, 1998, 2000b). Low wind speed and frequency in Restinclières compared with values found at the previous site, differences in the orientation of the experimental plot in relation to the position of neighbouring areas where the phytoseiid mites originate, and the prevailing wind direction, could all explain this difference. However, differences in the specific dispersal abilities of the various species involved in the process could also play a role, but it is impossible to say since these abilities are unknown at this time.

One new species to the French fauna was trapped in the funnels: *Proprioseiopsis okanagensis* (Chant). This species was captured only one time in 2000. It was previously reported in Europe and in Canada where it was observed on peach trees (Moraes *et al.*, 2004). This species was never collected in the uncultivated areas, suggesting its low abundance in the neighbouring environment. The number of phytoseiid mite species found in funnels was eight in 1999 and 2002 (Table 2), seven in 2000 and 2001, and two in 2003. The Shannon index and equitability showed that the specific diversity was high from 1999 (H' = 0.8, E = 0.9) to 2002 (H' = 0.7, E = 0.83). In 2003, H' decreased to 0.3 and E = 1. This result could be explained by the low number of individuals trapped, especially in 2003, because of the heat wave.

Conclusion

Thirty-seven phytoseiid mite species were reported on 76 host plants and in funnels. A single association between a predator and a host plant was found (*T. isotricha* — *I. viscosa*). Twenty-two species were trapped in funnels. This study provides new faunistic data and records of phytoseiid mites in France. Furthermore, this survey adds to our knowledge concerning phytoseiid mites and plant associations, essential for the application of biodiversity management in agrosystems. Some species, such as *T.* (*T.*) *phialatus* or *K. aberrans,* were found in cultivated and uncultivated areas. Other species whose biology is poorly known but that may be effective in controlling phytophagous mites were found only in uncultivated areas. The diversity and density of phytoseiid mite seem to depend on several factors: primarily, on soil and climatic conditions, the history of plant community evolution determining the type of vegetation and floristic composition, and also on the history of land use and agricultural practices. The hypotheses arising from this study could have implications for biodiversity management in uncultivated areas within a biological control framework. However, in order to determine the main factors affecting biodiversity and the abundance of phytoseiid mites, more surveys must be carried out, with specific emphasis on climatic, soil, ecological conditions and land use characteristics, as well as the evolution over time of the concerned agrosystems.

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