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WORKING GROUP 'INTEGRATED CONTROL IN GLASSHOUSES'

GROUPE DE TRAVAIL 'LUTTE INTEGREE EN CULTURES SOUS VERRE'

PROCEEDINGS AND BIBLIOGRAPHY OF

COMPTE-RENDU ET BIBLIOGRAPHIE DE

FRANKLINIELLA OCCIDENTALIS

EDITED BY J.C.VAN LENTEREN

EDITE PAR & L.R.WARDLOW

AALSMEER (THE NETHERLANDS)

14 - 17 DECEMBER 1987

WPRS BULLETIN

BULLETIN SROP

1989 / XII / 3

International Union of Biological Sciences

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL AND INTEGRATED CONTROL OF NOXIOUS ANIMALS AND PLANTS

WEST PALAEARCTIC REGIONAL SECTION

IOBC WPRS — OILB SROP

WORKING GROUP
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PREFACE

At the last full meeting of the IOBC/WPRS Working Group "Integrated Control in Glasshouses" in Budapest, Hungary, in April 1987 one of the important conclusions was that biological control in ornamentals lagged far behind that in vegetables.

In order to find out why application of IPM in ornamentals is applied on such a small scale, a workshop was organized in December 1987 at the Research Station for Floriculture in Aalsmeer, the Netherlands.

The aims of the workshop were the following:

1. To identify the most important pest problems in ornamentals in Europe
2. To estimate which pests and crops show the best possibilities for application of biological control
3. To make an inventory of research programmes already in operation in different countries
4. To develop a programme for cooperation

Participation was limited to persons having experience with biological pest control in floriculture.

M. van de Vrie functioned as the local organizer of this workshop, and thanks to him we were able to have an excellent meeting. Moreover, his good contacts with many of the leading authorities in floriculture in Holland resulted in interesting excursions to auctions, growers and breeding companies. The Research Station of Floriculture is thanked for providing meeting room facilities.

These proceedings contain some of the papers read at the workshop, as well as a summary of the workshop. During the workshop it became clear that, both for vegetables and ornamentals, the recently invaded pest *Frankliniella occidentalis* is the most serious threat for IPM. Some of the participants knew that W.P. Mantel of the Research Institute for Plant Protection, at Wageningen, was working on a bibliography of this pest, and he was so kind to allow us to include this bibliography in these proceedings.

J.C. van Lenteren
Convenor

IOBC/WPRS WORKSHOP BIOLOGICAL CONTROL OF PESTS IN ORNAMENTALS IN GREENHOUSES

AALSMEER 14 - 18 DECEMBER 1987

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SUMMARY OF THE DISCUSSIONS

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Ten workers, each from a different cuntry and who had some experience of the topic, met at Aalsmeer to discuss the present state of IPM in ornamentals and the possibilities for expansion in the future. Only 20 ha of ornamentals are grown under IPM in the world compared with 4000 ha vegetables.

Most important pest problems

A list of pests in order of importance was prepared. It was difficult to generalise because some pests were specifically important in some countries i.e. tortricid moths on carnations in Italy.

1. Western flower thrips (Frankliniella occidentalis)
2. Spider mites (Tetranychid spp)
3. Glasshouse whitefly (Trialeurodes vaporariorum)
4. Tobacco or cotton whitefly (Bemisia tabaci)
5. Aphids (several species)
6. Onion thrips (Thrips tabaci)
7. Tarsonemid mites
8. Leafminers (Liriomyza spp)
9. Vine weevil (Otiorrhynchus sulcatus)
10. Caterpillars (several species)
11. Mealybugs (Pseudococcidae)
12. Fungus gnats (Sciaridae)
13. Leafhoppers (Hauptidia maroccana)

Three new problems were reported:-

(a) Rhopalosiphum rufiabdominalis feeding on roots of South American pot plants.
(b) An African Gracilis sp feeding on poinsettia.
(c) The mites Tyrophagus neiswanderi and T. putrescentiae.

Potential for biological control

The group discussed each pest in turn pooling their experience on the success of any biological controls that had been tried. Of course, information was very sparse in almost every situation.

(a) Western flower thrips

Early work had given disappointing results. In 1987 a rate of 100 Amblyseius spp per plant did not work in Gerbera in the Netherlands and multiple introduction of up to 23 per pot failed in chrysanthemums in England. A large amount of research was deemed necessary especially on the Amblyseius/Neoseiulus complex. Orius spp are being examined in North America and Anthocoris spp in Europe. Mass production of predatory bugs is difficult and is not being studied intensively.

(b) Spider Mites

There was widespread confirmation that Phytoseiulis persimilis is effective so long as temperatures and crop culture method were suitable. Metaseiulus occidentalis has worked well on roses and the Amblyseius complex showed possibilities. Macroliphius sp. (predators) may also offer possibilities as natural enemies of spider mites.

(c) Glasshouse Whitefly

Encarsia formosa is effective although there can be problems with low temperatures and some crops (i.e. hairy leaves). Verticillium lecanii had been useful in some circumstances but the product had been withdrawn from the market. Aschersonia aleyrodis would be useful if it were commercialised. Other Encarsia species, particularly Encrasia tricolor in Spain, could be investigated more intensively. there may be need for public education regarding unsightly black scales caused by Encarsia. Host-plant guality and cultural methods will be influencing the possible success of E. formosa introductions.

(d) Cotton Whitefly

Seemingly, Encarsia formosa will mature in Bemisia tabaci but pupae do not turn black, however, young scales may be attacked (UK experience 1987). A wide range of predators and parasites has been listed but little IPM work has been done. Much research is needed especially considering the problem of virus transmission by the pest.

(e) Aphids

There is small scale commercial production of the parasite Aphidius matricariae and the predator Aphidoletes aphidimyza for use in vegetables and both natural enemies are untested in ornamentals. There are special problems in mass production which have yet to be overcome.

The lacewing, Chrysopa perla is produced in some countries and its mass-rearing may be improved using an artificial egg system but it is untested in ornamentals, large numbers of the predator are usually necessary.

The fungal pathogen, Verticillium lecanii has worked well in chrysanthemums (UK) and has possibilities in other ornamentals if it returns to the market.

There were interesting possibilities with other species of Aphidius (i.e. A. colemanii in Sweden) and Praon volucre had received little attention. There was much research on Entomophthora in France and Belgium for use on cereals but there were production problems.

(f) Thrips tabaci

There was no evidence, but there were possibilities with Amblyseius spp that also might work against broad mite.

(h) Phytomyza syngenesiae

Dacnusa sibirica and Diglyphus isaea were successful on chrysanthemums in UK, the latter was preferred because leafminer larvae did not complete development and mines were less obvious (an important consideration when marked foliage detracts from the marketability of the crop). there were supply problems with Diglyphussp and commercial production needs to be stepped up even for present requirements. Research is carried out in France on mass production.

(i) Pseudococcidae

The limited requirements for natural enemies particularly for use in amenity plantscapes seemed adequately supplied at present. A predatory beetle and three hymenopterous parasites were in use. In Italy, Planococcus citri was a problem on the outdoor grapes and created pressure on protected crops.

(j) Vine Weevil

Parasitic nematodes (Heterorhabditis sp.) were successful in begonia and cyclamen in the Netherlands and Switzerland but they were expensive and supplies were inadequate. A Swiss production unit was interested in a fermentation method of mass-rearing. Crop culture methods may have to be adapted to suit the nematodes.

(k) Sciaridae

There was no evidence but it was expected that parasitic nematodes would be useful. Yellow sticky trapping is useful.

(l) Leafhoppers

A major problem in Italy and it will eventually occur on most crops where IPM is practised. Outdoor use of Beauvaria (USA) or Metarhizium (Brazil) offered some hope for the future but the attendant registration problems may preclude their use. Information on other natural enemies is lacking.

(m) Liriomyza trifolii

Diglyphys sp in combination with yellow sticky traps showed promise in France and Italy on Gerbera. The importance of Diglyphus strain should be considered.

(n) Caterpillars

Bacillus thuringiensis would normally be selected for use in IPM but this had failed against the complex of tortricid moths (Epichoristodes acerbella, Cacaecimorpha pronuba) on roses and carnations in Italy and France. For E. acerbella no parasites up to now being found. The nematode Neoaplectana steinerii works but is expensive. Pheromone work in Italy gave only partial success. In the Netherlands, fenoxycarb (a juvenile hormone) worked well against Clepsis spectrana. Some work using Trichogramma sp against Heliothis sp had occurred in France. The application of pathogens, for example viruses, may be worthwhile considering.

(o) Other Pests

Several species of mites in bulbs were of concern in Poland and may be suitable prey for Gasamid mites. Glasshouse symphilids often damage ornamentals but there were no ideas for biological control. Control of nematodes by trapping-fungi was being used in South America and would be worth investigation.

Potential of Ornamental Crops for Biological Pest Control

(a) Chrysanthemums

IPM programmes had been used in UK since 1979, these had been successfull in spite of the absence of a biological control of Thrips tabaci hence the recent advent of Amblyseius was welcome. In the Netherlands IPM was not possible because of "zero-tolerance" of pests in plants for export and it was difficult to see any change in this situation. In the UK Verticillium lecanii played an important role in IPM until it was taken off the market, aphid control by parasites and predators now required investigations (particularly the effect of the blackout or shading).

Western flower thrips threatens this crop worldwide and in most countries only the pesticide dichlorvos is giving adequate control. Since resistance to pesticides is a feature of this pest, a biological control is desperately needed for the future.

IPM on chrysanthemums can be complicated when several plants of the year-round crop are grown in one glasshouse (each planting is a crop) and growers'attitudes needed changing. The main basic rule for successful IPM was that plants must be touching one another at some point in order to provide bridges for predators to spread.

(b) Roses

Dutch and UK experience showed that P. persimilis does not spread well in the year-round crop due to the colony-forming habit of T. urticae on this plant. French and Polish experience on a non-year-round crop was successful and the predator also worked against T. cinnabarinus in France. The control of caterpillars, particularly Tortricids created great problems in Italy. The threat of western flower thrips and aphids would have to be considered in any future IPM. Sulphur fumigation will probably harm IPM. It should be possible to develop IPM programmes for this crop but much research was required.

(c) Carnations

Spider mites are the main problem in the UK and no evidence regarding P. persimilis is available. Thrips (T. tabaci, T. dianthi and F. occidentalis) may be controlled by Amblyseius sp but no work had been done. The main aphid species was Myzus persicae which is a good candidate for Aphidius spp. Most work had been done in Italy (some also in France) on the control of Tortricids using pheromones as a confusing technique, but the synthesis of the pheromone is expensive and methods have not yet proved fully successful. The crop is a prime candidate for IPM in spite of the difficulties.

(d) Gerbera

P. persimilis had worked well in France, Denmark, Italy and UK. In the Netherlands and Poland P. persimilis failed to control spider mite populations probably due to leaf structures and a dissimilar distribution of prey and predator where there may have been temperature problems. Whiteflies are a major nuisance on this crop but Encarsia formosa had worked well in Denmark, France and UK (a banker system using tobacco plants in the last case). There had been good results using Diglyphus sp against Liriomyza trifolii in France but there had been problems in the Netherlands where most of the leafminer larvae were found in fully expanded leaves and not in young or old leaves. Mass-trapping of leafminers with yellow traps had worked well in several countries.

Amblyseius spp had been used against thrips with inconclusive results (DK and UK) but broad mite was possibly controlled (UK). There was no definite evidence on aphids but a range of parasites and predators could be found in crops grown under IPM and prespects were promising. One of the main problems for the IPM could be the residues of pesticides used by propagators.

(e) Poinsettia

There was no published evidence but Encarsia formosa had worked well in UK and WG (one/two parasites per 10 plants weekly) in combating the increasing problem of pesticide resistance in glasshouse whitefly.

IPM would have expanded in UK except that Bemisia tabaci was introduced to most crops on material propagated in Netherlands so programmes were abandoned. the other major pest is the Sciarid that is controlled by soil drenches of diazinon.

(f) Hibiscus

An IPM programme against glasshouse whitefly and two-spotted spider mite had worked well in UK. Aphidoletes aphidimyza was under test for aphid control and Amblyseius spp would be used against thrips in 1988.

(g) Orchids

P. persimilis worked well in several countries but no other biological controls had been tested. Thrips, mealybugs and scales would have to be considered.

(h) Cyclamen

No evidence of biological control on this good candidate for IPM. Amblyseius spp would be attractive for control of cyclamen mite as well as thrips. Nematode should be used for vine weevil control.

(i) Saintpaulia

No experience of IPM but the threat of western flower thrips to this crop makes IPM important in future.

(j) Gladiolus

A popular crop in Poland where Amblyseius spp would be an attractive proposition if Taeniothrips simplex could be controlled.

(k) Other Ornamentals (potplants)

Only J. Reitzel (Denmark) had any appreciable experience; he kindly presented his information and described the approach of his employers C. Hansen's Biosystems. IPM had been practised on 50 holdings and included 16 ornamental species. For each grower a programme for each crop is designed to give protection up to 4 weeks before harvest, by which time if there are any pests they are treated with insecticides;this reduces the risk of affecting crop quality. Growers need to consider the layout of crops in the greenhouse in order to get maximum benefit from IPM. Variability in pest susceptibility according to crop species, cultivar or stage or growth could often be used to manipulate IPM. Training of growers (and their substitutes) was essential in order that IPM is monitored satisfactorily.

Future Research and Development

All participants intended to monitor any use of IPM in their respective countries but there were some important considerations:

(a) In the absence of an effective biological control for western flower thrips any IPM programmes were at great risk of failure. An effective biological control would persuade many ornamental growers to take up IPM.

(b) In the Netherlands, the "zero pest tolerance" requirement for export of plants also includes presence of pest symptoms and this would need a fundamental change in attitude by importing countries for IPM to succeed. This may change when EEC border restrictions change in future.

(c) Although cotton whitefly is not so widespread as western flower thrips at present, its virus-transmission capability is an immense threat to the edible crops industry and its control by natural enemies may be of major importance. New pests of this nature will continue to arise.

A major consideration for development of IPM in ornamentals is that finding one effective natural enemy does not really improve IPM, but that complete crop protection programmes have to be developed, including selective pesticides. In such a programme use of disease and insect resistant plants should form one of the cornerstones.
Often, chemical control of one of the pests makes biological control impossible.

LIST OF PESTS IN ORDER OF IMPORTANCE IN RELATION TO EUROPEAN COUNTRIES.
J.J. Fransen, Research Station for Floriculture, Aalsmeer, The Netherlands.

	UK	Sweden	Belgium	France	Italy	Germany	Poland	Denmark	The Netherlands
a. *Frankliniella occidentalis*	2	3	4	2	-	3	-	2	1
b. *Trialeurodes vaporariorum*	-	1	5	7	2	1	1	1	5
c. *Bemisia tabaci*	3	4	-	-	-	-	-		4
d. *Tetranychus urticae*	-	2	3	1	2	2	2	6	3
e. 1) *Tetranychus cinnabarinus*	-	-	8			4			
2) *Tetranychus brevipalpus*	-	-							
f. Aphids total	5	-	6	8	-	6	-	4	6
1) *Myzus persicae*	-	-	-	-	-	-	3	-	-
2) *Aphis gossypii*	-	-	-	-	-	-	-	-	-
g. *Thrips tabaci*	-	-	-	9	5	-	4	2	7
h. *Tarsonemidae*	-	-	1	6	7	5	-	5	9
i. *Phytomyza*	-	-	-	-	4	-	-	-	8
j. *Pseudococcidae*	-	-	-	-	8	-	-	-	10
k. *Otiorrhynchus*	-	-	2	3	6	8	-	-	13
l. *Bradysia* sp. (Sciaridae)	-	-	7	-	-	7	6	3	11
m. *Liriomyza*	1	-	-	5	3	9	5	7	2
o. *Tortricids* (2 spec.)	-	-	-	4	1	-	-	-	12
p. *Acaridae*	-	-	-	-	-	-	7	-	-
q. *Spodoptera*	4	-	-	-	-	-	-	-	-
r. millepedes	-	-	-	-	-	-	-	-	-

EUROPEAN RESEARCH ORIENTATION ON THE DIFFERENT ORNAMENTALS

	UK	France	Italy	Germany	Poland	Denmark	Netherlands
Cut flowers	chrysanth	rose	rose	chrysanth	chrysanth	-	rose
	carnation	gerbera	gerbera		gerbera	-	gerbera
		ranunculus			carnation	-	chrysanth
pot plants	hibiscus	cyclamen	poinsettia	poinsettia	asparagus	chrysanth	poinsettia
	poinsettia					saint paulia	(begonia)
						and others	

BIOLOGICAL CONTROL ON ORNAMENTALS IN GREENHOUSES IN FRANCE

F. Bertaux, Regional Laboratory for Diagnostics and Control on Ornamental Plants.
GRISP - INRA, Antibes, France.

In France the latest data show about 2000 hectares used for growing ornamental and flower crops in greenhouses. The most important region for flowers (carnation, rose, gerbera, gladiolus etc.) is the French Riviera, the departments of Var and Alpes Maritimes. Pot plant production is more widespread in regions around Paris, the Loire valley, Alsace and Bretagne.

Because of the importance of the large area in which they are grown and their long period of culture, biological control should be developed first for carnation, rose, and gerbera.

1. Identification of the most imortant pest problems in ornamentals

	Pests	Importance	Crops
Mites:	-*Tetranychus urticae*	+++	Rose, carnation, chrysanthemum, gerbera
	-tarsonemid mites	+++	Cyclamen, gerbera, begonia, azalia
Whitefly:	-*Trialeurodes vaporariorum*	+++	Gerbera, fuchsia, pelargonium, lantana, (rose)
Leafminer:	*Phytomyza* sp.		
	-*Liriomyza trifolii*	+++	Gerbera, chrysanthemum
Aphids:	-many species	++	Rose, chrysanthemum, (gerbera), (carnation).
Thrips:	-*Frankliniella occidentalis*	(+++)	Rose, chrysanthemum, Saint-Paulia.
	-*Thrips dianthi*	++	Carnation
	-*Frankliniella intonsa*	++	Rose
Weevils:			
	-*Otiorrhynchus sulcatus*	+++	Cyclamen, pot plants
Totricids:			
	-*Cacoecimorpha pronubana*	+++	Carnation, rose
	-*Epichoristodes acarbella*	++	Carnation
Noctuids:			
	-*Chrisodeixis chalcites*		
	-*Plusia gamma*	+	Rose

2. Estimation of which pests and crops would show the best possibilities for application of biological control

Some applications have recently been done in France:

Crops	Pests	Biological control
Rose	Tetranychus urticae Tetranuchus cinnabarinus	Phytoseiulus persimilis
Gerbera	Trialeurodes vaporariorum Liriomyza trifolii	Encarsia formosa Diglyphus isaea
Ranunculus	Liriomyza trifolii	Diglyphus isaea
Pelargonium, fuchsia, lantana	Trialeurodes vaporariorum	Encarsia formosa
Chrysanthemum	Liriomyza trifolii	Diglyphus isaea
Carnation	Cacaecimorpha pronubana Epichoristodes acerbella	pheromone Bacillus thuringiensis
Cyclamen	Otiorrynchus sulcatus	Neoplectana sp.

Problems to solve are:

- residues of pesticides used against other pests or even against fungi
- finding biological control against pests like aphids and thrips.

3. Inventory of the research program already in action in France:

Studies have already been done on ornamental flowers in Antibes (INRA):
- roses: Phytoseiulus persimilis for Tetranychus urticae and Cinnabarinus; Mr. Millot, Mrs Pralavorio
- gerbera: biology of Trialeurodes vaporariorum: Mr. Onillon
- cyclamen: using nematodes against Otiorrhynchus sulcatus: Mr. Laumond

Other programs are now in action but none concerns directly ornamental plants; host plants are vegetables but experience may be transferred to ornamentals like:
- biology of different parasitoïds of Liriomyza trifolii especially Diglyphus isaea: Mr. Franco.
- study of different polyphagous bugs: Dicyphus, Macrolophus: Mr. Malausa Against Aphids, whiteflies, mites,...
- study of hymenopterous parasitoïds on aphids: Aphidius matricariae, Aphelinus abdominalis/Macrosiphum euphorbiae: Mr. Rabasse et Mr. Lafont.

Soon a study on natural enemies of thrips will be done.

4. Inventory and summary on pests and natural enemies in ornamentals

Proved to be effective in France:

Pests	Natural Enemies	Remarks
Tetranychus urticae (cinnabarinus)	Phytoseiulus persimilis	sprinkle method, early application
Trialeurodes vaporariorum	Encarsia formosa	take into account density and stage of whitefly
Liriomyza trifolii	Diglyphus isaea	early application
Noctuids	Bacillus thuringiensis	
Meloidogyne	Arthrobotrys irregularis	use a compost, take into account humidity.

Not yet effective:

Pests	Natural Enemies	Remarks
Aphids: Macrosiphum euphorbiae	Aphidius matricariae Aphelinus abdominalis	problems of using them: how much, when, mass breeding.
Thrips, aphids, whiteflies, Tetranychus	Bugs: Dicyphus sp. Macrolophus sp.	problems of mass breeding
Thrips	Amblyseius sp. Orius other thrips,..	biological studies

SUMMARY FROM ONE YEAR OF BIOCONTROL IN A SMALL-SCALE MIXED PRODUCTION OF ORNAMENTALS

Barbro Nedstam, Swedish University of Agricultural Sciences, Alnarp, Sweden.

Introduction

The Swedish production of ornamental plants in greenhouses consists mainly of pot plants (207 ha), some cut flowers (54 ha) and bedding plants (79 ha). The main pests have been *Trialeurodes vaporariorum*, *Tetranychus urticae* and various aphids. Recently two newcomers started to create problems, *Frankliniella occidentalis* and *Bemisia tabaci*. Before that *T. vaporariorum* was the most difficult pest to control due to insecticide resistance. "Pentac" still has effect against *T. urticae* and "Pirimor" against aphids.

The Department of Horticulture at SUAS, Alnarp, has some greenhouses (size: 880 m^2) for research on ornamental plants. Chemical control has been the rule, but increasing whitefly problems motivated the staf to ask for possible solutions using biological control methods.
There are many different species of plants in these greehouses, Chrysanthemum, Hibiscus,Gerbera, Aeschynanthus, Anisodonthea, Clerodendrum, Lantana and Verbena being the most common.
The last four seem to be extremely attractive to *T. vaporariorum*, surpassed only by Tabebuia, a plant species which certainly could be used as a trap crop in greenhouse production.

Start of biological control scheme

The routine treatments with chemicals stopped in Decmber 1985. Yellow sticky traps (5 per 100 m^2) were then put up to give a picture of the whitefly "hot spots". All empty tables and glass surfaces were thoroughly washed with water + detergent in order to minimize the pesticide residues. The first introduction of *Encarsia formosa* and *Phytoseiulus persimilis* was made in January 1986 (week 2). Five *E. formosa* and 1 *P. persimilis* per m^2 were used. As the greenhouse space was not fully utilized during this time of the year, the effective amounts were actually 50 - 75% higher. The yellow traps were relocated at the same time to several tables with Hibiscus and Lantana stock plants, which were heavily infested with *T. vaporariorum*. A second and third introduction of the same numbers of natural enemies were made at fortnightly intervals.
The plan was to keep on with these rather large introductions until a good establishment of *E. formosa* had been observed. Then introductions would continue at a lower level all year round.
During week 5 the first black scales were found. Within the next two weeks black scales could be seen everywhere in whitefly colonies, except on a few groups of plants that had been treated with aldicarb three months before. I then decided to, at least temporarily, switch over to weekly treatments and continue the biological control in the rest of the greenhouses.

Routine introduction of natural enemies

The program continued from week 8 with fortnightly introductions of 1 *E. formosa* and 0,5 *P. persimilis* per m^2. *E. formosa* was distributed evenly, *P. persimilis* was put into new spider mite infestations or just spread out at random. On the whole there was never any problem with spider mite damage throughout the season.
As for *T. vaporariorum* the soap sprays turned out to be very efficient. The method was sometimes also used to support the biocontrol in, for instance,

Verbena and Anisodonthea. In Gerbera and many other cultures E. formosa managed by itself.

Aphids had been observed in Cineraria (mainly Myzus persicae) in January, but strangely enough most of them were parasitized by Aphidius matricariae in spite of the previous heavy chemical load on the plants. Another species was also found later on (on Aphis gossypii), A. colemani. Both parasitoids have been reared and distributed to a number of growers with aphid problems since then and seem to do quite well. In the greenhouses at Alnarp this biological control has worked almost perfectly. Only a few instances of "soap aid" have been necessary.

Up until the end of May no other pests had been noticed. Everything seemed to be under control and the situation was improving every week. Recently started cultures, for instance of Gerbera and Lantana, looked very neat with a few black scales and almost no adult whiteflies. The aphids were not far from disappearing, even in Cineraria. But in June the real problems started.

Frankliniella occidentalis

The Western Flower Thrips came to Sweden as early as 1985. The first infection was in Saintpaulia (which is not cultured in the SUAS greenhouses) and later on it was found in Chrysanthemum, Gerbera, Pelargonium, Schefflera and others. In June 1986 this species was first noticed in various flowers in one of the greenhouses at Alnarp. Amblyseius cucumeris had already been introduced as a preventive measure against Thrips tabaci, and now repeated overall introductions of this predatory mite started. Altogether around 50 mites per m^2 were introduced in July and August. However, the thrips infestation increased and spread to almost all plants (except to some Ficus spp and ferns), while the mites seemed to disappear. Only on the Gerbera foliage could some A. cucumeris be found, but not in the flowers where a lot of thrips larvae were feeding. On some plant species, like Verbena, the WFT adults and larvae were mainly damaging the leaves. Here we tried to control the pest by repeated soap treatments. As this was quite succesful the method was later applied to all plants in both greenhouses.
First we sprayed three times a week for two weeks and later on once a week. The idea was to lower the infestation level as much as possible and then start again with the biocontrol and increase the amount of predatory mites. Unfortunately it was not possible to carry on with soap sprayings very long, because of phytotoxicity to some flowers. There was also a certain increase in spider mite infestations as the soap seems to damage P. persimilis more than T. urticae. Parasitization levels of E. formosa went down to half (from 98 to 47%) in Gerbera in the autumn, but on the other hand the soap also kept whitefly numbers low.

During the winter 1986/87 an intensive spray schedule with chemical insecticides was laid out. The purpose was to exterminate the WFT, but this was not possible with the available chemicals: acephate, cypermethrin, and endosulfan.

In spring 1987 we tried, once more, to start the biocontrol program, including up to 100 A. cucumeris per m^2, but this has been a failure. It was not possible to control F. occidentalis so there is now a routine program for chemical treatments against all pests.

The question is if we should have introduced much higher numbers of predatory mites? (In cucumber the method has been rather succesful with only 20 - 60 per m^2). Or are there other solutions? The only other predator we observed during summer was an Aeolothrips sp., both adults and larvae on the plants, but I don't have this in culture. Verticillium lecanii - thrips strain - is probably not suited to the environment in pot plants (low humidity). And there are no selective insecticides as far as far as I know.

Now this rather depressing situation looks even darker since B. tabaci has just arrived in Sweden. However this pest might be possible to control with E. formosa. I have, at least, noticed that the parasitoid can complete its life cycle on B. tabaci in a greenhouse culture with poinsettia. But whether it will show the same efficacy as against T. vaporariorum is too early to say.

SOME ASPECTS OF INFLUENCE OF TWO-SPOTTED SPIDER MITE FEEDING ON CHRYSANTHEMUM PLANTS

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1. Introduction

During recent years experiments on the influence of the two-spotted spider mite (*Tetranychus urticae* Koch) on chrysanthemum plants were conducted under laboratory and greenhouse conditions. The aim of the study was to investigate the plant response to low and high mite population densities and various feeding periods. The experiments were conducted on the following cultivars: Bronze Bornholm, Crimson Robe, Belcombe Yellow, White Horim, Super White, Pink Pompon and Dark Flamenco.

The influence of mite feeding on plant physiology was studied taking into consideration the following processes: mineral content and water balance; photosynthesis and respiration; biochemical changes in the leaves and plant growth and flowering. Most of the results of these studies have been published. In this review we will concentrate on topics which will allow to establish economic treshold levels.

2. Mineral content in the leaves and water balance

N, P and K-content in infested chrysanthemum leaves was studied in greenhouse and laboratory experiments (Tomczyk & Kropczynska, 1984). It was observed that after a few days of spider mite feeding on plants in a growth chamber, the content of these components was higher.

This was related to the acceleration of the growth during the initial period of spider mite feeding. Longer periods of mite feeding caused a decrease in the content of minerals. Under greenhouse conditions the mineral content of infested plants was higher after longer periods of mite feeding (90 days). In normal conditions of supply of these components in the soil, the infested plants showed a tendency for better uptake of minerals.

Studies on transpiration by infested plants were carried out with the chrysanthemum cultivar Bronze Bornholm under laboratory conditions. During the first 10 days of spider mite infestation the coefficient of transpiration of infested plants was 20% lower than in the check plants. During the next 10 days it remained lower in the infested plants. These differences vanished completely during the next two weeks of the experiment (Tomczyk & Kropczynska, 1984).

3. Photosynthesis and respiration

A number of experiments with different chrysanthemum cultivars infested with red spider mite were carried out. From all these experiments the following conclusions can be drawn.

- After a longer period of mite feeding a decrease in intensity of photosynthesis occurs. This phenomenon was observed in the cultivars Super White, Dark Flamenco and White Horim (Tomczyk & van de Vrie, 1982).
- Short periods of mite feeding, or low mite populations, caused in most cases a stimulation of photosynthesis. This stimulative effect can occur between 4 and 21 days of mite feeding on Bronze Bornholm, Super White and Pink Pompon, or longer when the average mite population varied around 0.2 mites per cm^2 of leaf om Crimson Robe or Belcombe Yellow (Tomczyk & Kropczynska, 1984, and unpublished data).

Other data showed that spider mites not only influenced the photosynthesis intensity but also changed the pathway of carbon in this process. By using 14^C it was found that after a few days of mite feeding carbon incorporation in infested leaves was stronger. Starch production was higher what caused a decrease in total soluble sugar content. After a longer period the situation was completely different. Starch synthesis was blocked by mite feeding and the content of sugars and aminoacids was much higher in infested leaves. This created new conditions for spider mite feeding (Kolodziej et al. 1975).

4. Biochemical changes in the leaves

The biochemical composition of 4 chrysanthemum cultivars Super White, Dark Flamenco, White Horim and Pink Pompon, was investigated after short or long periods of mite feeding (Tomczyk & van de Vrie, 1982, and unpublished data). After 4 days of mite feeding a lower soluble sugar content and higher phenol contents were found in Super White and Pink Pompon (unpublished data). After 5 weeks of mite feeding on Super White, White Horim and Dark Flamenco the sugar content was 2 - 3 times higher in infested leaves; the highest increase occurred in the most susceptible cultivar. It was followed by a decrease in starch. Chlorophyll and protein content was reduced in all cultivars and dry matter dcreased between 11 and 19%. These biochemical changes in infested leaves support the data obtained in experiments with the carbon pathway in photosynthesis (Kolodziej et al. 1975).

5. Rate of growth and flower quality

Plants growing in the greenhouse and infested with low densities of red spider mites (2.3 mites per leaf) showed an increase in growth rate. Chrysanthemums cultivated under laboratory conditions where growth and development is faster, showed a most evident increase in the growth rate during early spider mite feeding. After 10 days of spider mite feeding on Bronze Bornholm the plants were 25% higher as compared to the uninfested. Later the growth of the check and plants was similar, but after 25 days of infestation the infested plants remained higher (Tomczyk et al., in press). In another experiment the growth of two cultivars, Belcombe Perfection and Westland, was compared. The plants were divided into two groups: plants on which mites were feeding for three weeks and then removed by a Torque application and a group of plants on which mites were feeding during a period of 12 weeks. In Belcombe Perfection there was no difference in the rate of growth in the two groups of plants. In the Westland cultivar the rate of growth of the plants infested during 12 weeks was lower when compared to the plants on which the mites fed only three weeks (Tomczyk et al., in press). Comparison of the quality of flowers from infested and uninfested plants showed that mite populations which did not reach an average of 6 mites per leaf did not influence the quality (Kropczynska & Tomczyk, 1984).
From these results we can conclude that a low mite population, i.e. 1 - 6 mites per leaf, or short periods of mite feeding do not influence the growth or the flower quality of the chrysanthemum cultivars tested. In some cases even a stimulation of growth was observed.
Changes in sugar and protein content in infested leaves at the beginning of mite feeding created different conditions for spidermites. In the same time various compensative reactions can occur in the plant, viz. growth stimulation and photosynthesis stimulation.

6. Discussion

Knowledge of the occurrence of the phenomena mentioned above can give new possibilities for applying natural enemies in the control of red spider mite populations. Using them we can manipulate the mite population density on the plants or manipulate the period of mite feeding. The natural enemies should be introduced and should act before the mites break the resistance barrier of the host plant. Our results indicated that the defense mechanism of the plants usually is destroyed after 3 or 5 weeks of mite infestation, but not in the case when the mite population density is below 0.2 - 0.3 mites per cm^2 of leaf.
The defense reaction induced by spider mite feeding also can be directed to other pests; chrysanthemum leaves infested by spider mites are less attractive to leaf miners (unpublished data). The biochemical changes mentioned above can be considered to be responsible for this resistance to the leaf miner.

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PRESENT STATUS OF BIOLOGICAL/INTEGRATED CONTROL OF MITE AND INSECT PESTS IN FLORICULTURE IN THE NETHERLANDS

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1. Introduction

Several considerations have stimulated the interest in floriculture for biological and/or integrated control of mite and insect pests in greenhouse cultured ornamentals.The successes obtained in vegetable growing by using the predacious mite *Phytoseiulus persimilis* to control the red spider mite *Tetranychus urticae*, and the application of the parasite *Encarsia formosa* to control the greenhouse whitefly *Trialeurodes vaporariorum* encouraged the producers of these biocontrol agents, researchers and growers to try them out in floriculture. The danger in the application of poisonous pesticides for the workers in the greenhouses, the contamination of the environment, phytotoxic plant reactions and possible resistance development to pesticides in pest organisms also are arguments for studies on alternative methods for control. As all flowers and potted plants end up in homes, offices and other places of human activities, there should be considerable scope for biological control because the smell and the toxicity of pesticides, and a general dislike of chemical control, favour alternative solutions.

2. Present situation in floricultural practice

2.1. The black vine weevil (*Otiorrhynchus sulcatus*)

On Cyclamen, Begonia and Hedera the grubs of *O. sulcatus* feed on the root system and often cause outright death of the host plant. These larvae can be controlled very effectively by the entomophagous nematode *Heterorhabditis* spec. in pot plants. It can be applied by drenching, knapsack spraying or through the fertilizing system (van de Vrie, in press). One application, which has to be followed by light overhead watering of the plants usually results in a complete mortality of the larvae. This result was never obtained by chemical control; the most effective insecticide aldrin, has been banned in the Netherlands several years ago and other effective insecticides are not available (Evenhuis et al., 1984).

2.2. Red spider mite (*Tetranychus urticae*)

The red spider mite is a pest of many crops. On several occasions the effect of the predacious mite *Phytoseiulus persimilis* was studied on rose and other ornamental crops as chrysanthemum, *Gerbera jamesonii* and some pot plant species. However without acceptable results. In rose the distribution of the prey is dissimilar to that of the predator. Manipulation of the predators by hand and improving their distribution improves the predator's effectivity but is impractical for larger areas. On chrysanthemum and on *Gerbera* the application of insecticides for the control of the leaf miner *Liriomyza trifolii* and the thrips *Frankliniella occidentalis* prevents the use of *P. persimilis*.

2.3. Greenhouse whitefly (*Trialeurodes vaporariorum*)

The greenhouse whitefly is a pest on many floricultural crops as *Gerbera jamesonii*, *Bouvardia*, *Hibiscus*, *Poinsettia* and *Fuchsia*. Several attempts were made to introduce *Encarsia formosa* but a commercially acceptable control was not achieved mainly due to the necessity of applying insecticides against other pests. In some cases, like on *Gerbera* secondary pests like thrips or aphids, which normally are controlled by the application of insecticides against other pests, developed into major pests when the pressure from pesticide application was released.

2.4. The serpentine leaf miner (*Liriomyza trifolii*)

The leaf miner L. trifolii was kept under control in experiments and on small commercial plots by frequent release of the parasite Diglyphus isaea. As a zero tolerance on symptoms is demanded for export quality by several countries, this method was not successful. The parasites eventually kill the leafminer larvae but the symptoms remain present on chrysantemum leaves as mines.

2.5. Aphids (several species)
Experiments with the entomogenic fungus Vertcillium lecanii formulations to control aphids on chrysantemum, Gerbera jamesonii, and rose were not succesful. The results were variable and never reached an acceptable control level. Detailed studies of Myzus persicae and Aphis fabae on chrysanthemum showed various reasons for the poor results. Larvae which were artificially infested with V. lecanii ("Vertalec") frequently developed into adults and were still able to produce offspring before dying. When adults were treated, mortality usually was low and reproduction continued for some time.

3. Current situation in research
3.1. Red spider mite (Tetranychus urticae)
Experiments with the predacious mite P. persimilis to control red spider mite on rose and on chrysantemum have confirmed earlier results. The main reason for the failure of P. persimilis as an effective control agent on rose is the tendency of the predator to remain in the prey colonies and to leave new mite colonies undiscovered, even when they are at short distances. This results in locally high mite densities which may cause unacceptable leaf damage within a short period of time (van de Vrie, in preparation). Succesful introduction of P. persimilis has been reported (Pralavorio, 1973, 1977; Pruszynski, 1977). These introductions have been conducted exclusively in situations where roses are grown only during a part of the season, either in winter or in summer depending on the geographical situation. Under these conditions mass introductions apparently are succesful. However, when roses are grown all-year-round, mass-releases are impractical.
Another predacious mite species, Metaseiulus occidentalis, seems to be more suitable for the control of T. urticae on rose. It distributes itself more uniformly over the host plant and can remain for a longer period under conditions of low prey density. This species, however, enters diapause under the climatic conditions in the Netherlands. Recently a non-diapausing strain has been selected (Hoy, 1979). The potentials of this strain will be studied in the Netherlands.
On chrysanthemum P. persimilis can give excellent control of the red spider mite when released about three weeks after planting if left undisturbed. However, the intensive chemical control of the leaf miner L. trifolii and the thrips F. occidentalis, make the application of this predacious mite senseless (van de Vrie, in preparation).
On Gerbera famesonii, the situation for the introduction of P. persimilis is not clear. On several cultivars the predator has problems with its mobility, on others it disappears rapidly after being released. On some other cultivars, however, under experimental conditions an acceptable reduction of the red spider mite population was accomplished after the release of P. persimilis. The reasons for these inconsistent results are not clear and will be studied.
During release experiments the development of F. occidentalis necessitated the application of an insecticide lethal to P. persimilis. Also, under commercial conditions the leaf miner L. trifolii often needs to be controlled by insecticides lethal to P. persimilis.

3.2. Greenhouse whitefly (Trialeurodes vaporariorum)
The population development of the greenhouse whitefly on various Gerbera cultivars was studied at different temperature regimes (Dorsman and van de Vrie, 1987. Dorsman and van de Vrie, in preparation).

It was found that the rate of increase on all *Gerbera* cultivars tested was equal to that on tomato (van Lenteren and Hulspas-Jordaan, 1983). As climatical conditions for growing *Gerbera* as well as for growing tomato are rather similar it may be expected that release of *Encarsia formosa* will be succesful. In small release experiments the parasite indeed has shown potentials for reducing the host density considerably. However, so far the development and control of other pests as the serpentine leaf miner, thrips and aphids interfered with the release experiments.

3.3. Serpentine leaf miner (*Liriomyza trifolii*)
The population development of the leaf miner *L.trifolii* was studied on different *Gerbera* cultivars. Release experiments with the parasite *Diglyphus isaea* were conducted. This parasite has been found to be an effective parasite in France and Italy on *L. trifolii* on *Gerbera*. Moreover, it was easily obtainable from the Koppert Company, Berkel & Rodenrijs.
It was found that this parasite was only partially effective under commercial greenhouse conditions; the percentage leaf miner larvae being parasitized ranged between 15 and 25%. The reasons for this low parasitization rates may be unsuitable climatological conditions, incorrect timing of the releases, the presence of pesticide residues, or a dissimilar distribution of the parasite and its host. These experiments will be continued.

3.4. Rose leaf roller (*Clepsis spectrana*).
The rose leaf roller *Clepsis spectrana* has developed a greenhouse-adapted strain in the Netherlands. Under natural conditions this species enters diapause during August and has one generation per year. The greenhouse strain has lost its ability to enter diapause. This results in a continuous development and giving rise to 8 - 10 generations annually (van den Bos, 1983a).
The parasite *Campoplex punctulatus*, which occurs in commercial greenhouses, has been studied in some detail (van de Vrie and de Vos, in preparation). It occurs all year round and may reach a parasitization rate between 25 and 50%. Together with selective insecticides, as for instance the insect growth regulator fenoxycarb, the leaf roller population probably may be kept below the economic treshold level.
The sex pheromone of *C. spectrana* is ineffective in trapping males in greenhouses. This makes monitoring or mass trapping impossible (van den Bos, 1983a). Possibilities for mating disruption have to be studied.

3.5. Beet army worm (*Spodoptera exigua*)
The beet army worm was introduced accidentally into the Netherlands in 1976 (van de Vrie, 1977). The strain concerned had a history of heavy chemical treatment and had developed a high degree of resistance against many insecticides. This has led to great difficulties for effective control. Studies by Smits (1987, 1988) and Smits et al. 1984, 1986, 1987a,b,) have shown that the use of a nuclear polyhedrosis virus has good perspectives for economic control of this species, provided registration can be realized. Greenhouses provide ideal conditions for the application of this nuclear polyhedrosis virus as degradation by ultra-violet light is excluded.

3.6. Breeding for resistance against insect and mite pests
In chrysanthemum de Jong and de Vrie (1987) found widely varying susceptibility to the leaf miner *L. trifolii*, ranging from almost total resistance to high susceptibility. They identified the factors resposible for this resistance.
Also, in chrysantemum a wide diversity in susceptibility to thrips *F. occidentalis* was found (van de Vrie, unpublished). In *Gerbera* a wide variation in susceptibility to this leaf miner is known to occur. A further analysis of the host plant - insect relations in these crops may render interesting results for a further resistance breeding programme.

4. Integration of various cultural methods

In the production of ornamentals various cultural methods have to be integrated to provide optimal growing and production conditions. Each of these cultural measures may unfluence the interactions between prey or host and predator or parasite. The following considerations could be made:

- Climatic conditions may be optimal for crop growth but may adversely influence mite or insect development.
- Application of pesticides for fungal disease or insect control may be detrimental to beneficial organisms and the residual activity may extend over a long period of time.
- On several crops, pests and diseases may be present simultaneously and may require frequent pesticide applications.
- Some crops require a short period of growth; this may be in favour of inundative releases of bioagents. This in contrast to crops which may be grown for several years; under these conditions good regulative capacity of the bioagent is of primary importance.

All these aspects have to be considered in the development and the composition of a biological or integrated pest management programm in greenhouse ornamental production.

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BIOLOGICAL PEST CONTROL ON ORNAMENTALS: UNITED KINGDOM SUMMARY.

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1. Most important pest problems

These are given in descending order of importance below:

(a) Western flower thrips (*Frankliniella occidentalis*)
(b) Glasshouse whitefly (*Trialeurodes vaporariorum*)
(c) Tobacco whitefly (*Bemisia tabaci*)
(d) Two-spotted spidermite (*Tetranychus urticae*)
(e) Carmine spider mite (*Tetranychus cinnabarinus*)
(f) Aphids (all species)
(g) Thrips (*Thrips tabaci*)
(h) Broad mite (*Polyphagotarsonemus latus*)
(i) Chrysanthemum leaf miner (*Phytomyza syngenesiae*)
(j) Mealybugs (*Pseudococcidae*)
(k) Vine weevil (*Otiorrynchus sulcatus*)
(l) Sciarid flies (*Bradysia* spp.)
(m) Leaf hoppers (*Hauptidia maroccana*)

2. Crops and pests with potential for biological control

All ornamentals should have IPM programmes designed for them if these do not already exist. The criterion is the scale of crop production.

In the UK problems with *Tetranychus* prompted the design of IPM programmes for chrysanthemums and these worked well until *Verticillium lecanii* was lost and *Frankliniella* became a problem.

Other high value crops merit some urgency (ie. Hibiscus, ,Poinsettia, Begonia, Cyclamen, St. Paulia, Carnation). Lower value crops do not perhaps merit urgent work, but often these are grown on nurseries where high value crops are grown and IPM is necessary on these crops to avoid problems associated with the use of pesticides.

3. Research in progress

Limited commercial use of natural enemies, particularly *Phytoseiulus*, is carried out on a wide range of ornamentals in Britain but pesticides against other pests are eventually needed in most cases.

An IPM programme exists in Britain for chrysantemums but commercial take-up has been low, mainly because of the loss of *V. lecanii*. If an effective predator of *F. occidentalis* were found and suitable programmes designed, there would be a rapid expansion of IPM within this crop.

Encarsia formosa has given good control of *Traileurodes* on poinsettias (both stock plants and market crops) and this integrated well with compost treatments for Sciarid flies. The advent of *Bemisia*, however, has changed the general attitude to IPM on this crop.

IPM has worked well on hibiscus, rose and arum lily but fully formulated IPM programmes are not possible until a full range of parasites and predators is regularly available.

4. Inventory of pests and natural enemies important for IPM

(a) Control of thrips by predatory mites and bugs is the most important field work. Little is known about Amblyseius or Neoseiulus except on cucumbers and sweet peppers. Little is known about Orius or Anthocorid bugs.

(b) All species of aphids, particularly those resistant to pirimicarb, require work using predatory midges and parasites. Predatory bugs used for thrips would also be useful against aphids. Every effort should be made to reinstate Verticillium lecanii on the commercial market.

(c) Tetranychid mites are easily controlled by Phytoseiulus but certain basic rules for their use need to be laid down.

(d) Glasshouse whitefly should be easily controlled by Encarsia but certain basic rules for use of the parasite should be laid down.

(e) Tobacco whitefly needs to be researched fully as soon as possible. New Encarsia species against this pest require investigation. Existing commercial stocks of Encarsia should be examined in more detail in case stocks consist of more than one species.

(f) Broad mite would probably be controlled by predatory mites used for thrips.

(g) Leaf miner parasites (particularly Diglyphus spp.) are not easily commersialised but should always be available in quantities needed to support IPM programmes; this is not the case at present.

(h) Predators and parasites work well against mealybugs and scales but the market is limited resulting in poor commercialisation.

(i) In Britain there are problems with the availability and hence the commercialisation of parasitic nematodes against vine weevil and/or sciarid flies. If sufficient work was done in the mushroom crop, this would encourage a spin-off into the ornamentals field.

(j) There is no work on natural enemies of leaf hoppers. IPM programmes should cater for this pest biologically if possible.

(k) Much work has been done on the integration of fungicides with natural enemies but new diseases such as White Rust or Powdery Mildew necessitate the use of fungicides that are not compatible on the whole. There should be an acceleration in research into the biological control of fungi.

5. Cooperative research/development

The biological control world is dominated by a few major suppliers of natural enem who influence progress in two ways:

(a) Commercial necessity may produce a secretive approach (exacerbated by patent rights) that would arise if sufficient funding was available for researchers to keep ahead of commerce. Where this has not been the case (i.e. leaf miner control in France) it has been shown that problems can be solved relatively quickly with widespread benefit to IPM.

(b) Commercial suppliers can influence their clients more than researchers or advisers. This results in varied approaches to IPM that confuse growers and create difficulties for everyone.

Ideally, commercial companies should cooperate together in maintaining adequate supplies of sufficient natural enemies; perhaps partial specialisation should be considered to ease the economic burden of producing minor biological control agents.

Independent researchers/advisers should be responsible for creating basic IPM programmes that can be adapted on a regional basis to suit the climatic or cropping situations of each locale. Biological pest control is basically a "numbers game" in which numbers should be adjusted to suit pest infestation pattern and natural enemy efficiency. International cooperation in this area is already extensive but much duplication could be avoided with a more centralised approach. It is particularly important that there is cooperation to obtain basic biological information that is usually lacking by the time natural enemies are commercialised. Researchers/advisers should not need to depend entirely upon commercial producers for supplies of natural enemies for development work.

In Britain advisers and growers prefer IPM systems in which regular introductions of economic amounts of natural enemies are placed in crops. This can result in "overkill" of those pests controlled by natural enemies so that other pests can be controlled by pesticides that do not necessarily need to be safe to natural enemies (i.e. because the job has been done). In this situation it does not matter how many natural enemies are introduced on each occasion because the grower is merely carrying out a practical task and post-introduction monitoring is less critical. However, it would be important to growers that introduction methods are as quick and simple as possible. If these principles were widely accepted, there could be much cooperation on establishment of pest tresholds that are so useful for forecasting needs for success. Succesful IPM results in acceptance by the horticultural industry that encourages a steady commercial production of natural enemies.

There should be cooperation in all aspects of the promotion of IPM, there should be prominent sponsorship and every effort made to utilise modern communication aids to educate not only horticulturalists, but also the general public.

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FRANKLINIELLA OCCIDENTALIS

Bibliography of the western flower thrips, Frankliniella occidentalis (Pergande) (Thysanoptera : Thripidae)

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Abstract
A list of literature references on *Frankliniella occidentalis*, supplied with keywords, is presented.

Introduction
Since 1983 increasing problems caused by thrips have been reported in ornamental and vegetable crops in greenhouses in the Netherlands. At the beginning identification of the thrips offered problems when using the keys of Moulton (1948), Priesner (1964) and Schliephake & Klimt (1979). But after comparing these keys with a recent publication of Zur Strassen (1986), in which the closely related species *Frankliniella pallida* (Uzel) and *Frankliniella occidentalis* (Pergande) are distinguished reliably, it could be shown that *F. occidentalis* was responsible for the damage caused.

From the start chemical control of *F. occidentalis* turned out to be very difficult. This was a consequence (1) of the behaviour of the thrips that prefers living well-protected in flowers, buds and young unfolded leaves, and (2) of their great tolerance to most insecticides. Yet chemical control of *F. occidentalis* was the only solution directly at hand. However, it endangered the extended use of biological control methods against spider mite, white fly, leaf miner fly and onion thrips in cucumber and sweet pepper in greenhouse crops.

The serious threat was a sufficient reason to start extensive research and to install an ad-hoc Working Group to co-ordinate all activities. In this Working Group the author's task is to screen the literature and to distribute the relevant references among the members of the Group.

The following list is the result of this screening over the past two years.

Material
Quick information about *F. occidentalis* in recent literature was obtained from the databases of the German Institute for Medical Documentation and Information (DIMDI) at Cologne (FRG). Based on the keywords "western flower thrips" and "*F. occidentalis*" references were collected from:
1. "Commonwealth Agricultural Bureaux", based on the references of different abstract journals from CAB at London (UK), since 1973.
2. "Biosis Preview", based on the references from Biological Abstracts, since 1970.
3. "Phytomed", based on the references from Bibliographie der Pflanzenschutzliteratur, since 1965.
4. "Food and Agricultural Organisation", based on the references from FAO at Rome (Italy), since 1975.

1) The closing date of this review is 1 September 1988

Also were screened: Review of Applied Entomology, Series A, Vol. 1-75 (1913-1987), Entomology Abstracts, Vol. 1-18 (1970-1987), Zoological Record: Insecta, Vol. 70-123 (1933-1987), Bibliographie der Pflanzenschutzliteratur, Vol. 1-22 (1967-1987) and Catalogue of the Thysanoptera of the World (Jacot-Guillarmod, 1974). To the data collected from these sources references were added which were collected by other members of the Working Group during the years 1985-1987. Most of these references had originally been published in growers periodicals, but they were rarely referred in the major reference journals.

Results

All references are given in the section Literature. Attention is drawn to the fact that the references have been supplied with keywords, especially for those who are interested in topics concerning *F. occidentalis*. The number of keywords is kept limited and it could not be avoided that the classification is somewhat arbitrary. The keywords are mentioned below.
References of articles, not published in English, French or German, are supplied with an English translation.

Discussion

From the reference journals mentioned before only those titles are included from which it is certain that they deal with *F. occidentalis* or one of its synonyms. Unfortunately it is not always clear whether the authors studied *F. occidentalis*, or the very closely related *Frankliniella tritici* (Fitch).

The most comprehensive study on *F. occidentalis* was made by Bryan & Smith (1956). In addition to results of their rearing experiments they gave much information on the different hosts, the synonyms of *F. occidentalis* and the existing literature.

For a first impression the survey given by Jacot-Guillarmod (1974) is useful, especially because of its wide coverage. However, it does not give any information about the contents of the papers as no titles are given. Moreover it refers only to those pages on which the thrips species are mentioned. Thus, the relation with the total contents of the paper is lacking; it is difficult to study these papers. This is particularly problematic when a reference is to be found in other libraries. Comparison of our reference list with that of Jacot-Guillarmod (1974) learns that we did not include all his references. This is a result of the problems described above.

Of some references complete data are not always available, as e.g. volume number etc. In those cases the data of appearance are added. Although our survey does not claim to be complete, it may give the interested reader sufficient information on the most important literature available so far.

Acknowledgement

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ADDITIONAL KEYWORDS

List of keywords of literature on Frankliniella occidentalis (Pergande)

Notes: 1. All developmental stages of *Frankliniella occidentalis* are included.
2. The topics "Distribution" and "Host plant" are not specifically given as a keyword, because they are treated in almost all references.

keywords:

- Behaviour
- Biological control
- Chemical control
- Crop loss
- Cultural measures
- Damage symptoms
- Fungus
- Host plant resistance
- Insecticidal resistance
- Longevity
- Model studies
- Morphology
- Natural mortality
- Parasites
- Phenology
- Population density
- Post harvest control
- Predators
- Prey
- Reproduction
- Sampling techniques (e.g. estimating, monitoring)
- Virus

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