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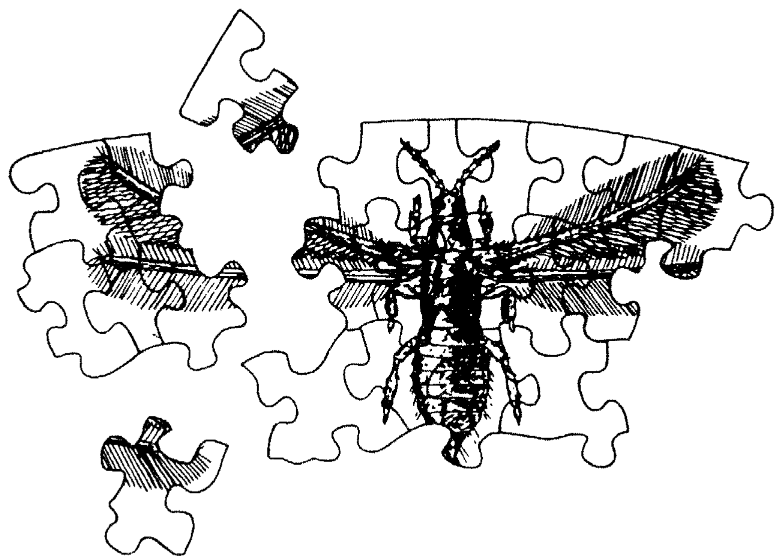

Editors:

Bruce L. Parker
Margaret Skinner
Trevor Lewis

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TOWARDS UNDERSTANDING THYSANOPTERA

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Edited by:

Bruce L. Parker
Margaret Skinner

Entomology Research Laboratory
The University of Vermont
South Burlington, VT USA

and

Trevor Lewis

Institute of Arable Crops Research
Rothamsted Experimental Station
Harpenden, Hertfordshire UK

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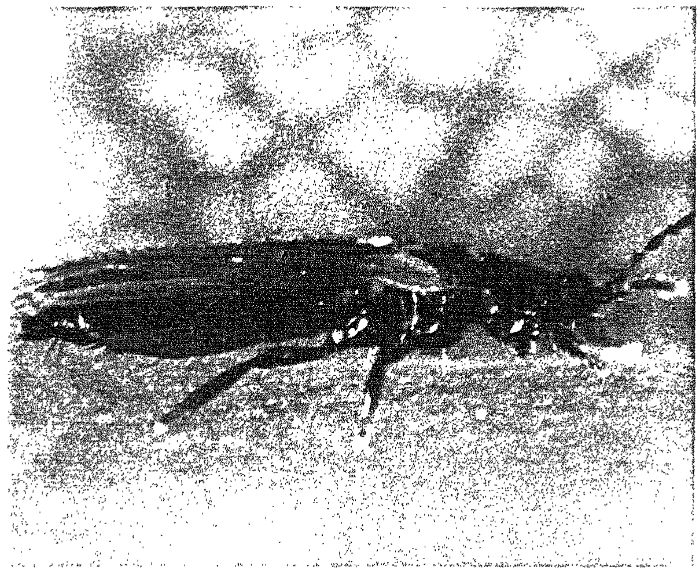

PEAR THRIPS, *Taeniothrips inconsequens* (Uzel)
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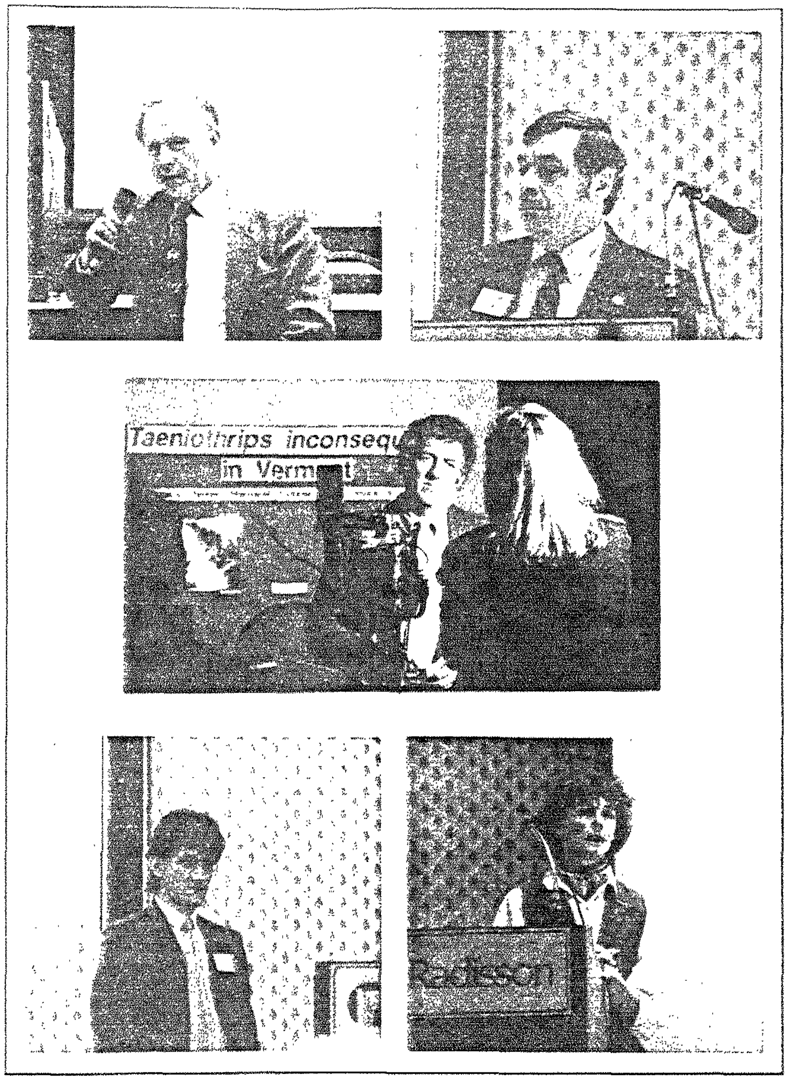

A few of the conference participants (from top left to bottom right): Trevor Lewis, Institute of Arable Crops Research; Conrad Motyka, VT Department of Forests, Parks and Recreation; Bruce L. Parker, The University of Vermont; Nick J. Mills, Commonwealth Institute of Biological Control; Margaret Skinner, The University of Vermont.

PREFACE

Pear thrips, *Taeniothrips inconsequens (Uzel)*, first surfaced as a pest of sugar maple, *Acer saccharum* Marsh, in Pennsylvania in the late 1970s. Though similar damage was observed in Vermont in the early 1980s, it was probably misdiagnosed as frost damage until 1985, when finally thrips were positively confirmed as the causal agent. Pear thrips damage to sugar maple fluctuated greatly from year to year, raising only slight concern among sugarmakers and forest managers. However, the situation changed dramatically in the spring of 1988, when pear thrips caused widespread, severe foliage damage to sugar maple in southern Vermont (over 200 thousand hectares) and other New England States. Recognized as a potential threat to forest health, pear thrips received tremendous media coverage, including the front page of the New York Times and the CBS Evening News!

The response in Vermont to this crisis was swift. With support from the Vermont legislature and the Department of Agriculture, a major research effort was launched, coordinated jointly by the University of Vermont and the VT Department of Forests, Parks and Recreation. This pest presented unique research and management challenges. Pear thrips on sugar maple represented a known pest on a new host in a new habitat. As of 1988 almost no information existed on this insect in a sugar maple forest. In addition thrips in general were virtually unknown as a northern hardwood forest pest, and forest managers knew little about how to handle such an insect. Finally, because thrips are such small insects, new and specialized methods were needed for survey and study of this pest.

As Vermont's research efforts got underway, it became clear that much could be learned from scientists familiar with other thrips species. The goal of this conference was to gather these specialists together to present their ideas on thrips survey and management methodology, particularly as it related to pear thrips in a forest setting. Participants came from across the United States, Canada and the United Kingdom to share their expertise. Though many didn't know that a "sugarbush" was not a shrub, but a natural stand of mature 30-m-tall sugar maple trees (100 ft), they all knew what maple syrup was! Certainly by the end of the conference all of the participants recognized the unique value of the sugar maple to the heritage and economy of Vermont and the Northeast, and shared our concern for its future in light of the threat of pear thrips.

We thank all of the conference participants who freely and enthusiastically shared their knowledge. Without their expertise and continued technical support, our pear thrips research would not have progressed as far or as fast as it has. We thank all those attending the conference for helping to make it a productive event. Though the pear thrips problem is far from being "solved," this conference started the research process on a solid footing.

THRIPS BIOCONTROL: OPPORTUNITIES FOR USE OF NATURAL ENEMIES AGAINST THE PEAR THRIPS

THRIPS BIOCONTROL: OPPORTUNITIES FOR USE OF NATURAL ENEMIES AGAINST THE PEAR THRIPS

Nick J. Mills[1]

Commonwealth Agricultural Bureaux
International Institute of Biological Control
Silwood Park
Ascot, Berkshire UK

Abstract

Thrips have been considered as both target pests and control agents in biological control. The main emphasis of this paper concerns the natural enemies of thrips and an appraisal of the potential for biological control of the pear thrips on sugar maple in the northeastern United States. Previous attempts at biological control of thrips pests have been confined to the Caribbean and Hawaii and have made use of eulophid larval parasitoids and anthocorid predators as control agents. A review of the literature indicates that while these two groups often figure most strongly in natural enemy complexes of thrips, fungal pathogens are an important, if neglected, group. For biological control of pear thrips it is considered that synchronized univoltine parasitoids and fungal pathogens from Europe, the region of origin of the pest, show most promise as potential biological control agents.

Introduction

Biological control has been widely practiced worldwide as an effective means of controlling accidentally introduced pests by the importation and release of specific natural enemies from their region of origin (Clausen 1977, Julien 1987). This approach led to the successful

[1]Current address: Div. of Biological Control, Univ. of Calif., Albany, Calif.

control of the cottony cushion scale, *Icerya purchasi* Maskell in California one hundred years ago through the importation of the Vedalia beetle, *Rodolia cardinalis* (Mulsant) (Caltagirone & Doutt 1989). While chemical treatments dominated pest management in the post-war years, environmental concerns have brought biological control back to the forefront of current integrated pest management practices.

Biological control of forest insects (Pschorn-Walcher 1977, Waters et al. 1976, Turnock et al. 1976) has enjoyed a long and successful history of natural enemy importations. The Commonwealth Institute of Biological Control (CIBC) database of classical biological control importation, BIOCAT, records 360 natural enemies released against 42 forest pests. From these importations, 29% have become established in the target area and 34% of these have provided at least some degree, if not lasting, of control. A recent review of the suitability of forest environments for biological control and the success or failure of key case histories is provided by Dahlsten & Mills (in press).

Thrips have figured in biological control both as target pests and as natural enemies of weeds. Four thrips have been targets for biological control (Table 1) and the natural enemy agents selected for importation have included both predators and parasitoids. The results of importations have not been so successful, with only the anthocorid, *Montandoniola moraguesi,* being credited with providing at least partial control of the ornamental laurel thrips, *Gynaikothrips ficorum* (Marchal) (Cock 1985). As biological control agents of weeds, thrips have had greater success (Table 2). Of two earlier projects one is a complete success and the other is uncertain due to confounding effects of other simultaneously imported and released agents.

Table 1. Classical biological control projects against thrips, data from Clausen (1977), Cock (1985) and McMurtry (this publication)

Target	Region (Date)	Agent (Origin)	Result
Thrips tabaci	Bermuda (1938) Hawaii (1930-32)	*Ceranisus brui* (Japan) *C. russelli* (USA) *C. vinctus* (Philippines) *Goetheana parvipennis* (Ghana)	- Established
Selenothrips rubrocinctus	Caribbean (1936-37) Hawaii (1936)	*Goetheana parvipennis* (Ghana)	- Established
Gynaikothrips ficorum	Hawaii (1964-65)	*Macrotrachelia thripiformis (Mexico)* *Montandoniola moraguesi* (Philippines) *Orius tristicolor* (USA) *Chrysopa* sp. (Mexico)	- Established
	Bermuda (1960-63, 1973)	*Montandoniola moraguesi* (Philippines) *Goetheana parvipennis* (Ghana) *Thripastichus gentilei* (Brazil)	- Provides partial control
Heliothrips haemorrhoidalis	California (1987?)	*Thripobius semiluteus* (Japan/Argentina)	- Probably established

Table 2. Weed biocontrol projects using thrips as natural enemies, data from Julien (1987) and Greenwood & Mills (1989)

Target	Region (Date)	Agent (Origin)	Result
Clidemia hirta	Fiji (1930)	*Liothrips urichi* (Trinidad)	Good lasting control
Alternanthera philoxeroides	Florida (1967)	*Amynothrips andersoni* (Brazil)	Uncertain
Mikania micrantha	Solomon Islands (1988) Malaysia (1989)	*Liothrips mikaniae* (Trinidad)	Not yet known

The Pear Thrips as a Target for Biological Control

The pear thrips, *Taeniothrips inconsequens* (Uzel), is an infrequent European thrips that was accidentally introduced into North America around the turn of the century. It initially caused some concern in pear and plum orchards in California but since the early 1980s has been responsible for severe defoliation of sugar maple in Vermont, Pennsylvania and Connecticut (see Parker, this publication).

The biology, life cycle and natural enemies of the pear thrips have not been studied in detail either in Europe or the United States. General observations from the United States (Foster & Jones 1915; Skinner et al., poster presentation, this publication) indicate that adults emerge from the soil in spring to feed on the expanding buds of the host tree. Adults oviposit on the leaves and the two larval stages then feed on the foliage for 4-6 weeks before dropping to the soil to produce earthen cells for overwintering.

Observations from Europe (Priesner 1924, Blunck & Neu 1949) indicate that the pear thrips is widespread in northern and central Europe and differs from the United States populations by the occurrence of males (Bournier 1956). Food plants include trees of the genera *Aesculus*, *Acer*, *Crataegus*, *Juglans*, *Malus*, *Pirus*, *Prunus*, *Populus* and *Salix*. Adult fecundity is estimated as approximately 100-200 eggs and adult feeding and larval development tend to occur between mid-March and the end of May.

Since no specific studies of the natural enemies of the pear thrips have been made, it is necessary to take a look at natural enemies of thrips in general to get an appreciation of the types of organisms likely to be associated with the pear thrips in Europe.

Thrips Natural Enemies

Predators

The slow moving larval thrips are easy prey for a wide range of general arthropod predators (Table 3). The majority of these accept a wide range of prey and thrips may not represent their preferred host in many cases. Some of the more specific thrips predators are the Aeolothripidae, the anthocorid genera *Orius* and *Montandoniola*, the cecidomyiid genus *Thripsobremia* and the sphecid genus *Microstigmus*.

Anthocorids have an important impact on thrips populations in cotton (Stoltz & Stern 1978), in soybean (Irwin & Kuhlman 1979), in ornamental fig (Cock 1985) and in Glyricidia flowers (Viswanathan & Ananthakrishnan 1974). In addition, the coccinellid, *Scymmus thoracicus*, is suggested to be able to regulate populations of *Chaetanaphothrips orchidii* (Moulton) on banana (Delattre & Torregrossa 1978). Most other predators will contribute to the control of their prey populations but are unlikely to be useful as biological control agents. In the context of glasshouse crops, the phytoseiid mites, *Amblysieus cucumeris* and *A. mackenziei* are mass reared for the control of *Thrips tabaci* (Ramakers 1983). Again, these mite predators are not so specific in their diet and can only be effective in confined situations.

Parasitoids

Thrips are attacked by both egg and larval parasitoids (Table 4). Egg parasitoids of the genus *Megaphragma* are some of the smallest known insects and have been recorded from a variety of thrips species (Lewis 1973). They have been little studied (McMurtry 1961), and do not appear to contribute significantly to thrips mortality. In contrast, the eulophid larval parasitoids play a more dominant role with 70-80% parasitism being recorded for *Ceranisus* species on bean thrips (Russell 1912), pea thrips (Kuetter 1936), onion thrips (Sakimura 1937); for *Goetheana parvipennis* on cocoa thrips (Cotterell 1927) and *Thripastichus gentilei* on olive thrips (Melis 1934).

Table 3. The range of arthropod predators known to attack thrips

Order	Family	Species	Reference
Thysanoptera	Aeolothripidae	*Aeolothrips* spp.	Bournier et al. 1978
		Franklinothrips spp.	Callan 1943
Hemiptera	Anthocoridae	*Orius* spp.	Irwin & Kuhlman 1979
		Montandoniola moraguesi	Muraleedharan & Ananthakrishnan 1978
	Lygaeidae	*Geocoris tricolor*	Ananthakrishnan 1984
	Miridae	*Termatophylidea* spp.	Doesberg 1964
Neuroptera	Chrysopidae	*Chrysopa* spp.	Callan 1943
Coleoptera	Coccinellidae	*Adalia* spp.	Priesner 1964
		Coccinella spp.	Ghabn 1948
		Scymnus spp.	Dyadechko 1977
	Malachiidae	*Malachius viridis*	Tansky 1958
Diptera	Syrphidae	*Metasyrphus corollae*	Ghabn 1948
	Cecidomyiidae	*Thripsobremia liothrips*	Barnes 1930
Hymenoptera	Sphecidae	*Microstigmus thripictenus*	Matthews 1970
Acari	Pyemotidae	*Adactylidium nicolae*	El Badry & Tawfik 1966
	Phytoseiidae	*Amblyseius cucumeris*	
		A. mackenziei	Ramakers 1983

Table 4. Egg and larval parasitoids of thrips

Family/ Genera/species	Host stage attacked	Distribution
Trichogrammatidae		
Megaphragma spp.	Egg	Tropical & sub - tropical
Eulophidae		
Ceranisus (= *Thripoctenus*)	Larval	Temperate - tropical
Goetheana parvipennis	Larval	Tropical & sub - tropical
Thripastichus (= *Tetrastichus*) spp.	Larval	Temperate - tropical
Thripobius spp.	Larval	Tropical & sub-tropical
Thripoctenoides gaussi	Larval	Temperate

The biologies of the larval parasitoids are similar (Russell 1912, Sakimura 1937, Dohanian 1937, Bournier 1967). Adults live approximately 3 weeks and oviposit into young thrips larvae. The solitary endoparasitoid larvae kill and pupate within the host pre-pupae and the life cycle is completed in about one month. The parasitoids are generally multivoltine, although there is some evidence that, at least in the case of *Thripastichus gentilei*, diapause may be controlled by that of its host. In association with the laurel thrips both host and parasitoid have continuous generations (Bournier 1967) but in association with the olive thrips, which has an overwintering adult diapause, the parasitoid remains in host pre-pupae from October through to April (Melis 1934).

Pathogens

Allantonematid nematodes have occasionally been found infesting thrips but records are few (Ananthakrishnan 1984). While these nematodes are internal parasites, they do not cause the death of their host and their impact is confined to a reduction of adult fecundity. It is probable that arboreal thrips, such as the pear thrips, are not attacked by nematodes on the foliage of their hosts but may well be attacked during the long period spent in the soil.

Raizada (1976a) notes the occurrence of heavy microsporidial infection of *Scirtothrips oligochaetus* on cotton but this is the only known record. In addition, there are no known viral (Martignoni & Iwai 1981) or bacterial diseases of thrips.

Thrips are attacked by fungi of many genera including *Beauveria*, *Neozygites* (*Entomophthora*), *Verticillium*, *Paecilomyces* and *Hirsutella* (Raizada 1976b). *Beauveria bassiana* infected up to 20% of larvae of *Haplothrips tritici* in Bulgaria (Lyubenov 1961) and probably attacks all thrips that pupate or overwinter in the soil. Two species of Entomophthorales have been described (MacLeod et al. 1976, Samson et al. 1979) that infest larval hosts while feeding on foliage and a *Hirsutella* sp. nov. has recently been isolated by CIBC from foliage feeding larvae of *Liothrips mikaniae* (Greenwood & Mills 1989). *Verticillium lecanii* gives good control of *Thrips tabaci* in glasshouses (Gillespie et al. 1983) and a water-miscible formulation reached an advanced stage of commercial development in England. While there are no records of fungal pathogens of the pear thrips it is probable that such natural enemies do exist, at least in their region of origin.

Appraisal and Discussion of the Potential of Natural Enemies for Biological Control of Pear Thrips

It is clear from the literature that pear thrips has not been a pest of concern in Europe in recent years and that it has never been considered a pest of broadleaf forest trees. The host range of the pear thrips in its native Europe is not well known but it appears to be more of an orchard than a forest species. No study of the natural enemies of the pear thrips has been made in Europe and it is not possible, therefore, to assess their role in maintaining this species at endemic densities in its area of origin.

Nutritional factors may affect the abundance of thrips populations and may be one of the factors involved in the recent outbreak of the pear thrips on sugar maple in the United States. Fennah (1955, 1965), in some classic studies of the cocoa thrips in Trinidad, found that the establishment of thrips on particular trees or parts of the trees was related to the extent of derangement of normal host tree physiology. Adverse factors affecting normal leaf metabolism lead to increased nitrogen availability and higher thrips populations. Similar interactions could occur between pear thrips and sugar maple trees, brought about by the action of recent years of lower than average rainfall or increased levels of acid rain. Fertilization to improve general tree health could be experimentally investigated as a means to reduce levels of thrips infestation.

Of the natural enemies that are known to attack thrips, predators are the least specific and of least interest in terms of potential for biocontrol. While some success has been achieved in Bermuda with the anthocorid *Montandoniola moraguesi* (Cock 1985), temperate predators appear less promising. These are represented by congeneric species in both the Nearctic and Palearctic faunas and the importation of European predators does not seem warranted.

Egg parasitoids appear to be infrequent and to have little impact on their host populations. Larval parasitoids, such as *Ceranisus* spp., have a very significant impact on their hosts but little is known of their host range or habitat preferences. The majority of host records for *Ceranisus* species are from the Thripidae (family including the pear thrips) but most records are from hosts feeding on crops and other low growing plants. This probably reflects the greater attention that has been paid to thrips pests of agricultural and horticultural importance, rather than a distinct habitat preference of the parasitoids. The most frequent species, *C. russelli*, is Holarctic but a number of other species are known from the Palearctic region. In contrast, *Thripastichus* species appear to be more associated with the Phlaeothripidae, and most of the records are from arboreal hosts. *T. gentilei* is an important parasitoid in Europe and there is some evidence that diapause in this species may be controlled by the host (Melis 1934).

The univoltinism and restricted time period in which the pear thrips is active above ground poses difficulties for biocontrol by parasitoids. To be able to use parasitoids effectively, a species must be found that can be induced into diapause by the host to provide the necessary synchronization and independence from alternative hosts. The currently known parasitoids are multivoltine and are better known from multivoltine thrips hosts. However, the limited knowledge of these parasitoids suggests that parasitoid diapause may well be controlled by that of the host. Thus the diapause of the pear thrips may induce univoltinism in some of the parasitoids. If not, then it is unlikely that parasitoids would be able to inflict significant levels of parasitism on this host, particularly at the early stage of the season when the pear thrips is active.

Of the known or probably occurring pathogens, the allantonematid nematodes have little potential for use in biocontrol. Nematodes of the genera *Heterorhabditis* and *Neoaplectana* have far greater potential for control of the pear thrips in the soil and local Vermont strains of these entomopathogenic genera, isolated from the soil in sugar maple forests would be the most appropriate to use in experimental trials.

Very little is known of the fungal and other pathogens of thrips and there are no records from the pear thrips. Rather than indicating an absence of important pathogens this is likely to reflect a lack of investigations on these rather small and often insignificant hosts. In recent years species of Entomophthorales have been discovered attacking thrips and it is probable that a range of other thrips-specific fungi have yet to be discovered. Members of the Entomophthorales and other specialized fungal pathogens infesting the pear thrips could be considered for classical biocontrol introductions. A precedent for this exists in the recent establishment in Australia of an introduced strain of *Erynia radicans* for control of the alfalfa aphid, an exotic pest (Milner et al. 1982).

Other fungi, such as *Beauveria*, *Metarhizium* and *Verticillium* species, can be more readily mass produced and formulated for application as myco-pesticides. The most appropriate fungal strains to use in either case would probably be those isolated from the pear thrips in its region of origin.

Several precedents exist for the application of formulated pathogens to perennial crops and forests. *Beauveria brongniartii* has been sprayed on swarming adults of the European cockchafer *Melolontha melolontha* (Coleoptera: Scarabaeidae) with subsequent contamination and suppression of larval populations in the soil for several years (Keller 1986). This success is encouraging for pear thrips control because here too, application of the pathogen to the insect on the trees could lead to an increase in the soil population of the pathogen and consequent long-term suppression of the pest.

Very large areas can be treated with myco-pesticides. In Brazil, 6000 ha are treated with the fungus *Metarhizium anisopliae* to control the spittlebug, *Mahanarva posticata* (Hemiptera: Cercopidae) (e.g., Ferron 1981). Even larger areas of Canadian forests are aerially sprayed with commercial formulations of *Bacillus thuringiensis* to control the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) (Morris et al. 1986). In this last case it was public concern about environmental damage from chemical control measures that led to the adoption of *B. thuringiensis* by the Canadian authorities. The environmental safety of biological pesticides is of particular relevance where large areas of land such as forests must be treated.

The conidia of dry-spored fungi such as *Beauveria* and *Metarhizium* are hydrophobic and are miscible in oil. Such oil formulations are much more infective than water suspensions because the oil adheres to the insects' cuticle (Prior et al. 1988). Oil formulations would be suitable for ultra-low volume aerial spraying, where the use of water sprays is precluded by their rapid evaporation and the large volumes of water required. The prospects for developing an oil-based, ultra-low volume myco-pesticide against pear thrips are good.

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