Union Internationale des Sciences Biologiques

Organisation Internationale de Lutte Biologique

contre les animaux et les plantes nuisibles

SECTION REGIONALE OUEST PALEARCTIQUE

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES

VANTAA, FINLAND, 12-15.5.79

GROUPE DE TRAVAIL LUTTE INTEGREE EN CULTURES SOUS VERRE

VANTAA, FINLANDE, 12-15.5.79

BULLETIN SROP

WPRS BULLETIN

1980 III/3

International Union for Biological Sciences

International Organization for Biological

Control of noxious animals and plants

WEST PALAEARCTIC REGIONAL SECTION

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES
REPORT OF THE MEETING HELD FROM 12 TO 15 JUNE 1979
AT THE AGRICULTURAL RESEARCH CENTRE, VANTAA, FINLAND

GROUPE DE TRAVAIL LUTTE INTEGREE EN CULTURES SOUS VERRE
RAPPORT DE LA REUNION TENUE DU 12 AU 15 JUIN 1979
A L'AGRICULTURAL RESEARCH CENTRE, VANTAA, FINLANDE

BULLETIN SROP
WPRS BULLETIN
1980 III/3

CONTENTS

PREFACE

This bulletin contains the papers presented at the fourth meeting of the working group 'Integrated control in glasshouses', held from 12 to 15 June, 1979 at Vantaa (Finland).

Again, most of the papers mainly relate to biological control, like the reports of the previous meetings held at Naaldwijk (the Netherlands), Littlehampton (U.K.) and Antibes (France). During the meeting many speakers drew special attention to factors that limit the application of biological control. Several interesting new possibilities for biological control in glasshouses were presented. Markkula's group gave results of biological control of aphids by the predator *Aphidoletes aphidimyza* and also provided a scheme for its mass production. Both in Canada and the Netherlands parasites of leafminers were collected and tests with these parasites in glasshouses in Holland proved that they are able to control leafminers below the economic threshold. Further positive results were obtained in thrips control by an *Amblyseius* species in the Netherlands. Still much research is being done on two of the classic biocontrol projects, with *Encarsia* and *Phytoseiulus*. The many new data collected during the past three years and presented at this meeting show that a frequency of one meeting per three years is certainly not too high.

This bulletin is a follow-up to the IOBC/WPRS Bulletin 1976/4, 'Integrated control in glasshouses'. We wish to thank Marianne van Lenteren-Bergeman, Hetty Vogelaar and C. Pelerents for their assistance in preparing these proceedings.

J.C. van Lenteren
Dept. of Ecology
University of Leiden
Leiden
the Netherlands

J. Woets
Glasshouse Crops
Research Station
Naaldwijk
the Netherlands

SURVEY OF TOPICS DISCUSSED IN THESE PROCEEDINGS

pest	natural enemy	subject	author	page
Aphids	*Aphidoletes aphidimyza*	mass production/ diapause	Forsberg	35
			Havelka	75
		mass production	Rimpiläinen	209
	Chrysopa carnea	mass production	Tulisalo	227
Macrosiphum rosae/Myzus persicae	*Coccinella septempunctata/ Adalia bipunctata*	evaluation	Hämäläinen	59
		mass production/ artificial diet	Kariluoto	99
		mass production/ photoperiod	Růžička	215
Myzus persicae	*Aphidius matricariae*	control attempt	Rabasse	175
		population dynamics 4 spp.	Rabasse	187
Trialeurodes vaporariorum	*Encarsia formosa*	control attempt/ spatial distribution	Ekbom	25
		control attempt	Nedstam	145
		control/introduction	Foster	41
		control	Onillon	155
		susceptibility to pesticides	Kowalska	101
		integration with adult traps	Webb	235
		decision model	Rodolphe	213
	Verticillium lecanii	occurrence	Ekbom	25
	plant resistance	testing	Berlinger	17
Liriomyza bryoniae	*Dacnusa sibirica*	control attempt	Hendrikse	83
	Opius pallipes	control attempt	Hendrikse	83
	Diglyphus isaea	occurrence	Hendrikse	83

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

OPENING SPEECH

Martti Markkula

Agricultural Research Centre
Department of Pest Investigation
SF-01301 Vantaa 30
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 9-10

OPENING SPEECH

Martti Markkula

Dear Colleagues, Ladies and Gentlemen,

We have got together to start the fourth meeting of the Working Group Integrated Control in Glasshouses. The first one was held in Naaldwijk, The Netherlands, and since then meetings have been arranged every three years. The second meeting was held in Littlehampton, England, and the third in Antibes, France.

When the first meeting was held in 1970, the predatory mite *Phytoseiulus persimilis* had already been used for some years in glasshouse cultures in The Netherlands, England and Finland. Actually the sale of the predatory mite was started to commercial growers that year in Finland. The good results in the control of the two-spotted spider mite *Tetranychus urticae* , especially in cucumber cultures, led to studies and applying of the control method in commercial cultures even in many other countries.

The success in biological control of the two-spotted spider mite made researchers pay their attention to the possibilities of controlling other pests on glasshouse cultures biologically. The first biological control method used in glasshouse cultures was in a way refound. This was the use of the aphelinid wasp *Encarsia formosa* against the whitefly *Trialeurodes vaporariorum*, a method that the English researcher E.R. Speyer had invented decades ago in 1927. *Encarsia formosa* was used with good results in England and Canada until the 1950's when new synthetic insecticides displaced it.

The aphid midge *Aphidoletes aphidimyza* became available for commercial glasshouse growers in Finland last year as a third biological control agent. The mass production and the use of the midge are based on the methods developed by my research group. About seventy growers bought pupae of the midge from Kemira Ltd. and the control results were good. This year the use of the aphid midge has continued.

We are very glad that it was decided to hold this meeting in Finland. The city of Vantaa and especially the Agricultural Research Centre are pleased to have you here. We hope that the excursions and the meeting as a whole will be a success.

The program is challenging. In fact there is nearly too much on it. We are going to hear 37 lectures altogether, which is remarkably more than at any of the previous meetings. This guarantees that every participant will receive plenty of new information.

We want to show that the commercial glasshouse growers in Finland have adopted biological control as an everyday practice in their cultures. We also want to show that *Aphidoletes aphidimyza* is as effective and usable an agent for controlling aphids as is *Phytoseiulus persimilis* for controlling the two-spotted spider mite and *Encarsia formosa* for controlling the whitefly.

Progress is continuously made on biological and integrated control of pests. When all pest problems on glasshouse cultures are solved by biological methods, investigations are moved to open air cultivations on the fields and in the garden.

I wish you all welcome to this meeting.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALÉARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

TREND OF BIOLOGICAL CONTROL IN GLASSHOUSES IN SWEDEN AND DENMARK

Ove Berendt

Anti-Cimex AB
Trädgårdshallen
Planteringsvägen
S-252 29 Helsingborg
Sweden

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 11-16

TREND OF BIOLOGICAL CONTROL IN GLASSHOUSES IN SWEDEN AND DENMARK

Ove Berendt

Introduction

At present the two-spotted spider mite is controlled by *Phytoseiulus persimilis* in cucumber crops under glass, and the whitefly is controlled by *Encarsia formosa* in tomato crops under glass. Other combinations of predator, parasite and host-plant species are only sporadically applied in commercial nurseries. The use, under glass, of other biological control agents has not been developed beyond the experimental stage. Due to the present range of commercial crops the demand for aphid control is limited. Rearing units for an aphid predator are, however, planned

History of biological control in Sweden

Phytoseiulus persimilis

In the late 1960's the National Plant Protection Institute and the National Agricultural Advisory Service carried out experiments with spider-mite control in cucumber crops, using the predator *P. persimilis*. Not all the trials resulted in control of the spider mite. Various introduction methods were tried and experience concerning the predator-prey system was gathered. During those years the public opinion in Sweden was very outspoken against the use of pesticides. The range of acaricides which could be used legally on cucumber crops was drastically reduced. Consequently, the growers were motivated for an alternative to chemical control.

During the early 1970's the growers pushed the experimental activity in cooperating with the mentioned national institutions, and large scale trials were carried out. The trials were financed by governmental funds. The public opinion was still against the use of pesticides, and the growers counted on the sale-promoting possibilities derived from a general use of biological control. Chemoresistance in the spider mite was another reason to develop biological control.

The pest-in-first method was not accepted by growers, as some had experienced late or no spontaneous spider-mite infestations the previous years. Further, the pest-in-first technique proved more laborious than introduction after spontaneous mite attack.

Information to the growers about biological control was intensified, and in 1974 it was regarded feasible to apply biological control of spider mites in cucumber crops on a commercial scale. A private company, Anticimex AB, established the necessary rearing facilities for *P. persimilis*. The South Swedish Growers Sales Organisation took care of the distribution to Swedish growers. In 1975 an agreement was made between the mentioned company and the sales organisation. According to this, Anticimex rears and supplies the predators as well as advisory service, and the South Swedish Growers Sales Organisation handles distribution to Swedish growers.

The scheme is financed by a fee paid by the cucumber growers being member of the sales organisation, and by a certain price paid for the delivered predators. Members of the sales organisation -representing the major part of Swedish cucumber nurseries- can even choose a combined delivery and advisory service. By this option the cost is based on glasshouse-area. The outlined scheme is still in operation.

Encarsia formosa

The introduction of the parasitic wasp for the control of whiteflies in tomato crops under glass has been developed along the same lines as described for the spider-mite control in cucumbers. The wasp is introduced on the tomato plants after spontaneous attack by the whitefly. The acceptance of biological control by the tomato growers has been delayed by only one year, as compared to the cucumber growers. The same rearing, distribution and advisory scheme as described for *P. persimilis* is in operation for *Encarsia formosa*.

History of biological control in Denmark

The development towards commercial application of biological control of spider mites and whiteflies in cucumber and tomato crops respectively, has been led by the National

Institute of Plant Pathology. The growers have been very interested in biological control and have readily accepted the technique. The evolution was the same as in Sweden with only one or two years of delay. In 1974 and 1975 the National Institute of Plant Pathology supplied the growers with *P. persimilis* and *E. formosa*, organizing large scale trials in commercial nurseries. From 1976 onwards, the Swedish company Anticimex AB supplies most of the predators and parasites needed by Danish cucumber and tomato growers. Due to a relatively short distance in the Danish Isles, growers will swop experience on biological control, and even predators and parasites.

Extension of biological control

No exact statistics as to the area of glasshouses where biological control is applied have been compiled. The number of distributed predators and parasites is available from Anticimex. Estimates are given in Tables 1 to 4.

Table 1 Development in the use of *Phytoseiulus persimilis* for control of *Tetranychus urticae* in cucumber crops under glass in Sweden. The number used in 1977 is taken as 100%

	relative figures	estimated % of total area (40 ha)
1975	50	35 %
1976	121	75 %
1977	100	70 %
1978	105	70 %

Table 2 Development in the use of *Encarsia formosa* for control of *Trialeurodes vaporariorum* in tomato crops under glass in Sweden.

	relative figures	estimated % of total area (90 ha)
1975	65	30 %
1976	90	45 %
1977	100	50 %
1978	72	45 %

Table 3 Development in the use of *Phytoseiulus persimilis* for control of *Tetranychus urticae* in cucumber crops under glass in Denmark.

	relative figures	estimated % of total area (40 ha)
1976	71	70 %
1977	100	80 %
1978	87	75 %

Table 4 Development in the use of *Encarsia formosa* for control of *Trialeurodes vaporariorum* in tomato crops under glass in Denmark.

	relative figures	estimated % of total area (100 ha)
1976	90	45 %
1977	100	60 %
1978	72	50 %

It should be stressed that the percentage of total glasshouse area to which biological control has been applied is a rough estimate. It must further be taken into consideration that only a certain fraction of the total glasshouse area with cucumbers and tomatoes suffers attack by the pests in question. This fraction will vary from year to year according, not in the least, to the climatic conditions. In Sweden many nurseries are situated in forest land, and therefore isolated from sources of glasshouse pests.

It is, however, my impression that biological control applied in Swedish and Danish glasshouses has stabilized since 1977. As far as spider mite control in cucumber crops and whitefly control in tomato crops are concerned, a saturation with the biological method has been reached.

Factors limiting biological control

Economic conditions

Along with the economic recession, profitability of cucumber and tomato crops has decreased. Due to this, young growers, being more minded for biological control, will often switch to ornamental crops, to which biological control is not yet applicable. Young growers are, as a rule, influenced by the Public School in favour of biological control. The economic recession has to some extent diverted the public opinion from the use of pesticides. The grower expects therefore less, in terms of sales promotion, from the biological control.

Novelty effect

To most growers biological control has lost the attraction of the novelty, which in itself could explain a decline. To the public, however, biological control still appears as something new and desirable.

Crop inspection

After having brushed on the more external factors the most important factor limiting biological control in Swedish and Danish glasshouses should be mentioned. It is the lack of an organized and regular crop inspection. If the crop is inspected in an organized way once a week during most of the growing season, attacks of spider mites and whiteflies, and other disorders for that matter, will be discovered in time. The biological control will be successful and other disorders can be controlled before they result in any economic loss. This point is as important as it is trivial.

The only alternative to regular crop inspection seems to be introduction at regular intervals of both predator and prey, at the same time. Similarly, parasite and host can be introduced simultaneously at regular intervals. In this way both species can be established before any spontaneous infestation occurs.

Other pests and diseases

Attacks by pests and diseases which cannot be controlled by biological agents, sometimes call for the use of pesticides. This may be difficult to integrate with a biological control programme. At present thrips, leafminers and mildew cause the more complicated problems in this context. Development towards biological control of the pests mentioned would be an important progress.

There are many other factors limiting a successful biological control in the individual nursery. Many so trivial that they are overlooked. For instance the grower's eyesight: if he is longsighted, he never discovers spider mites in time.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

RESISTANCE IN TOMATO TO THE GREENHOUSE WHITEFLY IN RELATION TO INTEGRATED CONTROL IN GLASSHOUSES

M.J. Berlinger

Institute for Horticultural Plant Breeding
Wageningen
the Netherlands
permanent adress:
Agricultural Research Organisation
Gilat Regional Experiment Station
Mobile Post Negev 2
Israel

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 17-24

RESISTANCE IN TOMATO TO THE GREENHOUSE WHITEFLY IN RELATION TO INTEGRATED CONTROL IN GLASSHOUSES

M.J. Berlinger

No plant is free from attack by insects. But there is also no one insect attacking all plant species. There is always some degree of specialisation among the insects and their host plants.

Damage by insects to host plants is usually caused when the insects are numerous, when their numbers increase above the economic threshold. The size of a pest population is determined by the birth rate, death rate, immigration and emigration. The damage is performed during feeding. But the food itself is also one of the essential components regulating the reproduction rate and thus population growth. Any insect will show different relative growth rates when fed on different host plants.

To control a pest population we usually try to increase its death rate, e.g. by means of toxic chemicals (chemical control) or by using natural enemies (biological control). Reducing the growth rate of a population could also be achieved by decreasing its birth rate through changing its food resource. This could be done by applying different cultural methods or, much more effectively, by using the genetic variation of the plants, i.e. by breeding varieties which meet all practical requirements but are bad host plants for the insect. Such plants are resistant. A resistant plant is one which possesses a complex of characteristics that reduce the growth rate of its insect population. If a plant possesses the ability to endure insect attack, we call it tolerant. It should be stressed that we speak about resistance as a relative figure - a plant might be more or less resistant in comparison with a standard.

As mentioned above, a critical moment in the development of an insect population is reached when the population growth curve crosses the economic threshold. The resistance of a variety is expressed by a flatter slope of the population growth curve, while tolerance is expressed by a rise of the economic threshold. The ideal will be a plant or variety possessing a level of resistance and tolerance which prevents its insect population from reaching the economic threshold. From this we may conclude that the desired variety need not necessarily be 100% resistant. Even if the rate of resistance is lower than 100%, its level might be just high enough to prevent economic damage. Indeed, varieties are known to have a different level of resistance and thus causing differences in the relative growth rate of insects (Pathak, 1970). An example of using this characteristic of partial resistance is the breeding programme for resistance in cucumber to the two-spotted spider mite (Fig. 1). Even a low level of resistance may be just enough for a parasitoid or predator to become an efficient control agent (Fig. 2).

Bottlenecks of a breeding programme for resistance to insects and mites are the methods used to detect the resistance, except when a plant is completely resistant. In the last case, the observations will result in a 'yes or no' phenomenon, while the results will not be affected too much by the way in which the experiment was performed. A much more complicated situation arises in the case of partial resistance, where the level of resistance can be influenced very much by the method used.

As we are looking for resistance in an agro-economic system, the level of resistance should preferably be determined by the damage. This is a very useful method provided the damage can be easily quantified and is pronounced immediately. If the damage can be discovered only after some time, the selection will be prolonged and its expenses become higher. Then the size of the insect population, or rather its relative growth rate, must be considered, provided the correlation between population size and damage is sufficient. More complicated is the situation, e.g. with the whitefly, where direct population counts are practically impossible and a reliable random sampling method is not yet available (Eggenkamp-Rotteveel Mansveld et al., 1978).

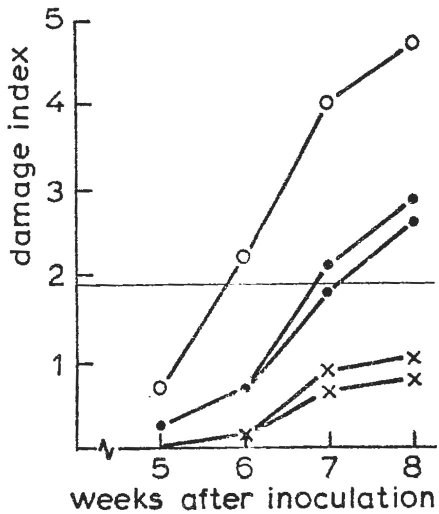


Figure 1. Increase of the damage index of two F_5 breeding lines (x) originating from a cross between two cucumber varieties (●) partially resistant to the two-spotted spider mite compared with a susceptible control (O). The economic damage threshold lies at 1.9 (De Ponti, 1979).

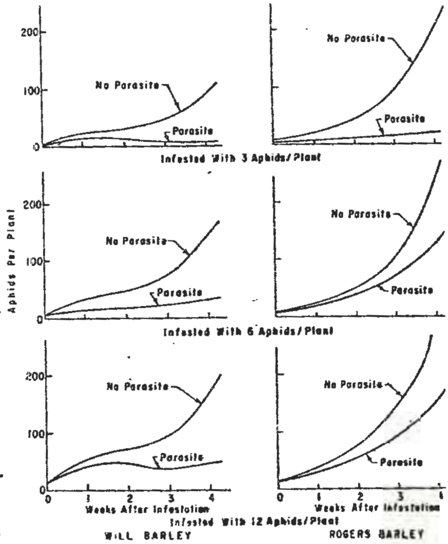


Figure 2. Increase of greenbugs in the absence and presence of 1 ♀ parasite caged on greenbug resistant (Will) and susceptible (Rogers) barley (Starks et al., 1972).

Therefore we used some other methods: (1) Visual rating of adult whitefly infestation, (2) using a yellow sticky petri trap (Berlinger, in prep.) for trapping adult whiteflies, (3) counting the number of leaves on a plant infested by no, few, moderately numerous or many scales, (4) punching discs from leaves at different heights of the plants and counting eggs and scales. The disadvantage of these methods is that they produce relative figures or estimates, some of which are subjective.

After a source of resistance is found in a variety of less economic importance or in a related wild species, a breeding programme can be started along the following lines: the resistant variety or species is crossed with a susceptible variety. The selection for resistance will be started in the F_2. If the crossability is good we may receive many, even hundreds, of segregating F_2 plants, each of which is a genotype by itself and must be observed individually. Such a breeding programme involves much expensive selection work. No wonder then that the breeders demand fast, simple and reliable methods for detecting resistance of various levels.

The greenhouse whitefly (*Trialeurodes vaporariorum* Westw.) is one of the most severe pests of glasshouse vegetables. Its chemical control is difficult and insufficient. Its biological control with *Encarsia formosa* Gahan is insufficient in eggplant and cucumber and rather efficient in tomato grown at the temperatures presently used (van Lenteren et al., 1977). But lowering of temperature in order to save energy might result in a less efficient control by *E. formosa* . Despite the reasons for this inefficiency of *E. formosa* one may assume that decreasing the rate of the whitefly population growth by breeding more resistant varieties will increase *E. formosa* efficiency.

T. vaporariorum is a very polyphagous insect. A comprehensive list of its host plants was presented by Russell (1963). Recently Koshihara et al. (1978) listed 181 host plants, belonging to 53 families. Nevertheless differences were found in host preference among various plant species (Verschoor-van der Poel & van Lenteren, 1978) while differences in reproduction among various plant species were found by Tanaka (1978), van de Merendonk & van Lenteren (1978), van Boxtel et al. (1978) and Van Sas et al. (1978). Within *Lycopersicum esculentum* a sufficient level of resistance has not been found (Curry & Pimentel, 1971; De Ponti et al., 1975). Therefore related species were examined for resistance (Gentile et al., 1968; De Ponti et al., 1975; Georgiev & Sotirova, 1978; Sotirova & Georgiev, 1979). The most promosing sources of resistance were found within *L. hirsutum*, *L. hirsutum glabratum* and *Solanum pennellii* .

In the years 1978/79 I studied the resistance of *L. hirsutum glabratum* and *S. pennellii* in glasshouse experiments as well as in detailed laboratory experiments at the Institute for Horticultural Plant Breeding at Wageningen, the Netherlands. The resistance of the above species was confirmed. The results of these experiments will be published soon.

We see that resistance, as a means of pest control, fits very well into an integrated pest control programme. It might, in some cases, even be the clue for the success of other control measures, e.g. biological control. Insect resistance of any level may also be of vital importance for diminishing the expenses on other control measures, including chemical control.

References

Boxtel, W. van, J. Woets & J.C. van Lenteren, 1978. Determination of host-plant quality of eggplant (Solanum melongena L.), cucumber (Cucumis sativus L.), tomato (Lycopersicum esculentum L.) and paprika (Capsicum annuum L.) for the greenhouse whitefly (Trialeurodes vaporariorum (Westwood)) (Homoptera: Aleyrodidae). Med. Fac. Landbouww. Rijksuniv. Gent 43(2): 397-408.

Curry, J.P. & D. Pimentel, 1971. Evaluation of tomato varieties for resistance to greenhouse whitefly. J. ec. Ent. 64: 1333-1334.

Eggenkamp-Rotteveel Mansveld, M.H. et al., 1978. The parasite--host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). VIII. Comparison and evaluation of an absolute count and a stratified random sampling programme. Z. angew. Ent. 85: 133-140.

Gentile, A.G., R.E. Webb & A.K. Stoner, 1968. Resistance in Lycopersicon and Solanum to greenhouse whiteflies. J. ec. Ent. 61: 1355-1357.

Georgiev, H. & V. Sotirova, 1978. Resistance of wild tomato species to the glasshouse whitefly (Trialeurodes vaporariorum Westw.). Gen. and Pl. Breed. 11: 214-217.

Koshihara, T., K. Tanaka & H. Yamada, 1978. Host plants of the greenhouse whitefly, Trialeurodes vaporariorum (Westwood). Bull. Veg. Orn. Crops Res. Station Ishinden Osogo, ser. A, 4: 163-171.

Lenteren, J.C. van et al., 1977. Biological control of the greenhouse whitefly Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae) by Encarsia formosa Gahan (Hymenoptera: Aphelinidae) in Holland: an example of successful applied ecological research. Med. Fac. Landbouww. Rijksuniv. Gent. 42: 1333-1342.

Merendonk, S. van de & J.C. van Lenteren, 1978. Determination of mortality of greenhouse whitefly Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae) eggs, larvae and pupae on four host-plant species: eggplant (Solanum melongena L.), cucumber (Cucumis sativus L.), tomato (Lycopersicum esculentum L.) and paprika (Capsicum annuum L.). Med. Fac. Landbouww. Rijksuniv. Gent 43: 421-429.

Pathak, M.D., 1970. Genetics of plants in pest management. In: R.L. Rabb & F.E. Guthrie (eds.), Concepts of pest management. North Carolina State Univ. Press, Raleigh: 138-157.

Ponti, O.M.B. de, 1979. Resistance in Cucumis sativus L. to Tetranychus urticae Koch. 5. Raising the resistance level by the exploitation of transgression. Euphytica 28(3): in press.

Ponti, O.M.B. de, G. Pet & N.G. Hogenboom, 1975. Resistance to the glasshouse whitefly (Trialeurodes vaporariorum Westw.) in tomato (Lycopersicon esculentum Mill.) and related species. Euphytica 24: 645-649.

Russell, L.M., 1963. Host and distribution of five species of Trialeurodes (Homoptera: Aleyrodidae). Ann. Ent. Soc. Am. 56: 149-153.

Sas, J. van, J. Woets & J.C. van Lenteren, 1978. Determination of host-plant quality of gherkin (Cucumis sativus L.), melon (Cucumis melo L.) and gerbera (Gerbera jamesonii

Hook) for the greenhouse whitefly, Trialeurodes vaporariorum (Westwood)) (Homoptera: Aleyrodidae). Med. Fac. Landbouww. Rijksuniv. Gent. 43: 409-420.

Sotirova, V. & H. Georgiev, 1979. Resistance of various Solanum pennellii Correll accessions to the glasshouse whitefly (Trialeurodes vaporariorum Westw.). Gen. and Pl. Breeding 12: 75-77.

Starks, K.J., R. Muniappan & R.D. Eikenbary, 1972. Interaction between plant resistance and parasitism against greenbug on barley and sorghum. Ann. ent. Soc. Am. 65: 650-655.

Tanaka, K., 1978. Differences in multiplication of greenhouse whiteflies, Trialeurodes vaporariorum (Westwood) on various vegetable crops. Bull. Veg. Orn. Crops Res. Stat. Ishinden-Osogo, ser. A, 4: 173-180,

Verschoor-van der Poel, P.J.G. & J.C. van Lenteren, 1978. Host-plant selection by the greenhouse whitefly Trialeurodes vaporariorum (Westwood). Med. Fac. Landbouww. Rijksuniv. Gent 43: 387-396.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

SOME ASPECTS OF THE POPULATION DYNAMICS OF *TRIALEURODES VAPORARIORUM* AND *ENCARSIA FORMOSA* AND THEIR IMPORTANCE FOR BIOLOGICAL CONTROL

Barbara Sohm Ekbom

Department of Plant and Forest Protection
Swedish University of Agricultural Sciences
S-750 07 Uppsala
Sweden

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 25-34

SOME ASPECTS OF THE POPULATION DYNAMICS OF TRIALEURODES VAPORARIORUM AND ENCARSIA FORMOSA AND THEIR IMPORTANCE FOR BIOLOGICAL CONTROL

Barbara Sohm Ekbom

Summary

The spatial distributions of the whitefly and its parasite are shown to be aggregated. This makes sampling for estimates of the whitefly population unfeasible and a different approach to monitoring the whitefly is needed. The use of a trap is suggested.

Because of problems with high temperature requirements for E. formosa, combining chemical control of other pest species and problems related to use of E. formosa in cucumber cultures, the use of alternatives or complements to control with E. formosa are discussed. Those alternatives mentioned are a fungal disease, Verticillium lecanii, and the use of a general predator, Anthocoris spp. Neither method has been fully investigated.

Introduction

During the years 1974-76, 25 greenhouses (16 tomato cultures and 9 cucumber cultures) were monitored while using *Encarsia formosa* as a biological control agent against the whitefly (*Trialeurodes vaporariorum*). The goal was that through observations of the parasite-host interactions something could be learned about the most effective method of application of *E. formosa*. Empirical evidence for the optimal number of parasites was gathered by varying the rate of parasite release. The populations of both whiteflies and parasites were monitored by direct counts. Observations were made on the use of pesticides and their effects on the host--parasite system. The results of these studies were, in general, good (Ekbom, 1977) (see Tables 1 and 2). However, in practice the use of the biological control agent *E. formosa* is not reliable unless the user is experienced and informed in the use of the parasite. The use of the parasite has declined greatly in cucumber cultures in Sweden. The failures

trials in tomato to control *Trialeurodes vaporariorum* with *Encarsia formosa*: initi
densities, number and frequencies of *Encarsia* introductions (frequency betwe
eses), numbers of *Encarsia* introduced per plant, qualifications of success and
for failure

y imagines m^2	*Encarsia* per m^2	*Encarsia* per plant	success	reason for failure
/	20(2)	8	+	
	23(4)	8.2	+	
5	20(2)	9.6	+	
7, 1	30(3), 30(3), 20(2)	18.6, 18.6, 12.4	-,-,+	too many whitefli
	20(2)	7	+	
	20(2)	8.4	+	
	10(2)	3.6	+	
8	10(2)	2.8	+,-	low temperature, whiteflies from c
2	12.5(2)	4.5	+	
4	10(2)	3.4	+	
5	15(2)	5.2	+	
7	7.5(2)	2.84	+	
8	5(2)	2	+	
3	10(2)	3.4	+	
75	5(2)	2	+	
7	10(2)	3.8	+	

Table 2 Data for trials in cucumber to control *Trialeurodes vaporariorum* with *Encarsia formosa*. For explanation see Table 1.

trial cucumbers	whitefly imagines per 100 m^2	*Encarsia* per m^2	*Encarsia* per plant	success	reason for failure
VII: 75	1.4	9(2)	5.9	+	
VIII: 75	237	13(2)	15.6	-	too many whiteflies
IX: 75	11.3	10(2)	7.5	-	too many whiteflies
X: 75	14	25(4)	17.9	-	Phoxim against Sciarid flies
V: 76	14	15(3)	12.9	+	
VI: 76	0.03	20(3)	16.8	+	
VII: 76	10.4	20(2)	12.4	+	
VIII: 76	8.1	20(2)	20	-	fungicides against powdery mildew?
IX: 76	1.75	20(3)	17.8	-	Fenitrithion against thrips

can be said to fall into several categories: 1) the first parasite releases are too late and there are too many whiteflies present in the greenhouse, 2) use of an insecticide against a pest other than the whitefly has destroyed the host-parasite balance, 3) the effects of the environment (here, the 'climate' in the greenhouse) have disrupted the host-parasite system, and finally, a catch-all category, 4) some external factor (such as pest or parasite interaction with the host plant) is disturbing the predicted host-parasite process.

The spatial distribution of the whitefly and *Encarsia formosa*

Late introduction of the parasite seems to be a rather widespread problem in Sweden. The use of stratified random sampling has been shown to be ineffective (Eggenkamp-Rotteveel Mansveld et al., 1978). In the studies done in Sweden it could be shown that the distribution of the whitefly and its larvae is, by and large, very aggregated. Laboratory observations have indicated that the whitefly does not move about excessively and will often disperse to a new plant only when there is a shortage of space.

In Table 3, data from 5 different greenhouses have been analysed with regard to the spatial distribution of the two insects, both adult and juvenile stages. The distribution of blackscales is, of course, related to the distribution of whitefly larvae. In the table the values shown are three different types of aggregation indices. The index called the Smith-Gill index is a standardization of the Morisita index. The reader is referred to the following references for details: Smith-Gill, 1975; Morisita, 1959; Myers, 1978. The Smith-Gill values in the table are averages over the duration of the experiment. The Smith-Gill index is not correlated to density and makes comparison of aggregation in different densities possible. The standardization allows easy comparison as it transforms the Morisita index to a scale of 1.0 to -1.0 and values above 0.5 indicate statistically significant aggregation or clumping. A value of 0.0 is an indication of a random distribution.

Table 3 Three different types of aggregation indices for greenhouse whitefly and *Encarsia formosa* distributions in five different greenhouses

greenhouse code	whitefly adults	whitefly larvae	*Encarsia formosa* adults	blackscales
F74				
Smith-Gill	0.529	0.559	0.542	0.604
Iwao	13.44	22.7	14.88	59.70
k	0.115	0.0865	0.103	0.0385
J74				
Smith-Gill	0.537	0.512	0.494	0.516
Iwao	4.13	5.26	2.48	8.26
k	0.178	0.432	0.614	0.73
S75				
Smith-Gill	0.503	0.534	0.574	0.538
Iwao	- *	- *	- *	- *
k	1.44	0.068	0.377	0.130
B75				
Smith-Gill	0.521	0.509	0.495	0.514
Iwao	17.88	2.09	3.10	1.65
k	0.262	0.517	0.507	0.593
A75				
Smith-Gill	0.488	0.525	0.519	0.534
Iwao	6.33	4.61	9.70	3.42
k	0.257	0.301	0.184	0.219

*The correlation coefficient for the linear regression was too low for the slope to be a reliable

The second value in the table is the slope in a linear regression of mean crowding m* (Lloyd, 1967) and the mean $\bar{x}$ as described in Iwao (1968). All slopes with values higher than 1.0 indicate an aggregated distribution. The third index in the table is the negative binomial parameter k. A method for obtaining a common k was used (Bliss, 1953).

The data, as presented in the table, point to the rather obvious conclusion that whitefly infestations occur in 'pockets'. Most experienced workers in this field are familiar with this observation. One can also use the data to get an estimate of the needed sample numbers for a satisfactory estimation of the population. Using the following formula (Karandinos, 1976):

$$n = \frac{z^2_{\frac{\alpha}{2}}\left(\frac{1}{\bar{x}} + \frac{1}{k}\right)}{D^2}$$

and the following values for the parameters for F74: k = 0.115, $\bar{x}$ = 0.53, D = 0.1, α = 0.05 and $z_{\alpha/2}$=1.96 the optimal sample size is 4065, which amounts to checking every single plant in the greenhouse.

The conclusion is that a random sampling program is useless in trying to determine the size of whitefly infestations. A total inventory of the plants in a greenhouse is the preferable approach to 'whitefly-finding', but is not always feasible for the grower, especially if infestation occurs after the young plants have been placed in the greenhouse. The use of the pest-in-first method, which would eliminate the problem of estimating the pest population, is not workable in Sweden. A good aid in finding the whiteflies early enough would be some sort of early warning device. In order to determine some sort of attraction mechanism, some studies on whitefly behaviour were started. As of this writing the only conclusion we have been able to reach is that the whitefly is strongly attracted to light. Weber (1931) writes of the orientation of the whitefly adult according to the source of light. This also helps explain the tendency of the whitefly to disperse upward rather than outward. If one were to use a light trap for whitefly detection, more than one light trap would most likely be necessary and this could be a costly proposition. Another method, on which investigations have just begun, is the use of yellow, sticky discs as traps. Yellow is the colour which is most attractive to the whitefly (Vaishampayan et al., 1975) and the use of paper discs is economically feasible. The radius of effectivity and the best possible locations for the discs remain to be determined. A disc placed just below plant height has given good results.

A tendency toward aggregation is also shown in the values for the adult parasites. An explanation of this is in the evident attraction of the whitefly larvae and their secretions for the adult *Encarsia formosa* (Ledieu, 1976). In theoretical situations the aggregation of the parasite in areas of host infestation is an important stabilizing factor (Hassell & May, 1973). The attraction of the whitefly and the clumping activity are important components of the host-parasite system and should be an important part of a model of the system. A model of the whitefly-*Encarsia formosa* system which incorporates the many findings of various workers would be a good way of presenting known information and unveiling gaps in present knowledge.

Alternatives or complements to biological control with *Encarsia formosa*

In Sweden, as in most countries, we are beginning to feel the effects of the growing energy problems. One of the prerequisites for the use of *E. formosa* is temperatures above 18°C. Such temperatures are difficult to maintain, other than in the summer, without a large input of energy. The poor results of *E. formosa* in cucumber have also given impetus to the search for alternative ideas.

One of the alternatives we have investigated is the use of the insect pathogenic fungus *Verticillium lecanii*. The fungus has earlier been investigated both as a pathogen of the whitefly and aphids in the greenhouse (Hussey, 1958 and Hall, 1976). Our strain of *V. lecanii* came from an epizootic in a commercial greenhouse in Sweden. Studies on culturing, infectivity, and temperature requirements have been done (Ekbom, 1979). The more practical trials have not been a

omparison of control results after releasing *Encarsia formosa* or after spraying *Verticillium lecanii* to control whitefly. Experiment in small greenhouses. Sprayir
8-05-08 and 78-05-23

	no. adult whiteflies	% larval mortality	temperature min.	temperature max.	humidity min.	humidity max.	average no. hour day at max -5% l
1							
	58	0	11	>35	32	75	6.9
	132	0	16	>35	50	98	0.2
	178	0	7	>35	33	100	6.6
	85	0	12	>35	58	100	10.3
	23	0.5	10	>35	50	100	13.4
2							
	5	0	8	>35	35	95	1
	7	6	16	>35	55	96	0.3
	63	77	9	>35	28	100	5.1
	170	41	13	>35	48	100	7.4
	265	78	12	>35	50	93	2.0
3							
	2	0	11	36	35	80	3.4
	1	0	19	39	62	100	1.3
	13	0	11	37	34	100	8.0
	78	0	18	37	52	100	11.1
	108	0	12	36	59	100	16

success (see Table 4). But with more refined methods of application better success may be gained. The humidity or, more specifically, moisture requirements of the fungus are very important and seem to be prohibitive, but alternatives to spray application such as traps or release of infected adults may create an area of use for the fungus disease. The clumping behaviour of the whitefly would be an asset in the spreading of a fungal epizootic.

Two general predators (Hemiptera) have also been investigated as control agents of the whitefly. *Nabis* spp. and *Anthocoris* spp. have both been able to eat whitefly larvae and develop on them. The *Anthocoris* spp. eat as much as the *Nabis* spp. and are easier to culture. They also seem to have a better survival and reproductive rate in culture than *Nabis* spp. Up to this time studies have only been done in the laboratory. Cage studies on the potential of *Anthocoris* spp. as a control agent for the whitefly are now in progress. The use of a general predator might also be an aid in controlling other pests.

References

Bliss, C.I. & R.A. Fisher, 1953. Fitting of the negative binomial distribution to biological data and note on the efficient fitting of the negative binomial. Biometrics 9: 176-200.

Eggenkamp-Rotteveel Mansveld, M.H., F.J.M. Ellenbroek, J.C. van Lenteren & J. Woets, 1978. The parasite-host relationship between Encarsia formosa and Trialeurodes vaporariorum. VIII. Comparison and evaluation of an absolute count and a stratified random sampling programme. Z. angew. Ent. 86: 133-140.

Ekbom, B.S., 1977. Development of a biological control program for greenhouse whiteflies (Trialeurodes vaporariorum) using its parasite Encarsia formosa in Sweden. Z. angew. Ent. 84: 145-154.

Ekbom, B.S., 1979. Investigations on the potential of a parasite fungus (Verticillium lecanii) for biological control of the greenhouse whitefly. Submitted to Swedish Journal of Agricultural Research.

Hall, R.A., 1976. Verticillium lecanii on the aphid, Macrosiphoniella sanborni. J. invert. Path. 28: 389-391.

Hassell, M.P. & R.M. May, 1973. Stability in insect host-parasite models. J. anim. Ecol. 42: 693-726.

Hussey, N.W., 1958. Notes on a fungus parasitic on greenhouse whitefly. Plant Path. 7: 71-72.

Iwao, S., 1968. A new regression method for analyzing the aggregation pattern of animal populations. Res. Popul. Ecol. 10: 1-20.

Karandinos, M.G., 1976. Optimum sample size and comments on some published formulae. Bull. Ent. Soc. Am. 22: 417-421.

Ledieu, M.S., 1976. Dispersal of the parasite Encarsia formosa as influenced by its host, Trialeurodes vaporariorum. WPRS Bull. 1976/4: 121-124.

Lloyd, M., 1967. Mean crowding. J. anim. Ecol. 36: 1-30.

Morisita, M., 1959. Measuring of the dispersion of individuals and analysis of the distributional patterns. Mem. Fac. Sci. Kyushu Univ. ser. E 2: 215-235.

Myers, J.H., 1978. Selecting a measure of dispersion. Env. Ent. 7: 619-621.

Smith-Gill, S.J., 1975. Cytophysiological basis of disruptive pigmentary patterns in the leopard frog Rana pipiens. II. Wild type and mutant cell-specific patterns. J. Morph. 146: 35-54.

Vaishampayan, S.M., G.R. Waldbauer & M. Kogan, 1975. Visual and olfactory responses in orientation to plants by the greenhouse whitefly. Ent. exp. appl. 18: 412-422.

Weber, H., 1931. Lebenweise und Umweltbeziehungen von Trialeurodes vaporariorum. Z. Morph. Ökol. Tiere 23: 575-753.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

POSSIBILITIES OF USING THE DIAPAUSE OF *APHIDOLETES APHIDIMYZA* (ROND.) (DIPTERA: CECIDOMYIIDAE) IN ITS MASS PRODUCTION

Anja Forsberg

Agricultural Research Centre
Department of Pest Investigation
SF-01301 Vantaa 30
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 35-40

POSSIBILITIES OF USING THE DIAPAUSE OF APHIDOLETES APHIDIMYZA (ROND.) (DIPTERA: CECIDOMYIIDAE) IN ITS MASS PRODUCTION

Anja Forsberg

The predatory mite *Aphidoletes aphidimyza* (Rond.) has proved to be efficient in biological control of aphids in glasshouse vegetable cultures. To improve the mass-production method developed and used in Finland (Markkula & Tiittanen, 1977) investigations were started to find out if the diapause of the midge can be used in its mass production by storing pupae (cocoons) for longer periods. Also disturbances caused by diapause in the mass production should be prevented.

The purpose of the preliminary studies was to find out a practical and simple method to cause the midge to enter diapause irrespective of the season of the year. The aim has also been to find out how long and in which ambient conditions the midge can be kept in diapause and how the diapause can be terminated. Preliminary experiments showed that a short photoperiod and a low temperature cause the mature larva that has built its cocoon to enter diapause. The ambient conditions used were 8 hours of light at 25°C and 16 hours of darkness at 10 or 12°C. The subsequent problem was to find out when the diapause was induced. Different developmental stages of the midge were kept at diapause-inducing conditions. Cocoons (pupae) were always taken to long photoperiod at room temperature to see whether the midges remained in diapause or not (Table 1).

When adults, eggs and larvae were kept in diapause-inducing conditions, more than 90% of the larvae diapaused. The duration of development from egg to mature larvae that disappeared in the pupation substrate was twelve or fourteen days. When the adults laid their eggs in the laboratory and the eggs and developing larvae were taken to the diapause--inducing conditions, all larvae remained in diapause. The duration of development from the egg stage to the mature larval stage that disappeared in the pupation substrate was about twelve days.

Table 1 Different ambient conditions influencing larval diapause and development of *Aphidoletes aphidimyza* (Rond.)

adults	eggs	larvae	cocoons	larvae in diapause (%) exp.1	exp.2	developmental period egg to mature larva exp.1 (days)	exp.2
S,A	S,A	S,A	L,CH	99,4	92,2	14,2	12,1
L,CH	S,A	S,A	L,CH	99,7	100,0	11,9	12,6
L,CH	S,CL	S,CL	L,CH	88,8	-	22,4	-
L,CH	L,CH	S,A	L,CH	54,7	65,0	7,5	10,3
L,CH	S,A	L,CH	L,CH	55,9	26,1	10,5	10,0
L,CH	L,CH	L,CH	L,CH	33,1	31,1	5,2	6,8

S/L: short/long photoperiod CH/CL: continuous high/low temperature
A: alternating temperatures

An almost corresponding result was obtained when the adults laid their eggs in the situation described above and the developing larvae were kept in the same short day conditions but at a continuous low temperature. Close to 90% of the larvae remained in diapause but the development, however, slowed down remarkably. When only the larvae were kept in the diapause-inducing conditions 55 or 65% of them remained in diapause. The developmental time was shorter than in the case when both eggs and larvae were kept in the diapause--inducing conditions. Finally when only the eggs were kept in the conditions mentioned above, 26 or 56% of the larvae remained in diapause and the developmental time was only 10 days.

From a practical point of view a simple method of making *A. aphidimyza* enter diapause is to keep both eggs and larvae in a short photoperiod at a low temperature (L 8 (25°C) and D 16 (10°C)). The highest percentage of diapausing larvae in cocoons was obtained by this method. According to Havelka (1978), however, diapause is induced in the active larva in the last instar a day before the cocoon is built and in the cocoon. It is more practical to use alternating temperatures than a continuous low temperature together with the short photoperiod because the development of the midge is faster at alternating temperatures. For the same reason it is not worth keeping adults in the diapause-inducing conditions. If a mass rearing of *A. aphidimyza* is done in the laboratory, 70 or 80% of the midges emerge when they are well taken care of and the developmental period from the egg stage to the disappearance of the larvae into the pupation substrate varies from 5 to 6 days.

To find out at which conditions the diapausing larvae in the cocoons should be stored, a three-month experiment was carried out. It was done twice, with 2600 and 2900 larvae in cocoons. They were produced by keeping eggs and larvae in the diapause-inducing conditions (L 8 (25^{o}), D 16 (10^{o})). The cocoons were divided in five groups. In each group half of the cocoons were kept in a humid substrate (sand and water) and the other half in a dry substrate (sand). After three months the larvae in the cocoons were taken from the different storage conditions to room temperature and long photoperiod. The sand was moistened and the emerging of adults followed. Cocoons of group a, the control group, were kept at room temperature at a long photoperiod (L 18, D 6) for 12 weeks. In group b the cocoons were kept in darkness at $+5^{o}$. Cocoons in group c were kept in darkness at $+5^{o}$ for 6 weeks and at -5^{o} for another 6 weeks. In group d the cocoons were first kept in darkness at $+5^{o}$ for 4 weeks, after this they were moved to -5^{o} for another 4-week period and finally back to $+5^{o}$ for the third 4-week period. In group e the 12-week period was divided into 4 parts. First 4 weeks of darkness at $+5^{o}$, then 4 weeks at -5^{o}, 2 weeks at $+5^{o}$ and finally 2 weeks at $+10^{o}$(see Table 2).

The percentage of adults that emerged was very low in all groups. It was highest in group b where about 10% of the midges emerged (Table 2). It took from 5 to 6 weeks until the emerging started after the cocoons had been taken to room temperature and long photoperiod and the sand had been moistened. Only a few midges emerged daily. The emergence was followed during several weeks. The percentages of the midges emerged from the dry and the humid substrates were the same.

The results show that *A. aphidimyza* can be made to enter

Table 2 Different storage conditions of diapausing *Aphidoletes aphidimyza* (Rond.) larvae in cocoons and adult emergence hereafter

weeks (2, 4, 6, 8, 10, 12)	a	b	c	d	e
	+25° L18 D6	+5° D24	+5° D24	+5° D24	+5° D24
			-5° D24	-5° D24	-5° D24
				+5° D24	+5° D24
					+10° D24
	Room temperature, long photoperiod				
adult emergence %	1,3	12,5	1,6	2,8	2,2
	0,2	8,0	1,3	2,4	2,0

diapause when necessary. The storage conditions used in the investigations have to be improved. In natural conditions in Finland larvae of *A. aphidimyza* are known to enter diapause in September, pupate in spring and emerge in the beginning of May (Markkula & Tiittanen, 1977). There are no records on a possible aestivation period of *A. aphidimyza* in the summer time. A longer storage period should be possible if only the right conditions can be found.

<u>References</u>

Havelka, J., 1978. Aphidophagous gallmidge Aphidoletes aphidimyza Rond. (Diptera, Cecidomyiidae) - her biology, ecology, methods of rearing, keeping and use against aphids in glasshouses. (In Russian)
CSc. Thesis. Acad. Agr. Sci. Leningrad. (Ref. from extract supplied by Dr. Ivo Hodek)

Markkula, M. & K. Tiittanen, 1977. Use of the predatory midge Aphidoletes aphidimyza (Rond.) (Diptera, Cecidomyiidae) against aphids in glasshouse cultures. Proc. Symp. XV Int. Congr. Entom. Washington, USDA AS ARS-NE-85: 41-44.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

BIOLOGICAL CONTROL OF WHITEFLY - INITIAL PEST DENSITY AS THE MOST IMPORTANT FACTOR GOVERNING SUCCESS

G.N. Foster

The West of Scotland Agricultural College
Department of Zoology
Auchincruive, Ayr KA6 5HW
Scotland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 41-44

BIOLOGICAL CONTROL OF WHITEFLY - INITIAL PEST DENSITY AS THE MOST IMPORTANT FACTOR GOVERNING SUCCESS

G.N. Foster

Summary

Analysis of data from 33 tomato crops in Scotland showed that introductions of Encarsia formosa at 30.000 parasitized scales per ha were successful in controlling greenhouse whitefly (Trialeurodes vaporariorum) when the initial density of the pest did not exceed 0.1 adults per upper leaf, but such introductions had a high risk of failure at higher pest densities.

Since 1974, tomato growers in Scotland have been advised to introduce *Encarsia formosa* at 30.000 parasitized scales per ha on two-three occasions at fortnightly intervals, starting when adult whiteflies are first seen. If this treatment fails to establish the parasite in sufficient numbers to gain control, the cost to the grower is small compared to that incurred if extra introductions also fail.

Routine data (weekly or fortnightly counts of adults whiteflies, black and white pupae) from 33 tomato crops treated with *E. formosa* at the standard rate have been analysed with respect to density of adult whiteflies at the time of the first introduction of the parasite. Ranked in ascending order of whitefly density, the first 22 crops (⩽0.094 adults per upper leaf) required no insecticidal treatment to maintain control satisfactory to the grower, whereas biological control 'failed' in ten of the eleven remaining glasshouses (⩾0.110 adults per upper leaf) (Table 1). 'Failure' ranged from the use of a single spray of resmethrin, directed at the heads of the plants to reduce adult numbers, to abandonment of biological control. Growers normally abandoned biological control where the whitefly population exceeded four adults per leaf or where sooty moulds affected more than one percent of the crop. Analysis of the data on

om 33 tomato crops in the west of Scotland, 1975-78. Each crop received
t two introductions of *Encarsia formosa*

	peak recorded whitefly density (geometric means)				
af)	adults/upper leaf	unparasitized pupae/lower leaf	mean % parasitization of pupae 6 weeks after 1st parasite introduction	insec appli 0	1
	1.2	6.4	46	11	0
	1.1	3.5	54	11	0
	6.9+	10.7+	37	1	3

ed by insecticide usage

the basis of the use of two as opposed to three or more parasite introductions, or on the month or year of introduction, or on site differences, did not divide successes from failures.

The most obvious reason for some growers not accepting biological control is that it is known to fail. The occasional failure receives far more publicity than any number of successes. If biological control of whitefly had proved a total success in the recent phase of its use, the relatively subsidiary problems of its cost, of its integration with other control methods and of supply would have been overcome owing to greater demand from growers. A major reason for failure appears to be excessive whitefly numbers at the time of parasite introduction. If the present rate of parasite introduction is the one most economically feasible, then growers must be dissuaded from attempting biological control where the chances of its success are reduced by a high whitefly density.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

POSSIBILITIES FOR THE CONTROL OF TOMATO MOTH (*LACANOBIA OLERACEA*)

G.N. Foster

The West of Scotland Agricultural College
Department of Zoology
Auchincruive, Ayr KA6 5HW
Scotland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 45-52

POSSIBILITIES FOR THE CONTROL OF TOMATO MOTH (LACANOBIA OLERACEA)

G.N. Foster

Summary

Tomato moth (Lacanobia oleracae) is now the second commonest pest of glasshouse tomatoes in Scotland. The main possibilities for integrating the control of this pest with biological control of other pests are reviewed.

Introduction

An annual survey of tomato growers in the Clyde Valley (the main area of tomato production in Scotland) showed that tomato moth (*Lacanobia oleracea*) replaced greenhouse whitefly (*Trialeurodes vaporariorum*) as the second commonest pest of the crop in 1977 (Figure 1). The proportion of growers reporting fruit damage increased from 4% in 1974 to 23% in 1977 (Foster & Kelly, 1978).

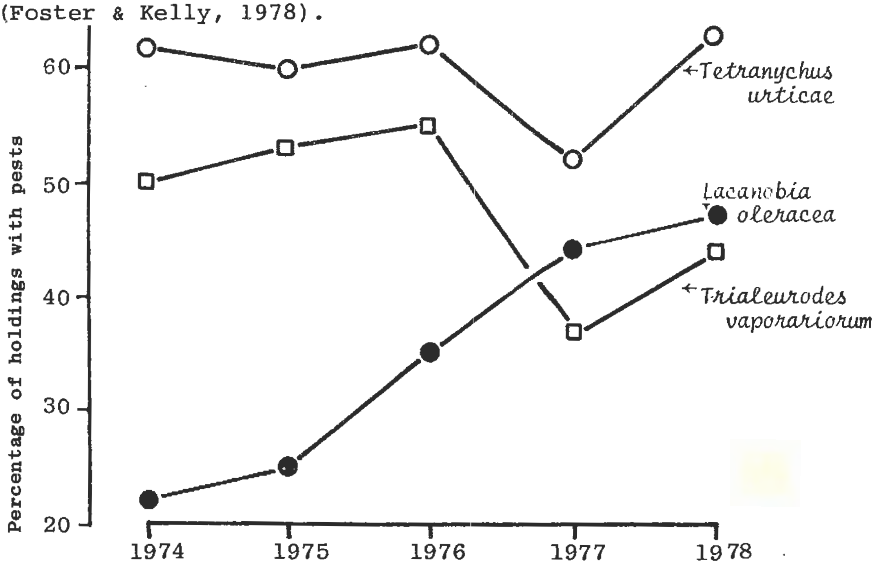


Figure 1. Proportion of growers reporting three glasshouse pests in the Clyde Valley, Scotland, 1974-78.

Lacanobia oleracea has two generations and a partial third under glass (Lloyd, 1920). Defoliation by first generation caterpillars is not economically significant but late instars scar the highly valued early fruit trusses and may also behead young plants. Attack by second generation larvae causes more substantial fruit losses and the fouling of sound fruit increases labour costs for cleaning as in the case of greenhouse whitefly damage.

The increasing risk of caterpillars outbreaks under glass has been recognised in Britain but a full appraisal of possible methods of control does not appear to have been attempted. The use of commercial preparations of *Bacillus thuringiensis* has readily been accepted as the sole solution to the problem of controlling caterpillars where other glasshouse pests are being controlled biologically. Any insecticide must be applied early in the season to kill first generation larvae in order to reduce the size of the second generation. It has proved difficult, and often impossible, to persuade growers to take action against a slight infestation at a time when labour is urgently required for other operations. The price structure of available insecticides favours use of broad spectrum insecticides with consequent risk to acceptance of biological control methods. This total reliance on larval control is thus unsatisfactory. Lloyd's (1920) programme of control (trapping adults throughout the season, insecticidal control of first generation larvae, trapping of fully fed larvae, and destruction of overwintering pupae) gave acceptable control until replaced by DDT and steam sterilization (Speyer & Parr, 1948); the possible components of a new control programme should be considered, with emphasis on minimal labour use and integration with biological control of other pests.

Chemical larvicides

Of the few effective materials cleared for use on edible crops under glass in Britain, DDT and dichlorvos have government approval for control of *L. oleracea*. DDT smokes, with a short harvest interval requirement, are still used effectively for caterpillar control. The usefulness of the organophosphate materials is limited by harvest interval requirements except for dichlorvos, which is not effective against late instars. Price structure and minimal residue problems favour permethrin and decamethrin, the rates cleared for use against greenhouse whitefly having been found to be highly effective against *L. oleracea*. Diflubenzuron is the only selective insecticide likely to be acceptable in integrated control programmes (Ledieu, 1978).

Microbial larvicides

At least three commercial formulations of *B. thuringiensis* are available. Burges & Jarrett (1978) indicated that high volume spraying at about 2.5 man-days per hectare was too costly and they developed a fogging technique, although fogging machines are also costly and of limited use. Growers in Scotland apply *B. thuringiensis* through overhead spray-lines, taking about 2.5 man-hours per hectare. The main disadvantages of *B. thuringiensis* are cost and the need for repeated application.

Lloyd (1920), Speyer & Parr (1948) noted laboratory cultured caterpillars dying of a disease with symptoms of granulosis in England. Shvetsova & Ts'ai (1962) recorded a polyhedrosis disease in Russia. Meynardier et al. (1969) described *Bergoldiavirus oleraceae* as a baculovirus causing granulosis in laboratory cultured *L. oleracea* in France. A baculovirus destroyed laboratory cultures of *L. oleracea* obtained from the Clyde Valley in 1978. An epizootic of the granulosis disease controlled a severe outbreak by caterpillars on one holding in 1978 and the disease has recurred in the same house in 1979.

Cultural management and larval behaviour

Spyer & Parr (1948) found that high larval mortality was due to starvation of dispersing caterpillars. Although hand-picking is not normally effective in controlling infestations, the disturbance associated with training, deleafing and harvesting increases the mortality of young larvae. Some growers react to infestations by earlier and more thorough deleafing. This also improves spray cover but would be detrimental to biological control of other pests.

Egg parasites

Zorin & Zorina (1929) recorded *Trichogramma evanescens* as a parasite of *O. oleracea* eggs on outdoor crops in Russia. Chepetilnikova & Fedorintchik (1964) claimed successful control of brassica pests including *L. oleracea* by the combined use of *Trichogramma* and *B. thuringiensis* but no attempt has been made to use *Trichogramma* under glass.

Larval parasites

At least 26 species of hymenopterous and tachinid parasites have been recorded from *L. oleracea* but none has given control under glass.

Pupal predators

Lloyd (1920) described several methods of reducing overwintering populations including the use of chickens and pigs. Speyer & Parr (1948) reported destruction of pupae by mice on one holding in 1927. In the severe winter of 1978/9, a glasshouse experiment in Scotland had to be abandoned because house mice (*Mus musculus*) destroyed pupae. One holding on which a severe infestation had occurred in 1978 was free from attack until June in 1979; the unsterilized soil was riddled with mouse burrows and the remains of pupae were common on the soil surface in the spring. The use of gleaning animals (or even mice) may have limited value; winter predation must be taken into account when forecasting outbreaks.

Pupal destruction

Abandonment of soil sterilization has been blamed for the increased incidence of *L. oleracea* in Scotland (Foster & Kelly, 1978) since it would lead to improved survival of pupae. Analysis of survey data obtained in 1978 only partly confirmed this. By 1978, sterilization had been partly abandoned on 39% of holdings in the west of Scotland. The chances of *L. oleracea* infestation were not significantly greater on these holdings (55%) than on holdings where all glasshouse soil was sterilized (45%).

Compounds generating methyl isothiocyanate, the use of which has partly replaced steam sterilization, were far less effective than steam in reducing the chances of reinfestation (Table 1). Thus it is the reduction in *steam* sterilization which has been responsible for the increased incidence of *L. oleracea* . Even before the advent of soil sterilization, Lloyd (1920) advocated drenching soil with boiling water to kill pupae. Now that soils are becoming permanently compacted where soilless cultivation is practiced, pupae will be confined to the soil surface; sheet steaming may be economic where pupal counts are high.

Table 1. Probability of attack by *Lacanobia oleracea* in 1978 following infestation in 1977, based on data from the Clyde Valley, Scotland.

Unsterilized units	94 %
Completely sterilized units	65 %
Steam sterilized units	40 %
Units sterilized with either dazomet or metham sodium	78 %

Trapping of adults

Lloyd's (1920) main method of control was the use of poisoned traps baited with sugar and fermenting material. Dochkova (1968) caught roughly equal numbers of *L. oleracea* in traps baited either with fermenting molasses or with an ultra-violet light source. Burges & Jarrett (1976), on the basis of a study of adult moth behaviour under glass, concluded that the use of ultra-violet light traps might supplement crop sprays in controlling moth outwith their natural flight period.

Commercially available electrocutor-grid traps with a 15 watt 'black light' source (3.300 - 3.700 Å) were operated in pairs in tomato crops planted in February and April, 1979. Each glasshouse contained 3.00 to 4.000 plants and was adjacent to a comparable unit; all four glasshouses had severe *L. oleracea* infestations in 1978.

Assuming no reduction in numbers of *L. oleracea* due to other causes, trapping small numbers of moths significantly ($P < 0.001$) reduced the numbers of plants damaged (Table 2). Inspection of the distribution of attack in relation to trap position in the early crop suggested that an extra trap may have proved sufficient to eliminate the infestation. The cost of trap installation would be offset by the minimal labour input associated with their use.

Table 2. Preliminary analysis of the numbers of adult *Lacanobia* caught in light traps in 1978 and 1979

		February crop		April crop	
Percentage of		1978	1979	1978	1979
plants damaged	*with traps*	7.3	1.5	4.4	2.4
by first generation larvae	*without traps*	3.5	3.3	2.9	7.1
χ^2(1 d.f.)		38.3		66.7	
Number of moths caught in both traps		59		20	

The pheromone of virgin female *L. oleracea* has not been identified, but its use under glass either to eliminate male moths or to disrupt breeding seems a logical development. Kishaba et al. (1970) used electrocutor grid traps to study response of male moths to pheromones, and Stanley et al. (1976) reviewed the development of traps for this purpose. One trap of each pair operated in 1979 was supplied with a polythene vial impregnated with 1 mg of Z-9, tetradecen-1-yl acetate (prepared by Dr. P.S. Beevor of the Tropical Products Institute, London). The complete assembly was alternated with the untreated trap at three-week intervals. The pheromone--baited traps caught more males in proportion to females than the unbaited traps, but differences were not significant.

<u>Forecasting</u>

Two important points emerged from this study. Firstly, severe outbreaks of *L. oleracea* usually followed on slight

caterpillar damage at the end of the previous season, then not thought by the grower to require action. Secondly, assuming that adult trapping indicated total numbers of overwintered pupae and that fecundity is about 1.000 eggs per female, very few pupae need survive the winter to place the crop at risk, possibly less than one per 20 m^2.
A sampling method should be developed to detect low pupal numbers.

References

Burges, H.D. & P. Jarrett, 1976. Adult behaviour and oviposition of five noctuid and tortricid moth pests and their control in glasshouses. Bull. ent. Res. 66: 501-510.

Burges, H.D. & P. Jarrett, 1978. Caterpillar control with Bacillus thuringiensis. Grower 1978: 589-595.

Chepetilnikova, V.A. & N.S. Fedorintchik, 1964. Utilisation combinée des entomophages et des microorganismes en vue du remplacement ou de la limitation de l'emploi des traintements chimiques. Proc. Int. Coll. Pathology of Insects and Microbiological Control, Paris 1962, Entomophaga, mém. hors série 2: 511-514.

Dochkova, B., 1968. [The possibilities of studying flight of noctuidae injurious to sugar beet]. Rastenievudni Nauki 5: 93-98. (abstract only)

Foster, G.N. & A. Kelly, 1978. Survey of pests of glasshouse tomato crops in Lanarkshire, 1974-77, with special reference to the biological control of glasshouse whitefly. Pl. Path. 27: 86-91.

Kishaba, A.N., W.W. Wolf, H.H. Toba, A.F. Howland & T. Gibson, 1970. Light and synthetic pheromone as attractants for cabbage loopers. J. econ. Ent. 63: 1417-1420,

Ledieu, M.S., 1978. Candidate insecticides for the control of larvae of Mamestra brassicae (Lepidoptera: Noctuidae). Ann. appl. Biol. 88: 251-255.

Lloyd, L., 1920. The habits of the glasshouse tomato moth, Hadena (Polia) oleracea, and its control. Ann. appl. Biol. 7: 66-102.

Meynardier, G., S. Poitout & G. Kuhl, 1969. Une granulose nouvelle affection de Mamestra oleracea L. (Lepidoptera, Noctuidae). Entomophaga 14: 421-427.

Shvetsova, O.I. & H. Ts'ai, 19[illegible]. [Virus disease in Agrotis segetum and Hadena sordida (Lepidoptera, Noctuidae) in cases of simultaneous infection by granulosis and polyhedrosis viruses]. Rev. Ent. URSS 41: 781-787 (abstract only).

Speyer, E.R. & W.J. Parr, 1948. The tomato moth (Diataraxia oleracea L.). Rep. exp. Res. Stn, Cheshunt, 1947: 41-64.

Stanley, J.M., J.C. Webb, W.W. Wolf & E.R. Mitchell, 1976. Electrocutor grid insect traps for research purposes. Trans. Am. Soc. agric. Engrs 20: 175-178.

Zorin, P.V. & L.M. Zorina, 1929. [Contributions to the biology of Polia oleracea L.]. Zashch. Rast. Vredit. (1928) 5: 475-486.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

THE DEVELOPMENT OF BIOLOGICAL CONTROL OF WHITEFLY AND RED SPIDER MITE ON TOMATOES AND CUCUMBERS IN ENGLAND AND WALES

H.J. Gould

Ministry of Agriculture, Fisheries and Food
Harpenden Laboratory
Hatching Green
Harpenden, Herts.
England

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 53-58

THE DEVELOPMENT OF BIOLOGICAL CONTROL OF WHITEFLY AND RED SPIDER MITE ON TOMATOES AND CUCUMBERS IN ENGLAND AND WALES

H.J. Gould

Summary

Surveys of biological control programmes on cucumbers and tomatoes in England and Wales between 1975 and 1978 showed a steady increase in the area on which these techniques were used. During 1978 it was estimated that biological control of red spider mite (Tetranychus urticae) was in use on 72% of the cucumber crop while biological control of whitefly (Trialeurodes vaporariorum) was being used on over 30% of the tomato crop. In all years results were generally considered to be satisfactory, but complete failures with both Phytoseiulus persimilis and Encarsia formosa sometimes occurred and on some crops selective spraying with suitable pesticides was necessary to prevent patches of heavy infestation developing.

Introduction

Gould (1971), Parr et al. (1976) and French et al. (1976) have described in detail suitable techniques for the control of glasshouse whitefly (*Trialeurodes vaporariorum*) and red spider mite (*Tetranychus urticae*) on tomatoes and cucumbers. Supplies of the whitefly parasite *Encarsia formosa* and the red spider mite predator *Phytoseiulus persimilis* have been available from a number of commercial producers for several years. Since 1975 annual surveys have been made to obtain information on the extent of use of biological techniques on commercial nurseries in England and Wales.

Method

Regional entomologists of the Agricultural Development & Advisory Service (ADAS) obtained details of all tomato and cucumber growers known by ADAS advisers to be using biological control programmes for the control of whitefly and red spider mite. The information received included details of the area of each crop on which *E. formosa* and/or *P. persimilis* was used and a subjective assessment by the grower or adviser of the control achieved. Growers were also asked whether they were introducing the agents and monitoring the technique themselves or whether they had taken out a contract with one of the commercial suppliers to do this work for them.

Results and discussion

The results of the surveys from 1975-1978 are shown in Table 1.

Table 1 Use of biological control on cucumbers and tomatoes, 1975-1978

				P. persimilis (ha)		*E. formosa* (ha)	
year	no. of growers	area (ha)	% increase	cucumber	tomato	cucumber	tomato
1975	117	57		15	11	20	22
1976	209	180	215	89	42	54	86
1977	236	249	38	94	79	87	146
1978	550	337	35	164	108	81	168

The results show that following the very rapid increase in the use of biological control in 1976, interest in the technique is still continuing, with a considerable increase in the cucumber area on which *P. persimilis* was used to control red spider mite in 1978. The data presented probably under-estimate the true position as they include only those growers known by ADAS advisers to be using biological control. The survey results expressed as percentages of the total area of heated tomatoes and cucumbers grown in England and Wales are shown in Table 2.

Table 2 Percentage of cropped area (heated crops only) using biological control

	cucumbers		tomatoes	
	P. persimilis	*E. formosa*	*P. persimilis*	*E. formosa*
1976	45	27	8	16
1977	47	43	15	27
1978	72	36	20	31

The surveys show that *P. persimilis* continues to be mainly used for the control of red spider mite on cucumbers. Following the difficult resistance situation with this pest which developed in the early 1960's, this was the first biological control programme to be successfully developed in the UK (Hussey et al., 1965) and it has now been in commercial use for about 10 years. The area of tomatoes on which *E. formosa* is being used for the control of glasshouse whitefly continues to increase slowly but in 1978 still only represented just over 30% of the crop. The much larger increase in the number of growers (133%) using *E. formosa* in 1978 compared with the increase in crop area (35%) treated suggests that many more small growers are now adopting the technique.

In 1978 at least 2 commercial producers again offered a biological control contract service on tomatoes and cucumbers, in which they undertake to supply and introduce the parasites and predators necessary to maintain effective control of whitefly and red spider mite and to monitor the situation regularly during the season.

The data available from the survey suggested that at least 149 ha of crop was treated under contract arrangements, a considerable increase over the estimated area of 86 ha in 1977.

Some information on the success of biological control was obtained from the subjective assessment of the treatment by the grower or adviser (Table 3).

Table 3 Percentage area of cucumbers and tomatoes treated on which biological control was satisfactory

year	*Phytoseiulus*	*Encarsia*
1975	87	72
1976	72 *	86
1977	80	86
1978	95	88

(* highest summer temperatures for many years)

The programmes used have not been entirely satisfactory and each year a small number of complete failures were reported. However, a large percentage of growers considered that they had obtained satisfactory results. In 1976 *P. persimilis* was less effective on some nurseries (Table 3). Reduced predator efficiency would be expected in the prolonged periods of high temperatures that occurred during the summer of 1976, in these conditions large numbers of red spider mites colonize the tops of the plants where they multiply rapidly while *P. persimilis* remain in the cooler areas down the plants (Anon. 1976). On some nurseries sprays of tetradifon, applied to the tops of the plants, were required to restore the balance between predator and prey.

Similarly unexplained problems occur with *E. formosa* where growers occasionally report small areas of plants heavily infested with whitefly in glasshouses where the parasite-prey interaction is otherwise satisfactory. These patches are usually held in check by selectively spraying the heavily infested areas with resmethrin or permethrin.

Reasons for unsatisfactory control include delay in introducing the parasites or predators, failure to monitor the pest/parasite relationship regularly, particularly in the early stages of the interaction, excessive deleafing in the early part of the season when large numbers of parasitized scales can be removed with the leaves and the use of pesticides which are harmful to the biological agents for the control of other pests and diseases.

Attempts are being made to establish threshold levels for whitefly adults on newly planted tomato crops above which biological control is unlikely to be satisfactory. Also training courses are regularly arranged by ADAS entomologists in the main glasshouse areas to explain the new techniques to growers.

References

Anon, 1976. The biological control of tomato pests. Growers' Bulletin No. 3. Glasshouse Crops Research Institute, Littlehampton, Sussex.

French, N., W.J. Parr, H.J. Gould, J.J. Williams & S.P. Simmonds, 1976. Development of biological methods for the control of Tetranychus urticae on tomatoes using Phytoseiulus persimilis. Ann. appl. Biol. 83: 177-189.

Gould, H.J., 1971. Large scale trials of an integrated control programme for cucumber pests on commercial nurseries. Plant Pathology 20: 149-156.

Hussey, N.W., W.J. Parr & H.J. Gould, 1965. Observations on the control of Tetranychus urticae on cucumbers by the predatory mite Phytoseiulus riegeli. Ent. exp. & appl. 8: 271-281.

Parr, W.J. H.J. Gould, W.H. Jessop & F.A.B. Ludlam, 1976. Progress towards a biological control programme for glasshouse whitefly on tomatoes. Ann. appl. Biol. 83: 349-363.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

EVALUATION OF TWO NATIVE COCCINELLIDS FOR APHID CONTROL IN GLASSHOUSES

Matti Hämäläinen

University of Helsinki
Department of Agricultural and Forest Zoology
Viikki
SF-00710 Helsinki
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 59-64

EVALUATION OF TWO NATIVE COCCINELLIDS FOR APHID CONTROL IN GLASSHOUSES

Matti Hämäläinen

The main emphasis in studies on biological control in Finland in the 1970's was concentrated on finding a suitable agent for controlling aphids in glasshouses. Besides the midge *Aphidoletes* and chrysopids also ladybeetles were evaluated as control agents. The project on ladybeetles was started in 1970 and was finished in 1977. The species studied were the common native ones: *Coccinella septempunctata* L. and *Adalia bipunctata* (L.). The control targets were mainly *Myzus persicae* (Sulz.) on green peppers and chrysanthemums and *Macrosiphum rosae* on roses. Because the results are scattered over several papers (Hämäläinen, 1976, 1977a, b; Hämäläinen & Markkula, 1972a, b, 1977; Hämäläinen et al., 1975; Markkula et al., 1972) and because a compiling synthesis was published in the Finnish language (Hämäläinen, 1977c), the main results are briefly reviewed here.

Effectiveness on plants

None of the ladybeetles proved ideal for use in practical control, because they did not form a self-perpetuating population in the glasshouse, which would prevent aphids from reaching destructive levels during the whole growing season. However, it was possible to suppress aphid populations by introducing predators on plants at intervals of a few weeks. Adult beetles were not suitable for release since they tended to fly out. Introducing larvae was more profitable. *Adalia bipunctata* larvae managed better on green pepper stands (see Table 1), possibly a reflection of the natural bushy habitat of this species. *Coccinella septempunctata* larvae succeeded on the other hand on the low and thick chrysanthemum stands. The failure of both species on roses was mainly due to the unability of small larvae to stay on the roses. Once fallen down, they did not find the infested rose tops, and succumbed.

Table 1 Ranking of the two ladybeetle species in relation to their properties relevant in biological control in glasshouses

	C. septempunctata	*A. bipunctata*
Efficacy on chrysanthemums	xxx	xx
Efficacy on green peppers	x	xxx
Efficacy on roses	x	x
Breeding in glasshouses	x	(x)x
Survival of eggs in glasshouses	xx	x
Supply from nature	xxx	xx
Possibility of continuous laboratory breeding	xxx	xxx
Storage of adults at cool temperatures	x	xxx
Storage of eggs at cool temperatures	x	xx
Possibility of using artificial diets	x	xx

Symbols: xxx good, xx satisfactory, x poor.
Using the symbols, the difference can be seen only between the two species in relation to a certain property. Different properties are not comparable as such.

In some experiments with *A. bipunctata* on green peppers, a second generation equal in size to that introduced was formed in the glasshouse. However, this required a very balanced original predator/prey ratio, which can seldom be obtained in a practical situation. Usually, if larvae were released in sufficient numbers to give good control of aphids, the larvae disappeared or died when aphids became scarce, and only a few pupated. If a less favourable predator/prey ratio was used at the introduction, more predators reached the pupal stage, but the aphids remained uncontrolled, and rapidly increased when predators were as pupae.

Transferring small larvae on plants was time consuming. Thus it was best to place egg clusters on plants. High temperature in glasshouses may cause problems, since eggs of *A. bipunctata* did not hatch at 35°C. *Coccinella septempunctata* eggs hatched normally at this temperature.

Mass production and handling

For practical control large quantities of ladybeetle eggs are needed. This calls for effective mass production of the beetles and eggs. Both species are native and can easily be obtained for mass breeding. It was possible to produce successive generations without diapause in both species under a long photoperiod (LD 18:6), at a temperature above 20°C, and with essential food available. Ten to 12 annual generations were produced in these conditions. However, a stock can be kept at cool storage when not required for control. *Adalia bipunctata* adults could very successfully be stored in a simple laboratory hibernacula at 6°C for six months, but at similar conditions *C. septempunctata* adults suffered a high mortality.

An artificial cool storage of eggs allows a greater flexibility in handling and delivering the eggs. It was possible to store eggs of *A. bipunctata* for two weeks and eggs of *C. septempunctata* for one week at 10°C without any marked decrease in the hatchability.

Providing natural food for ladybeetles is rather uneconomic, since it requires much space, material and time. An artificial diet would be a solution. At the Agricultural Research Centre in Vantaa, diets were developed for the two species (Kariluoto et al., 1976; Kariluoto, 1978). A suitable larval diet was developed for *A. bipunctata*, but results in breeding adults or larvae of *C. septempunctata* were less complete. Also a method for feeding large quantities of larvae at once with an artificial diet is not yet developed.

Finally, if the two ladybeetle species are compared (Table 1), *A. bipunctata* looks a little more promising as a biological agent in glasshouses, mainly because its mass production and handling are easier. Anyway, none of the species can at present be recommended for use in practice, because large numbers of them should be introduced at short intervals, an uneconomic enterprise at the moment.

References

Hämäläinen, M., 1976. Rearing the univoltine ladybeetles, Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae) all year around in the laboratory. Ann. Agr. Fenn. 15: 66-71.

Hämäläinen, M., 1977a. Control of aphids on sweet peppers, chrysanthemums and roses in small greenhouses using the ladybeetles Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae). Ann. Agr. Fenn. 16: 117-131.

Hämäläinen, M., 1977b. Storing dormant Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae) adults in the laboratory. Ann. Agr. Fenn. 16: 184-187.

Hämäläinen, M., 1977c. Evaluation of the ladybeetles, Coccinella septempunctata and Adalia bipunctata, for biological control of aphids in greenhouses . (Finnish, with English summary). 30 pp. Ph.D. thesis, University of Helsinki.

Hämäläinen, M. & M. Markkula, 1972a. Possibility of producing Coccinella septempunctata L. (Col., Coccinellidae) without a diapause. Ann. Ent. Fenn. 38: 193-194.

Hämäläinen, M. & M. Markkula, 1972b. Effect of type of food on fecundity in Coccinella septempunctata L. (Col., Coccinellidae). Ann. Ent. Fenn. 38: 195-199.

Hämäläinen, M. & M. Markkula, 1977. Cool storage of Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae) eggs for use in the biological control in greenhouses. Ann. Agr. Fenn. 16: 132-136.

Hämäläinen, M., M. Markkula & T. Raij, 1975. Fecundity and larval voracity of four ladybeetle species (Col., Coccinellidae). Ann. Ent. Fenn. 41: 124-127.

Kariluoto, K.T., 1978. Optimum levels of sorbic acid and methyl-p-hydroxybenzoate in an artificial diet for Adalia bipunctata (Coleoptera, Coccinellidae) larvae. Ann. Ent. Fenn. 44: 94-97.

Kariluoto, K., E. Junnikkala & M. Markkula, 1976. Attempts at rearing Adalia bipunctata L. (Col., Coccinellidae) on different artificial diets. Ann. Ent. Fenn. 42: 91-97.

Markkula, M., K. Tiittanen & M. Hämäläinen, 1972. Preliminary experiments on control of Myzus persicae (Sulz.) and Macrosiphum rosae (L.) with Coccinella septempunctata L. on greenhouse chrysanthemums and roses. Ann. Ent. Fenn. 38: 200-202.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

REPORT OF PHYTOSEIULUS MACROPILIS MANAGEMENT OF TETRANYCHUS URTICAE ON GREENHOUSE GROWN DIEFFENBACHIA

R.A. Hamlen

University of Florida
Agricultural Research Center
Route no. 3, box 580
Apopka, FL 32703
U.S.A.

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 65-74

REPORT OF PHYTOSEIULUS MACROPILIS MANAGEMENT OF TETRANYCHUS URTICAE ON GREENHOUSE GROWN DIEFFENBACHIA

R.A. Hamlen

Infestation of *Tetranychus urticae* Koch under intensive cropping environments common to tropical foliage plant production frequently results in significant economic reduction in host plant quality. Acaricidal control is often inadequate, can result in phytotoxicity and may enhance development of pesticide tolerance. The importance of the Phytoseiidae as biotic control agents for spider mites is well known (Hussey et al., 1965; Bravenboer, 1969; Huffaker et al., 1970) and *Phytoseiulus persimilis* Athias-Henriot has been evaluated on greenhouse ornamentals in Europe (Stenseth, 1976) and the United States (Boys & Burbutis, 1972; Lindquist et al., 1979). This report contains data on the effectiveness of an additional species, *P. macropilis* (Banks), in control of *T. urticae* populations on greenhouse grown dieffenbachia, an ornamental tropical foliage plant. *Phytoseiulus macropilis* naturally occurs in Florida (Poe, 1972; Saba, 1974) and has been collected from greenhouse plants (Shih et al., 1979). Prasad (1967) described the life cycle duration of this species and Shih et al. (1979) provided data on biology, population increase and predation on *T. urticae*.

Results of previous studies

In a preliminary study using recently propagated dieffenbachia, *Dieffenbachia maculata* (Lodd.) G. Don cv. Perfection Compacta, initially infested with a mean 34.7 *T. urticae* / 15 cm leaf, 10 adult female *P. macropilis* were released per plant (ca. predator:prey ratio 1:17). The mean period for significant reductions in *T. urticae* numbers was 2 weeks and < 1 mite/leaf detected 3 weeks following *P. macropilis* introductions at 23-31^{o}C (Hamlen, 1978). Frequency distribution (% of leaves containing *P. macropilis*) followed *T. urticae* densities and reached 96% of assayed foliage with collapse of predator populations within 2 weeks after prey were no longer detectable. Approximately 4 times the number of leaves contained both predator and prey as contained only *P. macropilis*. By use of foliar damage indexes of 0-4 (definitions in Table 2), the critical level of damage occuring from *T. urticae* feeding, i.e. that above which aesthetic or market value loss occurs, was established at a mean value of 1.5. This value represented a midpoint between incipient damage, i.e. index of 1, and damage detectable on close inspection, i.e. index of 2. Significant differences in damage indexes between predator-present and predator-absent treatments, i.e. lower damage values with predator-present, were noted one week after *P. macropilis* release and damage indexes below 1,5 occurred 3 weeks later. *Phytoseiulus macropilis* were again released at 8 weeks and marketable plants were maintained for ca. 14 weeks. The ability of *P. macropilis* to suppress established and damaging populations of *T. urticae* was evident and the data are summarized in Table 1.

Table 1. Effect of *Phytoseiulus macropilis* released into damaging *Tetranychus urticae* populations on dieffenbachia (data from Hamlen, 1978).

treatment	$\bar{x}$ leaf damage initially [a]	weeks from release to <1 mite/leaf	$\bar{x}$ leaf damage by <1 mite/leaf	final $\bar{x}$ leaf damage (14 weeks)
P. macropilis	2.0 [b]	3	2.2	0.7
control	2.3 [c]	-	3.7 [d]	3.8

[a] Damage level above 1.5 considered unacceptable

[b] $\bar{x}$ no. of 34.7 *T. urticae* /15 cm leaf. Initially 10 *P. macropilis* released/plant and again after 8 weeks

[c] $\bar{x}$ no. of 41.0 *T. urticae* /15 cm leaf

[d] Damage level at 3 weeks without predators. $\bar{x}$ no. of 98.3 *T. urticae*/leaf.

In releases of *P. macropilis* on *T. urticae* infested parlor palm, *Chamaedora elegans* Mart., *T. urticae* populations were significantly reduced 2 weeks after release; however, control and damage index results were not as satisfactory as those recorded for dieffenbachia (Hamlen, 1978).

The following two studies were carried out to further determine the number of *P. macropilis* , in relation to *T. urticae* density, that would be necessary to effect satisfactory control before the host plants incurred economic injury.

Effects of P. macropilis at specific predator-prey ratios on introduction into established T. urticae populations

Materials and methods

Culture indexed and tissue culture produced *Dieffenbachia maculata* cv. Perfection (Knauss, 1976; Taylor & Knauss, 1978) obtained as cuttings ca. 20 cm tall, were each propagated in containers ringed with Tack-Trap (Animal Repellents Inc., Griffen, GA, USA) and infested with 15 *T. urticae*/plant. After 2 weeks, total numbers of *T. urticae*/3 leaves were counted and *P. macropilis* adults and nymphs were introduced onto infested plants in each of 5 replicates at predator-prey ratios of 1:5, 1:10 and 1:20. A second introduction at 1:5 and 1:20 was completed after 11 weeks. Numbers of *T. urticae* , *P. macropilis*, predator frequency (% of leaves containing *P. macropilis*) and a leaf damage index (Table 2) were recorded weekly from 3 newly expanded leaves/plant. Final plant height was measured 15 weeks after *P. macropilis* release. Dieffenbachia infested with *T. urticae* but without *P. macropilis* functioned as controls. Plants were maintained on raised benches in a 46.5 m^2 greenhouse area and temperatures ranged from 19-28^{O}C.

Results and discussion

Tetranychus urticae populations were reduced to <1 mite/leaf by two weeks at the release ratio of 1:5 and by three weeks at ratios of 1:10 and 1:20 (Table 3). The lower the release ratio the longer the period for *T. urticae* increases and the higher the population prior to suppression by *P. macropilis*.

Table 2 Definition of levels of mite damage to dieffenbachia foliage and relative populations of *Tetranychus urticae*

leaf damage index[b]	definition	$\bar{x}$ no.mites ± SE/leaf[a] exp. 1[c]	exp. 2[d]
0	no visible damage	5.6 ± 0.7	9.7 ± 1.4
1	incipient damage	26.9 ± 4.3	17.0 ± 4.1
2	feeding areas covering ca. 1/3 leaf area	80.5 ± 10.6	202.8 ± 54.4
3	two-thirds leaf area affected, chlorotic areas evident	106.5 ± 7.9	362.1 ± 27.4
4	dense feeding over entire leaf, leaf chlorotic	189.5 ± 20.6	219.3 ± 22.3

[a] Mean leaf length ± SE of 27.4±0.5 cm
[b] Damage index above 1.5 considered unacceptable
[c] Sampled 15 weeks following release of *P. macropilis* into established *T. urticae* populations
[d] Sampled 11 weeks following simulataneous release of *P. macropilis* and *T. urticae*.

Following initial reductions, populations of *T. urticae* were barely detectable until ca. 6 weeks at the 1:5 ratio and 8 weeks at 1:20. Subsequent increases necessitated additional releases of *P. macropilis* at 11 weeks which resulted in effective reductions in 2 weeks (1:5 ratio) and 4 weeks (1:20 ratio). *Phytoseiulus macropilis* increased rapidly at all release ratios and inhabited 86-100% of assayed leaves one week after release (Table 3). Density of *P. macropilis* followed closely the changes in *T. urticae* density with collapse of predator populations by three weeks at 1:5 and by four weeks at 1:10 and 1:20.

By the time *T. urticae* populations were reduced to <1 mite/leaf, the mean leaf damage index was 0.3, 0.6 and 0.8 for ratios 1:5, 1:10 and 1:20 respectively (Table 3).

Table 3 *Tetranychus urticae* and *Phytoseiulus macropilis* populations, leaf damage index and plant height resulting with introduction of *P. macropilis* at specific ratios into established *T. urticae* populations

$\bar{x}$ no. T. urticae/leaf [1]

predator/ prey ratio	prior *P. macropilis*	weeks after introduction of *P. macropilis* 1	2	3	4	11[2]	13	15
1:5	45.1a	3.4a	0.0a	0.1a	0.2a	31.2a	1.0a	1.7a
1:10	39.6a	10.6ab	4.3a	0.0a	0.3a	0.0a	0.0a	0.8a
1:20	45.9a	19.0b	33.5a	0.3a	0.0a	26.7a	68.4b	0.0a
no predators	55.7a	37.1c	99.5b	175.4b	141.1b	88.9b	130.5c	133.9b

$\bar{x}$ no. P. macropilis/leaf (predator frequency)[3]

predator/ prey ratio	prior *P. macropilis*	1	2	3	4	11	13	15
1:5	-	6.5(100)	0.3(13)	0 (0)	0 (0)	0.9(40)	10.1(40)	0.5(20)
1:10	-	5.9(100)	3.8(100)	2.3(73)	0.1(7)	0 (0)	0 (0)	1.0(33)
1:20	-	3.9(86)	7.5(100)	24.5(100)	0 (0)	0.3(20)	14.8(100)	0.6(40)

$\bar{x}$ leaf damage index [1]

predator/ prey ratio	prior *P. macropilis*	1	2	3	4	11	13	15	*final $\bar{x}$ plant height (cm)*
1:5	0.6a	0.3a	0.3a	0.3a	0.3a	1.1b	0.6ab	0.8ab	67.4a
1:10	0.5a	0.3a	0.5a	0.6ab	0.4a	0.2a	0.04a	0.4a	69.1a
1:20	0.5a	0.7a	1.1b	0.8b	0.8a	0.7ab	1.1b	1.3b	69.3a
no predators	0.2a	0.4a	1.0b	2.0c	2.3b	3.1c	2.9c	3.5c	59.3b

[1] means in a column sharing common letters are not significantly different at the 5% level by Duncan's multiple range test

[2] 2nd introduction of *P. macropilis* in treatments 1:5 and 1:20

[3] % leaves containing *P. macropilis*

Damage to control plants for the same period ranged from an index of 1.0-2.0 and was significantly greater damage than occurred to plants where predators were present. Final damage indexes after 15 weeks where *P. macropilis* was present on dieffenbachia ranged from a mean of 0.4-1.3 while a 3.5 mean damage level was recorded where predators were absent. As in the previous study (Hamlen, 1978), an index above 1.5 was considered to indicate an unmarketable plant. Definitions for leaf damage indexes and the mean numbers of *T. urticae* detected appear in Table 2. Final plant height measurements demonstrated significant increases in growth by dieffenbachias with control of *T. urticae* (Table 3).

Effects of simultaneous introductions of P. macropilis and T. urticae at specific ratios

Materials and methods

Dieffenbachia obtained and propagated as in the previous study were infested with 80 *T. urticae*/plant with a simultaneous release of *P. macropilis* at levels to establish predator-prey ratios of 1:5, 1:10 and 1:20. This initial level of *T. urticae* approximated that occurring in the previous study at the time of *P. macropilis* introductions. Observations were carried out as in the previous study and temperatures ranged from 20-27°C. No additional releases of *P. macropilis* were carried out.

Results and discussion

Tetranychus urticae populations were reduced to undetectable levels within two weeks at the 1:5 and 1:10 ratios and by three weeks at 1:20 (Table 4). Populations of *T. urticae* remained barely detectable for 11 weeks, with exception of the 9 week observation at the 1:5 ratio. As in the previous test, the 1:20 ratio required a longer period for reductions of *T. urticae*. Again, *P. macropilis* numbers and occurrence followed population changes of *T. urticae*. No significant differences in mean damage indexes were detected between *P. macropilis*-present and control plants by the time *T. urticae* were no longer detected (Table 4). However, by four weeks after infestation

Table 4 *Tetranychus urticae* and *Phytoseiulus macropilis* populations, leaf damage index and plant height resulting with simultaneous release of *T. urticae* and *P. macropilis* at specific ratios

predator/ prey ratio	1	2	3	4	6	9	11	*final $\bar{x}$ plant height (cm)*
	$\bar{x}$ no. T. urticae/leaf [1)] weeks after infestation							
1:5	10.1a	0.0a	0.5a	0.7a	0.0a	22.7a	0.2a	
1:10	13.5b	0.0a	0.1a	0.1a	0.0a	0.0a	0.0a	
1:20	19.2c	7.6a	0.0a	0.0a	0.0a	0.0a	0.0a	
no predators	44.1d	116.6b	134.3b	200.5b	452.6b	256.7b	163.5b	
	$\bar{x}$ no. P. macropilis/leaf (predator frequency) [2)]							
1:5	3.3(93)	0.5(26)	0.2(20)	0.9(53)	0.2(26)	1.8(73)	1.5(60)	
1:10	3.6(100)	2.1(80)	0 (0)	0.4(18)	0 (0)	1.0(40)	0.1(17)	
1:20	5.9(100)	5.0(100)	1.1(40)	0.9(33)	0.1(7)	0.1(7)	0.3(26)	
	$\bar{x}$ leaf damage index [1)]							
1:5	0.0a	0.2a	0.7a	0.7a	0.9b	1.2b	0.9a	70.6a
1:10	0.0a	0.1a	0.4a	0.4a	0.1a	0.6a	0.6a	71.1a
1:20	0.0a	0.9a	0.6a	0.6a	0.2a	0.7a	0.7a	70.5a
no predators	0.2b	0.7a	0.8a	1.5b	3 1c	3.5c	3.8c	63.7b

[1)] means in a column sharing common letters are nog significantly different at the 5% level by Duncan's multiple range test

[2)] % leaves containing *P. macropilis* and release, an index of 1.5 was recorded from the controls. Final damage levels for *P. macropilis* -present treatments were 0.9, 0.6 and 0.7 for ratios 1:5, 1:10 and 1:20 respectively, and these values were significantly less than those recorded from control plants, i.e. 3.8. As in the previous study, dieffenbachia with suppressed *T. urticae* populations were significantly larger and of better quality than were control plants (Table 4).

These studies represent preliminary efforts in the use of *P. macropilis* and clearly demonstrate the potential of this phytoseiid as a biotic agent for management of *T. urticae* and preventing damage of economic importance. Results indicated the importance of having effective numbers of *P. macropilis* present at relatively low densities of *T. urticae* in order to achieve population suppression before loss of aesthetic or marketable value. Future studies will assay the effectiveness of lower predator numbers, include additional tropical foliage plant species and evaluations under interior landscape environments.

References

Boys, F.E. & P.P. Burbutis, 1972. Influence of Phytoseiulus persimilis on populations of Tetranychus turkestani at the economic threshold on roses. J. econ. Ent. 65: 114-116.

Bravenboer, L., 1969. Biological control of mites in glass-houses. Proc. 2nd Int. Congr. Acarol. 1967: 365-371.

Hamlen, R.A., 1978. Biological control of spider mites on greenhouse ornamentals using predaceous mites. Proc. Fla. State Hort. Soc. 91 (in press).

Huffaker, C.B., M. van de Vrie & J.A. McMurtry, 1970. II. Tetranychid populations and their possible control by predators: an evaluation. Hilgardia 40: 391-458.

Hussey, N.W., W.J. Parr & H.J. Gould, 1965. Observations on the control of Tetranychus urticae Koch on cucumbers by the predatory mite Phytoseiulus riegeli Dosse. Ent. exp. appl. 8: 271-281.

Knauss, J.F., 1976. A tissue culture method for producing Dieffenbachia picta cv. Perfection free of fungi and bacteria. Proc. Fla. State Hort. Soc. 89: 293-296.

Lindquist, R.K., C. Forst & M.L. Wolgamott, 1979. Integrated control of insects and mites on greenhouse crops. Ohio Agric. Res. and Dec. Centre, Res. Circ. 245. 20 p.

Poe, S.L., 1972. Agroecological factors influencing the biology and management of predaceous mites. Proc. Tall Timbers Conf., Ecological Animal Control by Habitat Management 4: 205-217.

Prasad, V., 1967. Biology of the predatory mite Phytoseiulus macropilis in Hawaii (Acarina: Phytoseiidae). Ann. Ent. Soc. Am. 60: 905-908.

Saba, F., 1974. Life history and population dynamics of Tetranychus tumidus in Florida (Acarina: Tetranychidae). Fla. Ent. 57: 47-63.

Shih, C.I., S.L. Poe & H.L. Cromroy, 1979. Biology and predation of Phytoseiulus macropilis on Tetranychus urticae. Fla. Entom. 62: 48-53.

Stenseth, C., 1976. Rovmidd for bekjempelse av veksthusspinmidd pa morplanter av kroton og diffenbachia. Gartneryrket 66: 780-782.

Taylor, M.E. & J.F. Knauss, 1978. In vitro multiplication and subsequent handling of known pathogen-free Dieffenbachia x Exotica Perfection. Proc. Fla. State Hort. Soc. 91 (in press).

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

SOME ASPECTS OF PHOTOPERIODISM OF THE APHIDOPHAGOUS GALLMIDGE APHIDOLETES APHIDIMYZA ROND.

J. Havelka

Czechoslovak Academy of Sciences
Institute of Entomology
Viničná 7
128 00 Praha 2
Czechoslovakia

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 75-82

SOME ASPECTS OF PHOTOPERIODISM OF THE APHIDOPHAGOUS GALLMIDGE APHIDOLETES APHIDIMYZA ROND.

J. Havelka

The aphidophagous gallmidge *Aphidoletes aphidimyza* Rond. seems to be one of the most perspective species in biological suppression of aphid populations in greenhouses. Storing is an important problem of the mass rearing of this insect. The solution for storing is closely connected with the phenomenon of diapause. We read works on diapause of De Wilde (1962), Danilevski (1961), Beck (1968), Tyschenko (1977) and others and decided to study some unknown aspects of the photoperiodism of *A. aphidimyza*.

Our investigations demonstrated that the photoperiod is a leading factor in the induction of diapause in the larvae of this gallmidge. The results stimulated a more detailed study on the influence of photoperiod. We studied the effect of long day conditions (18 hours photophase) at 24°C and short day conditions (6 hours photophase) at 15°C, The short day conditions and a low temperature induced the diapause in all specimens at the stage of a larva in the cocoon. The stage that is sensitive to the photoperiod is demonstrated in Fig. 1. As you can see, the sensitive period is the period of the last larval instar and the cocooned larva. The photoperiodic curves in populations of Leningrad (60° northern latitude) and Kischinev (47° n.l.) at 20°C were also determined. The critical photophase was found to be 17 hours in the population of Leningrad and 15.5 hours in the population of Kischinev (Fig. 2).

Another important problem which was studied is a diapause development including reactivation. If we stored the diapausing larvae at 4°C the cold-reactivation can proceed, as you can see in Table 1. Such a pattern is typical for insect species of the temperate and boreal climate. The reactivation was indicated by the adult

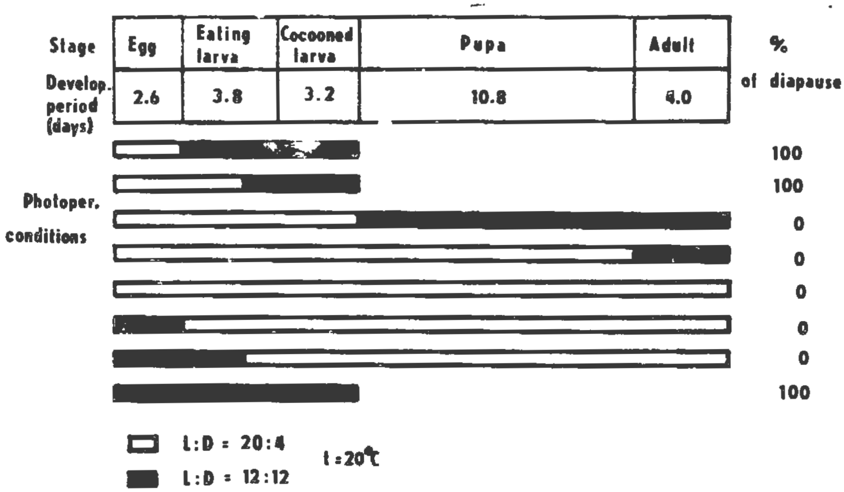


Fig. 1 The influence of short day conditions on induction of diapause during different stages of the development of *Aphidoletes aphidimyza*.

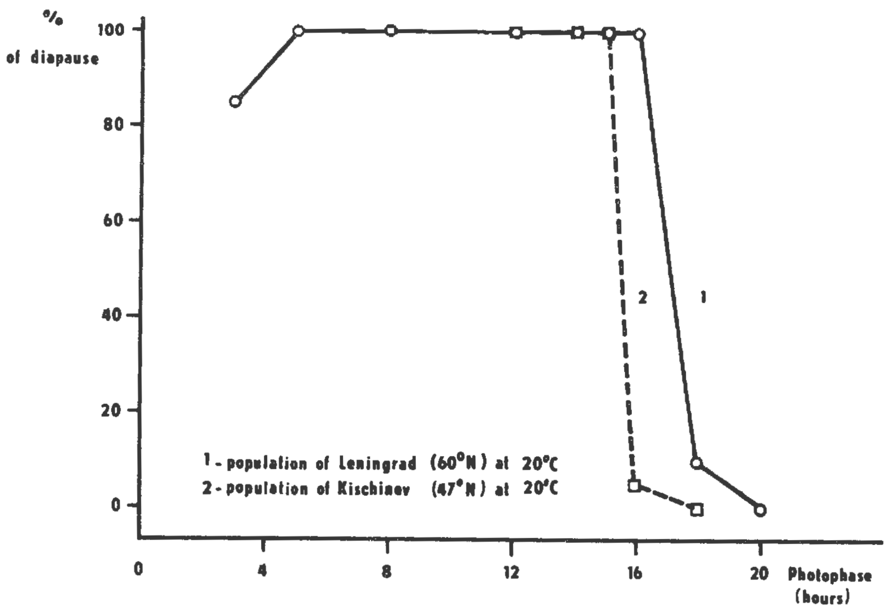


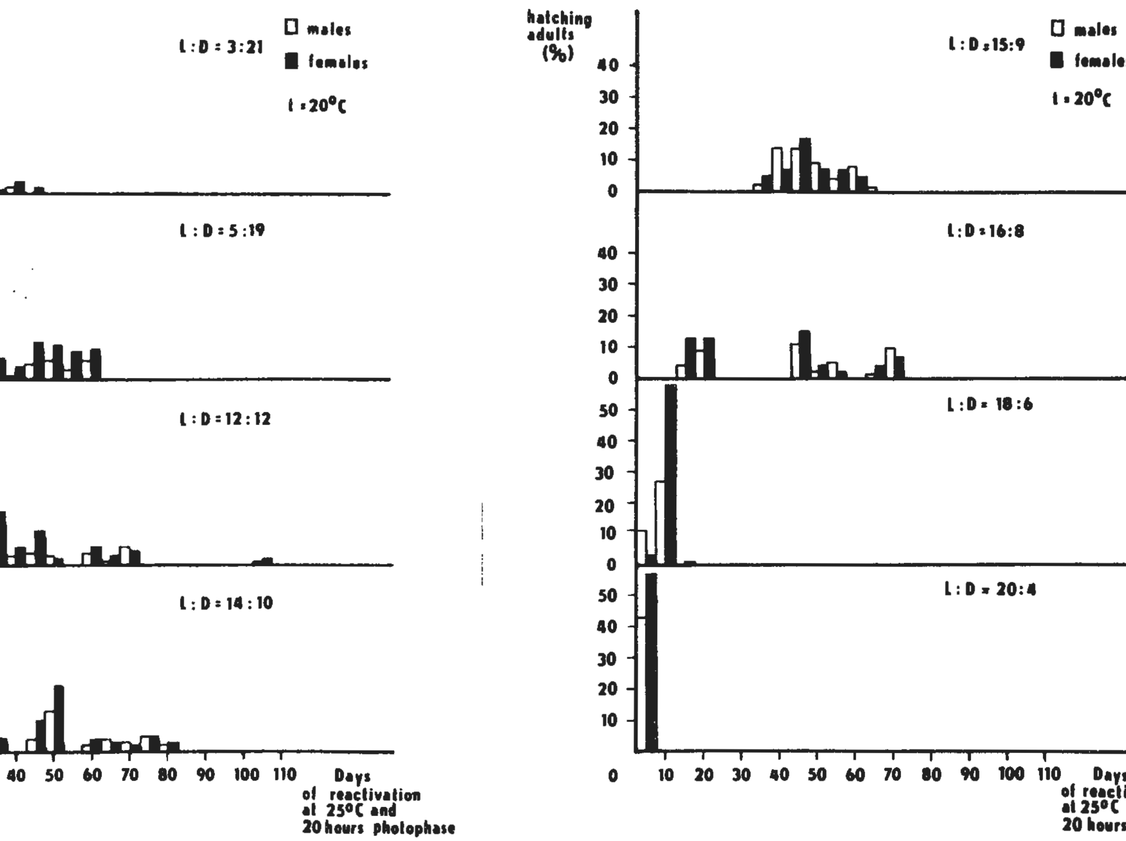
Fig. 2 Effect of the length of photophase on the induction of diapause in two populations of *Aphidoletes aphidimyza*.

Table 1 Cold-reactivation and mortality at 24°C and 18 hours photoperiod of diapausing larvae of *Aphidoletes Aphidimyza* in relation to the period of storing. Induction of diapause was at 6 hours photophase and 15°C.

stored at 4±1°C (days)	no. of larvae	developmental period after cold treatment start	50% emergence	% mortality	no. of non-reactivating larvae
0	100	28	51	16	0
20	100	27	44	18	2
40	100	8	27	16	2
60	100	14	26	22	0
80	100	12	38	18	2
100	100	18	42	20	1
120	100	10	35	26	1

emergence at 24°C and 18 hours photophase after a cold period of 4°C and 0 hours photophase. The period during which 50% of the adults emerged was accepted as a quantitative index. A cold reactivation period of 40 days is proposed, because this period gives a significant shortening of the post-diapause development. In the control experiment in which no cooling occurred, done at 24°C and 18 hours photophase, emergence started on the 28th day and after 51 days 50% of the adults had emerged. This fact provides evidence that there is, besides reactivation through low temperature, also photoperiodic reactivation in *A. aphidimyza.* Under short day conditions they would not reactivate so fast (see Table 4).

The results dealing with photoperiodic reactivation are presented in Table 2. The depth of diapause depends on photoperiodic and temperature conditions during the time of diapause induction. The deepest diapause, expressed as the longest time necessary for reactivation, in the population of Leningrad was induced by a photophase of 12-14 hours at 20°C. The dynamics of adult emergence



elation between the reactivation period (at 25°C and 20 hours photophase) and
he percentage emergence of adult *Aphidoletes aphidimyza*.

Table 2 Depth of diapause in *Aphidoletes aphidimyza* of the Leningrad population, expressed as the number of days necessary after a diapause induced by the specific photoperiods. This provides a quantitative index of photoperiodic reaction. Temperature at diapause induction: 20°C.

photophase at diapause induction (hours)	no. of larvae	period of reactivation at 25°C and 20 hours photophase (days)			% mortality
		min.	max.	average	
3	125	8	45	17.3 ± 1.82	10.4
5	125	20	60	38.6 ± 2.53	5.6
12	375	20	105	36.9 ± 2.06	15.4
14	250	10	80	41.6 ± 1.58	11.6
15	125	35	65	40.4 ± 1.66	10.4
16	125	15	75	36.9 ± 4.04	8.0
18	250	5	15	5.4 ± 0.23	21.6
20	250	5	10	6.6 ± 0.27	14.0

after different photophases at diapause induction are presented in Figs. 3 and 4. The emergence of the adults proceeds with periodical gaps but both sexes emerge simultaneously in the course of the process.

The clean cocoons that do not contain organic sweepings are the most suitable form for storing this species. For short-period storage (up to two months approximately) non-diapausing cocooned larvae can be used. The mortality during storage at 4°C reached approximately 50% in 30 days and roughly 80% in 80 days (see Table 3).

For long-period storage deep-diapausing larvae in the cocoon must be used (see Tables 1 and 4). The larvae can be stored succesfully at higher teperature (20°C), but under short photophase (12 hours) (see Table 4). The mortality after a 6-month period of storing and after reactivation at a photophase of 20 hours and a temperature of 25°C was 28%. The influence of the relative humidity on stored cocoons is presented in Table 5. A relative humidity of

tion of photoperiodic reactivation and mortality of cocooned *Aphidoletes aphidim*
ae, stored at long day conditions (20 hours photophase and 25°C)

no. of larvae	duration of reactivation in days to 30% adult emergence	50% adult emergence	% mortality of cocooned stage to 50% adult emer
150	35	40	22.0
125	45	55	28.0

uence of relative humidity on emergence of *Aphidoletes aphidimyza* at 25°C and 20
ophase from diapausing and non-diapausing cocooned stages

dity)	humidity sustaining compound	no. of larvae	% emergence of adults non-diapausing	diapausing
	KOH	30	16.6	0.0
	KOH	30	16.6	0.0
	$Ca(NO_3)_2$	30	40.0	0.0
	KOH	30	73.3	0.0
	-	50	88.0	76.0
act	-	50	90.0	82.0

Table 3 Mortality and developmental period at 24°C, 18 hours photophase of non-diapausing cocooned *Aphidoletes aphidimyza* larvae in relation to the length of storage at a temperature of 4°C.

storage at 4± 1°C (days)	no. of larvae	developmental period after storage to emergence of adults (days) start	50% emergence	% mortality
0	100	7	9	12
20	100	16	19	43
40	100	43	-	63
60	100	38	-	64
80	100	46	-	85
100	100	42	-	94
120	100	26	-	99

of 100% is necessary to obtain the maximum number of emerging adults.

<u>References</u>

Beck, S.D., 1968. Insect photoperiodism. Academic Press, New York. 288 pp.

Danilevski, A.S., 1961. Photoperiodism and insect's seasonal development. Leningrad State University Press, Leningrad. 243 pp. (in Russian).

Tyschenko, V.P., 1977. Fysiology of insect's photoperiodism. Trudy VEO 59: 1-156.

Wilde, J. de, 1962. Photoperiodism in insects and mites. Ann. Rev. Entom. 7: 1-26.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

DACNUSA SIBIRICA TELENGA AND OPIUS PALLIPES WESMAEL (HYM., BRACONIDAE) IN THE CONTROL OF THE TOMATO LEAFMINER LIRIOMYZA BRYONIAE KALT.

Ans Hendrikse[1], R. Zucchi[2], J.C. van Lenteren[1] & J. Woets[3]

[1]Dept. of Ecology, University of Leiden, Leiden, the Netherlands

[2]permanent adress: Dept. of Biology, Faculty of Sciences (USP), Ribeirao Preto (SP), Brasil

[3]Glasshouse Crops Research Station, Naaldwijk, the Netherlands

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 83-98

DACNUSA SIBIRICA TELENGA AND OPIUS PALLIPES WESMAEL (HYM.,BRACONIDAE) IN THE CONTROL OF THE TOMATO LEAFMINER LIRIOMYZA BRYONIAE KALT.

Ans Hendrikse, R. Zucchi, J.C. van Lenteren & J. Woets

Summary

Since 1976 the tomato leafminer Liriomyza bryoniae causes pest problems in the Netherlands. Pesticides used against this leafminer disrupt the successful biological control of the other main pest, the glasshouse whitefly (Trialeurodes vaporariorum) by Encarsia formosa. Therefore it is desirable to control L. bryoniae biologically.

A research programme was started to follow the pest development in commercial glasshouses. The presence of leafminers shortly after the tomatoes are planted (January) causes problems, because no natural enemies are present at that time. Introduction of Dacnusa sibirica, a parasite of L. bryoniae, seems to give good results when introduced during the first or second generation of leafminer larvae. Leafminers that appear in early summer did not cause outbreaks, because natural enemies were able to enter the glasshouse.

In order to obtain information about the control capacity of D. sibirica and Opius pallipes, and to develop mass-rearing and introduction methods, their life history and behaviour were studied. Data on reproductive capacity and development indicate that D. sibirica and O. pallipes are able to control the tomato leafminer. Opius pallipes seems to be more efficient in finding infested plants, but both species do locate a host in a leaf equally efficient. Both parasite species do not select larvae of a specific host stage for oviposition, but O. pallipes is not able to parasitize medium or large sized host larvae very efficiently. Dacnusa sibirica and O. pallipes do discriminate between parasitized and unparasitized hosts and avoid oviposition in parasitized hosts.

Introduction

Agromyzid leafminers are reported to cause damage to glasshouse crops of tomatoes, chrysanthemums, lettuce and cucumbers in the United States, Canada and several European countries (Lane, 1977; Lindquist, 1976; McClanahan, 1974; Oatman, 1959; Woets, 1976). Several attempts have been made to find natural enemies (Oatman, 1959; McClanahan, 1977) and to find selective insecticides (Lema & Poe, 1978; Poe, 1974; Schuster et al., 1979; Wolfenbarger & Getzin, 1963) to control this pest. No specific programme to control leafminers has been developed yet.

In the Netherlands the tomato leafminer (*Liriomyza bryoniae* Kalt.) has frequently developed to pest levels since 1976. The other main pest in tomatoes is the glasshouse whitefly (*Trialeurodes vaporariorum* (Westwood)), which is successfully controlled by the chalcid wasp *Encarsia formosa* Gahan in 30% of the acreage of heated tomato houses (Woets, 1976). Because of the susceptibility of *Encarsia formosa* to insecticides it is highly undesirable to control *L. bryoniae* chemically and therefore a biological control method has to be developed. In 1977 the Glasshouse Crops Research and Experiment Station (Naaldwijk), the Department of Ecology (Leiden) and the Koppert company (producer of natural enemies, Berkel en Rodenrijs) started investigations to this end.

Parasites of *L. bryoniae* were collected from infested tomato crops in the main glasshouse area (Westland). A mass rearing of one of these 15 parasites, the braconid *Dacnusa sibirica* Telenga, is in development. Subsequently we made observations on population dynamics of and introduction trials with *D. sibirica* . In the laboratory an evaluation of the parasite species that we collected was started. This paper deals with the first results of our observations on population dynamics in commercial glasshouses, and contributes to our previous studies (Hendrikse & Zucchi, 1979; Zucchi & van Lenteren, 1978) on life history and behaviour of *L. bryoniae* and two braconid parasites: *D. sibirica* and *Opius pallipes* Wesmael.

Observations in commercial glasshouses

Introduction

Damage caused by larvae of *L. bryoniae* may appear in commercial glasshouses at different moments during the growing season. In general two characteristic situations can be distinguished: 1) leafminers are present shortly after the tomatoes are planted, and 2) leafminers start to occur when outside temperatures are quite high, that is mainly at the end of May. Most infestations that occur early in the growing season are probably caused by leafminers that were still in the glasshouse (through bad sanitary measures) or by introduction of leafminers on young plants from the nurseries.

During 1978 we performed some try-outs in glasshouses by releasing the braconid parasite *D. sibirica* . The population fluctuations of *L. bryoniae* were examined by weekly observations as follows: the main path in a glasshouse runs from the entrance to the back, perpendicular to the path are small working paths, between which two rows of tomatoes are planted. Observations were made of the plants on working paths 5, 15, 25, etc. In this way about 10% of the tomato crop was examined. Each week we determined the presence of feeding punctures, larvae and empty mines of *L. bryoniae* , and we counted the number of leafminer larvae on these plants. From the not-observed plants we removed about 200 leaves with larvae. The larvae were dissected to determine the degree of parasitization. All parasite introductions were done by the Koppert company, parasites were released as adults.

Early leafminer infestation (January)

In a glasshouse (0.9 ha) where leafminers appeared in January and the infestation was less than 5 larvae per 10 plants shortly after infestation, adult parasites (*D. sibirica* , approx. 1 per 150 m^2) were distributed over the entire glasshouse immediately after discovery of the leafminers. Two additional releases (in February and March, 50 *Dacnusa* individuals in total) proved sufficient to control the leafminers. The infestation decreased to about 2 larvae per 10 plants. The results are presented in Fig. 1 and show that parasitization varies from 0 to 100% in April/May. The low percentage of parasitism found on May 11 can be explained by the fact that we could collect only very few larvae at that date, because the infestation level was very low. The outbreak of leafminers in July to 30 larvae per 10 plants is probably the result of a combination of high temperatures and the planting of young tomatoes amidst the old ones. The parasites that were present were able to reduce the number of larvae in a short period of time.

In another glasshouse (1 ha) where leafminers also appeared in January, adult parasites (50 *Dacnusa* females) were first introduced in April. Other introductions (a total of 1350 *Dacnusa* females) followed in June (4 times) and July (once), as is indicated by the arrows in Fig. 2. In June the number of leafminers increased to about 60 larvae per 10 plants or even more. Nevertheless the percentage of parasitism increased from 50 to 95% during July. To avoid serious crop damage, the grower sprayed the heaviest infested part of the tomato crop with Dipterex in July. After this treatment we stopped our weekly observations. However, parasitism remained high: in August complete suppression of the leafminers was observed, because we then found an infestation of less than 2 larvae per 10 plants. The final

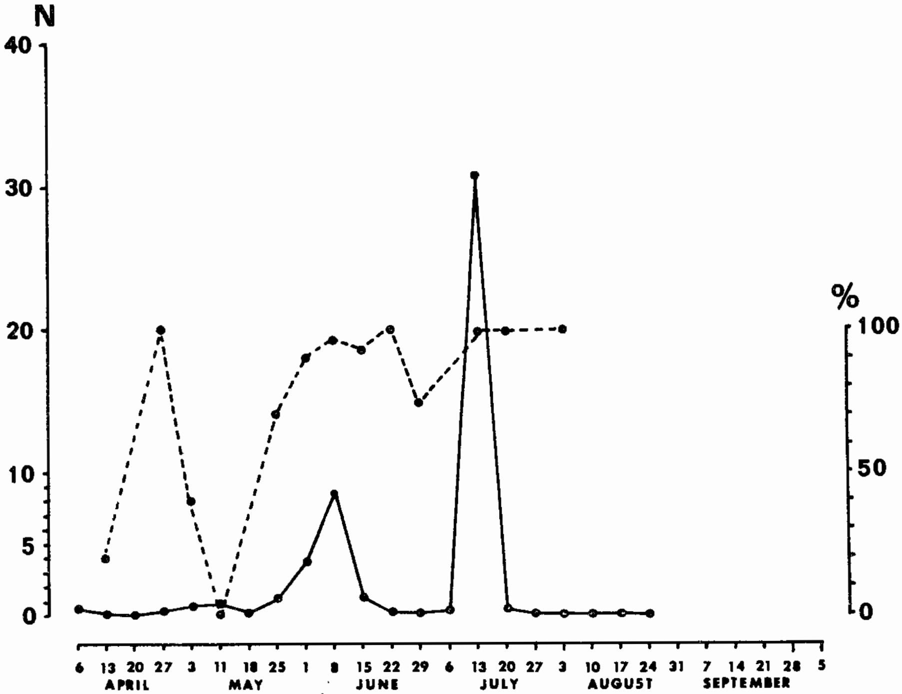


Fig. 1 Number of leafminer larvae per 10 plants (N) and the percentage of parasitism (dotted line) by *D. sibirica*. Infection started in January, introduction of parasites on January 17, February 22 and March 8.

parasitization of 90% was caused by *D.sibirica* (<10%), *Opius pallipes* (approx. 20%) and *Diglyphus isaea* Walker (70%). *Opius pallipes* and *D. isaea* most probably entered the glasshouse through the open windows.

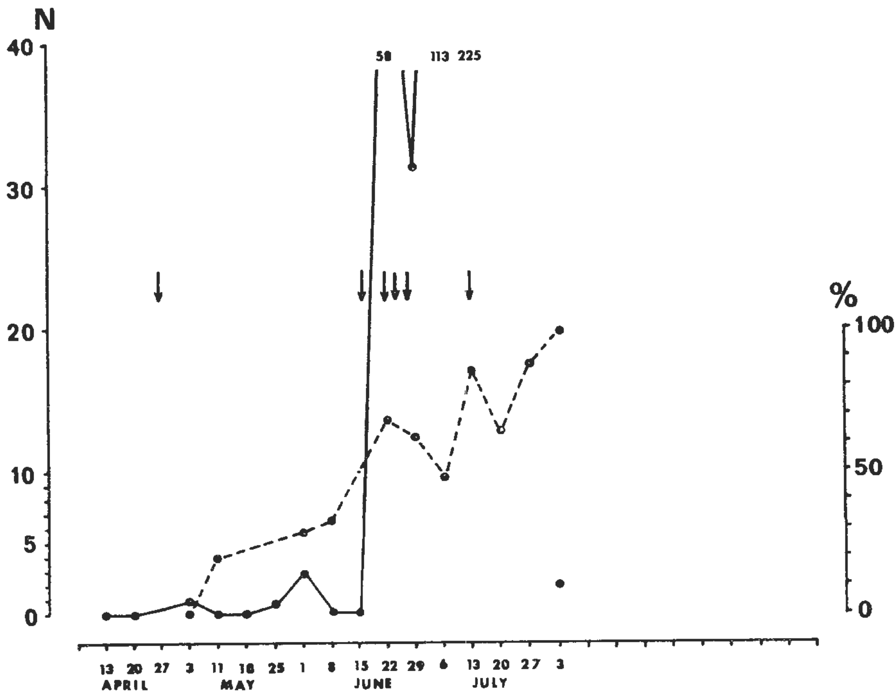


Fig. 2 Number of leafminer larvae per 10 plants (N) and the percentage of parasitism (dotted line) by *D. sibirica*. Infection started in January, introduction of parasites on April 28, June 15, 22, 25, 26 and July 13.

Late leafminer infestation (May-June)

In a third glasshouse (0.43 ha) leafminers appeared in early June (Fig. 3). At that time approx. 90% of the larvae was parasitized mainly by *O. pallipes*. The parasites that had immigrated into the glasshouse were perfectly able to suppress the pest. Only in July the infestation increased to 40 larvae per 10 plants for a short period. In August the parasitization by *O. pallipes* was replaced by chalcid wasps, mainly *D. isaea*, but also a *Chrysocharis* species and two unidentified species. The presence of these ectoparasites can easily be recognised by the large amount of young larvae found dead or dying, inside the mines.

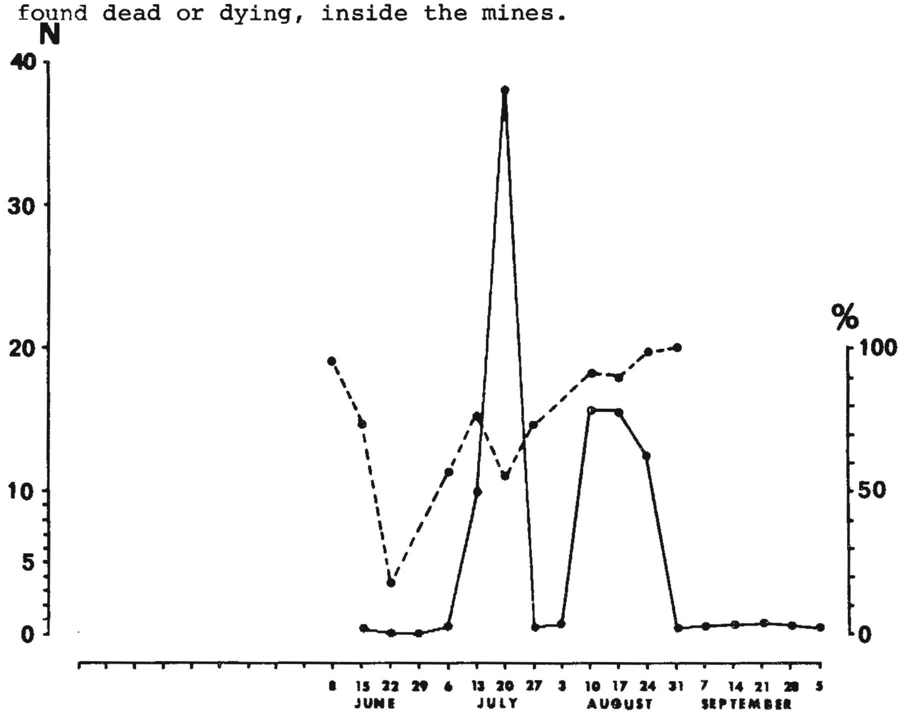


Fig. 3 Number of leafminer larvae per 10 plants (N) and the percentage of parasitism (dotted line). Infection started in June. No parasite introductions.

Conclusions

From these observations we may conclude that:

- the early presence of leafminers causes problems in tomato holdings where the greenhouse whitefly is controlled in a biological way, because there are no natural enemies of leafminers present at that time,
- parasites of *L. bryoniae* should be introduced preferably as soon as possible after the appearance of the pest, and
- it is clear that leafminers appearing in early summer can be controlled by naturally occurring parasites and do not necessitate additional measures.

Comparison of *Dacnusa sibirica* and *Opius pallipes* in the laboratory

Introduction

For the evaluation of the effectiveness of parasites for biological control, several characteristics have been listed as important, e.g. by DeBach & Huffaker (1971). The methods advised to determine the effectiveness of natural enemies before introductions are made, are usually very laborious and predictions about the success of application are still difficult to make. The evaluation method we use is simple. The first selection is based on two biological characteristics:

1) the rate of development, the development of the parasite must preferably be shorter than that of the host; and
2) the reproductive capacity, parasites should have the same or a higher reproductive capacity than the host.

If the parasites fulfill these conditions, some behavioural characteristics are measured to determine whether they might be able to control the host under glasshouse conditions. Data about the behaviour are also important for the development of a mass-production and introduction method of the parasites. The behavioural characteristics we measured are: a)host-habitat finding and host finding to determine the efficiency in finding infested plants, b) searching ability to determine the efficiency in discovering hosts on the plants, c) host selection to determine the selection of hosts of certain stages for oviposition, and d) host discrimination to determine the ability of the parasite to distinguish unparasitized from parasitized hosts.

The environmental conditions during the experiments were: temperature 20 to 25^{o}C; relative humidity 60 to 80%; 16 h light (approx. 3000 Lx) and 8 h darkness. Methods of behavioural observations are described in Hendrikse & Zucchi (1979) and consist of continuous observations of the behaviour of the parasite towards its host.

Biological characteristics

The two braconid wasps *O. pallipes* and *D. sibirica* were studied first, because they are fairly easy to handle and are common in glasshouses. They are both endoparasites, oviposit in larvae and emerge from the leafminer pupa.

The reproductive capacity was determined in the following way: an adult fly was placed in a gauze bag on a tomato leaf. Each day the fly was transferred to another leaf. After some days fly larvae were counted and leaves containing sufficient larvae (approx. 20) were put into a petri dish (diameter 18 cm) in which also a parasite was introduced for 6 hours. By dissecting the larvae the number of parasite eggs was determined.

The rate of development and lifespan of the adults were also studied under laboratory conditions. Data of these experiments are summarized in Table 1.

Table 1 Adult lifespan, rate of development and number of eggs of *Liriomyza bryoniae* and its parasites *Opius pallipes* and *Dacnusa sibirica* (at 22°C ± 2)

	adult lifespan (days) mean s.d.		development (days) mean s.d.		no. eggs mean s.d.	
L. bryoniae	8.7± 4.1	(n=21)	19.6± 1.1	(n=38)	67.3±71.9	(n=21
O. pallipes	10.6± 1.1	(n= 5)	18.3± 1.4	(n=30)	37.0±14.1	(n= 5
D. sibirica	11.4± 1.3	(n= 5)	15.7± 1.5	(n=54)	55.6±22.8	(n= 5

The data for the reproductive capacity of the wasps are preliminary and probably too low. We did not develop a proper set-up yet. On the basis of the number of oocytes in the ovaries we expect the reproductive capacity of the parasites to be at least the same as that of the host. The data indicate that both *D. sibirica* and *O. pallipes* might be able to control the leafminer and we started therefore a study into the host-searching and host-acceptance behaviour.

Behavioural characteristics

- Finding an infested leaf

When searching, both *D. sibirica* and *O. pallipes* hover around plants. Sometimes parasites land on a leaf and start searching there. Observations in glasshouses indicate that parasites can locate the hosts before landing. For *Encarsia formosa* it is known that she lands preferably on plants infested with *Trialeurodes vaporariorum* (van Lenteren et al., 1977). Stimuli important in host-habitat location may come from the host's food (e.g. plant), the host or a combination of these stimuli (Vinson, 1975). To determine whether the leafminer parasites search at random or are directed by certain stimuli, we released individual female parasites in a cage containing a plant with hosts and one without hosts. Results of this experiment are summarized in Table 2.

Table 2 Number of first landings of *Opius pallipes* and *Dacnusa sibirica* on plants with (+) or without (-) host larvae, if released in a cage. The number of females that did not land is given under 0.

	+	-	0
Opius pallipes	80 [1)]	27	29
Dacnusa sibirica	39	34	57

[1)] significant difference $\chi^2 = 13.12$ $P < 0.005$

The *O. pallipes* females flew significantly more to the plant with hosts than to the other plant. The number of landings of *D. sibirica* did not differ significantly from random. *Opius pallipes* is apparently more efficient in locating a plant with hosts than *D. sibirica*.

- Finding a host within a leaf

After landing on a leaf, the female must locate the host. Stimuli involved in this host location are either produced by the host or associated with the presence of the host (Vinson, 1976). A host can be found by random search (e.g. finding of *T. vaporariorum* by *E. formosa*, van Lenteren et al., 1976) or by the ability of the parasite to detect the host from a distance (e.g. the location of *Heliothis virescens* (F.) by *Cardiochiles nigriceps* Viereck, Vinson & Lewis, 1965).

After landing the parasites of both species we studied scan the leaf surface with their antennae and sting the leaf with their ovipositor. If the parasite finds a mine she will follow it till she locates the host, again by scanning with her antennae and stinging with her ovipositor. Ovipositor contact with the host may result in oviposition. In a petri dish experiment (diameter 18 cm, 10 leaves with 1 larva each, either 5 small and 5 medium ones, 5 small and 5 large ones, or 5 medium and 5 large ones) the time necessary to discover a small, medium or large larva was determined. The results (Table 3) show that small larvae are more difficult to detect than medium or large larvae. Parasites of both species seem to be equally efficient in host location after landing on an infested leaf.

Table 3 Time (in sec.) between introduction in the petri dish and discovery of small, medium or large larvae by the wasps *Opius pallipes* and *Dacnusa sibirica*

	small	medium	large
	mean s.d.	mean s.d.	mean s.d.
Opius pallipes	3735[1] ±2252 (n=7)	1105±924 (n=10)	1399±1484 (n=10)
Dacnusa sibirica	4052[1] ±1882 (n=8)	1195±718 (n= 7)	1235±1338 (n= 9)

[1] significant difference $P < 0.05$

When a host is found, the wasp does not always accept it for oviposition. Apparently she tests whether it is suitable for the development of an egg. We studied host selection (among others the selection of larvae of a certain stage for oviposition) and host discrimination (distinguishing parasitized from unparasitized hosts).

- Host selection

If parasites do select larvae of certain stages, this will result in the parasitization of only a specific part of the host population. Information on host selection is important for the development of methods for mass rearing and the determination of the moment of introduction of the parasites into the glasshouse, because parasites should be introduced only at the moment that the right host stages are available. Direct observations were used to test whether host selection occurred: 10 unparasitized larvae were brought into a petri dish (diameter 18 cm) with either 5 small and 5 medium, 5 small and 5 large, or 5 medium and 5 large larvae. The results on acceptance are presented in Table 4.

Table 4 Number of encounters with and oviposition in small, medium or large *Liriomyza bryoniae* larvae by the wasps *Opius pallipes* and *Dacnusa sibirica* (10 tests per parasite species)

		larvae found	number of contacts	number of oviposition	ovipos / contacts	contacts/ larvae found
O.pallipes	s	14	16	7	0.44	1.14
	m	27	58	9	0.16	2.15
	l	22	53	8	0.15	2.41
D.sibirica	s	17	18	12	0.67	1.06
	m	24	24	19	0.79	1.00
	l	35	37	31	0.84	1.06

For *D. sibirica* the ratio between the number of ovipositions and the number of contacts with larvae is about equal for the three larval size groups, viz. 0.67, 0.79 and 0.84 for small, medium and large larvae respectively. We may conclude that *D. sibirica* does not show host selection. For *O. pallipes* the ratio between ovipositions and contacts is 0.44, 0.16 and 0.15 for small, medium and large larvae respectively. Contrary to *D. sibirica* , contacts with larvae of different instars by *O. pallipes* does not equally often result in oviposition. If we calculate an expected number of ovipositions based on the number of contacts with larvae of the three size classes and an equal acceptance of these classes, we find a significant difference with the observed distribution of ovipositions. The large difference between this ratio for small and medium/large larvae is not a matter of selection of small hosts above the medium and large ones. From our observations we know that often the female is hindered in ovipositing in a medium or large larvae because these larvae react by strong movements of their body when the parasite tries to insert her ovipositor. Apart from this, it seems that the parasite has problems in stinging through the thicker skin of these larvae. This also explains the high ratio between contacts and larvae found for medium and large larvae (viz. 2.15 and 2.41): the wasp has to contact the same host several times before an oviposition is realized. These results show that *O. pallipes* does not select specific host stages for oviposition either, but that she is not able to parasitize medium and large sized larvae very easily.

Host discrimination

When a parasite distinguishes between parasitized and unparasitized hosts or between hosts containing different numbers of parasite eggs and lays eggs preferably in unparasitized hosts or in hosts with the lowest number of eggs, we say that she can discriminate (van Lenteren et al., 1978). For solitary parasites it is important to oviposit only once in each host because every supernumerary parasite will be eliminated. So the ability to discriminate prevents wastage of parasite eggs and if probing a host takes less time than oviposition, it also saves time. Parasites who can discriminate may also soon leave a spot where most hosts are parasitized and start to search for other spots with unparasitized hosts. This migration will result in better control (Messenger et al., 1976). Wasps that cannot discriminate will remain searching on the same spot (van Lenteren, 1976; van Lenteren & Bakker, 1976, 1978).

Host discrimination was tested by direct observations of the behaviour of parasites towards unparasitized and parasitized hosts. The results of experiments in which 5 unparasitized medium sized larvae were offered in a petri dish are given in Table 5.

Parasites of both species accept unparasitized larvae more frequently than parasitized larvae: both species are able to discriminate therefore and avoid superparasitism. We further observed that the parasites try to escape from the experimental set-up after encountering mostly parasitized hosts. We may explain this as migration trials. *Opius pallipes* contacted unparasitized hosts more frequently than *D. sibirica* (223 and 158 respectively) but these contacts resulted in less

Table 5 Acceptance of unparasitized and parasitized *L. bryoniae* larvae by *Opius pallipes* and *Dacnusa sibirica*

	hosts	no. contacts	no.ovipositions	acceptance
Opius	unparasitized	223	53	23.8%
pallipes	parasitized	155	5	3.2%
Dacnusa	unparasitized	158	100	63.3%
sibirica	parasitized	121	11	9.1%

ovipositions. This is in agreement with the results of the host-selection experiment, because medium sized larvae were offered in this experiment and *O. pallipes* has difficulties in parasitizing these hosts.

Conclusions

From the behavioural observations we may conclude that:

- *O. pallipes* seems to be more efficient in finding plants with hosts than *D. sibirica*,
- parasites of both species are equally efficient in locating a host in a leaf,
- both *O. pallipes* and *D. sibirica* are able to distinguish between parasitized and unparasitized hosts and avoid laying eggs in parasitized larvae,
- *O. pallipes* and *D. sibirica* do not select larvae of a special stage for oviposition,
- *O. pallipes* is less efficient in parasitizing medium- or large-sized larvae than is *D. sibirica*, and
- *O. pallipes* and *D. sibirica* are promising candidates for biological control of the tomato leafminer, *L. bryoniae*, in Dutch glasshouses.

Results of behavioural studies in the laboratory give the impression that *D. sibirica* is the better one.

To determine the quality of the parasites in the situation where they have to be applied, two sets of tests in glasshouses were done. Details of these experiments will be published elsewhere. The results show clearly that parasites of both species are able to keep *L. bryoniae* on densities far below the economic threshold for a long period. *Opius pallipes* appeared to be the best parasite under these glasshouse conditions: wasps of this species suppressed the host population faster than *D. sibirica*. In the glasshouse where only *L. bryoniae* was introduced *O. pallipes* immigrated and was after some time responsible for control. Immigration of *O. pallipes* also happened in glasshouses where *D. sibirica* was introduced, and *O. pallipes* was responsible for about 90% of the total parasitism in these glasshouses. *Opius pallipes* apparently has a better ability to detect infested spots.

A mass-production method for host and parasites is in development.

Acknowledgements

We are indebted to C.B. van Bommel, P.A.M. Dijkgraaf, R.A. van Egmond, J.G.M. Kooloos and Lidy Mensinga for their assistance with the observations, to the growers P.F. Moerman, C. van Winden and A.J. van der Goes who allowed us to work in their glasshouses. Prof.dr. K. Bakker improved and Hetty Vogelaar typed the manuscript.

References

DeBach, P. & C.B.Huffaker, 1971. Experimental techniques for evaluation of the effectiveness of natural enemies. In: Biological control, C.B. Huffaker, ed.: 113-140. Plenum Press, New York.

Hendrikse, A. & R. Zucchi, 1979. The importance of observing parasite behaviour for the development of biological control of the tomato leafminer (Liriomyza bryoniae Kalt.). Med. Fac. Landbouww. Rijksuniv. Gent 44: in press.

Lane, A., 1977. Tomato leafminer on overwintering tomatoes in Kent. Pl. Path. 26: 150-151.

Lema, K.M. & S.L. Poe, 1978. Juvenile hormone analogs: effects of ZR-777 on Liriomyza sativae and its parasite. Fla. Entom. 61: 67-68.

Lenteren, J.C. van, 1976. The development of host discrimination and the prevention of superparasitism in the parasite Pseudeucoila bochei (Hym., Cynipidae). Neth. J. Zool. 26: 1-83.

Lenteren, J.C. van & K. Bakker, 1976. Functional responses in invertebrates. Neth. J.Zool. 26: 567-572.

Lenteren, J.C. van, K. Bakker & J.J.M. van Alphen, 1978. How to analyse host discrimination. Ecol. Entom. 3: 71-75.

Lenteren, J.C. van & K. Bakker, 1978. Behavioural aspects of the functional responses of a parasite (Pseudeucoila bochei Weld) to its host (Drosophila melanogaster). Neth. J. Zool. 28: 213-233.

Lenteren, J.C. van, H.W. Nell, L.A. Sevenster-van der Lelie & J. Woets, 1976. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). III. Discrimination between parasitized and unparasitized hosts by the parasite. Z. angew. Ent. 81: 377-380.

Lenteren, J.C. van, J. Woets, N. van der Poel, W. van Boxtel, S. van de Merendonk, R. van der Kamp, H. Nell & L. Sevenster-van der Lelie, 1977. Biological control of the greenhouse whitefly Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae) by Encarsia formosa Gahan (Hymenoptera: Aphelinidae) in Holland, an example of successful applied ecological research. Meded. Fac. Landbouww. Rijksuniv. Gent 42: 1333-1342.

Lindquist, R.K., 1976. Status of integrated control in the US greenhouse industry. Bull. O.I.L.B./S.R.O.P. 1976/4: 1-4.

McClanahan, R.J., 1974. Notes on the vegetable leafminer Liriomyza sativae (Diptera, Agromyzidae) in Ontario. Proc. Ent. Soc. Ontario 105: 40-44.

McClanahan, R.J., 1977. Biological control of the leafminer Liriomyza sativae in greenhouse crops. In: Pest management in protected culture crops. USDA ARS-NE-85: 45-48.

Messenger, P.S., F. Wilson & M.J. Whitten, 1976. Variation, fitness and adaptability of natural enemies. In: Theory and practice of biological control, ed. C.B. Huffaker & P.S. Messenger: 209-227. Academic Press, New York.

Oatman, E.R., 1959. Natural control studies of the melon leafminer, Liriomyza pictella (Thomson). J. econ. Ent. 52: 895-898.

Poe, S.L., 1974. Liriomyza munda and parasite mortality from insect growth regulation. Fla. Entom. 54: 415-417.

Schuster, D.J., C.A. Musgrave & J.P. Jones, 1979. Vegetable leafminer and parasite emergence from tomato foliage sprayed with Oxamyl. J. econ. Ent. 72: 208-210.

Vinson, S.B., 1975. Biochemical coevolution between parasitoids and their hosts. In: Evolutionary strategies of parasitic insects and mites, ed. P.W. Price: 14-48. Plenum Press, New York.

Vinson, S.B., 1976. Host selection by insect parasitoids. Ann. Rev. Ent. 21: 109-133.

Vinson, S.B. & W.J. Lewis, 1965. A method of host selection by Cardiochiles nigriceps. J. econ. Ent. 58: 869-871.

Woets, J., 1976. Progress report on the integrated pest control in glasshouses in Holland. Bull. O.I.L.B./S.R.O.P. 1976/4: 34-38.

Wolfenbarger, D.A. & L.W. Getzin, 1963. Selective toxicants and toxicant-surfactant combinations for leafminer, Liriomyza munda Frick, control and parasite survival. Fla. Entom. 46: 251-265.

Zucchi, R. & J.C. van Lenteren, 1978. Biological characteristics of Dacnusa sibirica Telenga (Hymenoptera: Braconidae), parasite of the tomato leafminer, Liriomyza bryoniae Kalt. Med. Fac. Landbouww. Rijksuniv. Gent. 43: 455-462.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

DEVELOPING ARTIFICIAL DIETS FOR *ADALIA BIPUNCTATA* (L.) AND *COCCINELLA SEPTEMPUNCTATA* L.

Kari Kariluoto

Agricultural Research Centre
Department of Pest Investigation
SF-01301 Vantaa 30
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 99-100

DEVELOPING ARTIFICIAL DIETS FOR ADALIA BIPUNCTATA (L.) AND COCCINELLA SEPTEMPUNCTATA L.

Kari Kariluoto

While trying to mass produce coccinellids for the biological control of aphids, one problem is how to produce enough food for rearing. One solution is an artificial diet, on which adults could be reared to produce eggs for greenhouses early in the spring. Continuous rearing should also be possible. Two coccinellids, *Adalia bipunctata* (L.) and *Coccinella septempunctata* L. had proved to be effective against aphids in greenhouses (Hämäläinen, 1977). *Adalia bipunctata* was chosen as the test species after preliminary experiments on different artificial insect diets.

The work was carried out on the principle of trial-and-error, making new modifications from the basic diet (Atallah & Newsom, 1966) and selecting the best ones for further modification. No phagostimulants able to speed up the work were found in the natural or artificial diets. At least 200 different modifications were prepared, and observations with 50-500 larvae were made on each modification. Rearing results of the best, present, artificial diet (= Ad) (Kariluoto, 1978) with sorbic acid + nipagin M (1250 + 750 ppm, respectively) were compared to the results of an excellent natural prey, *Myzus persicae* (Sulz.) (= Mp). One group was reared throughout their life on Mp, the second on Ad, the third as larvae on Mp and as adults on Ad, and the fourth vice versa. Rearing results are as follows:

- the postembryonic (larval + pupal) development is retarded on Ad, i.e. it takes about 40% longer than on Mp.
- the postembryonic mortality on Ad is four times that on Mp, and the proportion of malformed adults is about twice that on Mp.
- Ad produces about 20% lighter adults than Mp.
- sex ratios on Ad and Mp are about the same (40% ♂♂).
- adult diet principally determines the fecundity of the

beetles, but the larval diet also has a minor effect.
- on Mp, the egg-laying percentage of all females is near 90%, but on Ad only 60%. If larvae are reared on Ad, egg-laying is 80% and 50%, respectively.
- the pre-oviposition time on Ad (also as larvae on Ad) is three times that on Mp.
- the egg-laying and the survival periods of females are longer on Ad than on Mp, and these are even lengthened in those groups which have also been reared on Ad as larvae.
- the egg numbers on Ad are lower than on Mp. The well fed or suitably fed females exhaust their lives sooner while laying eggs than those females badly or unsuitably fed on Ad.
- the hatching potentials of eggs on Ad are about half of those on Mp, and the larval diet also has an influence.

In spite of these unfavourable facts, it is possible to rear *A. bipunctata* for 3-4 generations on Ad in the laboratory for experimental purposes. Adults produced in this way are not physiologically comparable to those collected in the wild.

It has also been possible to rear some other predatory insect larvae to adults on Ad and among them are three *Coccinella* spp. *Coccinella septempunctata* even laid fertile eggs on this diet (Kariluoto, unpubl.).

References

Atallah, Y.H. & L.D. Newsom, 1966. Ecological and nutritional studies on Coleomegilla maculata DeGeer (Coleoptera: Coccinellidae). I. The development of an artificial diet and a laboratory rearing technique. J. econ.Ent. 59: 1173-1179.

Hämäläinen, M., 1977. Control of aphids on sweet peppers, chrysanthemums and roses in small greenhouses using the ladybeetles Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae). Ann.Agric. Fenn.16: 117-131

Kariluoto, K.T., 1978. Optimum levels of sorbic acid and methyl-p-hydroxybenzoate in an artificial diet for Adalia bipunctata (Coleoptera, Coccinellidae) larvae. Ann. Ent. Fenn. 44: 94-97.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

STUDIES ON PESTICIDES EFFECT ON TRIALEURODES VAPORARIORUM AND ITS PARASITE ENCARSIA FORMOSA

T. Kowalska, K. Szczepańska & A. Bartkowiak

Institute of Plant Protection
Miczurina 20
60-318 Poznań
Poland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 101-112

STUDIES ON PESTICIDES EFFECT ON TRIALEURODES VAPORARIORUM AND ITS PARASITE ENCARSIA FORMOSA

T. Kowalska, K. Szczepańska & A. Bartkowiak

Introduction

For several years our institute has been studying the possibility of integrated control of whitefly, particularly in tomato and cucumber. In this paper the results of the investigations on toxic effects of several insecticides on the developing stages and adults of *Trialeurodes vaporariorum* and its parasite *Encarsia formosa* are reported.

The main aim was the selection of pesticides with a low toxicity for those developmental stages of the greenhouse whitefly that serve as food and hosts for *Encarsia formosa* , i.e. the 2nd, 3rd and 4th instar of the pest. Consecutively, these pesticides have to be highly toxic to adults of whitefly, eggs and 1st instars, because they have no direct relation with the parasite.

Toxic effects of insecticides on developing stages of the greenhouse whitefly

The toxic effect of 15 insecticides was studied during the period 1976-1977 (Table 1). The white (2-3 days old) eggs of *Trialeurodes vaporariorum* were treated with pesticides by spraying and the mortality of particular developmental stages was checked afterwards and the total number of emerging adults were recorded. During 1976 the biggest reduction of the pest population was obtained after treatment with Decis EC2,5, Ultracid 40 EC, Permethrin and Curacron. The emergence of imagines ranged from 6.92% to 17.32%, whereas after spraying with Isathrine and Alvora-P the hatching of larvae and the emergence of adults did not differ from the untreated ones (Table 2). During the investigations carried out in 1977, the most toxic pesticide was Ripcord, in the concentration 0.02 and 0.03%. In this case the emergence of adults after treatment was 0.6 and 2.08% resp.

Table 1 List of insecticides

trade name	producer	common name	active ingredients %	acute oral LD 50
Altocid	Procida	metaprene	65	34600
Alvora-P	Nordisk Alkali Biokemii	naled	60	430
Curacron 500 EC	Ciba-Geigy	profenofos	50	358
Decis EC 2,5	Procida	decamethin	2.5	128-138
Fekama Naled	VEB Fettchemie	naled	90	430
Fosbrown 65	Azot	naled	65	430
Isathrine	Procida	bioresmethrin	10	9000
Nogos 500 EC	Ciba-Geigy	dichlorvos	50	56-80
Padan 50 SP	Takeda	cartap hydro-chloride	50	380-390
Permethrin	ICI Plant Prot.	permethrin	40	4000
Ripcord WL 4367	Shell	cypermethrin	40	251
Selecron 500 EC	Ciba-Geigy	profenofos	50	358
Tamaron EC 50	Bayer	methamidophos	50	29.9
Temik 10 G	Union-Carbide	aldikarb	10	0.93
Ultracid 40 EC	Ciba-Geigy	methidathion	40	25-48

Table 2 Reduction of populations of whitefly after treatment of insecticides on eggs, 1976

insecticide	concentration % or dose	emergence of adults %	emergence of adults degrees Bliss	Dancan's test
Decis EC 2,5	0,1	6,92	12,96	
Ultracid 40 EC	0,1	7,60	14,16	
Permethrin	0,04	10,15	16,02	
Curacron	0,08	9,67	17,29	
Decis EC 2,5	0,3	10,82	17,40	
Decis EC 2,5	0,05	17,32	22,29	
Permethrin	0,08	22,07	24,55	
Fosbrom 65	0,2	56,37	48,44	
Padan 50 SP	0,16	57,02	49,40	
Fosbrom 65	0,1	59,42	51,71	
Nogos 500 EC	0,1	71,37	57,79	
Alvora - P	0,1	83,67	66,58	
Isathrine	0,025	84,80	67,10	
Check		89,47	77,36	
Isathrine	0,05	94,62	78,87	
Isathrine	0,1	96,57	81,21	

Among the other pesticides used, high reduction of the population was obtained with a mixture of Altocid and Isathrine - 30.95% emergence of adults - and one of Fecama-Naled, and with Selecron - 35.80 and 36.70% emergence respectively (Table 3).

In investigations carried out on the effect of insecticides on the larval stages, we found that the early stages were the most sensitive. The lowest hatching percentage and highest mortality of the 1st instar were recorded after application of Ultracid 40 EC, Decis EC 2,5, Curacron 500 EC and Permethrin (Figs. 1 and 2). In the experiments carried out in 1977 no considerable effect of pesticides on hatching of larvae was found, except for Ripcord, which caused a high mortality of the 1st instar, in concentrations of 0,02 and 0,03% (Fig. 2).

After a direct spray on the larvae of the 3rd and 4th stages, the mortality ranged from 7.0 to 34.8%. Quite toxic were Curacron 500 EC, Decis EC 2,5 and Ultracid 40 EC (Fig. 3). Ripcord was the most toxic, causing a mortality from 77.6 to 88.4% (Fig. 4).

The adults of the greenhouse whitefly were most sensitive to pesticides. Their mortality was from 70 to 100%. Very toxic were Ultracid 40 EC and Isathrine in the concentrations 0.1 and 0.05%, causing 100% mortality after 24 hours. The same level of mortality was recorded on the third day after treatment with Curacron 500 EC in the concentration 0.08% and Permethrin in the concentration 0.04%. Also a high mortality (96.2 - 98.7%) was observed after using the preparations Alvora-P, Fosbrom 65, Decis EC 2,5 and Permethrin (Fig. 5). All pesticides tested in 1977 were very toxic to whitefly adults, ranging from 95 to 100%. The fastest activity was demonstrated by Isathrine, Altocid + Isathrine, Tamaron EC 50, Selecron 500 EC and Altocid 0.08%. The mortality 24 hours after application of these preparations ranged from 96 to 100% (Fig. 6).

Table 3.

...n of population of whitefly
...ment of insecticides on eggs. 1977.

...ncentration per cent ... dose	Emergence of adults in per cent	Emergence of adults in degrees of Bliss	Dancaw's test
0,02	0,60	6,29	
0,03	2,08	6,73	
0,04 +0,025	30,95	33,95	
0,1	35,80	36,42	
0,08	36,70	36,97	
0,05	37,78	37,51	
0,1	47,33	43,29	
5g/m²	54,18	45,70	
2,5g/m²	54,95	47,89	
0,08	57,23	49,46	
0,1	58,75	50,11	
	64,03	55,31	

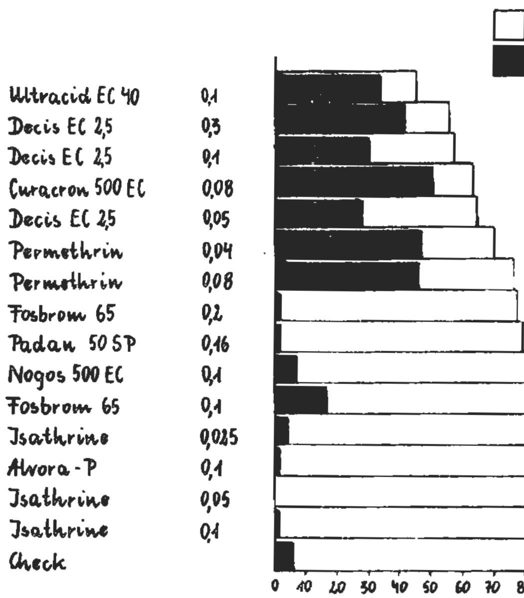


Fig. 1. Hatching and mortality of larvae L4 T. vapora...
after treatment of insecticides on eggs. /1976...

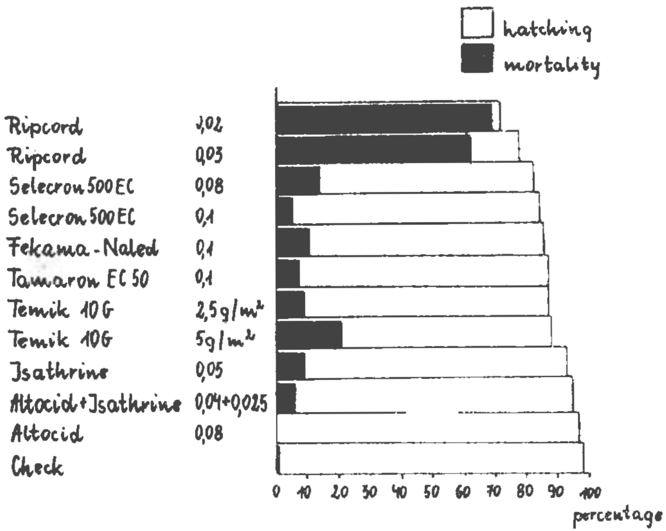


Fig. 2. Hatching and mortality of larvae L_1 T. vaporariorum after treatment of insecticides on eggs. /1977/.

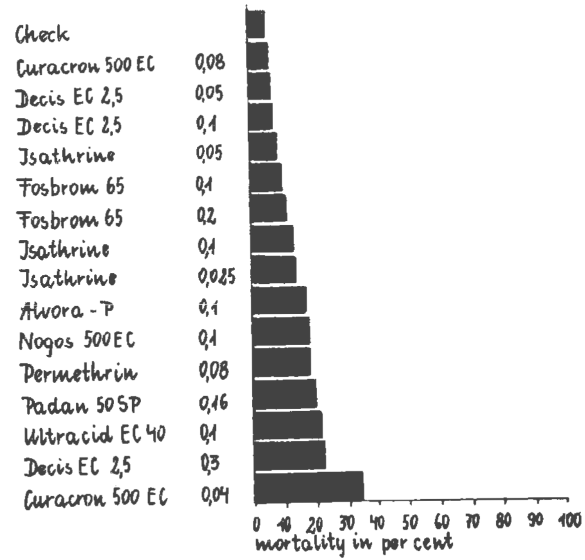


Fig. 3. Mortality of larvae L_3, L_4 T. vaporariorum immediately after treatment of insecticides. /1976/.

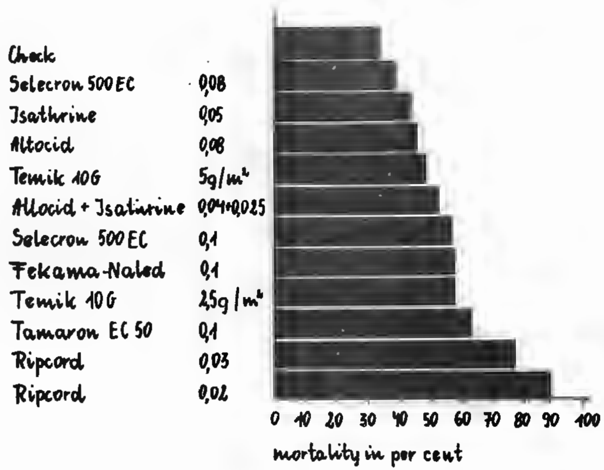


Fig. 4 Mortality of larvae L_3, L_4 T. vaporariorum immediately after treatment of insecticides. /1977/.

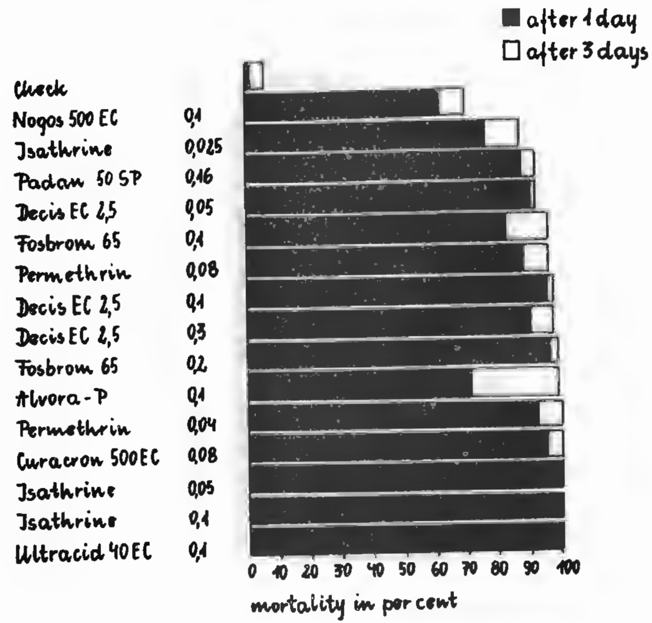
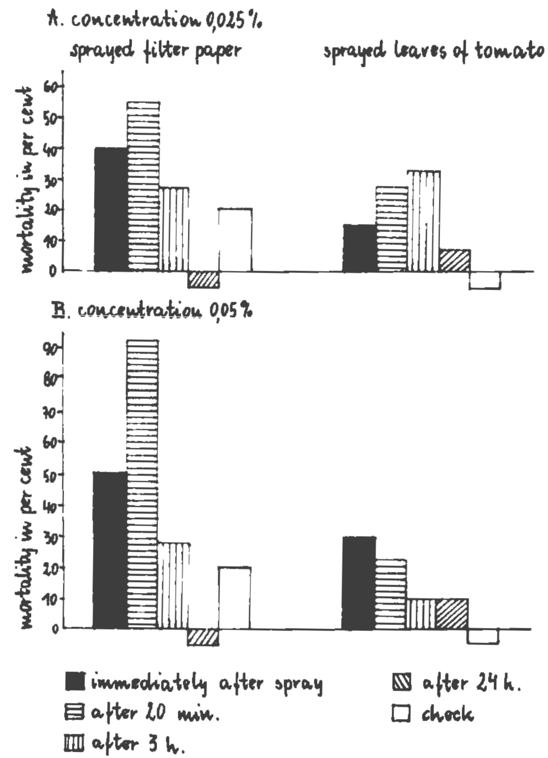


Fig. 5 Mortality of adults Trialeurodes vaporariorum after treatment of insecticides. /1976/.

Fig. 7 Selectivity of Isathrine on adults *Encarsia formosa* Gah.



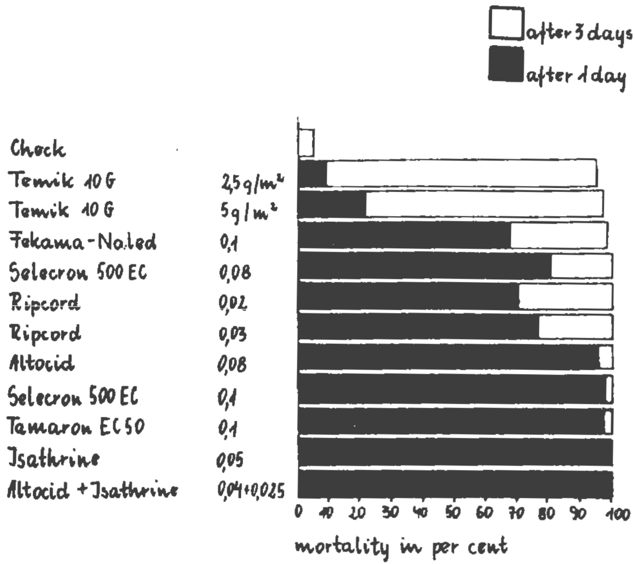


Fig 6 Mortality of adults *Trialeurodes vaporariorum* after treatment of insecticides. /1977/.

Fig. 8 Toxicity of insecticides for Encarsia formosa Gah.
Test I - on the eggs of E. formosa.

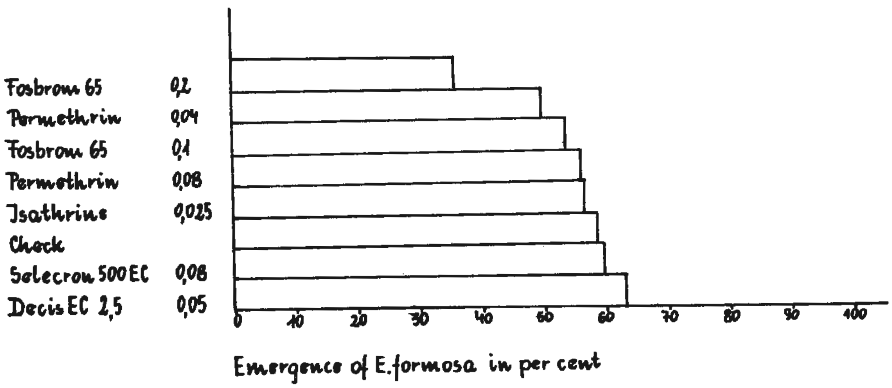
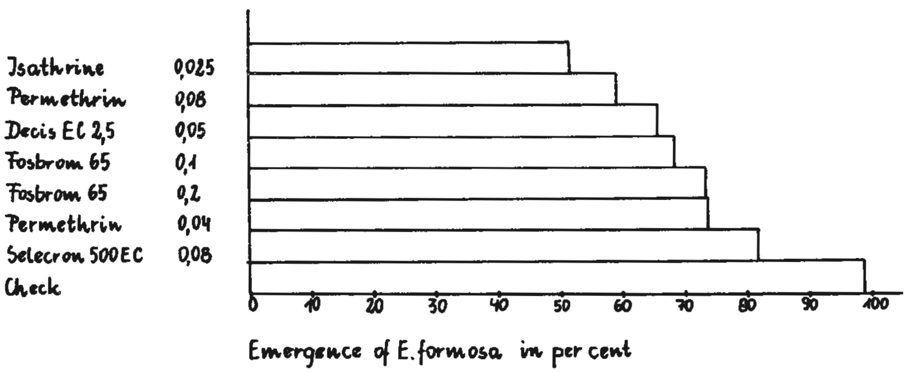


Fig. 9 Test II - on the larvae of E. formosa.



Toxic effects of pesticides on *Encarsia formosa*

The toxic influence of pesticides on some stages of *Encarsia formosa* was investigated on the basis of the results obtained during the experiments carried out in the preceding years (Kowalska & Szczepańska, 1969, 1971, 1973, 1975, 1976). Isathrine was tested on imagines of *E. formosa* in two concentrations: 0.05 and 0.025% respectively. The following two methods were used: 1) the imagines were placed on filter paper previously treated with pesticides, and 2) the imagines were put on tomato leaves previously treated with pesticides. Observations on the contact-activity were done by putting the insect on the substrate: 1) immediately after spraying, 2) 20 minutes after spraying, 3) 3 hours after spraying, and 4) 24 hours after spraying.
The observations on insect mortality were carried out after 1, 3 and 24 hours respectively.

No mortality of *E. formosa* was recorded after 1 and 3 hours of exposure, but after 24 hours a higher mortality of adults was observed on filter paper than on the leaves. The highest mortality occurred when the parasite was put on the substrate immediately after spraying, after 20 minutes and 3 hours, during observations after 24 hours, on filter paper ranging from 27.5 to 92.5% and on leaves from 10 to 32.5% respectively.

If the insects were put on the substrate 24 hours after spraying, no mortality was observed on filter paper, whereas on leaves a low mortality was recorded: 7-10%, compared with no mortality in the check (Fig. 7).

During the experiments carried out on the plants grown in pots, the toxicity of some pesticides to eggs, larvae and pupae of *E. formosa* living inside the larval stages of whitefly was investigated. The insecticides were applied on hosts with eggs of *E. formosa*, the percentage emergence of the parasite did not differ substantially from the check, except when Fosbrom 65 was used (Fig. 8). However, in this case the spraying was performed three days after parasitization of the whitefly by the parasite. Applying the insecticides on the larval stage of *E. formosa* (the seventh day after parasitization) the decrease in emergence ranged between 18 and 42% (Fig. 9). Treatment with pesticides performed on black, parasitized larvae of *T. vaporariorum* (with *E. formosa* pupae inside) did evidently not influence the emergence of adult parasites, except in the combination with Isathrine, where a decrease in emergence was observed: 33.5% and in the check 69.0% emergence, respectively (Fig. 10).

Conclusions

On the basis of the results obtained, it seems that none of the pesticides investigated fully fullfil the conditions of a selective pesticide, which could be applied in integrated systems. Some of the insecticides are, however, somewhat selective in respect to some larval stages of both the host, *T. vaporariorum* and the parasite, *E. formosa*. Isathrine seems to be the most useful for integrated control, because it decomposes fast and is also selective. It is not so harmful to the larval stages of greenhouse whitefly which are important for parasite development. However, its relative toxicity to *E. formosa* should be taken into account. Use of this insecticide could only be recommended before parasite introductions are made.

References

Kowalska, T. & K. Szczepańska, 1969. Communication from the susceptibility of Encarsia formosa, parasite of the greenhouse whitefly (Trialeurodes vaporariorum (Westwood)) to pesticides used in glasshouses. Biul. IOR 45: 93-98.

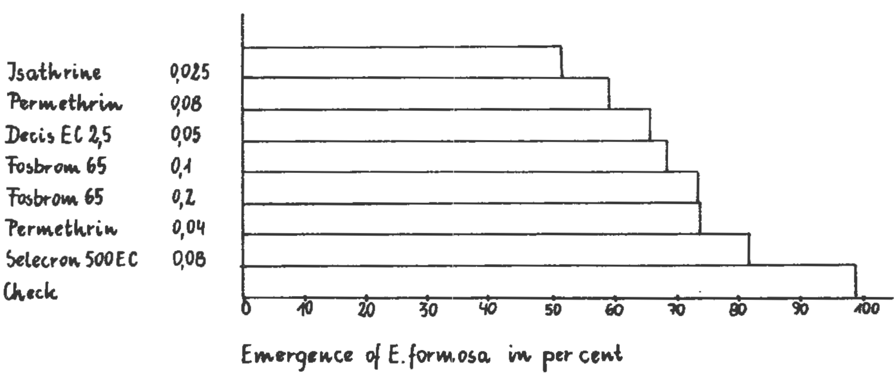
Kowalska, T. & K. Szczepańska, 1971. The toxicity of some pesticides, applied in Poland, for entomophagous insects. Biul. IOR 50: 179-194.

Kowalska, T. & K. Szczepańska, 1973. Toxicity of some insecticides for some Chrysopae, Coccinellidae and Hymenoptera. Zeszyty Problemowe Postepow Nauk Rolniczych 44: 228-232.

Kowalska, T. & K. Szczepańska, 1975. Integration of biological and chemical methods of control of greenhouse whitefly (Trialeurodes vaporariorum Westw.) in greenhouse cultivation of tomatoes. 8th Int. Plant Prot. Congr. Moscow VI: 132-238.

Kowalska, T. & K. Szczepańska, 1976. Biological control of greenhouse whitefly (Trialeurodes vaporariorum Westw.). Biul. IOR, XVI Sesja Naukowa IOR: 163-184.

Fig. 10 Test II - on the larvae of E. formosa.



ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

PROBLEMS OF CONTROLLING MINOR PESTS IN INTEGRATED CONTROL PROGRAMMES

M. Ledieu

Glasshouse Crops Research Institute
Littlehampton
England

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 113-118

PROBLEMS OF CONTROLLING MINOR PESTS IN INTEGRATED CONTROL PROGRAMMES

M. Ledieu

The use of biological control agents is now well established in the UK and results are usually acceptable to growers (see contribution by H. Gould). However, many problems remain, especially when incorporating biological control into fully integrated pest and disease control programmes. These problems can be separated into several categories and stem mainly from a lack of communication between scientists, advisors and growers. The main problems are posed by the changing pesticide situation, ignorance of detailed biology of both pests and natural enemies, and changes in methods of crop culture.

1. The changing pesticide situation

The growing use of biological control has resulted in a reduction in the volume of pesticides used and in their nature. Broad spectrum pesticides are generally unsuitable for use in the presence of natural enemies and have been replaced by selective ones. Pests have thus been able to overcome reduced pesticidal pressure and we have seen the resurgence of pests such as tomato moth and leafhoppers which were previously suppressed by chemicals used against major pests.

The number of pesticides suitable for use in integrated control is relatively small and the development of resistance can rob us of valuable items in our armoury. Pirimicarb is the ideal selective chemical, but there is evidence that *Myzus persicae* is developing resistance to this aphicide and alternatives must be sought.

A possible biological alternative to pirimicarb is the fungus *Verticillium lecanii*. This is more versatile than the aphid parasite *Aphidius matricariae* because it will attack most aphid species rather than *Myzus persicae* alone. There are now about four prototype formulations of the fungus and trials have been very encouraging. The problem with this and other 'living' pesticides, such as bacteria and viruses, is that there is no precedent for their use and a new registration process has been drawn up to safeguard both users and the public in the UK. Their commercial release may therefore be delayed while their safety is thoroughly scrutinised.

Growers are still entrenched in the 'chemical' philosophy of pest control. They are accustomed to tackling problems as and when they arise by reaching for a can of the latest 'wonder' chemical. They need to be educated to match their use of pesticides to suit their natural enemies rather than vice-versa.

On the other hand there is the danger that the biological sector will become too complex. This could happen in the case of biological leafminer control. There are two species of parasites that could be marketed: *Dacnusa* sp/*Opius* sp. is a candidate for use on tomatoes but since this is a pupal parasite, its use will leave visible mines, which would clearly not be acceptable on chrysanthemums. *Diglyphus* sp. is an alternative for this crop, since it parasitizes young larvae before significant mines develop. *Diglyphus* sp., although more difficult to rear, could be used for both crops and this would allow the infant biological pesticide industry to specialise and build up the 'volume' sales vital to its survival. This same problem applies to the possibility of using predators for thrips control on cucumbers. The demand would not justify their use, so chemical control of thrips is likely to persist.

New pesticides are always a potential threat to integrated control and growers are keen to exploit them as soon as possible. Scientists must maintain a constant screening process so that they are ready to inform advisors and growers how pesticides are likely to affect their natural enemies. Indeed, J.M. Franz and his colleagues on the 'Pesticides and Beneficial Arthropods' working party suggest that such screening should be included in the process of registration for new pesticides. However, there is also much ignorance about the effect of pesticides on minor pests and diseases, so that planning of integrated control is greatly hampered.

The new synthetic pyrethroids provide an interesting example of the problems that new pesticides can pose. The fact that they are potent, persistent materials makes them particularly unsuitable for integrated control. However, we cannot just dismiss them; they are ideal chemical pesticides and chrysanthemum growers, for instance, are sure to adopt them as the new 'cure-all' to replace failing Temik. Hopes of establishing integrated control in chrysanthemums would thus be dashed and even the fact that the pyrethroids have no acaricidal activity would probably not discourage growers, at least until spider mites become uncontrollable - and even this could be avoided by the use of Pentac. The success of these pyrethroids may well affect the short-term market for biological control.

2. Ignorance of detailed biology

A detailed knowledge of the basic biology of all possible components of integrated control systems is central to success. However, much of our knowledge is sketchy and based on work done many years ago. A simple example concerns leafhoppers, which although they are easily killed by chemicals, are difficult to eradicate because the incubation period of their eggs is not accurately known. This makes it difficult to predict when repeat treatments should be applied.

Thrips can easily be controlled by soil treatments with gamma HCH, but this poses problems early in the season, when ventilation is restricted, because vapours harmful to natural enemies build up in the glasshouse. Little helpful information on the pupation of thrips was available, so observations were made of the behaviour of pre-pupal thrips on a rockwool-grown cucumber crop so as to answer questions as: where do thrips pupate? How do they get there? How deeply do they bury themselves? Thrips were found to reach the ground by walking down the stems, though some fell from the foliage. They did not pupate in or on the rockwool blocks, but crawled beneath polyethylene sheeting on which the rockwool stood. They then pupated in the damp soil near drainage holes pierced in the polyethylene to avoid waterlogging. Having pinpointed the pupation sites, the quantity of gamma HCH used could be drastically reduced and the danger of vapour problems avoided. HCH should be applied to the soil beneath polyethylene before setting out the blocks and the soil pathways need treating only at the very edges, where they meet the polyethylene channels. The quantity of chemical can be reduced even further by using sprays rather than drenches.

An understanding of the biology of leafminers also helps in their control. The tomato leafminer, *Liriomyza solani*, has no alternative hosts outside glasshouses in the UK and so control relies on excluding the pest and eliminating overwintering populations from a previous infestation. Young plants can be protected from attack by mixing 10 ppm Rogor (dimethoate) into the potting compost. The first adults can be prevented from emerging from overwintering pupae by applying gamma HCH to the soil before laying the continuous polyethylene sheeting used in peat bag culture.

This method cannot be used for the chrysanthemum leafminer, *Phytomyza syngenesiae* , because it does not pupate in the soil. The adults feed and lay eggs almost exclusively in the apical foliage. Fine sprays of insecticide can therefore be misted onto these leaves without penetrating into the lower foliage where natural enemies are active.

On the other hand, the tomato leafminer prefers to feed and oviposit in older leaves about 1 m below the head of plants. Since this coincides with the portion where natural enemies are active, chemical sprays cannot be used without destroying biological control agents.

A third leafminer, *Liriomyza trifolii* , is an important pest which has become a potential problem in the UK. The important feature of this pest is its polyphagous habit, which allows it to infest many glasshouse crops and thus to spread and overwinter easily. Very little is known about the biology of this pest and its oviposition sites on our crops have yet to be established. Selective techniques of control have yet to be worked out and indeed will not be while it is a prohibited pest in the UK.

3. Changing cultural methods

The introduction of biological control methods has been so successful in controlling major pests that the need to use chemicals has often been delayed until much later in the season than formerly. Thus the use of chemicals is now coinciding with natural enemies rather than preceeding them and the grower is faced with the dilemma of destroying his natural enemies with pesticides or allowing minor pests to multiply unchecked.

The new methods of culture, such as peat bags, nutrient film and rockwool, have become popular partly because they release the grower from the chore of sterilising his soil. However, this has allowed pests which overwinter in the soil, such as tomato moth (see G.N. Foster's contribution), leaf-miner and thrips, to survive and multiply. The omission of steamsterilisation of soil (or some alternative) is, without doubt, a false economy. There are also reports of problems with sciarids in the hydroponic culture methods.

Increases in labour costs have encouraged the use of ULV methods of application instead of HV. However, research has shown that pesticides applied by ULV and fogging do not get onto the undersides of leaves, whereas HV sprays - well applied - do. Pest control problems are therefore likely to be more common where the newer methods of application are used.

The use of peat bags with systemic pesticides such as Vydate (oxamyl) is also causing problems. The compost is not uniformly compacted or watered, which leads to large variations in uptake of systemics by plants. Vydate is often used as an early season chemical control which is followed by natural enemies when weather conditions are more suitable. However, the unpredictable uptake of pesticide results in whitefly, for example, being able to colonise some plants much earlier than others and so a 'patchy' infestation develops. This is then very difficult to control biologically because the parasite is preferentially attracted to the 'patches' leaving other less infested plants unprotected until later.

Widespread adoption of contract trimming of tomato plants is another danger to pest control, because the gangs are not trained or concerned about the need to preserve the black parasitized whitefly scales until adults have emerged from them.

Plant breeders in Holland, motivated by increasing fuel costs, are searching for varieties of glasshouse plants which will tolerate lower growing temperatures and so a parallel search is needed for natural enemies to work under cooler conditions.

To summarize - the adoption of biological control techniques inevitably commits the grower to integrated control and he often does not realise the full implications of this. Although biological control is generally successful, we are doing growers and advisors a great disservice if we do not concentrate our efforts on providing and continually adapting integrated programmes for the whole pest and disease complex on a crop.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

INTEGRATED CONTROL OF INSECTS AND MITES ON OHIO GREENHOUSE CROPS

R.K. Lindquist, C. Frost & M. Wolgamott

Ohio Agricultural Research and Development Center
Wooster, Ohio 44691
U.S.A.

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 119-126

INTEGRATED CONTROL OF INSECTS AND MITES ON OHIO GREENHOUSE CROPS

R.K. Lindquist, C. Frost & M. Wolgamott

Introduction

This paper is intended to summarize the results of research and development on several aspects of our program in Ohio. Much of the data were obtained under a project funded by the U.S. Environmental Protection Agency. We are attempting to develop integrated management procedures for three insect and mite pests: *Trialeurodes vaporariorum*, *Tetranychus urticae* and *Liriomyza* spp. The crops involved are tomato, cucumber, poinsettia, carnation, rose and various foliage plants. No one element of this program is more important than the other (although more effort is being directed at leafminer and spider mite control), because all have to be successfully utilized in the major crops for IPM to be adopted by U.S. growers.

Trialeurodes vaporariorum - Encarsia formosa

Results of work with this host-parasite system have been similar to those obtained in many other countries around the world. We have been adapting previously-obtained information to U.S. growing practices. The major goal now is to expand our rearing capability so that large-scale demonstration trials can be conducted. Probably *Encarsia* could be utilized now on tomato, cucumber and poinsettia stock plants, if an adequate supply of parasites was available. Low greenhouse temperatures and light during early winter months, especially in the northern states, may prevent effective use of *Encarsia* until the latter part of February. This should not pose a problem, because many growers are waiting until at least that time to plant their vegetable crops, due to high energy costs.

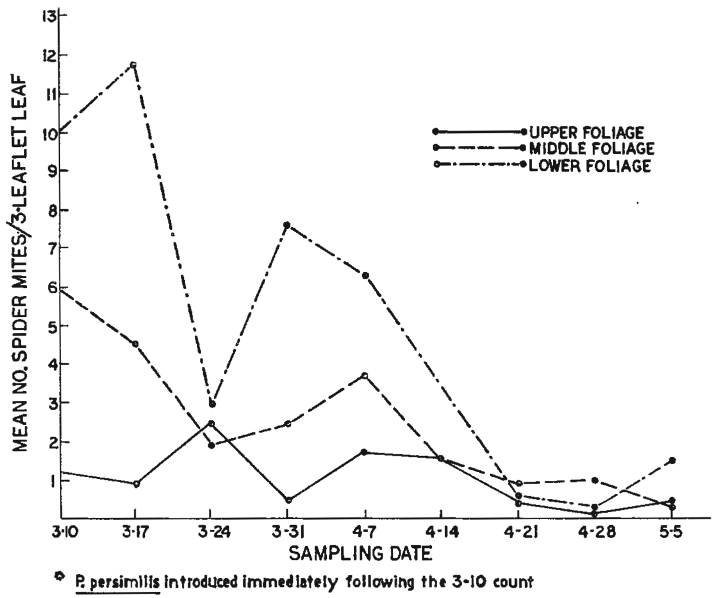


Figure 1 Mean number of *Tetranychus urticae* on roses after introduction of the predatory mite *Phytoseiulus persimilis* , immediately following the 3-10 count.

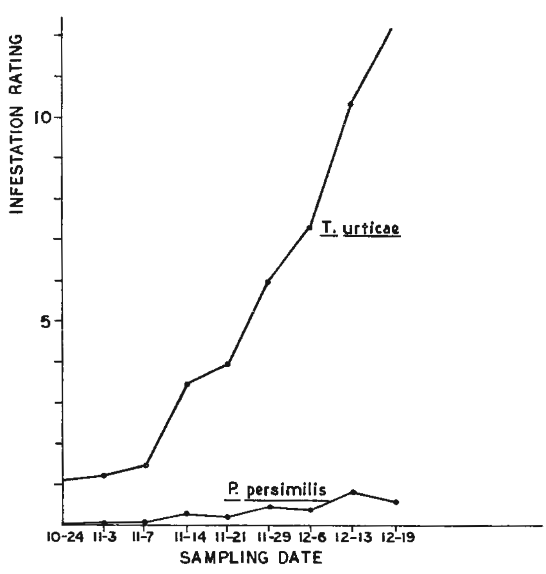


Figure 2 *Phytoseiulus persimilis* and *Tetranychus urticae* ratings on a commercial rose planting.

Tetranychus urticae - Phytoseiulus spp.

Phytoseiulus persimilis predators have been successfully utilized in a number of demonstration trials on cucumbers. One to two predators were introduced per plant when spider mite injury was first seen. As with *Encarsia*, rearing capacity is the main limiting factor to more widespread use of *P. persimilis*. Also, several trials have been conducted on various ornamental species, including rose, carnation, Schefflera and Dieffenbachia.

Rose : results of trials at the OARDC (Figure 1) and a commercial planting (Figure 2) are presented. In the OARDC trial 94 established potted rose plants were used in a greenhouse experiment. *Phytoseiulus persimilis* was introduced at an overall ratio of 5 per plant, and distributed in areas with the heaviest *T. urticae* infestation. *Tetranychus urticae* populations were monitored on lower, middle and upper leaves. Results indicated that control of *T. urticae* on upper foliage was satisfactory, and that flowers could be sold without noticeable mite injury. However, the number of predators that was required was probably too high to be economical. In a subsequent experiment predator-plant ratios of 0.5 to 1, 1 to 1, 2 to 1 and 3 to 1 were used in an attempt to further define the number required, but results were inconclusive (the lowest predator-plant ratio provided the best control), possibly because *T. urticae* populations were different at the beginning of the trial. Obviously, the *T. urticae* population at the beginning of a control program is very important.

Figure 2 shows results of a trial on an established commercial planting of 2400 roses in a greenhouse in central Ohio. An earlier trial, during the summer when these plants were newly set, was not successful although *T. urticae* populations were initially very low on these plants. We felt that the combination of too few predators (0.5 per plant, uniformly distributed in 3 weekly introductions) and very warm weather probably resulted in failure of *P. persimilis* to be effective, and the grower began a spray program. The experiment reported here was begun in autumn, when scattered patches of *T. urticae* were noted. Two releases of 250 predators were made in these infested areas, 14 days apart. The original infested area consisted of ca. 30 plants, but each week's evaluation showed that the *T. urticae* infestation was spreading, and that injury was increasing. The infestation rating shown was arrived at by the following formula:

$$\frac{\text{no. plants with } T.\ urticae \text{ or } P.\ persimilis \times \text{abundance rating (1-4)}}{\text{no. counting sites}}$$

Each row was rated according to this formula, and this provided an index both of *T. urticae* and *P. persimilis* distribution and abundance. The grower sprayed with a combination of fenbutatin-oxide and acephate, and on 29 December no predatory mites were observed. The experiment was then discontinued.

Carnation. We decided to evaluate *P. persimilis* in our greenhouses on smaller plants where both predator and *T. urticae* populations could be more easily evaluated. Dr. R.A. Hamlen of Apopka, Florida, provided a culture of *P. macropilis*, a predator native to more subtropical areas. Both *Phytoseiulus* species were evaluated on carnation plants growing in 10-cm diam pots. Treatments were separated by water barriers. Instead of introducing *Phytoseiulus* at a predator per plant ratio, a predator per prey ratio was used. This reduced the need to have uniform *T. urticae* numbers at the start of an experiment. Predators were introduced as adult females onto plants where the *T. urticae* adult population had been estimated. The infestation had been established for several weeks prior to predator introduction. Figure 3 shows results of comparing the two species at two introduction ratios, 1 to 50 and 1 to 100. Both predator species reduced *T. urticae* populations below that on check plants, but after 21 days no predators were found, and the experiment was terminated.

In a second experiment with both predators, also on carnations, we used higher predator-prey ratios (Figure 4). *Phytoseiulus persimilis* apparently did reduce *T. urticae* populations somewhat, and the amount of reduction was according to the number of predators introduced. Results of using *P. macropilis* are not presented because no *T. urticae* reduction

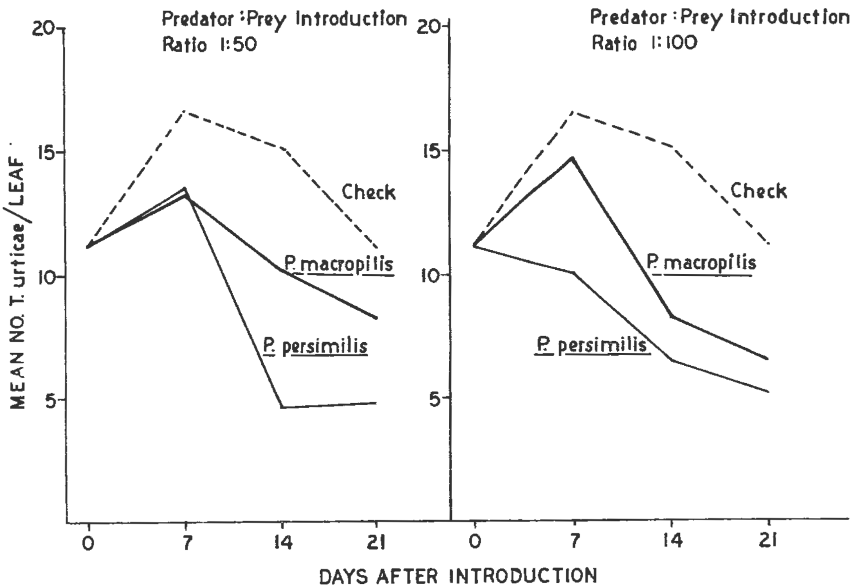


Figure 3 Mean number of *Tetranychus urticae* per leaf on carnations after introduction of *Phytoseiulus persimilis* or *P. macropilis*. Two predator-prey ratios were tested.

was obtained. Predator counts on plants showed that almost no *P. macropilis* were present 14 days after introduction, whereas *P. persimilis* were found after 28 days. During the above experiments, daytime maximum temperatures averaged 33.5°C and the night minimum averaged 21.3°C, which may explain the apparent failure of *P. persimilis* and *P. macropilis* to more effectively reduce *T. urticae* populations. Also, because *T. urticae* populations were already well-established, estimating only adult mite numbers prior to predator introduction may not be adequate. The reason for the decline of *T. urticae* populations on untreated plants is not known. Plants became too large after 28 days, and the experiment was terminated. We plan to continue our experiments on ornamental plants, with both *P. persimilis* and *P. macropilis*. A cooperative study with Dr. Hamlen is being initiated to compare results obtained in southern and northern U.S. greenhouses.

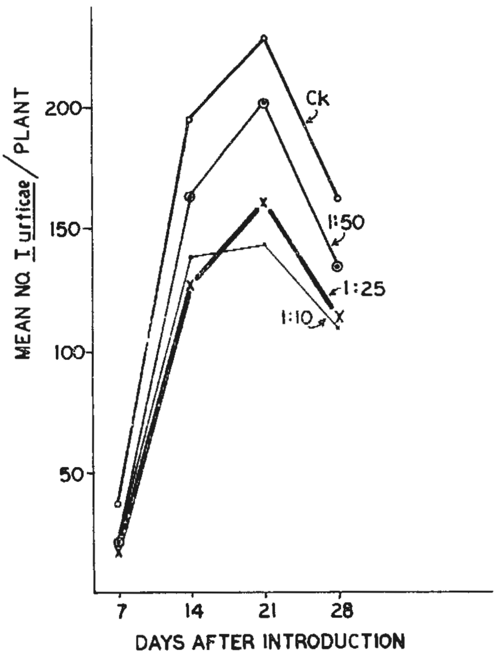


Figure 4 Mean number of *Tetranychus urticae* per leaf on carnations after introduction of *Phytoseiulus persimilis* at several predator-prey ratios.

Integration with pesticides

Because of the lack of rapid control obtained with predators alone, an experiment was conducted with *P. persimilis* and fenbutatin-oxide (= Vendex®), a miticide that apparently has some selectivity for predatory mites (Lindquist et al., 1979). Results (Figure 5) indicated that a combination of predators (at a predator-host ratio of 1 to 100) and one miticide application (300 ppm) was more effective than either used alone. Fenbutatin-oxide was applied 7 days following predator introduction. Results of this and other experiments show that, on many ornamental plants, a miticide compatible with predators will be useful to regulate *T. urticae* populations, and necessary if the number of predators

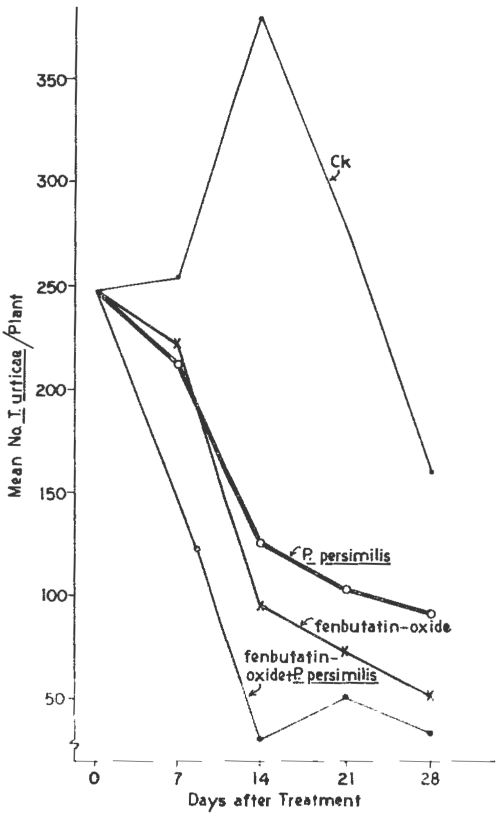


Figure 5 Mean number of *Tetranychus urticae* per leaf on carnations after introduction of *Phytoseiulus persimilis* treatment with fenbutatin- oxide (300 ppm), a treatment with a combination of predator and chemical or without treatment.

Leafminers (Liriomyza sativae and L. trifolii)

Injury to tomato, cucumber, chrysanthemums and other plantings by larvae of the above species has increased dramatically in recent years. Efforts are underway to collect parasite species that may be useful in managing leafminer populations. A trapping program, using bean plants infested with *L. sativae* placed in various outdoor locations, was begun in 1978. *Diglyphus pulchriceps* Craw. (Eulophidae), collected from larvae, and *Opius dimidiatus* Ashm. (Braconidae), collected from pupae, were the most abundant, but trapping only was done for 4 months. We also collected *Halicoptera circulus* Walker from pupae and *Achrysocharella* sp. from larvae. This program is being expanded in 1979. We hope to determine the potential of one or more of the most abundant species for *Liriomyza* spp. control, and cooperate with Dr. Robert McClanahan of Harrow, Ontario, in determining the best species for our areas of North America.

Reference

Lindquist, R.K., C. Frost & M.L. Wolgamott, 1979. Integrated control of insects and mites on greenhouse crops. Ohio Agr. Res. & Dev. Center Res. Circ. 245, 18 p.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

BIOLOGICAL CONTROL OF PESTS IN GLASSHOUSES IN FINLAND - THE SITUATION TODAY AND IN THE FUTURE

Martti Markkula & Katri Tiittanen

Agricultural Research Centre
Department of Pest Investigation
SF-01301 Vantaa 30
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 127-134

BIOLOGICAL CONTROL OF PESTS IN GLASSHOUSES IN FINLAND - THE SITUATION TODAY AND IN THE FUTURE

Martti Markkula and Katri Tiitanen

Introduction

Use of vegetables and ornamental plants in Finland has lately increased. The area where they are grown has doubled during the last ten years. Import has increased during the same period, so self-support in glasshouse products has remained at about the same level, being 80-90%. Nowadays we have 2500 glasshouse cultures in the country and their total area amounts to 386 hectares. Vegetables are grown on 286 hectares and ornamental plants on 100 hectares. Tomato is most prevalent, being grown on 156 hectares. Second comes cucumber with 61 hectares. The cultures are almost without an exception family holdings. Outside labour is usually hired only for the busiest season. The most important jobs on which the success of the culture depends are kept to the family.

Pests to be controlled

On the basis of long-term experience and inquiries sent to growers the most damaging pests on different glasshouse plants are known, see e.g. Markkula, 1969. On tomato cultures the only pest that has commonly to be controlled is the whitefly *Trialeurodes vaporariorum*. The two-spotted spider mite *Tetranychus urticae* and aphids cause harm occasionally. Noctuid larvae are rare pests on tomatoes.

The most harmful pest on cucumber cultures is the two-spotted spider mite, which is also the most important pest in glasshouse cultures in Finland. Cucumber can hardly be grown unless the spider mite is controlled either biologically or chemically. Sometimes *Thrips tabaci, T. nigropilosus* and *Aphis gossypii* also cause harm in cucumber cultures. The whitefly is rather rare, but it can cause considerable damage when it occurs in great numbers.

On lettuce, capsicum peppers, parsley and other vegetables aphids are the most common pests. However, there is seldom need for control.

The most harmful pests of cut flowers and other ornamental plants are the two-spotted spider mite, the whitefly, aphids and thrips. Their economic importance varies remarkably according to the plant species. Spider mites and aphids have to be controlled nearly regularly on chrysanthemums and roses. The carnation grower has regularly to be prepared to control spider mites and thrips.

Pest control as a whole is an important part of the growing techniques in glasshouse cultures. A grower that has a command of pest control received a bigger yield.

Biological control today

Biological pest control is nowadays a normal practice in glasshouse cultures in Finland. There is a biological alternative for the control of the most damaging pests, the spider mite, the whitefly and aphids. Growers can buy biological control agents to prevent the damages of these pests from Kemira Ltd, which belongs to one of our biggest firms. Kemira is also a leading pesticide producer in the country.

Biological control of the two-spotted spider mite started after four years of research in 1970 in commercial cucumber cultures. That year Kemira Ltd (then Rikkihappo Ltd) started the mass production and the sales of the predatory mite *Phytoseiulus persimilis*. During the first year the predatory mite was used on 6 hectares which meant about 22% of the cucumber growing area at the time (Markkula et al., 1972). During the fifth year of use in 1974 the area had grown to 31 hectares or to 70% of the cucumber growing area (Markkula, 1976). The last two years the spider mite has been controlled biologically on about 45 hectares or on 75% of the cucumber area. Nowadays it seems that the use of predatory mites will not become more prevalent. On most of the remaining 25% pesticides are still used and a few growers seem to have no spider mites at all.

The chalcid wasp *Encarsia formosa* was first used in commercial cultures as an experiment in 1973 and 1974, when Kemira Ltd imported wasps from England and Holland. Our researchers followed the effectiveness of *Encarsia* , but no actual studies were considered necessary. Kemira Ltd started its own mass production of *Encarsia* in 1975. That year about 100 vegetable growers used *Encarsia formosa* (Markkula, 1976), the area being estimated 15 hectares, in other words 7% of the total area of tomato and cucumber cultures. The use of *Encarsia formosa* has increased every year since then. In 1978 the whitefly was controlled biologically on 50 hectares, which is 23% of the total area of tomato and cucumber cultures.

Possibilities to control aphids biologically have been studied since 1970. Especially the following predatory insects have been the objects of many investigations: the lady beetles *Coccinella septempunctata* and *Adalia bipunctata* (e.g. Hämäläinen, 1977), the green lace wing *Chrysopa carnea* (Tulisalo et al., 1977) and the aphid midge *Aphidoletes aphidimyza* (e.g. Markkula and Tiittanen, 1976). They all have given positive results being efficient aphidophages. However, it was only *Aphidoletes aphidimyza* that proved to be able to develop a continuous population for the whole growing season in the glasshouse. In this respect it turned out to be similar to *Phytoseiulus* and *Encarsia* being at the same time a remarkably better control agent than the other natural enemies of aphids. After seven years of research a mass production method of the midge was developed, as well as a method for its use in glasshouses. Several control experiments were also done in commercial cultivations with good results. In 1978 Kemira Ltd decided to start the sales of the aphid midge to growers. During that first year of use 70 growers bought over 100.000 pupae and spread them on the soil in the glasshouses. Because half of the midges were used on small glasshouse cultures of agricultural schools and hospitals, the midge was used only on 2 or 3 hectares. The control was generally successful and the growers have been satisfied with the new control method for aphids.

This year the use of the aphid midge has continued. The demand for pupae has been somewhat greater than the previous year. The results have still been good. The midge is recommended primarily for vegetable cultures. It is an efficient aphidophage even on ornamental plants, but its use is limited to the beginning of the growing season. The plants and the flowers have to be cleared chemically from both aphids and midge larvae in good time before the sale.

All the biological agents used in glasshouses, *Phytoseiulus*, *Encarsia* and *Aphidoletes* have the same three properties, which make them efficient as control agents: 1) they are easy to mass-produce, 2) they withstand transport and spreading, and 3) they form permanent populations in the glasshouses.

Biological control has a wide popularity among growers in Finland. The results have been at least as good as when using chemical control and the costs have been less (Markkula et al., 1972). Among vegetable growers biological control is the most common control method. In fact it is no longer an alternative for chemical control but a primary control method. Many growers nowadays avoid the use of chemicals, because it is in many ways inconvenient to handle them in hot and humid glasshouses. Also growers want to sell vegetables free from pesticides.

After biological control has become prevalent, the use of pesticides has declined in glasshouses. Consequently some pest species that used to be low in number because of chemical control of major pests, have now become more numerous. Especially thrips but also leafminers and sometimes even caterpillars are harmful. It would be very hopeful if an efficient control agent were found to prevent damages caused by thrips.

Biological control in the future

Biological control has not yet reached its highest point in our glasshouse cultures. The use of biological methods to control the two-spotted spider mite with the predatory mite will hardly increase. On the contrary, biological control of the whitefly and aphids can still increase two- or threefold. If new biological methods are developed for controlling thrips and other minor pests, biological control will become more common.

Biological control suits especially in vegetable cultures and it is also a needful substitute for chemicals. On ornamental plants its possibilities are not so good. The premise of successful and economic biological control - a balance between predator and prey or parasite and host - does not suit ornamental plants, because cut flowers or potted plants that are sold have to be completely clean and cleared from pests, their exuviae and control agents. This cannot be achieved when using biological agents. That is why integrated control is necessary. The control agents prevent the pests from reaching the economic threshold of damage during the growing season. When marketing time approaches the plants are cleared in good time chemically.

We have a very positive atmosphere for biological control in this country. It is connected with the general discussion on the environmental protection and with the requirement to develop new methods of soft technology. A tendency towards healthier foodstuffs with less chemicals has increased and kept up the vegetable growers' interest in biological control. When good results have been received in glasshouse cultures, the growers want the effective biological control methods also for open air cultures in the fields and in gardens. In the future it is important to maintain the growers' positive attitudes towards biological control. Also biological control agents should be available following the demand.

Research on biological control

For the moment main emphasis of research is put on the aphid midge, the development of its mass production and the method of using it. The diapause of the aphid midge is studied especially in what ambient conditions it enters diapause and terminates it. The purpose is to prevent the disturbances caused by diapause to the mass production. The aim is also to take advantage of the diapause to be able to store diapausing larvae in cocoons for long periods. The aphid midge overwinters in the glasshouse soil as a larva in the cocoon and a practical experience is that adults emerge late in the winter, soon after new plants have been set and the growth substrate has been watered.

Another interesting research subject is the composition of the aphid-paralysing saliva of the midge larva. No practical results can be expected from this research subject at this point. By using thin layer chromatography and autoradiography tens of small molecular compounds have been isolated. Most of these have been defined as regular amino acids, sugars and organic acids. No big differences have been found in the chemical composition of the salivary glands compared to the other parts of the larva and its food, i.e. aphids. So far no such compounds have been found which could be a primary reason for the paralysing effect of the saliva. Further studies have been started to find out if the paralysing effect could be based on enzymatic activity.

Studies of the use of the aphid midge in open air cultures were started last summer. According to the first results, it is likely that the aphid midge is not suitable for biological control on field crops. However, it seems to be an efficient control agent in dense, shady bushes according to its biotype requirements. It is possible to use it to destroy aphids on different ornamental bushes, garden roses and both red and black currants.

Research work in the Soviet Union indicates that another predatory midge, *A. urticariae*, would be more suitable than *A. aphidimyza* to control aphids on fields. *A. urticariae* has not been found in Finland. That is why we would like to get starting material from the Soviet Union or anywhere else. If we are able to prevent the great damages of aphids with biological agents, e.g. in cereal crops, we have made a very important discovery.

References

Hämäläinen, M., 1977. Control of aphids on sweet peppers, chrysanthemums and roses in small greenhouses using the ladybeetles Coccinella septempunctata and Adalia bipunctata (Col., Coccinellidae). Ann. Agric. Fenn. 16: 117-131.

Markkula, M., 1969. Abundance of pests in greenhouses. Ann. Agric. Fenn. 8: 320-322.

Markkula, M., 1976. Studies and experiences on the biological control of the most important pests in glasshouse cultures in Finland. Bull. SROP/WPRS 1976/4: 19-24.

Markkula, M. & K. Tiittanen, 1976. Use of the predatory midge Aphidoletes aphidimyza (Rond.) (Diptera, Cecidomyiidae) against aphids in glasshouse cultures. Proc. Symp. XV Int. Congr. Ent., Washington, USDA AS ARS-NE 85: 43-44.

Markkula, M., K. Tiittanen & M. Nieminen, 1972. Experiences of cucumber growers in control of the two-spotted spider mite Tetranychus telarius (L.) with the phytoseiid mite Phytoseiulus persimilis A.H. Ann. Agric. Fenn. 11: 74-78.

Tulisalo, U., T. Tuovinen & S. Kurppa, 1977. Biological control of aphids with Chrysopa carnea on parsley and green pepper in the greenhouse. Ann. Ent. Fenn. 43: 97-100.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE
INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

BIOLOGICAL CONTROL OF *LIRIOMYZA SATIVAE* ON GREENHOUSE TOMATOES

Robert J. McClanahan

Agriculture Canada
Research Station
Harrow, Ontario N0R 1G0
Canada

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING
BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 135-140

BIOLOGICAL CONTROL OF LIRIOMYZA SATIVAE ON GREENHOUSE TOMATOES

Robert J. McClanahan

Introduction

Liriomyza sativae Blanchard (Diptera: Agromyzidae) is a widespread problem in greenhouses in the northern United States and Canada. It was called *L. munda* until 1973, and vegetable leafminer is recognized as the common name in many papers. Previously published notes relate the incidence of the vegetable leafminer in Ontario, and the complex of native parasites which find it a suitable host (McClanahan, 1975, 1977). Recent work includes some biology studies and biological control trials, which I will report on here, although the project is still under way.

The leafminer infesting greenhouse tomatoes in Europe is a different species, *L. bryoniae*, but since many parasites accept any dipterous leafminer, the results of these experiments with the vegetable leafminer should be of general interest. Although the species *Phytomyza syngenesiae* (Hardy) is found in North America it is not nearly as serious a problem as *L. sativae*. I have not seen this chrysanthemum pest in Canada.

Leafminer biology

The vegetable leafminer was tested for fecundity on lima beans at 24°C. Mated pairs were provided with a fresh bean plant three times a week. Larvae were counted since it was difficult to distinguish eggs from feeding punctures. Four females provided the data shown in Figure 1. Oviposition started soon after mating and persisted for two weeks. It is not difficult to see how leafminer numbers can build up rapidly.

The relation of development and temperature was investigated. The period from oviposition to emergence of adults was found for temperatures of 20, 24 and 28°C. Figure 2 shows the linear relationship found within this range. Development at 28°C was about twice as fast as it was at 20°C. The same data may be expressed as rate of development against temperature, and

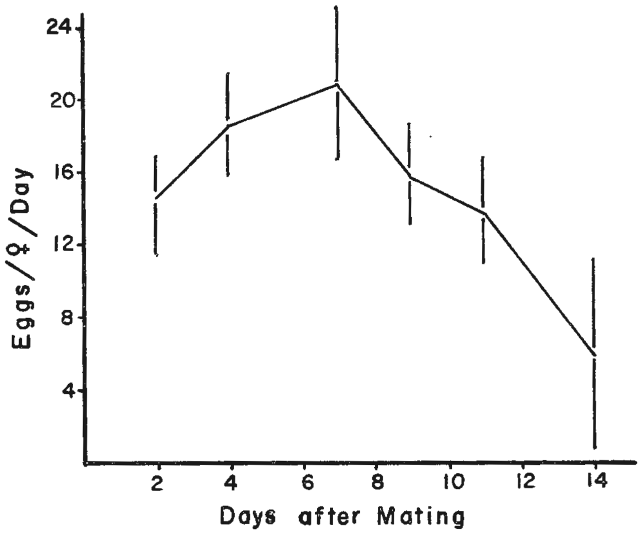


Figure 1. Oviposition by *Liriomyza sativae*. Mean total eggs per female was 228.7

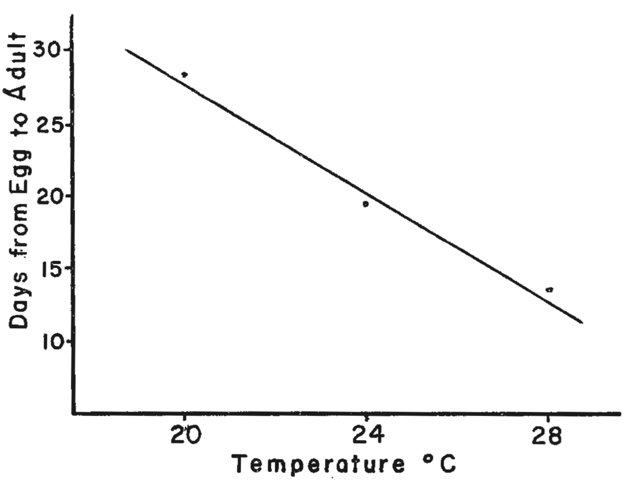


Figure 2. Development of *Liriomyza sativae* at various constant temperatures

regression analysis indicates a very close fit to linearity (r=0.998). Substitution in the equation y=0.0046x - 0.0576 predicts that no development would occur at 12.5^{o}C or lower.

This was not considered important since greenhouse temperatures would seldom be this low. The time taken from egg to adult can also be calculated as a day-degree requirement. The best agreement for the three temperatures was achieved with a base temperature of 12.3°C, and 220.8±2.3 day-degrees were required. It is readily apparent that this pest is well adapted to the greenhouse environment.

Over the past winter, the growth of leafminer populations on tomato seemed to indicate that length of daylight is a factor that influences fecundity. Through the months of December to March, adults punctured the leaves, but fewer eggs were laid.

Biology of leafminer parasites

Limited studies in the common parasites of the vegetable leafminer showed significant differences in their developmental period. Leafminer infested beans were exposed for 3 days in the field. They were then kept at room temperature (22-24°C) and parasite emergence recorded daily. The average time of development, from the mid-point of exposure to the time of emergence was as follows:

Diglyphus begini	14.25
Pnigalio flavipes	16.06
Opius dimidiatus	20.37
Chrysocharis viridis	22.43
Halticoptera patellana	24.64

Parasites with short development periods have considerable advantage over the others in terms of reproductive potential. Higher temperatures speed up parasite development but the exact relationship has not been determined yet.

Parasite rearing

The parasites mentioned above, with the exception of *P. flavipes*, have been reared continuously for a year. The rearing cages are plexiglass with the two side panels fine silk screening. They are 50 cm each dimension, and are kept in a growth cabinet at 28°C with a 16 hr photoperiod. Potted bean plants with the primary leaves infested with leafminer larvae just starting to tunnel are moved into the parasite cages twice-weekly. Recovery of parasite adults has recently been improved by removing the bean leaves before the leafminers are at the pupal stage. Placing the leaves over fine sand resulted in pupae in the sand which could be separated by gentle sieving.

The most consistent parasite was *Opius dimidiatus*, followed by *Halticoptera patellana*. *Diglyphus begini* and *Chrysocharis viridis* did well for three or four months, then the numbers declined until the colonies were barely established. Some of the rearing problems were physical. Too many leafminer larvae in a leaf causes wilting and poor larval survival. Other problems concerned the degree of moisture in the substrate, which was generally best when only slightly moist. The more detailed preferences of particular parasites have not been worked out, in part because it has not been found possible to obtain oviposition by a single female parasite. In some experiments, 6 pairs of parasites reproduced successfully with a multiplication factor of 4 to 7 fold, depending on the species.

Greenhouse biological control tests

A small greenhouse section, with 8 tomato plants in the soil has been used for initial biological control tests. A trial of *O. dimidiatus* at 9 per plant, was followed for 4 months. The leafminer numbers were assessed by counting new mines twice a week and marking them. Samples of leafmines were reared separately to determine the parasitism. *O. dimidiatus* became established but never achieved over 2% parasitism. Leafminers continued through the experiment, with numbers cycling somewhat but generally increasing. The next experiment used *D. begini*. Leafminers were well established by Aug. 20 when 4.75 parasites per plant were released. Leafminer adults averaged 36 per plant on Sept. 7, but dropped to 0 by Sept. 22. A resurgence of leafminer adults on Oct. 3 was accompanied by observation of 2.8 parasite adults per plant. Low numbers of leafminers and parasites continued for another month. A trial of *C. viridis* at 5 per plant in the same small greenhouse resulted in a low level of establishment, but the parasites failed after 2 months.

Commercial greenhouse trials have been surprising but not very satisfactory to date. When *O. dimidiatus* was released at 6 per plant, a month later there was 45% parasitization by *D. begini* . Evidently the latter species had moved into the greenhouse from an outdoor source about the same time as the release in July.

References

McClanahan, R.J., 1975. Notes on the vegetable leafminer, Liriomyza sativae (Diptera: Agromyzidae) in Ontario. Proc. Ent. Soc. Ontario 105: 40-44.

McClanahan, R.J., 1977. Biological control of the leafminer Liriomyza sativae in greenhouse crops. In: Pest management in protected culture crops, F.F. Smith & R.E. Webb, eds., USDA ARS-NE-85: 45-48.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

WHY HAS INTEGRATED CONTROL PRACTICE IN THE GREENHOUSE LEVELLED OFF IN CANADA ?

Robert J. McClanahan

Agriculture Canada
Research Station
Harrow, Ontario N0R 1G0
Canada

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 141-144

WHY HAS INTEGRATED CONTROL PRACTICE IN THE GREENHOUSE LEVELLED OFF IN CANADA ?

Robert J. McClanahan

Introduction

There is no doubt that greenhouse crops provide an ideal situation for the utilization of integrated control schedules. Briefly, the areas are limited and divided into discrete units, the pest problems are well-known and limited, the environment is controlled, and the crop value is high. Both the growers and research scientists are enthusiastic when they see a good biological control experiment, the cost seems reasonable and the advantages over chemical treatments are numerous. Why then has there not been more production and use of biological control agents for greenhouse crops in Canada. This presentation discusses the Canadian situation, with particular emphasis on the Essex County (southwestern Ontario) greenhouse crops of cucumber, tomato and chrysanthemums.

Encarsia formosa

The whitefly parasite, *Encarsia formosa*, was mass produced in 1970 at the Harrow Research Station and the scale of production rapidly increased, so that about 3½ million were distributed in 1972 (McClanahan, 1973). Figures for production since then are not available since several commercial operations are selling *Encarsia* . An estimated 4 million in 1973 probably represents the peak volume and 1978 production was not likely over 1½ million.

The bulk of the mass rearing is supported by the Ontario Greenhouse Vegetable Producers' Marketing Board (OGVPMB). *Encarsia*'s are reared by a salaried employee, and the growers belonging to OGVPMB support the system only indirectly, as a portion of the levy they pay which is based on the volume of produce marketed. Hence production of *Encarsia* is not linked to monetary returns but is geared more or less to growers' request, which peak in March and April and may be quite low the rest of the year. The small commercial production unit is a part time business which mainly supplies parasites to small greenhouse operations and for hobby greenhouses. The level of production has never been sufficient to meet the potential demand which would result from promotion and advertising. Overall then, supplies of *Encarsia* are limited and may not be available when required. If a large rearing unit were set up, increased sales could result in reasonable profits and encouragement of promotion and advertising. This would also take care of the local greenhouse vegetable requirements at a cost related to numbers needed.

The requirement pattern for *Encarsia* has changed over the past three years in the Leamington area. An important limiting factor is the degree of establishment of the parasite in the area. The 10 years of distribution to local growers has definitely established *Encarsia* on a permanent basis. They move outside in the summer, back into the greenhouse in the fall, and from one greenhouse to another. The last type of transfer is done purposefully by the growers, especially when supplies of reared parasites are scarce. This is all to the good, and means an increased distribution of parasites as well as an area-wide reduction in whiteflies. The reduced demand for reared parasites through OGVPMB indicates the success of the program and should not be interpreted as a decline in actual use of the parasites.

In Canada the synthetic pyrethroid insecticide permethrin has been registered for a year on chrysanthemums and other ornamentals. Its use has been widespread since it controls the vegetable leafminer as well as the greenhouse whitefly. The recent registration April 1979, of permethrin on greenhouse cucumbers and tomatoes makes available a spray material that will reduce heavy whitefly populations to a level below that causing economic injury, and parasites could be reintroduced if necessary. Likely chemical control will be the main tool of the flower growers, but ideally permethrin will not need to be used much on the vegetable crops. It does not fill the gap left by the deregistration of oxythioquinox (Morestan), since that material was safe for *Encarsia*.

So the situation with *Encarsia* is optimistic, but would be better with a commercial large-scale rearing unit supplying most of the parasites needed in Canada, and perhaps by nearby growers in the United States.

Phytoseiulus persimilis

The use of the predaceous mite, *Phytoseiulus persimilis*, for control of the two-spotted mite in greenhouses is still in the experimental stage in Canada. This is partly because of the priority placed on whitefly control, and in the last few years on the vegetable leafminer, as research projects at the Harrow Research Station. There are a number of factors which would limit the use of *P. persimilis* in Canadian greenhouses and these must be considered in setting research priorities and establishing mass rearing units.

Although *Tetranychus urticae* attacks tomatoes and chrysanthemums as well as cucumber, it is only a serious pest on the cucumbers in Canada. Damage to tomatoes seems to be limited to lower leaves, and on most chrysanthemum varieties the mite reproduction is limited, so that chemical control provides protection in those cases. The Ontario production of greenhouse cucumbers involves 42 ha under glass or plastic, and the rest of Canada has about 8 ha. The crop is mostly planted in the winter for spring and summer production, so many of the greenhouses are mite-free until late spring, and in some isolated greenhouses many crops can be free of mites. Thus the area requiring *Phytoseiulus persimilis* is much less than that needing *Encarsia formosa*.

Chemical control of spider mites is still possible with acaricides still providing control in spite of resistance. Dicofol at 0.1% gave 57 to 100% control of adult mites in 48 hr, in samples from 7 different greenhouses.

Demonstrations in commercial greenhouses of the use of *P. persimilis* have not given consistently good results.

The predators usually become established, but often there is a problem of poor dispersal. The main problem seems to be sudden jumps in the numbers of two-spotted mites when the greenhouse temperatures rise to 30°C or over. This leads to areas where there are many mites, especially on the top growth, and predators are scarce or badly outnumbered.

Finally, where biological control agents are being used in cucumbers, a build-up of thrips or leafminers may take place. Considerable time must be spent by the scientist, a technician, or an extension specialist watching the progress of the interaction and advising on manipulation of *P. persimilis*.

Leafminer parasites

Although this aspect of greenhouse pest management is still in the research stage, there is considerable interest in the possibility of parasite releases. It has been noted that the vegetable leafminer sometimes does not persist on a greenhouse crop, perhaps an indication that it is not adapted to short day conditions. An inundation of parasites at a time of reduced leafminer vitality might eliminate the pest from Canadian greenhouses.

Reference

McClanahan, R.J., 1973. Integrated control of greenhouse pests. Canada Agriculture 18(3): 34-35.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

CONTROL OF WHITEFLY (TRIALEURODES VAPORARIORUM) IN CUCUMBER WITH THE PARASITE ENCARSIA FORMOSA. EXPERIENCES FROM SOME GLASSHOUSES IN SWEDEN

Barbro Nedstam

Swedish University of Agricultural Sciences
Box 78
S-230 53 Alnarp
Sweden

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 145-154

CONTROL OF WHITEFLY (TRIALEURODES VAPORARIORUM) IN CUCUMBER WITH THE PARASITE ENCARSIA FORMOSA. EXPERIENCES FROM SOME GLASSHOUSES IN SWEDEN

Barbro Nedstam

Introduction

The use of *Encarsia formosa* Gahan against the greenhouse whitefly (*Trialeurodes vaporariorum* Westw.) in cucumber production is not common in Sweden. Experiments have shown that introductions of the wasp after the pest has established naturally quite often will not lead to successful biological control (Ekbom, 1977). In the U.K. two different methods of controlling whitefly by *E. formosa* have been developed: a) the 'classical' method where a low number of whiteflies is first introduced on every fifth plant, followed 14 days later by an introduction of *E. formosa*, and b) the 'dribble' method with routine, fortnightly introductions of *E. formosa* on every 40th plant until black, parasitized scales are found (Anon., 1972).

For practical use in Sweden neither of these methods is quite applicable: the classical one because of the risk in establishing a rather heavy infestation of whiteflies all over the crop - even with a high degree of parasitism. A disturbance of the system, e.g. by repeated chemical treatments of thrips or leafminers could later on wipe out the wasps and leave the grower with a difficult whitefly problem. It is not yet possible to take the 'dribble' method into practice as the 'black scales' are normally delivered on *Nicotiana* leaves with a low number (around 5%) of unparasitized scales. The method tested during 1978 in some Swedish cucumber nurseries is related to both these U.K. methods, but diverges in some respects: 1) introductions are made at fortnightly intervals, 2) there is one site of introduction per 250 m^2 glasshouse area (300-400 plants), 3) *Nicotiana* leaves are used, the numbers of black and unparasitized scales per m^2 are 1 and 0.05 respectively each time, and 4) introductions are continued for 4 to 5 months (around 10 introductions).

The purpose was both to have a constant supply of wasps in the crop (as with the 'dribble' method) and to establish small colonies of whiteflies that will serve as a source of food for the emerging wasps. Parasitism will also take place at these sites and increase the total number of *E. formosa* in the glasshouse. The introduced whiteflies stay on the spot for a long period as they spread slowly, while the wasps move around searching for attack of whitefly nymphs.

Description of the trials

All houses in which we performed trials (see Table 1) belonged to commercial growers using normal production methods. The substrate was mineral wool. Night temperature was +18°C. *Phytoseiulus persimilis* was used against the glasshouse red spider mite. No leafminer (*Liriomyza* spp.) attacks were found. Yields were normal to high. In house A, with the longest growing period, yields exceeded 50 kg per m^2.

Table 1. Description of glasshouses in which a new *Encarsia* introduction method was tested

	glasshouse area (m^2)	Cultivar	Plants per m^2	Date of planting	1st introduction	End of season
A	500	WW 446	1.4	26-2	2-3	28-9
B	500	Farbio	1.6	21-2	28-2	Sept.
C	600	Farbio	1.3	23-2	19-4	26-7
D	500	Farbio	1.4	21-2	9-3	1-9

Individual comments

Glasshouse A. There were no whiteflies at the first *Encarsia* introduction, though glasshouses nearby had some infestation. Six % of the plants died of root rot early in the season and when these were removed, one introduction site was disturbed and whiteflies were spreading.

Glasshouse B. There was some infestation by the time of planting on 4% of the plants, the infestations were randomly distributed throughout the house. All leaves with whitefly nymphs were found by the wasps.

Glasshouse C. At the first introduction there was already a severe and well-defined pocket infestation in one corner of the house. Those plants (9.6% of all) were regularly sprayed with bioresmethrine while the rest of the house was used for trying the biological control method. The tabulated results only apply to the unsprayed part of the house (roughly 540 m^2).

Glasshouse D. At this place only 'black scales' were used like in the 'dribble' method. To ensure a constant supply of wasps, weekly introductions with 0.5 per m^2 were made. These introductions continued five weeks after the first parasitized nymphs were found.

Sampling methods

Both absolute countings and countings on a fixed sample of 50 plants, selected in a stratified random system, were made. As whiteflies show a markedly clustered distribution and thus variability of the infestation on plants is high, it is preferable to use a fixed sample to get information on population change (Yates, 1953). Countings on 19 plants surrounding each release point were also made. Absolute countings were not made at glasshouse C. Adult whiteflies were counted on four top leaves of the main stem or all side shoots of the plant, weekly or once a month as absolute countings or on the sample and 'release' plants. No countings were made on older leaves with adults just emerging from pupae.

Pupal instar and parasitism were counted on whole leaves; the first 12 and 16 main stem leaves respectively in glasshouse B and A (absolute countings), then on remaining stem leaves only on sample and 'release' plants. Later the leaves of the top side shoot only were counted and late in the season only randomly selected leaves on the plant. No leaf counts were made simultaneously, so these late figures can only give a measure of percentage parasitism, not the total infestation. Dead nymphs were also counted on the leaves, but these figures are generally 10-20% too low, as the first and second instars are sometimes not noticed. Fungal attack on the scales was observed now and then from July onwards but not recorded.

Table 2 Number of whiteflies and percentage of parasitism in glasshouse A

date of count	9-3	30-3	6-4	20-4	27-4	4-5	18-5	15-6	27-7	27-9
no. of plants attacked by whiteflies (all stages)	11	19	24	36	37	NR	NR	152	NR	NR
%	1.6	2.7	3.4	5.1	5.3	NR	NR	22	70	98
total no. adult whiteflies	26	22	23	30	9	NR	88	240	NR	NR
mean no. per 100 m^2 glasshouse	5	4	4	6	2	NR	18	48	910	NR
mean no. per plant with attack	2.4	2.0	1.2	2.0	1.0	NR	12.6	12	16	NR
total no. of scales	0	NR	NR	69	245	385	NR	NR	NR	NR
mean no. per plant with attack	-	-	-	12	16	23	-	-	-	-
% parasitism	-	NR	NR	98	98	96	97	89	84	70
total no. dead nymphs [1)]	NR	NR	NR	19	144	294	NR	NR	NR	NR
mean no. per plant with attack	-	-	-	4	10	17	-	-	-	-
no. of plants with sooty moulds [2)]	0	0	0	0	0	0	0	1	NR	91
% attack sooty moulds									4	13

[1)] counted on the same leaves as the scales

[2)] almost only plants with small damages (1-3 leaves)

NR = not recorded

Table 3 Number of whiteflies and percentage of parasitsm in glasshouse B

date of count	28-2	7-3	14-3	21-3	8-4	18-4	19-5	20-6	5-7	9-8
no. of plants attacked by whiteflies (all stages)	29	31	44	46	NR	107	NR	500	NR	NR
%	3.6	3.9	5.5	5.8	NR	13	NR	63	94	100
total no. adult whiteflies	15	72	77	81	NR	2-300	NR	NR	NR	NR
mean no. per 100 m^2 glasshouse	3	14	15	16	NR	40-60	NR	3500	3100	7900
mean no. per plant with attack	1.0	3.3	2.2	2.3	NR	2-3	NR	25	21	50
total no. of scales	NR	NR	125	NR	3470	NR	NR	NR	NR	NR
mean no. per plant with attack	-	-	14	-	87	-	-	-	-	-
% parasitism	-	NR	68	NR	89	91	97	75	61	59
total no. dead nymphs [1]	NR	NR	NR	NR	102	(5%) [2]	NR	NR	NR	NR
mean no. per plant with attack	-	-	-	-	2.5	-	-	-	-	-
no. of plants with sooty moulds	0	0	0	0	0	0	0	2	NR	NR
% attack sooty moulds	-	-	-	-	-	-	-	0.3	5	44

[1] counted on the same leaves as the scales
[2] of all nymphs on the leaves
NR = not recorded

Table 4 Number of whiteflies and percentage parasitism in glasshouse C

date of count	31-5	7-6	21-6	5-7	19-7
% plants attacked by whiteflies (all stages)	41	NR	63	90	98
mean no. <u>adult</u> whiteflies per 100 m^2 glasshouse	170	NR	2030	2900	4300
mean no. per plant with attack	3	-	26	36	42
% <u>parasitism</u>	NR	80	87	86	96
% attack with <u>sooty</u> <u>moulds</u>	0	0	0	0	2

Table 5 Number of whiteflies and percentage of parasitism in glasshouse D

date of count	2-6	8-6	22-6	6-7	13-7	27-7	17-8	31-8
no. of plants attacked by whiteflies (all stages)	2	13	NR	30	NR	61	86	190
%	0.3	1.9	NR	4.3	NR	8.7	12	27
total no. adult whiteflies	13	22	NR	42	NR	NR	NR	NR
mean no. per 100 m^2 glasshouse	2.6	4.4	-	8.4	-	-	-	200
mean no. per plant with attack	13	1.8	-	2.2	-	-	-	4.0
total no. of scales	NR	30	NR	NR	415	NR	NR	NR
mean no. per plant with attack	-	30	-	-	30	-	-	-
% parasitism	NR	73	85	NR	74	53	53	62
total no. dead nymphs [1]	NR	9	NR	NR	78	(8%) [2]	NR	(6%) [2]
mean no. per plant with attack	-	9	-	-	6	-	-	-

[1] counted on the same leaves as the scales
[2] of all nymphs on the leaves
NR = not recorded

Sooty moulds did not develop

Results and discussion

The results of the countings are given in Tables 2 to 5. The biological control method worked nicely at glasshouses A and B for more than four months. The result at B would have been even better when no chemical thrips control had been necessary from the end of May onwards. At A some treatments of mildew with pyrazophos were done and in August bioresmethrine had to be used against thrips and adult whiteflies (Figs. 1 and 2). At glasshouse C the trial lasted only three months, due to replanting. Seven introductions of a total of 4000 *E. formosa* were enough to avoid sooty moulds from damaging the crop, despite the severe pocket infestation. In fact these plants with hundreds of nymphs on each leaf served as a 'bank' for building up the wasp population. Glasshouse D got the natural attack late, by the end of May, and also here only three months of studies were possible. With the 'dribble' method it is probably better to distribute the 'black scales' more evenly, but in this case *E. formosa* immediately found the first few nymphs at a distance of 10 m from the release point. This house had the lowest level of parasitism which at least cannot be explained by chemical treatments. It is too early to judge whether the introduction method here described is more efficient than the 'dribble' method.

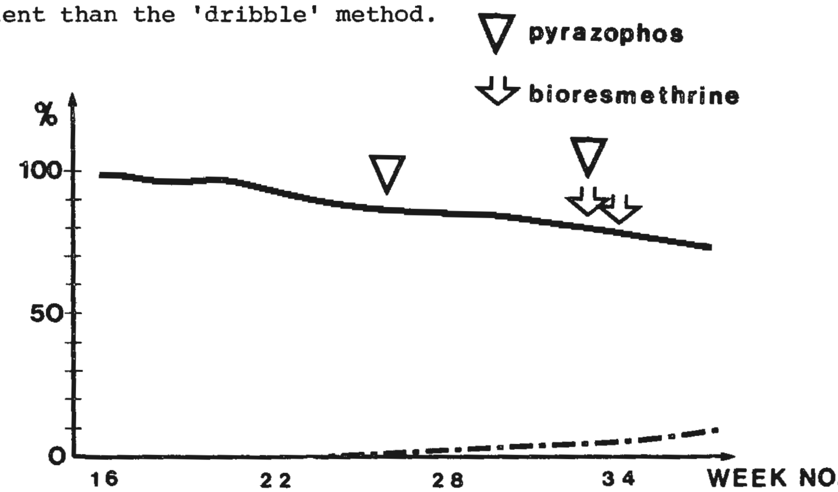


Fig. 1 Chemical treatments, percentage parasitism (—) and percentage of plants attacked by sooty moulds (--) in glasshouse A

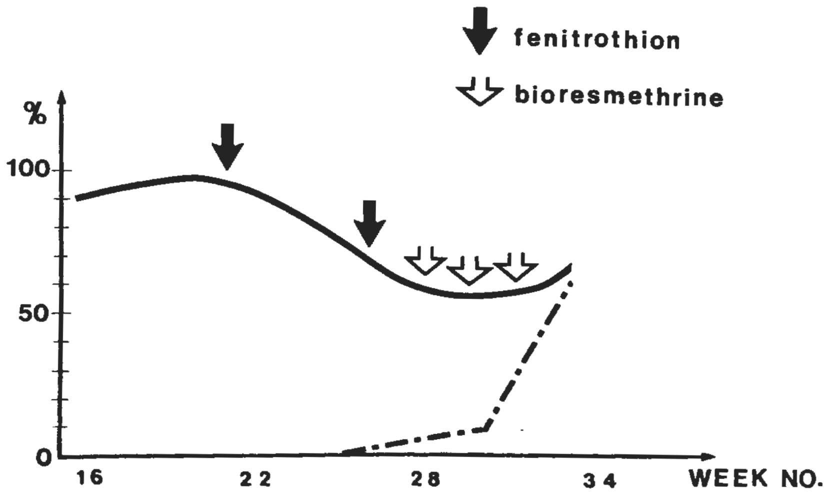


Fig. 2 Chemical treatments, percentage parasitism (——) and percentage of plants attacked by sooty moulds (---) in glasshouse B

The death causes for nymphs were not studied in detail. Some natural mortality occurs (van Lenteren et al., 1977) but more important is probably the host feeding by *E. formosa* together with unsuccessful parasitism (van Alphen et al., 1976). Numbers of dead nymphs were especially high at site A where the ratio whiteflies to wasps was kept low during the first two months.

If the method is taken into practice there are several ways in which the biocontrol might develop:

1. There are no whiteflies present when the introductions start and no attack from outside will come during the whole season. (This situation would be very uncommon as only the growers having regular problems with whiteflies would accept the method). The small colonies of heavily parasitized whiteflies should not disturb the culture. However, if the grower is forced to spray chemicals against other pests a few pocket infestations might develop with the risk of increased damage.

2. There are no whiteflies from the start but during the season (normally before June) adult whiteflies will enter

the house from outside. This should lead to efficient biological control by wasps always present in the glasshouse. Disturbances from chemicals could affect the result but would not worsen the situation in comparison with a chemical control programme also for whiteflies.

3. There is a whitefly infestation already by planting. (This situation is rather uncommon but would need the first introduction to be made very soon after planting). As no. 2.

Using this method of introduction it seems possible to suppress the glasshouse whitefly on cucumber by *Encarsia formosa* for several months. If, however, other pests enter the crop and chemicals have to be used, this will affect biocontrol negatively. Until insecticide-resistant strains of *E. formosa* will come on the market, there is a great need for reliable predators and parasites of thrips and leafminers.

References

Alphen, J.J.M. van, H.W. Nell & L.A. Sevenster-van der Lelie, 1976. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). VII. The importance of host feeding as a mortality factor in greenhouse whitefly nymphs. Bull. O.I.L.B./S.R.O.P. 1976/4: 165-169.

Anon., 1972. The biological control of cucumber pests. Glasshouse Crops Research Institute, Growers Bull. no. 1.

Ekbom, B.S., 1977. Development of a biological control program for greenhouse whiteflies (Trialeurodes vaporariorum Westwood) using its parasite Encarsia formosa (Gahan) in Sweden. Z. angew. Ent. 84: 145-154.

Lenteren, J.C. van, J. Woets, N. van der Poel, W. van Boxtel, S. van de Merendonk, R. van der Kamp, H. Nell & L.A. Sevenster-van der Lelie, 1977. Biological control of the greenhouse whitefly Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae) by Encarsia formosa Gahan (Hymenoptera: Aphelinidae) in Holland, an example of successful applied ecological research. Meded. Fac. Lnadbouww. Rijksuniv. Gent. 42: 1333-1342.

Yates, F., 1953. Sampling methods for censuses and surveys. London.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

SUR LE CONTROLE BIOLOGIQUE DE L' ALEURODE DES SERRES (*TRIALEURODES VAPORARIORUM*) PAR *ENCARSIA FORMOSA* EN SERRES D' AUBERGINE

J.C. Onillon, J. Onillon, J.P. Di Pietro & E. Franco

Station de Zoologie et de Lutte Biologique
37, Boulevard du Cap
06602 Antibes
France

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 155-156

SUR LE CONTROLE BIOLOGIQUE DE L'ALEURODE DES SERRES (TRIALEURODES VAPORARIORUM) PAR ENCARSIA FORMOSA EN SERRES D'AUBERGINE

J.C. Onillon, J. Onillon, J.P. Di Pietro & E. Franco

Résumé

Au cours de ces quatre dernière années ont été étudiées sur aubergine, plante maraîchère la plus sensible aux attaques de l'aleurode des serres Trialeurodes vaporariorum, les modalités du contrôle biologique par Encarsia formosa et le degré de nocivité du ravageur.

Les contaminations artificielles des jeunes plants d'aubergine ont été réalisées à raison de 16, 8, 4 et 1 adultes par plant. A partir d'un inoculum de 16 adultes de Trialeurodes vaporariorum/plant et d'un lâcher trois à quatre semaines plus tard d'adultes d'Encarsia formosa dans un rapport E.F.:T.V. = 1:1, le contrôle biologique de l' aleurode est suivi pendant toute la durée de la culture. Lorsque les contaminations sont élevées, 16 adultes de Trialeurodes vaporariorum, un lâcher de 16 adultes d'Encarsia formosa est insuffisant et 50% de larves sont parasités à la fin de la culture.

Pour les contaminations inférieures (8, 4 et 1 adultes de Trialeurodes vaporariorum) un excellent contrôle biologique est obtenue avec un lâcher du parasite dans la rapport 3:1. Le taux de parasitisme obtenue en fin de culture est très voisin de 85% et aucun dégât n'est observé.

Dans le cas de serre témoin où aucun adulte d'Encarsia formosa n'a été introduit pour une contamination artificielle de 4 adultes de Trialeurodes vaporariorum par plant, les dégâts qualitatifs et quantitatifs sont observés et chiffrés au niveau de chacune des récoltes hebdomadaires. Les seuils de nuisibilité sont donnés en fonction des infestations des larves du dernier stade par unité de surface foliaire.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

INFLUENCE DE LA TEMPERATURE ET DE L'HUMIDITE RELATIVE SUR LE DEVELOPPEMENT ET LA REPRODUCTION DE *PHYTOSEIULUS PERSIMILIS*

M. Pralavorio & L. Almaguel-Rojas

Station de Zoologie et de Lutte Biologique
37, Boulevard du Cap
06602 Antibes
France

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDING OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.R.P.S. 1980 III / 3, 157-162

INFLUENCE DE LA TEMPERATURE ET DE L'HUMIDITE RELATIVE SUR LE DEVELOPPEMENT ET LA REPRODUCTION DE PHYTOSEIULUS PERSIMILIS

M. Pralavorio & L. Almaguel-Rojas

Introduction

De nombreux auteurs Dosse (1959), Force (1967), McClanahan (1968) ont noté le rôle important joué par la température dans la dynamique des populations de *Phytoseiulus persimilis*. Mori & Chant (1966), Begliarov (1967), Ushekov & Begliarov (1968) ont particulièrement souligné le rôle joué par l'humidité relative dans le développement et la reproduction de *P. persimilis*.

Il nous a paru intéressant de préciser l'importance de ce facteur dans une expérimentation portant simultanément sur plusieurs températures et plusieurs conditions d'hygrométrie afin d'une part d'améliorer les conditions de conservation et de stockage de cette espèce et d'autre part d'être à même de saisir les répercussions des modifications climatiques de la serre sur une population de prédateurs.

Le dispositif expérimental

Un certain nombre d'unités est placé dans les différentes conditions de température: chacune d'entre elles est constituée par une boîte en plastique rectangulaire de 26x13x7 cm hermétiquement close et munie intérieurement d'un support inoxydable sur lequel sont disposées 32 cellules individuelles au couvercle grillagé. Au fond de ce récipient une solution de 100 cc d'eau distillée et d'un sel ou d'une base à concentration donnée permet de maintenir un taux d'humidité constant contrôlé au préalable par hygrostat aux différentes températures.

Les adultes de *P. persimilis* mis en expérience ont été prélevés au stade deutonymphe dans l'élevage puis mis par couples dans les cellules; les oeufs ont été prélevés quotidiennement dans un élevage d'adultes.

Les résultats

Les résultats de l'étude du développement embryonnaire et post-embryonnaire ont été rassemblés dans le tableau 1. En ce qui concerne le développement post-embryonnaire seule l'observation de la première mue après éclosion c'est-à-dire le passage du stade larvaire au stade protonymphe, a été retenue; en effet la larve ne s'alimentant pas, seuls les facteurs abiotiques peuvent empêcher sa transformation en protonymphe.

Tableau 1 L'influence de l'humidité et de la température sur le développement des oeufs de *Phytoseiulus persimilis*

% H.R.	t(°C)	no. oeufs	% éclosions	% de protonymphs sur 100 oeufs
93	30	42	94	84
	20	43	92	72
	10	23	100	39
	12-5	38	89	56
	5	22	0	-
75	30	46	72	15
	20	47	60	29
50	30	50	6	2
	20	36	8	0
	10	25	8	0
	12-5	38	8	0
33	30	50	0	-
	20	50	4	0

On constate qu'aux humidités élevées (93%) les pourcentages d'éclosion sont supérieurs ou proches de 90% à toutes les températures sauf à 5°C ou aucune éclosion n'est possible (température inférieure au seuil de développement). A 75% H.R. un pourcentage non négligeable d'individus arrive au stade protonymphe et termine son développement.

parcontre à 50 % H.R. et au-dessous pratiquement aucun développement ne peut s'effectuer. Les larves ayant pu éclore ne franchissent pas le stade suivant.
Les résultats de l'étude de la vie imaginale sont représentés sur le tableau 2. Seuls la fécondité et la longévité des femelles ont été retenues.

Il apparaît tout d'abort que si la température joue un rôle déterminant sur le taux de fécondité et de longévité des adultes, l'humidité relative n'est pas moins importante puisqu'on constate que le nombre moyen d'oeufs déposé par femelle diminue de moitié ou plus aux mêmes températures quand on passe de 93 à 50% H.R.. La durée de via imaginale est elle-même réduite dans les mêmes proportions.

Discussion et conclusions

Un des facteurs essentiels favorisant ou limitant la dynamique de populations de *Phytoseiulus persimilis* est, d'après nos essais, l'humidité relative du milieu. C'est elle qui en définitive, détermine la fécondité des femelles, la durée de la vie imaginale ainsi que les possibilités de développement des oeufs et des stades immatures: ceci, dans les limites imposées par la température, le seuil thermique supérieur n'ayant pas été envisagé dans l'expérimentation (34^{o} à $35^{o}C$ selon Ushekov qui note qu'une hausse temporaire à 40, $42^{o}C$, ne gêne pas la multiplication du prédateur).

En contrepartie de l'effet favourable de l'humidité relative élevée sur le prédateur de nombreux auteurs, Begliarov (1967), Mori & Chant (1966), notent que l'activité prédatrice diminue et particulièrement à 98% d'H.R.. En effet une hygrométrie basse, si elle diminue la fécondité, augmente la capacité de destruction du prédateur, Begliarov constate une grande différence (du simple au double environ) entre le nombre de proies sucées à 50-70% d'H.R. d'une part et 98% d'H.R. d'autre part pour une température de $25^{o}C$. Il est probable d'après cet auteur que l'augmentation de l'alimentation est liée à la nécessité d'un rééquilibre hydrique.

Par ailleurs, il est intéressant de noter que d'après Ushekov & Begliarov (1968) le développement des oeufs est

Tableau 2 L'influence de l'humidité et de la température sur la fécondité et la longévité des femelles de *Phytoseiulus persimilis*

% H.R.	t(^{o}C)	nombre de couples	nombre moyen oeufs/femelle	ecart type	nombre moyen jours de ponte	longévité des femelles (jours)
93	30	25	16,36	11,77	5,5	9
	20	24	80,20	28,71	30	45
	10	25	31,04	11,29	44	68
	12-5	21	16,80	7,46	43	65
	5	14	0	-	-	52
50	20	23	30,43	15,27	13	19
	10	22	15,27	12,11	23	34
	12-5	24	7,75	5,39	33	58

possible à 60% d'H.R. pour des températures inférieures à 30°C et à 80% d'H.R. pour des températures supérieures à 30°C.

L'étude que nous avons effectué nous a seulement permis de marquer les étapes qui doivent encore être francies dans l'étude des répercussions des facteurs abiotiques sur le développement des populations de *P. persimilis*. Une bonne connaissance du rôle joué par le climat est nécessaire lors de l'introduction du prédateur dans les serres et permettrait de pallier à certains échecs.

Par ailleurs les conditions de conservation de cet auxiliaire pourrait être sensiblement amélioré par un choix judicieux de la température et un contrôle des conditions d'hygrométrie de l'enceinte de stockage.

Bibliographie

Begliarov, G.A., 1967. Ergebnisse der Undersuchungen und der Anwendung von Phytoseiulus persimilis Athias-Henriot als biologische Bekämpfungsmittel gegen Spinnmilben in der Sowjetunion. Nachrbl. Dtsch. Pflanz. Dienst Berlin 21: 197-200.

Dosse, G., 1959. Der Einfluss von Temperatur und Nahrung auf verschiedene Raubmilbenarten und Hinweise auf die Möglichkeit einer biologischen Bekämpfung von Spinnmilben in Gewächshäusern. Verh. 4. Pflanz.Kongr. (Hamburg 1957)1: 929-932.

Force, D.C., 1967. Effect of temperature on biological control of two-spotted spider mites by Phytoseiulus persimilis. J. Ec. Ent. 60: 1308-1311.

McClanahan, R.J., 1968. Influence of temperature on the reproduction potential of two mites predators of the two-spotted spider mite. Can. Ent. 100: 549-556.

Mori, H. & D.A. Chant, 1966. The influence of prey density, relative humidity and starvation on the predaceous behaviour of Phytoseiulus persimilis Athias-Henriot. Can. J. Zool. 44: 483-491.

Mori, H. & D.A. Chant, 1966. The influence of humidity on the activity of Phytoseiulus persimilis Athias-Henriot and its prey, Tetranychus urticae Koch (Acarina: Phytoseiidae, Tetranychidae). Can. Ent. 44: 863-971.

Ushekov, A.T. & G.A. Begliarov, 1968. The effect of air temperature and relative humidity on the development of the predaceous mite Phytoseiulus persimilis A.H. (Acarina: Phytoseiidae). Proc. 13th Int. Congr. Ent., 198-199.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

INFLUENCE OF SOME FACTORS ON THE FECUNDITY OF *PHYTOSEIULUS PERSIMILIS* ATHIAS-HENRIOT FEMALES

Stefan Pruszyński

Institute for Plant Protection
Miczurina 20
60-318 Poznań
Poland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 163-174

INFLUENCE OF SOME FACTORS ON THE FECUNDITY OF PHYTOSEIULUS PERSIMILIS ATHIAS-HENRIOT FEMALES

Stefan Pruszyński

Introduction

The number of eggs laid by a female is one of the conditions determining the effectiveness of the species as well as its usefulness in biological control methods. For this reason the determination of the fecundity of females as well as the influence of various factors on the quantity of eggs laid by a female belong to essential researches carried out on each species. Such researches have also been accomplished in relation to the predator *P. persimilis*. In the experiments carried out in the Institute for Plant Protection in Poznań we determined, among others, the influence of temperature, relative air humidity, term of copulation, kind of food and quantity of food on the fecundity of *P. persimilis* females. In order to determine optimal conditions ensuring high fecundity of *P. persimilis* females, the results obtained are presented and they are compared with the results obtained by other authors.

Material and methods

The *Phytoseiulus persimilis* strain we used for experiments has been brought to Poland August 2nd, 1966, from England. Additionally in 1967 the predator has been brought from the Plant Protection Institute in Leningrad and from the Institute of Glasshouse Cultures in Naaldwijk, the Netherlands.
As food the spider mite, *Tetranychus urticae* Koch, was used, reared under glasshouse conditions mainly on bean plants, as well as collected in the summer on attacked glasshouse and field plants.

The majority of observations was carried out on bean leaves submerged in a 1,5% agar solution in test-tubes. The upper opening of the tube was closed using bolting-cloth. The research on the influence of the temperature on the fecundity of *P. persimilis* females has been carried out in a thermostat without light at three temperatures: 17, 21 and 26°C. For the research on the influence of relative air humidity, saturated solutions of the following salts have been applied: LiCl, $K_2CO_3.2H_2O$, NH_4NO_3, NaCl, KCl and KNO_3. With these solutions the following relative air humidities have been obtained: 18, 45, 60, 75, 85 and 95%. Experiments were carried out in the thermostat at three temperatures. The females of *P. persimilis* were placed in glass tubes with an excess of food. Tubes were then placed in Weck jars, in which saturated solutions of the salts were placed on the bottom.

In the experiments on the fecundity individually reared females of the predator were used. Females, 0 to 24 hours old, were individually transferred to the tubes and a male was added. The number of eggs laid was noted every 24 hours. After the egg count the eggs were removed or the females were transferred to a new tube.

In order to determine the influence of the term of copulation on the fecundity, females of various ages were coupled with males. Four combinations have been applied: in the first one the females copulated shortly after reaching adult stage, in the second one after 2 weeks, in the third one after 4 weeks and in the fourth one 6 weeks after the emergence from the deutonymph.

The influence of the kind of food was studied in the following way: one group received only eggs during the whole period of egg laying, the other one received only larvae of the spider mite. The influence of the quantity of food on the number of eggs laid by the females was studied according to the method described earlier (Pruszyński, 1973).

Results and discussion

Influence of the temperature

In the experiment carried out at temperatures of 17, 21 and 26°C the mean fecundity of females amounted to 65.3, 73.1 and 74.1 eggs per female respectively. The fecundity

Table 1 Influence of the temperature and the kind of food on the fecundity and longevity of *Phytoseiulus persimilis* females

	no. females tested	fecundity		period egg laying (days)		no. eggs/day/female		longevity	
		min-max	mean	min-max	mean	min-max	mean	min-max	mean
temperature									
17°C	12	51 - 79	65.5	26 - 38	33.6	1.63 - 2.13	1.90	23 - 92	56.3
21°C	12	60 - 85	73.1	22 - 37	26.3	2.29 - 3.16	2.68	19 - 93	54.1
26°C	12	66 - 87	74.1	16 - 23	18.8	3.47 - 4.70	3.95	15 - 58	38.2
laboratory conditions	18	52 - 93	78.0	25 - 48	33.8	1.90 - 2.56	2.31	49 -123	77.9
food: eggs	19	42 - 91	70.9	13 - 33	24.3	1.86 - 3.93	2.82	15 -138	51.1
larvae	12	36 - 89	57.9	12 - 36	23.1	1.56 - 3.16	2.49	19 -128	37.5

Table 2 Influence of relative air humidity and temperature on daily fecundity of *Phytoseiulus persimilis* females

relative air humidity (%)	fecundity at 17°C min-max	fecundity at 17°C mean	fecundity at 21°C min-max	fecundity at 21°C mean	fecundity at 26°C min-max	fecundity at 26°C mean
18	0 - 2	1.29	1 - 3	2.17	0 - 3	1.88
45	0 - 2	1.11	2 - 4	2.30	1 - 5	3.28
60	0 - 2	1.43	0 - 3	2.13	2 - 5	3.88
75	1 - 3	1.67	0 - 4	2.58	3 - 6	4.75
85	0 - 2	1.52	0 - 4	2.63	4 - 6	5.16
95	0 - 3	1.70	0 - 5	2.92	3 - 5	4.27

of females reared at laboratory conditions at a variable temperature amounted at the same time to a mean of 78 eggs (Table 1). The increase of temperature in the range of 17-26°C thus caused a small but regular increase in the number of eggs laid by the females. The increase of the temperature also caused the reduction of the period of egg laying from 33.6 days at the temperature of 17°C to 18.8 days at a temperature of 26°C, increased the daily female fecundity from 1.9 to 3.95 eggs per one female, and reduced the life period of females from 56.3 to 38.2 days. Bravenboer & Dosse (1962) and McClanahan (1968) obtained identical results. The results of these authors on the increase of temperature in the range of 15-35°C showed higher mean and daily fecundity of females as well as the reduction of the period of egg laying.

Influence of relative air humidity

The increase of relative air humidity in the range of 18-95% causes an increase in the number of eggs laid by the females (Table 2). Differences in the number of eggs laid were largest at the highest temperatures.
At the temperature of 26°C the difference between the highest and the lowest daily fecundity obtained amounted to 3.28 eggs. At the temperatures of 17 and 21°C the differences were 0.59 and 0.79 eggs per day per female, respectively. A similar influence of relative air humidity on the fecundity of females was found by Uscekova & Beglarov (1968) at a temperature of 25°C and relative humidities of 30, 50 and 70-90%. The fecundities per day were 0.8, 1.3 and 4.2-4.3 eggs, respectively.

Influence of the quantity of food

The amount of food always determines the egg laying. We do not, however, have exact data concerning the lowest quantity of food necessary for the start of egg laying. In our experiments the fecundity obtained when the females received 2 deutonymphs daily amounted to 0.47 - 0.62 eggs. Many experiments have shown that an increase in the quantity of food caused an increase in the number of eggs laid by uence of the date of copulation on the fecundity of *Phytoseiulus persimilis* female

	no. females	fecundity		egg laying period		no. eggs/day/female		longev
		min-max	mean	min-max	mean	min-max	mean	min-ma
t	10	62 - 85	76.9	21 - 31	21.1	2.42 - 3.03	2.73	25 - 8
	8	10 - 88	54.6	4 - 33	22.7	1.95 - 2.67	2.38	20 - 8
	11	0 - 85	48.5	0 - 32	20.9	2.07 - 2.95	2.32	43 - 6
	7	0 - 60	34.0	0 - 26	16.5	1.75 - 2.80	2.06	58 - 8

the females (Laing & Osborn, 1974; Kamath, 1968; Pruszyński, 1973; Shehata, 1973). The observed increase in the number of eggs laid always took place to a certain level, above which an increase in food did not result in an increased oviposition. In our research the increase in the number of eggs laid levelled off when the amount of food was about 3 deutonymphs of spider mite per one cm^2 of leaf surface. In the publications of other authors, however, it depended both upon the kind and the quantity of food.

Influence of the term of copulation

Phytoseiulus persimilis females do not begin to lay eggs without previous copulation, and the necessity of both copulation and fertilization is discussed by Kennett & Caltagirone (1968). In an experiment we transferred the term of copulation. This caused the decrease of the mean fecundity of females from 76 eggs, in the case of females copulating shortly after reaching the adult form, to 34 eggs when the copulation took place 6 weeks later (Table 3). It is important to note, however, that even the females of 42 days old keep the capacity for copulation and egg laying. Kennett & Caltagirone (1968) describe an individual case, similar to our result, in which they coupled a female of 37 days old with a male: the female started to lay eggs 48 hours after the copulation (42 eggs in total).

Influence of the kind of food

Females were either fed with larvae or with spider mite eggs. The highest fecundity has been obtained in females that received spider mite eggs. Beglarov & Hlopceva (1965) have also obtained a lower mean fecundity when the females of *P. persimilis* were fed only on diapausing spider mite females. Kamath (1968) fed females with spider mite eggs only. He obtained a mean fecundity of 62 eggs. Shehata (1973) stated a higher fecundity of females when fed with larvae and adults than when fed with spider mite eggs. All the authors state, however, that the highest fecundity is obtained if females obtain an excess of individuals of all developmental for the fecundity of *Phytoseiulus persimilis* females found by different authors

	temperature	no. eggs/ day/female	fecundity mean	fecundity maximum	author
e		3.7	81.2	105	Beglarov & Hlop
arinus		3.5	75.0	87	Ibidem
e		2.8	51.8	63	Ibidem
les					
tiliarum		3.3	76.8	92	Ibidem
e	20	2.4	53.5	101	Laing (1968)
'	20		43.8	78	McClanahan (196
'	26		53.5	87	Ibidem
'		3.2	74.5		Plotnikov & Sadl
arinus	10	0.4		26	Bravenboer & Do
'	15	1.2		64	Ibidem
iaca	25	4.0		104	Ibidem
'	30	4.2			Ibidem
			62.0		Kamath (1968)
			68.0		Ibidem
			22.3		Ibidem
e	25-26		58-60		Böhm (1966)
'	17	1.90	65.5	79	Pruszyński
'	21	2.68	73.1	85	Ibidem
'	26	3.95	74.1	87	Ibidem
'	lab.	2.31	78.0	93	Ibidem

stages of the spider mite as food.

Influence of rearing and hybridization

Poe & Enns (1970) have stated that inbred rearing of *P. persimilis* leads to the reduction of female vitality, to a decrease in the number of eggs laid and to sterile eggs. Vorosilov (1976) found no differences between the numbers of eggs laid by females obtained from France and Canada. After hybridization of the two populations, he observed that the number of eggs laid was twice as high as for the original strains. This author also stated that a too high density of *P. persimilis* females causes a decrease in their fecundity. Kennett & Caltagirone (1968) also obtained differences in fecundity after hybridization of predator populations from Sicily and Chile.

Conclusions

In Table 4 results are presented on the fecundity of *P. persimilis* females as found by various authors. It is striking that when the same kind of food is used, the mean fecundity of females measured by McClanahan (1968) and Laing (1968) is about 20 eggs lower than the fecundity obtained by Beglarov & Hlopceva (1965), Plotnikov & Sadkovskij (1972) and Pruszyński (1977). The cause of this difference may lay in the many years of rearing of this predator, i.e. in genetic attenuation of the population.

In mass rearing as well as in the use of the predator in commercial glasshouses, high fecundity of females is of special importance. Based on the results presented, the following factors determining a high fecundity of the females can be listed:

- temperature in the range of 25-30^{o}C
- relative air humidity above 70%
- excess of food and the presence of all developmental stages of spider mite
- presence of males
- hybridization from time to time of reared populations with individuals collected in natural conditions or originating

from other rearings.

The last remark needs special studies. Results obtained up to now are too poor and detailed determination of the influence of many years of rearing on the vitality of the predator, its predation capacity and fecundity of the females is necessary.

Results of these researches should make it possible to eliminate the decrease of the fecundity of *P. persimilis* females as a result of many years of rearing.

References

Beglarov, G.A. & R.I. Hlopceva, 1965. Razvitie chiscnogo klesca Phytoseiulus persimilis Athias-Henriot pri pitani razlicnymi vidami pautinnych klescej. W 'Issledovania po biologiceskomu metodu borby s vreditelami selskogo i lesnogo chozajstva': 104-106.

Böhm, H., 1966. Ein Beitrag zur biologischen Bekämpfung von Spinnmilben in Gewächshäusern. Pflanzenschutz-Berichte 34: 67-78.

Bravenboer, L. & G. Dosse, 1962. Phytoseiulus riegeli Dosse als Predator einiger Schadmilben aus der Tetranychus urticae-Gruppe. Entom. exp. appl. 5: 291-304.

Kamath, S.M., 1968. Studies on the feeding habits, development and reproduction of the predacious mite Phytoseiulus persimilis A.-H. (Acarina: Phytoseiidae) on some phytophagous mites in India. C.I.B.C. Techn. Bull. 10: 49-56.

Kennett, C.E. & L.E. Caltagirone, 1968. Biosystematics of Phytoseiulus persimilis Athias-Henriot (Acarina: Phytoseiidae). Acarologia 10: 563-577.

Laing, J.E., 1968. Life history and life table of Phytoseiulus persimilis Athias-Henriot. Acarologia 10: 578-588.

Laing, J.E. & J.A.L. Osborn, 1974. The effect of prey density on the functional and numerical responses of three species of predatory mites. Entomophaga 19: 267-277.

Plotnikov, V.F. & V.P. Sadkovskij, 1972. Primenienie fitoseiulusa dla borby s pautinnym klescom v gitroponnych teplicach kolchoza 'Belaa Daca'. W 'Biologiceskij

metod borby s vreditelami ovoscnych kultur', Moskva: 18-25.
Poe, S.L. & W.R. Enns, 1970. Effects of inbreeding on closed populations of predaceous mites (Acarina: Phytoseiidae). Can. Entom. 102: 1222-1229.
Pruszyński, S., 1973. The influence of prey density on prey consumption and oviposition of Phytoseiulus persimilis Athias-Henriot (Acarina: Phytoseiidae). Bull. O.I.B.C./ W.P.R.S. 1973/4: 41-46.
Pruszyński, S., 1977. Z badań nad drapieznym roztoczem Phyto-seiulus persimilis Athias-Henriot. I. Obserwacje nad rozwojem i plodnoscia samis P. persimilis. Prac. Nauk IOR XIX: 145-166.
Shehata, K.K., 1973. Prey type and density and their effect on the potentiality of Phytoseiulus persimilis Athias--Henriot (Acarina: Phytoseiidae). Biologia 28: 619-626.
Voroshilov, N.V., 1976. Vliyanie gibridizatsii i plotnosti populyatsii na plodovitost fitoseiulyusa (The effect of hybridization and population density of Phytoseiulus fecundity). Byul. Vses. Nauch.-Issled. Inst. Zashch. Rast. 39: 43-46.
Uscekova, A.T. & G.A. Beglarov, 1963. Vlijanie temperatury i otnositelnoj vlaznosti vozducha na razvitie chiscnogo klesca Phytoseiulus persimilis A. (Parasitiformes, Phytoseiidae). Proc. XII Int. Congr. Entom. Moskva 1968: 198-199.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

DYNAMIQUE DES POPULATIONS D'APHIDES SUR AUBERGINE EN SERRE
1. CONSIDERATIONS GENERALES SUR LA COLONISATION ET LE DEVELOPPEMENT DES POPULATIONS DE QUATRE ESPECES DANS LE SUD DE LA FRANCE

J.M. Rabasse

Station de Zoologie et de Lutte Biologique
37, Boulevard du Cap
06602 Antibes
France

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 187-198

.5915

DYNAMIQUE DES POPULATIONS D'APHIDES SUR AUBERGINE EN SERRE

1. CONSIDERATIONS GENERALES SUR LA COLONISATION ET LE DEVELOPPEMEN DES POPULATIONS DE QUATRE ESPECES DANS LE SUD DE LA FRANCE

J.M. Rabasse
(avec la collaboration technique de J.P. Lafont et J. Molinari)

Summary

Population dynamics of aphids on egg-plant in glasshouses. 1. General statement about colonization and population growth of 4 species in the South of France.

During two years, a detailed study of the changes in space and time of the populations of aphids and of the host plant was carried out. The aphids were counted on the plant itself during five weeks, then for four weeks they were removed from a regular sample of half the leaves on one plant out of each four (1/8 of the total leaf surface). Myzus persicae and Macrosiphum euphorbiae were more numerous, but Aulacorthum solani and Aphis gossypii were also studied.

The spatial pattern of aphid distribution and its evolution in time is presented in Figs. 1 and 2. The first focus of M. euphorbiae, A. solani or A. gossypii was established by alate aphids coming from outside. For each species, there was only one focus, that developed steadily, leading to a clustered distribution. It is assumed that the way the crop is colonized is not basically different in the glasshouse and in the open fields.

Figs. 3 and 4 show (in log.) the evolution with time of: 1. the mean population of each aphid per plant; 2. min., max. and mean air temperatures; 3. phenology (leaf surface and reference of the extreme leaves). During a long period, the aphid populations had more or less an exponential growth and the doubling-time calculated for each species is given in the text. In 1977, M. euphorbiae was by far the most numerous; in 1978 it was M. persicae. In our conditions, M. euphorbiae (the biggest aphid) had the fastest population growth. An egg-plant with a leaf surface of 1 sq.m. was not saturated by 10.000 aphids. At that level, the dominant aphid only reduced its rate of increase.

In the glasshouse the heterogeneity of aphid infestation seems to be an essential feature of its dynamics. A regular sampling has to be preferred to a random sampling in this respect. A very low number of

aphids entering the glasshouse build a population up to a very high level. The growth of these populations is regular and could be forecasted. The four species seem to be able to reach high levels, so all four are considered as first-rank potential enemies of egg-plant.

Introduction

Pendant deux années, nous avons étudié la dynamique des populations de pucerons sur aubergine en serre dans le Midi de la France. C'est surtout *Myzus persicae* Sulz. et *Macrosiphum euphorbiae* Thom., qui ont été pris en considération dans nos essais, les deux autres espèces, *Aulacorthum solani* Kalt. et *Aphis gossypii* Kalt. étant moins abondantes. L'objectif de ce travail est l'étude détaillée de l'evolution spatiale et temporelle des aphides et de leur plante-hôte. Nous présentons ici deux éléments de cette dynamique, qui ont une incidente directe sur la conception de la lutte contre ces déprédateurs: le processus de colonisation et la vitesse d'évolution globale des populations.

Conduite de la culture

Nos essais sont conduits dans un ensemble de six serres expérimentales de 100 m^2 environ chacune. Elles sont situées à Valbonne (06) dans une zone non agricole appartenant à l'étage de végétation méditerranéen supérieur et couverte de garrigue à chêne pubescent. La serre mesure environ 5 m sur 20; elle contient 200 plants, soit la densité habituelle de 2 plants/m^2. Les aubergines sont plantées à 50 cm, l'une de l'autre sur des rangs transversaux espacés de 80 cm.

Les aubergines cv. Bonica sont greffées sur tomate K.N.V.F.; les plantes n'ont donc à supporter aucune intervention phytosanitaire. Elles sont palissées sur ficelle et conduites à un bras. Seul un rameau principal est conservé et étêté à 1,8 m; les rameaux secondaires sont pincés au-dessus de la 5ème feuille. Le repérage phénologique se fait de la façon suivante: sur la tige, les feuilles sont numérotées à partir de la première fleur de -1 à -n vers le bas et de +1 à +m vers le haut; les feuilles des rameaux sont numérotées de p1 à p5, p étant le numéro d'ordre du

rameau concerné. Une fleur ou un bouquet floral se forme toutes les deux feuilles aussi bien sur la tige que sur les rameaux; ceux-ci apparaissent au niveau de chaque fleur. La surface moyenne des plantes est calculée sur un échantillon d'une douzaine de plantes, d'après la formule de calcul de la surface d'une feuille établie par Onillon et al. (1976).
Sur les figures 3 et 4, le repérage phénologique indique les feuilles extrêmes. La plantation a eu lieu le 16 Mars 1977 et le 7 Mars 1978.

La température est mesurée à l'aide d'un capteur ventilé situé à 1,30 m du sol au centre de la serre. Nous avons indiqué sur les figures 3 et 4 d'une part la température moyenne, d'autre part les températures minimale et maximale absolues des périodes entre deux observations.

Methodes d'observation

Les caractéristiques démographiques des aphides et l'heterogénéité de leur répartition spatiale imposent des contraintes assez grandes pour l'établissement d'un protocole. Les observations sont hebdomaires. Les premières consistent en des dénombrements en place sur l'intégralité du végétal. Dans un deuxième temps, on observe 1/8 de la végétation: une feuille sur deux sur une plante sur quatre. Les plantes observées sont disposées régulièrement et changent à chaque observation: il s'agit d'un échantillonnage systématique. Enfin, dans une troisième phase, les pucerons de différentes espèces peuvent être en mélange sur les mêmes feuilles et les populations sont trop importantes pour être dénombrées en place. 1/8 des feuilles sont alors prélevées et traitées par lavage sans sous-échantillonnage (Rabasse & Bouchery, 1977). Seulement quatre prélèvements de ce type peuvent être effectués, car il n'est pas possible de prélever sur une plante préalablement mutilée.

Colonisation de la culture

Les figures 1 et 2 présentent respectivement pour les deux années 1977 et 1978 l'évolution de la répartition spatiale des différentes espèces de pucerons. Lors des premières observations, la présence ou l'absence d'une

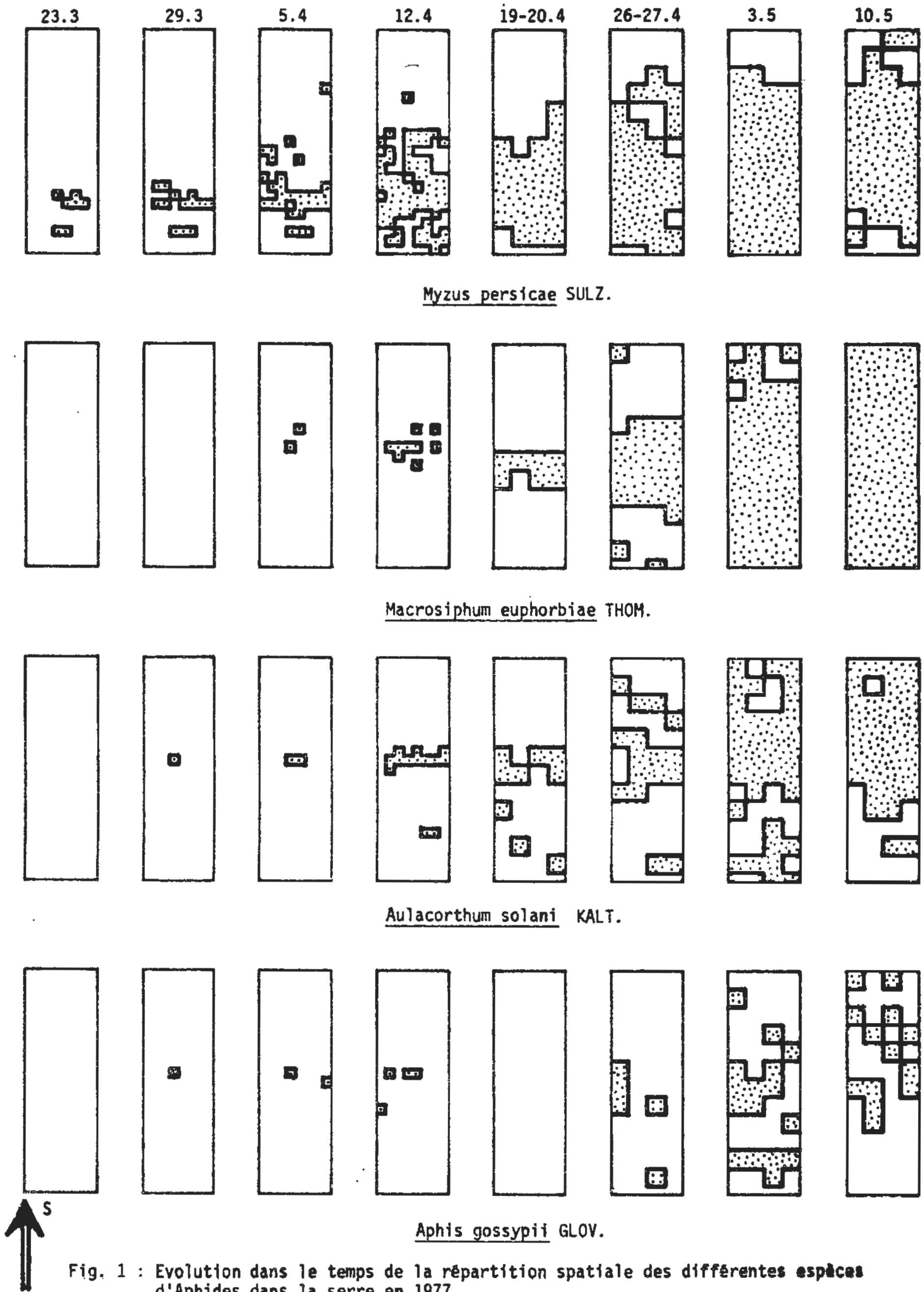


Fig. 1 : Evolution dans le temps de la répartition spatiale des différentes espèces d'Aphides dans la serre en 1977.

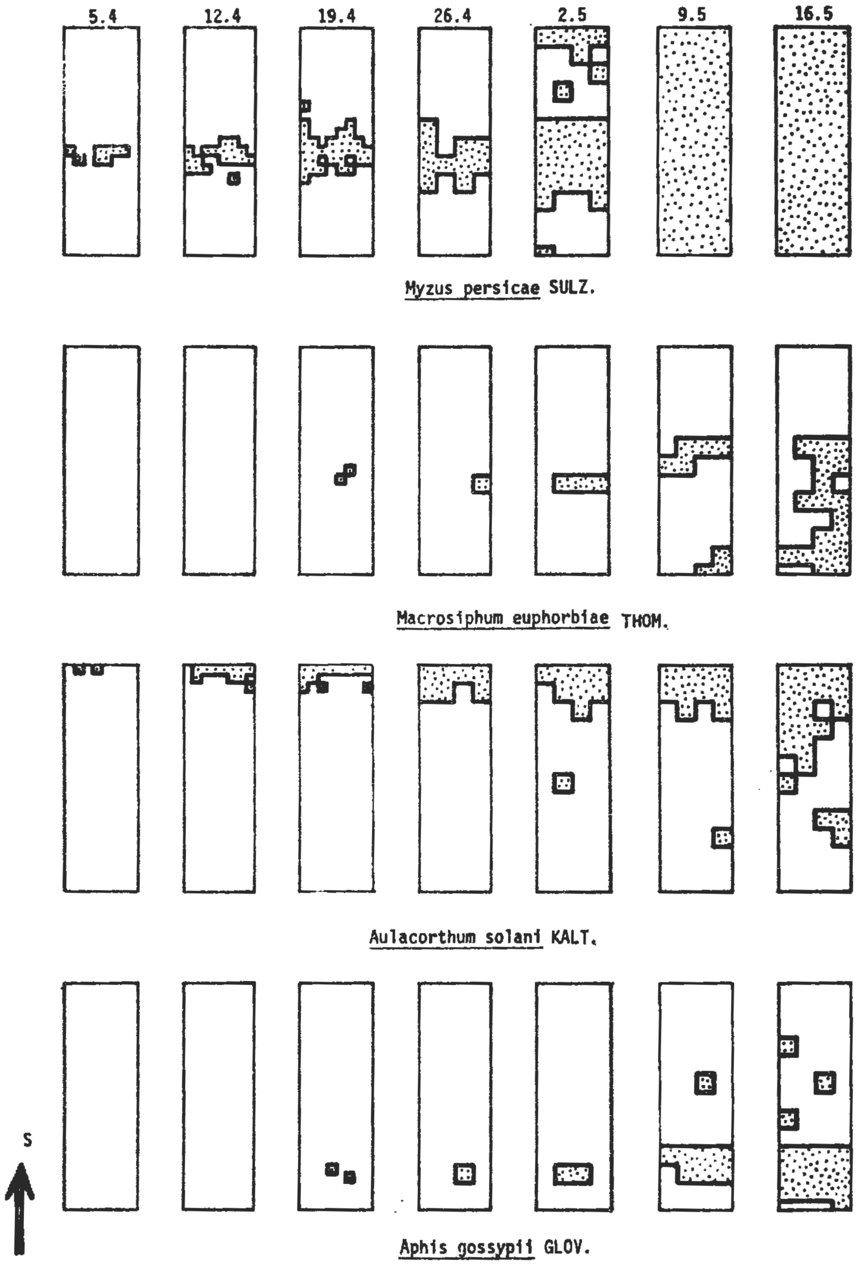


Fig. 2 : Evolution dans le temps de la répartition spatiale des différentes espèces d'Aphides dans la serre en 1978.

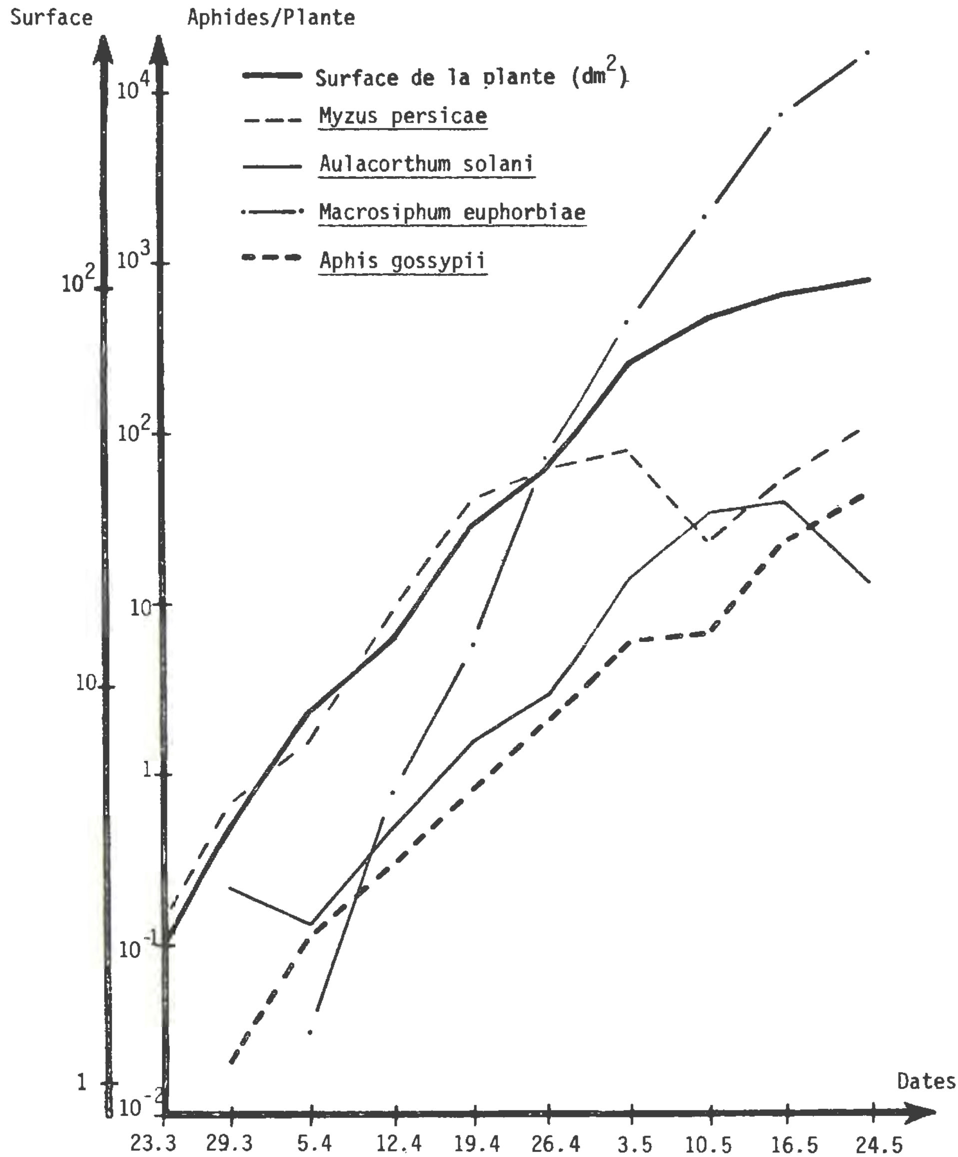
espèce est notée sur l'ensemble de chaque plante; ultérieurement, chaque bloc de 4 plantes est consideré comme infesté si l'échantillon (1/8) contient le puceron: la notion d'absence d'un bloc prend alors une valeur relative.

Toutes les situations se présentent quant à la localisation du premier foyer. Il ne semble pas qu'il faille rechercher une explication valable dans tous les cas - microclimatique ou topographique par exemple - à cette localisation.

Les infestations décrites sont le fait de virginipares ailés provenant de l'extérieur pour *M. euphorbiae*, *A. solani* et *A. gossypii* . Pour ces trois espèces, elles ont lieu les deux années entre le 29 Mars et le 19 Avril. En 1977, l'infestation de *M. persicae* provient de pépinière, quelques individus étant demeurés sur les plants; en 1978 par contre, les plants ayant été traités à l'expédition, nous avons lâché une centaine d'ailés au centre de la serre, dans les derniers jours de Mars. A l'échelle de nos observations, le foyer d'origine est toujours unique et s'étend de proche en proche avec une progressivité frappante. Malgré nos passages répétés, il semble que tant que les colonies no produisent pas d'ailés, les pucerons ont peu tendance à former des foyers secondaires.

Nous devons donc considérer que dans les conditions de Valbonne (bloc de 6 serres de 100 m^2 chacune, équipées d'une porte et de 4 ouvrants sur toute la longueur et situées dans une zone non agricole), il y a une seule colonisation initiale efficace pour chaque espèce. Le mode de contamination que nous observons correspond à une infestation très ponctuelle dans le temps et dans l'espace, qui peut correspondre au plus à un très petit nombre d'ailés volant ensemble. Les aptères qui se disséminent de proche en proche et les ailés qui sont formés sur la culture elle-même plus d'un mois après l'installation de l'espèce, généralisent ensuite l'infestation. L'aire de dissémination d'*A. gossypii* est vraisemblablement moins grande que celle des autres espèces; on observe souvent plusieurs colonies très agrégées sur une même plante. La contamination de l'ensemble des aubergines par ce puceron est donc obtenue plus tard.

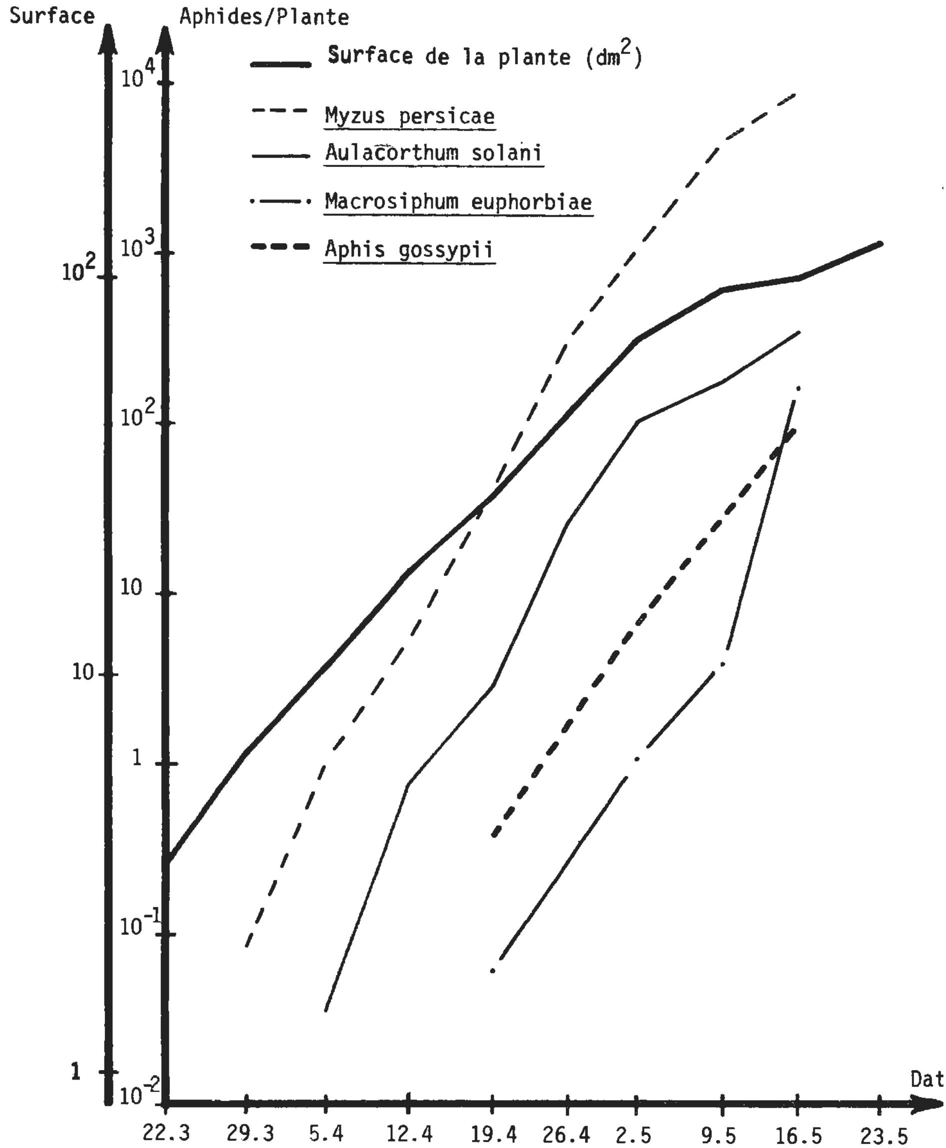
Le processus d'implantation des pucerons en serre n'est pas fondamentalement différent de celui que l'on observe au champ: fondation de colonies par les ailés/extension des foyers/généralisation par les ailés formés sur la culture.



Températures									
	Max.	26	29	24	23	26	26	24	24
	Moy.	18	19	19	20	21	20	21	21
	Min.	14	13	15	12	16	8	17	18

Phénologie	23.3	29.3	5.4	12.4	19.4	26.4	3.5	10.5	16.5	24.5
	-4	-3	-1	+1	+3	+4	+6	+7	+8	+10
						21	31	32	41	43
					12	13	23	24	34	35
	-6	-6	-6	-6	-6	-5	-4	-4	-4	-3
								1°récolte		

Fig. 3 : Evolution des populations d'Aphides dans une serre d'aubergines de 100 m2
- 1977 -



		22.3	29.3	5.4	12.4	19.4	26.4	2.5	9.5	16.5	23.5
	Max.	26	26	27	26	31	24	24	23	23	26
Températures	Moy.	20	20	20	20	20	20	20	20	20	20
	Min.	14	13	16	15	16	15	17	12	17	17
		-4	-2	-1	+2	+3	+5	+7	+9	+10	+12
Phénologie						21	22	31	41	42	52
					11	13	14	24	33	34	44
		-8	-8	-7	-7	-6	-6	-6	-6	-5	-4
									1°récolte		

Fig. 4 : Evolution des populations d'Aphides dans une serre d'aubergines de 100m2
- 1978 -

Cependant, le nombre de foyers primaires est grand dans un champ et l'infestation de celui-ci sera considerée comme homogène; par contre, le nombre de foyers primaires est très petit en serre et l'héterogénéité de la colonisation devient un élément essentiel de la dynamique de la population.

Croissance des populations des différents aphides

Pendant une longue période l'evolution des populations des différents espèces peut être considerée comme exponentielle. Les figures 3 et 4 les représentent pendant les neuf semaines d'observation.

Les deux années sont très differentes. 1977 est une 'année à *M. euphorbiae*', puisqu'à la dernière observation, le 24 mai, alors que les populations sont les plus fortes, plus de 99% des aphides appartiennent à cette espèce. 1978 est une 'année à *M. persicae*': de même, le 16 mai, ce puceron représente 94% des individus. Or, la représentation graphique logarithmique nous montre, au contraire, de grandes analogies entre l'évolution des populations des différentes espèces. Considérons les périodes pendant lesquelles les graphiques sont assez droits, c'est-à-dire pendant lesquelles on peut dire que l'évolution de la population est exponentielle et exprimons la vitesse d'évolution par le temps de doublement. Nous obtenons les valeurs suivantes:

M. euphorbiae

2,7 jours (12.4 au 25.5.77) et 2.4 jours (19.4 au 16.5.78)

M. persicae

3,3 jours (23.3 au 20.4.77) et 3.2 jours (22.3 au 16.5.78)

A. solani

4.3 jours (5.4 au 10.5.77) et 3.1 jours (5.4 au 16.5.78)

A. gossypii

5.1 jours (29.3 au 25.5.77) et 3.4 jours (19.4 au 16.5.78)

En 1977, l'évolution des populations est systématiquement plus lente qu'en 1978 à cause des températures de début de saison, qui sont légèrement plus basses. On peut rapprocher les valeurs obtenues pour *M. persicae*, des 2,60 jours obtenus en laboratoire à une température constante de 20°C sur des disques de feuilles d'aubergine du même cultivar (Rabasse & Shalaby, 1979). On peut aussi les comparer à des temps de doublement que nous avons calculés d'après les données de Della Giustina (1972), obtenues en serre dans la région parisienne pendant la phase exponentielle des populations de *M. persicae* sur tomate au printemps: 5.2 jours et d'*A. gossypii* sur concombre en été: 3.9 jours. D'après les temps de doublement observés, dans les conditions considérées, *M. euphorbiae* est le puceron qui se multiplie le plus vite (c'est aussi le plus gros!), suivi de *M. persicae*, d'*A. solani* et d'*A. gossypii*. *A. solani*, puceron longtemps négligé à tort (Robert & Rabasse, 1977; Robert, 1979) se trouve très près de *M. persicae*. *A. gossypii* enfin aurait certainement un autre classement à une température un peu supérieure, plus tard en saison. Il ne faut cependant pas oublier que pour un aphide ayant les plus médiocres performances observées, c'est-à-dire un temps de doublement de 5 jours, pour passer de 10 pucerons dans la serre à 100 pucerons par plante, il faut moins de deux mois (56,3 jours).

10.000 pucerons en moyenne ne saturent pas une aubergine dont la surface foliaire est de l'ordre de 1 m^2; à ce niveau, la population du puceron dominant ralentit simplement sa croissance. La vitesse d'évolution de la surface foliaire de la plante est beaucoup plus lente que celle des populations d'aphides et il est évident qu'à terme, la plante est condamnée.

Discussion

Les données recueillies permettent d'ores et déjà certaines réflexions sur la conceptions de la lutte contre les aphides sur aubergine en culture protégée.

Dans une serre contaminée à partir d'un faible inoculum, l'infestation des aphides observés se développe sous forme de foyers. Cette répartition spatiale en foyers est sans doute le fait d'autres phytophages en serre; van Lenteren et al. (1976) l'ont écrite pour *Trialeurodes vaporariorum*. Dans ces conditions, un échantillonnage systématique est préférable à un échantillonnage au hasard pour estimer les populations aphidiennes existant dans la serre. La connaissance du processus de colonisation et de la vitesse d'extension des foyers nous semble particulièrement importante, tant pour comprendre la dynamique de la population, que pour apprécier le danger couru par la culture. Des populations déjà faciles à déceler sont portées par un petit nombre de plantes en début de saison et il semble réaliste d'envisager des traitements chimiques ou biologiques localisées.

Un inoculum de départ certainement très faible conduit aux populations observées, qui dépassent de loin la tolérance de la plante. On assiste à une course de vitesse entre les espèces, chacune ayant ses caractéristiques propres: date d'arrivée, vitesse de multiplication à la température donnée, sensibilité à la concurrence..Il semble que les quatre aphides observés soient capable de développer des populations très fortes. Il s'agit donc de déprédateurs potentiels de premier plan et une méthode de lutte ne doit négliger aucun d'entre eux, sous peine de le voir occuper la niche écologique laissée vacante. Ces populations aphidiennes évoluent de façon régulière jusqu'à un niveau très élevé de surpopulation; elles se prêtent donc bien à des prévisions de pullulation à partir du piégeage des ailés à l'extérieur, ou à partir du repérage des premiers foyers.

Bibliographie

Giustina, W. della, 1972. Etude sur les fluctuations des populations d'insectes vivant dans les serres légumières de la région parisienne. Ann. Zool. Ecol. anim. 4: 5-33.

Lenteren, J.C. van, M.H. Eggenkamp-Rotteveel Mansveld & F.J.M. Ellenbroek, 1976. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). V. Population dynamics of Trialeurodes vaporariorum and Encarsia formosa in a glasshouse. Bull. O.I.L.B./S.R.O.P. 1976/4: 125-137.

Onillon, J.C., J. Onillon & J.P. di Pietro, 1976. Résultats préliminaires du contrôle biologique de l'Aleurode des serres, T. vaporariorum West. (Homopt., Aleurodidae) par E. formosa G. (Hymenopt., Aphelinidae) en serres

d'aubergines. Bull. O.I.L.B./S.R.O.P. 1976/4: 138-150.
Rabasse, J.M. & Y. Bouchery, 1977. Nouvelles données sur les méthodes d'évaluation des populations de pucerons (Homoptères, Aphididae); séparation des insects de leur plante-hôte et dénombrement. Ann. Zool. Ecol. anim. 9: 407-423.
Rabasse, J.M. & F.F. Shalaby, 1979. Incidence du parasite Aphidius matricariae Hal. (Hym., Aphidiidae) sur la fécondité de son hôte Myzus persicae Sulz. (Hom., Aphididae) à différentes températures. Ann. Zool. Ecol. anim. (sous presse).
Robert, Y., 1979. Recherches écologiques sur les pucerons Aulacorthum solani Kltb, Macrosiphum euphorbiae Thomas et Myzus persicae Sulz. dans l'Ouest de la France. II. Evolution spatio temporelle de leurs populations sur la pomme-de-terre. Ann. Zool. Ecol. anim. (sous presse).
Robert, Y. & J.M. Rabasse, 1977. Rôle écologique de Digitalis purpurea dans la limitation naturelle des populations du puceron strié de la pomme de terre Aulacorthum solani par Aphidius urticae dans l'Ouest de la France. Entomophaga 22: 373-382.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

PRACTICAL EXPERIENCES OF BIOLOGICAL CONTROL IN COMMERCIAL GLASSHOUSE CULTURES

Pauli Raiskinmäki

SF-64200 Närpiö
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 199-202

PRACTICAL EXPERIENCES OF BIOLOGICAL CONTROL IN COMMERCIAL GLASSHOUSE CULTURES

Pauli Raiskinmäki

Närpiö, a town of 11.000 people, is located in Southern Ostrobothnia. There are many commerical glasshouse cultures concentrated in Närpiö and its surroundings, a characteristic that is unique in the Nordic countries. Growing vegetables under glass started in Närpiö as early as the 1930's, but only after the Second World War did it gain more importance. In 1978 there were 609 commercial glasshouses in Närpiö. Their total area was 680.000 m^2. The size of the glasshouses varies from 250 to 8600 m^2, the average being 1120 m^2. Most of the glasshouses are family holdings, the glasshouses being taken care of by the family without outside labor. The industry is a very important employer in the town. Partly because of this, the unemployment rate has remained relatively low in the Närpiö area. Today about 1200 people in Närpiö work in glasshouses. In addition to this there are people working with handling, transportation and marketing of both supplies and products. The town of Närpiö receives 25% of all its tax income from glasshouse cultures. In addition to this comes taxation of other industries connected with it, i.e. transportation, packing, marketing and business that has developed with it, plus building operations.

In Southern Ostrobothnia, the glasshouse cultures amount a little over 100 ha and 68 ha of this area is located in Närpiö, which is almost a quarter of the area under glass in the entire country. Fifty-eight % of the tomato production and 42% of the cucumber production in the country comes from Southern Ostrobothnia. In Närpiö we have also small scale experimental activities concerning glasshouse cultures on the holdings of the Martens Garden Foundation. These activities have given results that are important to the whole of Southern Ostrobothnia and to other areas, too.

Tomatoes are grown on about 75% of the area under glass and cucumbers on 22%. This is reflected in the pest problems, too. The production of tomato and cucumber seedlings in the area has been concentrated to only a few growers who also grow poinsettias. With the poinsettia cuttings that mainly come from abroad, we get every summer a new whitefly (*Trialeurodes vaporariorum*) population that is difficult to control. So the whiteflies move over from poinsettias to tomato and cucumber seedlings when their growing starts and the growers who buy these seedlings also get whiteflies.

Another difficult pest is the two-spotted spider mite (*Tetranychus urticae*). In the Närpiö area a strong organophosphorous-resistant strain developed, so the best method of controlling the mite is biological control by the predatory mite *Phytoseiulus persimilis* . Without the organophosphorous-resistant strains of the spider mite the use of the predatory mite would not have become as common as it is now.

After having started with biological control of the two most harmful pests in glasshouses, thrips, noctuids and woodlice, which earlier used to be quite rare, have become more abundant. This depends on the tendency today to avoid the use of chemicals. Another change in the culture methods is that growers do not desinfect the glasshouse soil, but change it yearly.

Nowadays thrips has to be controlled in cucumber cultures, but the work is started only when there really is a need for it. At least one chemical treatment is required every spring on many tomato cultures to control noctuids. This is difficult to do when the grower has already started with biological methods against other pests. Woodlice are usually controlled after the growing season when the glasshouses are empty. These pests cause harm mainly in old glasshouses. Today chemical control of pests on vegetable cultures is more or less occasional and it is done whenever it is possible after the growing season.

The growers in Närpiö started with biological control mainly because they did not receive a satisfactory result with chemical control of the two-spotted spider mite and the whitefly. In the beginning this raised several problems: because of poor light conditions at the beginning of the growing season, viz. at the end of January and in February, the temperature has to be kept low in the glasshouses. Under such conditions biological control does not work. On the other hand control is not needed so badly during that period, because of the slow development of the pests. The most serious problem is the whitefly as it develops relatively fast even at low temperatures, while *Encarsia formosa* does not. In practice we have noticed that in our light conditions the use of *Encarsia formosa* is not worthwhile before the end of February and the beginning of March. The predatory mite *Phytoseiulus persimilis* can be used as early as February.

When controlling pests biologically, one has to take into consideration the fact that results are not obtained immediately but after a longer period of time. But when one has succeeded in reducing the pest population by biological methods, the plants are still clean, which is not the situation after chemical control. If biological control is started too late, heavy infestations will develop in the glasshouse. These infestations can be cleared by chemical means and a balance between the pest and the biological control agent is reached sooner.

The most important factor contributing to successful biological control is a suitable temperature. For the predatory mite the average daily temperature should be 20^{o}C or higher and for *Encarsia formosa* at least 18^{o}C. If these temperature factors are not taken into consideration biological control is likely to fail.

In practice, biological pest control is a normal procedure for the growers. Advisers, though, are worried about the population growth of woodlice, thrips, slugs, snails, noctuid-larvae, etc. which usually are not considered pests but which, because of their large numbers, cause much trouble. It is difficult to control these chemically if biological control is being used against whiteflies and spider mites. This problem should be solved as soon as possible. Hopefully biological control methods will be developed for these pests, too. Another possibility would be to develop such chemicals that do not harm the biological control agents that are already used.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

BIOLOGICAL CONTROL OF *THRIPS TABACI* (THYSANOPTERA: THRIPIDAE) WITH AMBLYSEIUS SPP. (ACARI: PHYTOSEIIDAE)

P.M.J. Ramakers

Research Institute for Plant Protection
Wageningen
the Netherlands

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 203-208

BIOLOGICAL CONTROL OF THRIPS TABACI (THYSANOPTERA: THRIPIDAE) WITH AMBLYSEIUS SPP. (ACARI: PHYTOSEIIDAE)

P.M.J. Ramakers

Introduction

More than 50% of the cucumber growers and about 20% of the sweet pepper growers in the Netherlands use *Phytoseiulus persimilis* A.-H. for the control of *Tetranychus urticae* Koch. Chemical control of *Thrips tabaci* often disturbs the balance between phytophagous and predatory mites.

A study of the natural enemies of *Thrips tabaci* was started in 1975 (Ramakers, 1978). This paper deals with the first trial to use native Phytoseiids (*Amblyseius* spp.) for the control of this pest.

Integrated control

For chemical control of thrips within the integrated programme growers use mainly diazinon and dichlorvos. Both compounds involve frequent application, thus reducing one of the main advantages of integrated control in greenhouses: labour saving. Dichlorvos can be applied as an aerosol and is therefore preferred by many growers to diazinon sprays for thrips control on sweet pepper; this chemical, however, may exterminate *P. persimilis* if it is used at short intervals.

In chemical programmes permethrin is available for thrips control (see Table 1). It presents an easier way of control than diazinon does, because of its residual effect, but it is completely incompatible with predatory mites.

Excellent thrips control without disturbing the biocontrol of spider mites was obtained by low doses of tetrachlorvinphos (75% wettable powder; 0,35 g per liter). Like permethrin this compound gives sufficient residual effect to kill the hatching young larvae and the adults emerging from the soil. On sweet pepper crops, where only low numbers of thrips are tolerated, a frequency of one application in two months gave sufficient control in winter and spring. In summer the

olonization of cucumber plants by *Amblyseius mackenziei* after artificial
ntroduction

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	2[illegible]
	X																	X			
0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	[illegible]
+	+	+	0	0	+	0	0	+	+	0	0	+	+	+	+	+	+	0	+	+	[illegible]
+	+	0	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	[illegible]

uction
or(s) observed
dators observed

Table 1 Simultaneous control of *Tetranychus urticae* and *Thrips tabaci* on glasshouse vegetables

	Tetranychus urticae		*Thrips tabaci*	
programme	control agent	frequency	control agent	frequency
chemical	fenbutatinoxid	high	permethrin	low
integrated	*Phytoseiulus persimilis*	1-4	diazinon, dichlorvos	high
improved integrated (exp.)	*Phytoseiulus persimilis*	1-2	tetrachlor-vinphos	low
biological (exp.)	*Phytoseiulus persimilis*	1-2	*Amblyseius* spp.	1

high: once in ± 2 weeks
low : once in ± 6 weeks

frequency should be increased proportional to the amount of immigrating adults and the temperature (see Table 1).

In laboratory tests, LD_{50} of tetrachlorvinphos and permethrin for *P. persimilis* is 2700 and ≪30 mg a.i. per liter respectively (Theune & Van der Staay, 1978). At present tetrachlorvinphos is not authorized for glasshouse vegetables.

Biological control

In autumn crops, native Phytoseiid mites are sometimes found preying on *Thrips tabaci* (Woets, 1973). Several species may occur, but mainly *Amblyseius mackenziei* Sch. & Pr. is seen on cucumber and *A. cucumeris* (Oud.) is found on sweet pepper. Although these mites prey on various insects and mites (e.g. *Tetranychus urticae*), they show a pronounced association with thrips (see MacGill, 1939; *Typhlodromus thripsi* is probably synonymous with *A. cucumeris*), either because they prefer thrips as a prey or because they have a similar habitat preference as *T. tabaci*.

In the winter of 1977/78 a small laboratory stock of *A. mackenziei* was maintained, using *Parthenothrips dracaenae* as prey species. From this stock predators were introduced in a small experimental glasshouse containing 107 cucumber plants. The crop was planted in February after steam des-infection of the soil. The minimum air temperature was 20°C, and an additional soil heating system was present. No chemical control was performed. The plants were resistent against powdery mildew, *Sphaerotheca fuliginea*. *Phytoseiulus persimilis* was introduced on May 3 to control *T. urticae*. *Trialeurodes vaporariorum* was controlled (with only partial success) by introducing *Encarsia formosa*.

Between May 25 and May 31 eighty-two individuals of *A. mackenziei* were released on three single leaves. During the following weeks migration of the predators from these foci was observed by inspecting part of the plants with a hand-lens; three leaves per plant were searched. After colonization of the majority of the plants (see Fig. 1), countings were started. For this purpose samples of leaves were cut in strips of about 2 cm. The underside of the strips was examined under a stereo-microscope; thrips larvae and all instars of the predatory mites were counted. Thrips adults were not counted, because they often jump from the leaves; they constitute only a minority of the population. *Amblyseius* eggs can be discri-minated from *Phytoseiulus* eggs, because the former are smaller, white and often attached to plant hairs.

The results of the countings are shown in Figure 2. The level of control that was realized (less than 2 thrips larvae

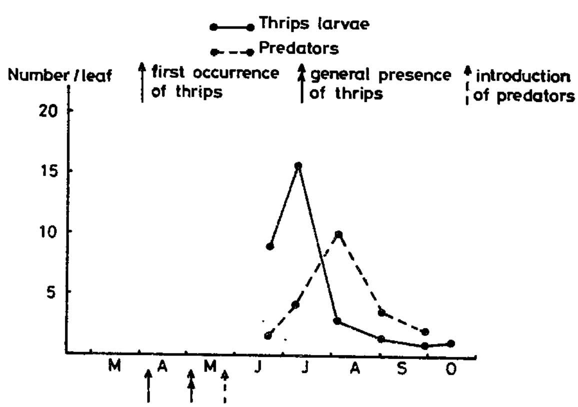


Fig. 2 Control of *Thrips tabaci* by *Amblyseius mackenziei*

per cucumber leaf) guarantees that leave damage is practically invisible. Although the economic threshold of thrips damage is not known precisely, it was evident that this threshold was not reached in this experiment, even at the peak density of about 16 larvae per leaf.

Entomophthora thripidum, sometimes an important mortality factor in glasshouse populations of *T. tabaci* (Samson et al., 1979) was not observed during this experiment. The fungus was found in other glasshouses, but not earlier than October 19.

References

MacGill, E.I., 1939. A Gamasid mite (Typhlodromus thripsi N.Sp.), a predator of Thrips tabaci Lind. Ann. appl. Biol. 26: 309-317.

Ramakers, P.M.J., 1978. Possibilities for biological control of Thrips tabaci Lind. (Thysanoptera: Thripidae) in glasshouses. Med. Fac. Landbouww. Rijksuniv. Gent 43: 463-469.

Samson, R.A., P.M.J. Ramakers & T. Oswald, 1979. Entomophthora thripidum, a new fungal pathogen of Thrips tabaci. Can. J. Bot. 57: 1317-1323.

Theune, D. & M. van der Staay, 1978. Internal reports of Proefstation voor Tuinbouw onder Glas, Naaldwijk, the Netherlands.

Woets, J., 1973. Integrated control in vegetables under glass in the Netherlands. Bull. O.I.L.B./S.R.O.P. 1973/4: 26-31.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

DEVELOPING A MASS-PRODUCTION METHOD OF *APHIDOLETES APHIDIMYZA* (ROND.) SUITABLE FOR COMMERCIAL PRODUCTION

Maija Rimpiläinen

Agricultural Research Centre
Department of Pest Investigation
SF-01301 Vantaa 30
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 209-212

DEVELOPING A MASS-PRODUCTION METHOD OF APHIDOLETES APHIDIMYZA (ROND.) SUITABLE FOR COMMERCIAL PRODUCTION

Maija Rimpiläinen

In order to develop further the mass-production method which has been used in Finland since 1976 (Markkula & Tiittanen, 1976) some trials were made during the summers of 1977 and 1978. The method used was already good, but it was desirable to develop it to a commercial production on a larger scale than possible in the laboratory. The aim of mass-production is to produce as many pupae (cocoons) of about the same age as possible in the shortest possible time and in the smallest possible space

First, to clarify what it is in the mass production that requires most time, time studies were made of the different stages in the mass production. The results showed that production in greenhouses is much more economical in that it requires less work and time than in the laboratory and that production of 1000 pupae requires an area of 1 m^2. The mass production of larvae/pupae depends on the egg-laying capacity of *A. aphidimyza* . When the factors affecting egg laying are known, they can be optimized for a successful mass production. Among these factors are: (a) the host plant, (b) the aphid population, and (c) climatical conditions.

Different plant species have different anatomical and physiological structures which may influence the egg-laying adult. The plant density, height of plants, and the age of plants are also of importance. *A. aphidimyza*'s egg laying is proportional to the size of the aphid population and the midge prefers aggregated aphid populations. Climatical conditions play an important role: *A. aphidimyza* prefers relatively high humidities, shade, and temperatures of about 20°C. To maximize the production of pupae, trials were made with different plants, different plant densities and with different ages of plants. *Capsicum* peppers planted 50% closer than normal, that is 6 plants/m^2 and renewed after about 3 weeks gave the best production. As a result of this knowledge and trials a plan can be made for a rational mass production in glasshouses.

Plan for a rational mass production in glasshouses

1. In one glasshouse with optimal conditions for growing *Capsicum* peppers the plants are grown to a height of about 30 cm.
2. In the next house peach aphids (*Myzus persicae*) are fed on these plants.
3. In the third glasshouse the aphid midges are reared. Aphid infested plants are planted 6 per m^2 and pupae of *A. Aphidimyza*, a suitable amount, are spread out. Maximal larvae production occurs then each three weeks (Generation time of the midge is about 3 weeks at 20°C).
4. These plants are changed after 3-4 weeks at a time when most of the midges are in the soil as pupae. The aim is that there are always fresh, new plants for egg laying.
5. Other natural enemies of aphids and possible hyperparasites of the aphid midge are kept in control.
6. The glasshouse for mass rearing of the midge should be shaded and the relative humidity held high through watering/dust. The temperature of the air should be about 20°C and that of the soil never under 10°C. The soil must also be kept moist enough.

In this way an area of 5-10 m^2 gives thousands of pupae per day.

To ensure the best handling of pupae during storage and transport, the substrate for pupating must have optimal conditions for the pupae. Therefore different substrates were tested: sand (control), perlite, vermiculite, and fine peat (Markkula et al., 1979). Fine peat showed to have the best properties of the substrates tested. It is light, keeps moisture, and gives a high hatchability. This method to ship the pupae within a substrate ensures that they will stay alive and will not enter diapause during transportation. *Aphidoletes aphidimyza* has been in use during two growing seasons and this method of mass production has proved to be very useful and economical.

References

Markkula, M. & K. Tiittanen, 1976. A method for mass-rearing of Aphidoletes aphidimyza (Rond.). S.R.O.P./W.P.R.S. Bull. 1976/4: 183-184.

Markkula, M., M. Rimpiläinen & K. Tiittanen, 1979. Effect of pupation substrate on the emergence of Aphidoletes aphidimyza (Rond.) (Dipt., Cecidomyiidae) adults. Ann. Agr. Fenn. 18 (in press).

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

LA STRATEGIE D'INTERVENTION EN LUTTE INTEGREE CONTRE L'ALEURODE DES SERRES, ELABORATION D'UN MODELE DE DECISION

F. Rodolphe[1], J.C. Onillon[2], El Shishiny[3], C. Millier[3] & Hennequin[4]

[1]Laboratoire de Biométrie, 78250 Jouy-en-Josas, France
[2]Station de Lutte Biologique, 06602 Antibes, France
[3]Laboratoire de Biométrie, 54280 Champenoux, France
[4]Laboratoire de Phytopharmacie, 78000 Versailles, France

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDING OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.R.P.S. 1980 III / 3, 213-214

LA STRATEGIE D'INTERVENTION EN LUTTE INTEGREE CONTRE L'ALEUREDE DES SERRES, ELABORATION D'UN MODELE DE DECISION

F. Rodolphe, J.C. Onillon, El Shishiny, C. Milier & Hennequin

Résumé

La lutte biologique contre l'Aleurode des serres au moyen d'Encarsia formosa ne peut se concevoir que lorsque les contaminations initiales du ravageur sont faibles. Dans le cas contraire, une intervention chimique est nécessaire pour réduire le niveau des populations du ravageur.

Les données biologiques sur la durée de développement et la mortalité des stades embryonnaires et larvaires et sur le potentiel biotique des femelles de Trialeurodes vaporariorum sur aubergine sont données. Parallèlement a été testée l'action d'un insecticide, le pirimiphos-methyl sur les larves de l'aleurode.

Un modèle de simulation des populations de l'aleurode, élaboré précédemment, permet à partir de données de terrain sur l'évolution des adultes de Trialeurodes vaporariorum de reconstituer l'évolution des stades larvaires du ravageur.

L'insertion des données portant sur l'emploi de l'insecticide (dose utilisée, coût d'application, appréciation des dégâts) permet d'optimiser après traitement sur ordinateur, la dose et la date du traitement pour minimiser l'apparition des larves du dernier stade autorisant ultérieurement l'emploi d'Encarsia formosa face à une population connue de larves du ravageur.

Un schéma de décision de lutte integrée contre l'Aleurode des serres est donné.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

REGULATION OF THE REPRODUCTIVE ACTIVITY AFTER HIBERNATION IN *COCCINELLA SEPTEMPUNCTATA* L. BY PHOTOPERIOD

Z. Růžička

Czechoslovak Academy of Sciences
Institute of Entomology
Vinicna 7
128 00 Praha 2
Czechoslovakia

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 215-220

REGULATION OF THE REPRODUCTIVE ACTIVITY AFTER HIBERNATION IN COCCINELLA SEPTEMPUNCTATA L. BY PHOTOPERIOD

Z. Růžička

The palearctic coccinellid, *Coccinella septempunctata* L., has been used in Finland to control *Myzus persicae* on chrysanthemums in greenhouses (Markkula et al., 1972; Hämäläinen, 1977) and as an introduced species to control the potato aphids in the field in the United States (Shands et al., 1972). Eggs in a water solution of agar or laboratory-bred larvae have been released. The species seems to be most effective to suppress high aphid infestations. The possibility of permanent mass production of this species is unfortunately hampered by gradual decrease in vigour (Hämäläinen & Markkula, 1972). The culture must therefore be renewed with coccinellids collected in nature. A large number of adults can be collected in the hibernation quarters over a period of nine months.

We have recently studied the influence of the light regime on reproduction of beetles collected in mid-May, shortly before their dispersal from dormancy sites occurs. The adults were reared on *Acyrthosiphon pisum* at a temperature regularly alternating from 20 to 25 $^{\circ}C$ and under normal 24 hrs photoperiodic cycle with 12 hrs light or 18 hrs light.

Individual females revealed considerable polymorphism in the oviposition pattern under both regimens. We divided the females arbitrarily into two groups according to their continuity of oviposition. As females with continuous oviposition we denoted those which did not stop egg laying for more than three days. We declared females with a longer period of oviposition inactivity as females with inter-ovipositional arrest.

Under short day conditions about 66% of the females displayed such an arrest of oviposition and under long day conditions this proportion was about 33% of the population. The markedly higher longevity of females displaying such an arrest, particularly under short day conditions, indicates that a second diapause was entered by these females.

The continuously ovipositing females started to lay eggs after 6 days, the females with interoviposition arrest after 16 days under short day regime and after 3 to 15 days under a long day regime. A similar difference also occurred in the length of the postoviposition period. Under short day conditions the continuously ovipositing females survived 5 days after the last egg was laid, the females with interoviposition arrest survived 10 days. Under a long day regime the females died almost immediately after they stopped egg laying. The mean duration of interoviposition arrest differed a little between females reared under short and long day regimes. The arrest amounted to 50 and 42 days, respectively.

The average oviposition of 1780 eggs per female was suppressed to 72% under short day conditions. The highest fecundity of a female, 4920 eggs, was also recorded under a long day regime. Females with interovipositional arrest laid less eggs at both regimes. The difference, however, was clearly pronounced only under long day conditions, where oviposition of these females decreased to 74.8% of that recorded for the continuously ovipositing group.

Females with interoviposition arrest under short day conditions laid only 18% of all eggs during the first oviposition period. This figure was 30% for females reared at a long day regime. When we compared the daily oviposition in continuously ovipositing females and females with interoviposition arrest over the period during which the eggs were actually laid, we could see a higher oviposition rate under both regimes in continuously ovipositing females. Under short day conditions the continuously laying females laid 46 eggs per day, whereas females with interoviposition arrest laid 38 eggs per day. Under long day conditions these figures are 51 and 46 eggs per day respectively.

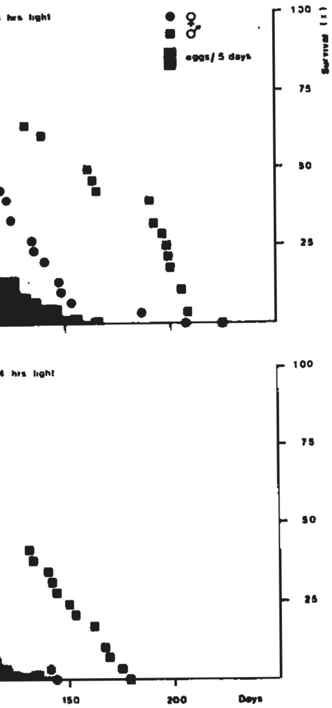
A great difference has been found between longevity of females with continuous oviposition and those with oviposition arrest at a short day regime. Mean longevity of continuously ovipositing females was 51 days while females with interoviposition arrest lived on average 131 days. This difference was less pronounced in females cultured at a long day regime. We recorded 58 and 96 days, respectively. The males survived under both conditions considerably (1.5 times) longer than the females. Longevity of both sexes was distinctly higher (1.5 times) under short day conditions.

The possibility to induce a recurrent photoperiodic response in a part of the very heterogenous and plastic population of *C. septempunctata* enables us to modify easily the course of oviposition in overwintered females by the photoperiod (Fig. 1).

The relation between longevity and fecundity shows that under both conditions the population splits into two considerably different groups (Fig. 2). A test of the difference between the regressions of the first and the second group under short day conditions is significant at $p<0.05$, under long day conditions at $p<0.01$. At the same time there is neither a significant difference in regressions of continuously ovipositing females under short and long day, nor in regressions of females with interoviposition arrest under these two light regimes.

Changes in hatchability of eggs during the egg-laying period are given in Fig. 3. (We did not follow whether the hatchability depended on females or males). The approximate total mortality, calculated in such a way that the mortality recorded in 15-day intervals was related to the total number of eggs laid in corresponding periods, was very similar under both regimes. It was 15% at short day and 17% at long day conditions.

The second hibernation might have been developed as a security behaviour of the species which preserves a part of the population for the next year and at the same time makes use of periods favourable for its development. Occurrence of second diapause was perhaps originally formed in colder climatic conditions. This species occurs far to the North. There is no doubt that the knowledge of the life-cycle has a great importance when overwintered beetles are used in biological control. It enables to modify the



oviposition and longevity
la septempunctata

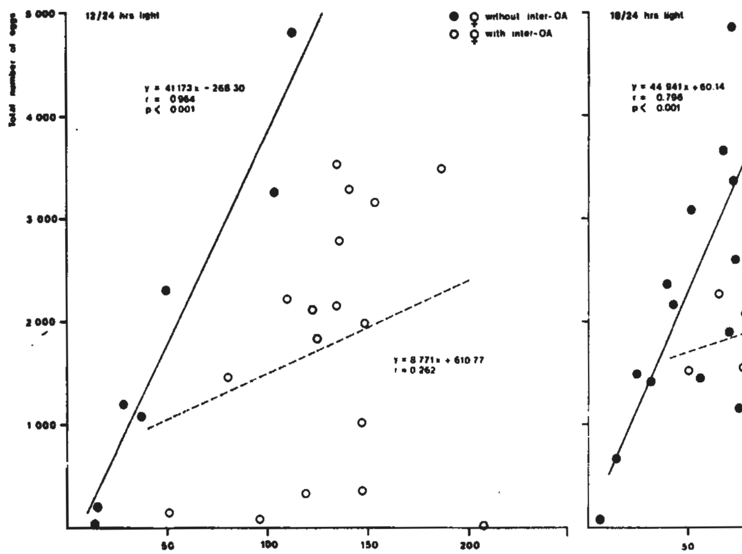


Fig. 2 Relation between longev
oviposition in *Coccinella*
punctata

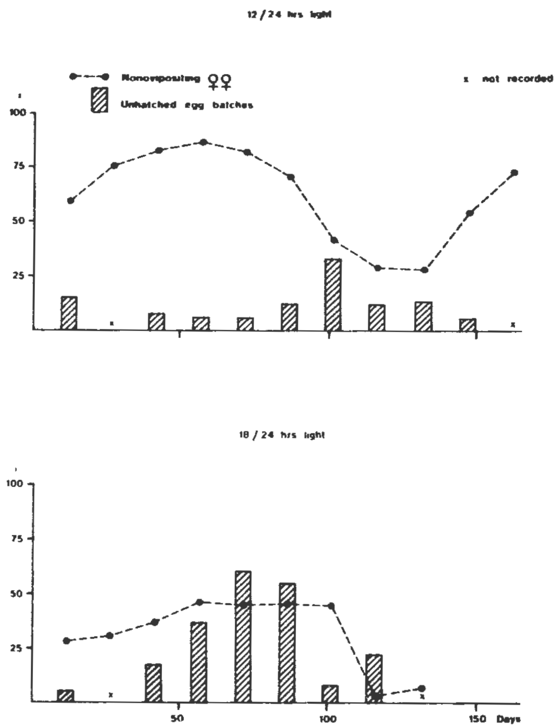


Fig. 3 Hatchability of eggs and degree of nonovipositing females in 15-day intervals in *Coccinella septempunctata*

production of eggs in a culture by a simple change of photoperiod while other conditions remain unchanged.

References

Hämäläinen, M., 1977. Control of aphids on sweet peppers, chrysanthemums and roses in small greenhouses using the ladybeetles Coccinella septempunctata and Adalia bipunctata (Col. Coccinellidae). Ann. Agric. Fenn. 16: 117-131.

Hämäläinen, M.& M. Markkula, 1972: Possibility of producing Coccinella septempunctata L. (Col., Coccinellidae) without a diapause. Ann. Ent. Fenn. 38: 193-194.

Markkula, M., K. Tiittanen & M. Hämäläinen, 1972. Preliminary experiments on control of Myzus persicae (Sulz.) and Macrosiphum rosae (L.) with Coccinella septempunctata L. on greenhouse chrysanthemums and roses. Ann. Ent. Fenn. 38: 200-202.

Shands, W.A., G.W. Simpson & G.C. Gordon, 1972. Insect predators for controlling aphids on potatoes. 5. Number of eggs and schedules for introducing them in large field cages. J. Econ. Entom. 65: 810-817.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

METHODS FOR USING *PHYTOSEIULUS PERSIMILIS* FOR CONTROL OF *TETRANYCHUS URTICAE* ON CUCUMBER

Christian Stenseth

Norwegian Plant Protection Institute
Division of Entomology
1432 Ås-NLH
Norway

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 221-224

METHODS FOR USING PHYTOSEIULUS PERSIMILIS FOR CONTROL OF TETRANYCHUS URTICAE ON CUCUMBER

Christian Stenseth

Introduction

The practical use of *Phytoseiulus persimilis* for control of the two-spotted spider mite (*Tetranychus urticae*) in Norway started in 1971. A common method for introduction of the predator has been to introduce the predator onto attacked plants at the first sign of natural infestation by the spider mite with subsequent removal of the predator to new infestations of the spider mite. Large scale experiments have been conducted in glasshouses on cucumber in order to investigaste the effect of different methods for introduction of *P. persimilis*.

Introduction methods employed

1. Patch introduction.

At the first sign of natural infestation by two-spotted spider mite in the glasshouse, 2-4 predators were introduced onto attacked plants. The plants were inspected every week or fortnight and the predator removed to a new infestation if necessary.

2. 'Pest in first'

Twenty spider mites were placed on every fourth plant. Nine days later 2-4 predators were introduced on the same spots.

3. Prey/predator introduction

In this case the spider mite and the predator were introduced at the same time on pieces of bean leaves in a ratio of about 20:1. The pieces of leaves contained all stages of the mites, however the ratio mentioned refers to the mobile stages.
The prey/predator introductions were made in two different ways:

A. The introductions were made at the first sign of natural infestation by spider mites. All attacked plants were

infestation of *Tetranychus urticae* and the results of different introduction met
oseiulus persimilis on cucumber

	initial infestation		results		
	% plants	L.D.I. plants	max. L.D.I.	max. % plants	int
ent	attacked	attacked 1)	per 100 leaves	L.D.I.> 1.9	per
	4,6	-	21,6	0	
	25,0	0,12	76,0	2,5	
	4,5	-	11,0	0	
	0,1	0,1	31,0	1,0	
	4,6	0,13	23,0	0,9	
	0,2	0,2	18,9	0	
	0	0	28,0	1,8	
	0	0	12,5	0	
	0	0	3,4	0	

f damage index (Hussey & Parr, 1963)
me re-introduction of *P. persimilis* necessary
topped for practical reasons

treated and every third individual of non-attacked plants.

B. Introductions of prey/predator were made on every third plant before leaf damage symptoms indicated spider-mite infestation.

Results

The results from the different introduction methods are shown in Table 1. All the methods used gave a long-lasting interaction of spider mite and predator, and no method seemed consistently better than the others. Method 3 was started both during winter and summer. Experiments which started in July had shorter interaction periods than experiments which started in February and May. When the latter experiments were stopped after 13 to 23 weeks, the predator was still present in the glasshouses. When the predator was introduced in July re-introduction of the predator was necessary after 12 weeks. These differences may be a result of more efficient predation at higher temperatures during the summer. Long interaction periods (17 to 19 weeks) for method 3A may however also be a result of long emerging period of reactivated diapause females.

The conclusion is that the safest practical way of using *Phytoseiulus persimilis* is a uniform introduction, as has also been suggested by Hussey et al. (1965), but a successful interaction of prey and predator can be obtained with 'Pest in first' introduction or with a simultaneous introduction of prey and predator.

References

Hussey, N.W. & W.G. Parr, 1963. The effect of glasshouse red spider mite (Tetranychus urticae Koch) on the yield of cucumbers. J. hort. Sci. 38: 255-263.

Hussey, N.W., W.G. Parr & H.G. Gould, 1965. Observations on the control of Tetranychus urticae Koch on cucumber by the predatory mite Phytoseiulus riegeli Dosse. Ent. exp. & appl. 8: 271-281.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

SOME ASPECTS OF THE USE OF *PHYTOSEIULUS PERSIMILIS*

Christian Stenseth

Norwegian Plant Protection Institute
Division of Entomology
1432 Ås-NLH
Norway

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 225-226

SOME ASPECTS OF THE USE OF PHYTOSEIULUS PERSIMILIS

Christian Stenseth

In 1976 a survey was carried out on the practical results of the use of *Phytoseiulus persimilis* for control of the two-spotted spider mite (*Tetranychus urticae*) in Norway. The control results, which are shown in Table 1, were classified into three groups:

1. Good control: the spider mite was controlled without economic damage on the plants.
2. Satisfactory control: ultimately good control of the spider mite but with incidental economic damage.
3. Failure in control: biological control was replaced by chemical control.

In most cases the predator had been introduced on attacked plants when the grower detected the first sign of natural infestation by spider mite; the predator was later removed to new infestations. Of forty cucumber-growers and twenty-one tomato-growers, fifteen and ten respectively obtained good control of spider mite. The main reasons for satisfactory control or failure in control of spider mite seemed to be connected with late detection of their natural infestation. Watch over and removal of the predator had often not been carried out in cases with satisfactory control or failure in control.

In glasshouses where chemical control of spider mite had been used the autumn before, there had undoubtedly been a high number of diapausing females. In these cases large numbers of spider mites emerging from diapause had caused an initial economic damage before the predator managed to regulate the spider-mite population.

Another factor to be considered is the climate, as experiments (Stenseth, 1979) have shown that *Phytoseiulus persimilis* is a more efficient predator at high (24-27°C) than at low (15-18°C) temperatures (70-90% R.H.). These experiments also show that low relative humidity (40% R.H.) combined with a high temperature (27°C) cause high mortality in eggs of

P. persimilis , and consequently poor control of spider mite under these conditions.

When the biological control of spider mite is unsatisfactory, there are probably several factors involved, but the key factor for good biocontrol is an early introduction of *P. persimilis* .

References

Stenseth, C., 1979. Effect of temperature and humidity on the development of Phytoseiulus persimilis Athias-Henriot and its ability to regulate populations of Tetranychus urticae (Koch) (Acarina: Phytoseiidae, Tetranychidae). Entomophaga 24 (in press).

Table 1 Practical results with *Phytoseiulus persimilis* for control of *Tetranychus urticae* in 1976

	numbers of cucumber	
control results	growers	glasshouses
good control	15	33
satisfactory control	20	35
failure in control	5	7

	numbers of tomato	
control results	growers	glasshouses
good control	10	13
satisfactory control	6	7
failure in control	5	5

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

REARING CHRYSOPA CARNEA IN MIXED POPULATION WITH SITOTROGA CEREALELLA

Unto Tulisalo

Agricultural Research Centre
Department of Pest Investigation
SF-01301 Vantaa 30
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 227-230

REARING CHRYSOPA CARNEA IN MIXED POPULATION WITH SITOTROGA CEREALELLA

Unto Tulisalo

Following Finney's early innovation (1948) the mass rearing of the green lacewing has been modified a number of times.

Nowadays, rearing is generally accomplished by using the Morrison and Ridgway method, whereby adults are fed an artificial diet and the larvae are reared on the eggs of *Sitotroga cerealella* . Many attempts have been made to devise an artificial diet for the larvae, but so far they have not led to practical application. This rearing method was developed over a number of years on the basis of experience gained in rearing green lacewings for various pest-control experiments. From the earliest attempts, the adults in the rearing cage have been fed on yeast hydrolysate, mixed with sugar and water, and this method is still in practice. The rearing of the larvae has undergone great changes over the years.

At first the green lacewing larvae were fed on aphids. This proved to be extremely laborious and so the change was made to *Sitotroga cerealella* eggs for the feeding of larvae. This required the rearing of the *Chrysopa* larvae in separate cells which, for its part, was also time-consuming from the point of view of large-scale production. When it was discovered that *Chrysopa* larvae could also feed on the *Sitotroga cerealella* adults and larvae, the rearing of the larvae of *Chrysopa* was commenced in rearing jars, in which they were given a *Sitotroga* adult 'mass' (Tulisalo & Kurppa, 1977).

But, even when using this method, *Sitotroga* food had to be fed to the lacewings several times during their larval stage. Thus, the described mixed-population rearing was arrived at, whereby the larvae of *Chrysopa* require no special tending. The larvae, depending on their stage of development, now feed on the *Sitotroga* eggs, larvae and adults and also on each other. The loss in eggs resulting from this cannibalism is economically small compared with the savings in labour in the rearing of the larvae.

In this method the adults of the following generation are produced in rearing cabinets as a mixed population, together with *Sitotroga cerealella* . Each 'comb' in the cabinet is filled with 10 kgs of barley which has been treated with dikophole to ward off mites. At this stage *Sitotroga* adults are introduced into the cabinet. As soon as the *Sitotroga* population has increased sufficiently, *Chrysopa* eggs are placed in the cabinet. About 25.000 eggs are strewn over the floor of the cabinet at a time. After an average of 16 days the first *Chrysopa* adults hatch and are collected from the walls and the roof of the cabinet with the help of a sucking device.

In the rearing cabinet, about 3700 *Chrysopa* adults were produced in one rearing cycle. The percentage of hatched adults from those eggs placed in the cabinet varies from 10 to 20%. Thus about 10% of the adults' total egg production had to be used to reproduce the new generation. It was possible to use the remaining 90% for pest control experiments. In the event of establishing a large mass rearing, a larger percentage of the eggs must be used to yield this increased population.

Most of the lacewings hatch within a period of 3 to 6 days, after which the next batch of *Chrysopa* eggs may be placed in the cabinet. About twice a week the cabinet is vacuum cleaned through a gauze filter to remove wingscales. One breeding period is from 6 to 12 months. Green lacewings have now been produced by this method for a couple of years, in other words, for several generations. The old laboratory strain from the year 1972 and the new strain gathered from nature did not differ from each other in this cabinet rearing.

Because the amounts of *Chrysopa* for experiments have not been very large, it has not been possible to discover how many thousand eggs one laboratory assistant would be able to produce in a day. On the basis of calculation at least as good a result as that of Morrison and Ridgway (1976) would be achieved. However, in spite of easier rearing and good pest control results it is still very difficult for the green lacewing to compete economically with pesticides.

References

Finney, G.L., 1948. Culturing Chrysopa californica and obtaining eggs for field distribution. J. econ. Ent. 41: 719-721.

Morrison, R.K., U.S. House & R.L. Ridgway, 1975. Improved rearing unit for larvae of a common green lacewing. J. econ. Ent. 68: 821-822.

Tulisalo, U. & S. Kurppa, 1977. Adult angounois grain moths Sitotroga cerealella Oliv. as a food source for the green lacewing Chrysopa carnea Steph. in mass rearing. Ann. Agric. Fenn. 16: 167-171.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

THE ROLE OF PESTICIDE PRODUCER IN BIOLOGICAL CONTROL

Juhani Uoti

Kemira Oy
Malminkatu 30
SF-00100 Helsinki 10
Finland

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 231-234

THE ROLE OF PESTICIDE PRODUCER IN BIOLOGICAL CONTROL

Juhani Uoti

Finland is a small country. Geographically and climatically it is situated at such a location, where no sensible human being would consider farming a profitable occupation. Since we have here in Finland, however, some 250.000 farms and the total cultivated area is more than 2.5 million hectares, there must be quite a few people out of their minds.

The situation is actually not quite so bad. Of course, it is clear that our soils have low pH, winter is long and hard and the summer season very short. But these three summer months are really something special. You may have noticed that there is no real night at this time of the year. Long days with intensive sunlight make the crops grow very vigorously. When the summer is favourable the farmer can even harvest quite satisfactory yields of wheat, barley, oats, sugar-beet or potato crops.

There are also some advantages owing to the rough climate. Normally the insect and fungus problems are not as severe as they regularly are in warmer countries. From the pesticide sales statistics one can see that herbicides account for 70% of the total monetary value of the sales. Also the total sales are rather low. In 1977 pesticides were sold for 63.8 million Finnish marks (16 million dollars) which represents some 1800 tons of active ingredients. When the cake to be shared is not so big, it is understandable that there are only few pesticide firms in Finland. One of them is Kemira.

Traditionally Kemira has been a fertilizer producer. Fertilizers are still the major products, but also various other basically chemical products are gaining more importance. Pesticides have been along with the fertilizers as supporting agricultural chemicals for growing better and higher yields. Originally the company was not very interested in pesticides. The policy changed in the 1960's when Kemira's activity quickly grew in this sector and the company became the biggest pesticide firm in this country. Even today Kemira is not really synthesizing many active ingredients, but is mainly formulating products. With the limited home market, the very basic chemical production is not profitable enough.

The position as a leading producer of agricultural chemicals is not always easy. Particularly in the early 1970's when people suddenly realized that their environment was in danger, also Kemira became the target of many accusations. Our factories were polluting their surroundings and even the end products were responsible for spoiling nature. At the same time Professor Markkula and his group had been able to 'tame' the predatory mite for the control of spider mites in cucumber greenhouses, and they were wondering how to put the method into practice. As our biologists had long been in close co-operation and had good personal contacts with the Agricultural Research Centre, it seemed a good idea to us to start selling biological agents as a counterbalance to the public concern about the synthetic plant protectants.

Since *Phytoseiulus persimilis*, we have been happy to receive also other methods from the Markkula's group. *Encarsia formosa* and *Aphidoletes aphidimyza* are now also in our sales catalogue. Apart from the insect agents Kemira also produces a polyhedral virus to control pine sawfly and has quite recently introduced *Phlebia gigantea* for the control of *Fomes annosus* in spruce forests.

Frankly speaking, none of these products really brings any money to the firm. We are barely able to cover the production costs. Still some of these biological control agents are obviously very important to their users.

And why then are we, as a chemical company, still in this business with biological control? Of course, public relations are not the only reason. As a pesticide producer we believe in the basic idea of integrated control. Biological control has its future and even at present it is in some cases complementary to chemical control. Still we do not believe that biological control ever would completely replace chemicals in crop protection.

The development of biological control or integrated control has not been very rapid. But the progress is steady and the direction is clear. The importance of all other protective methods than simple chemical control is increasing. More and more biological methods to control insects, fungi and weeds are discovered every year.

We here in Finland have been happy enough to maintain close and good contacts between the independent research workers and the industrial researchers. The roles of these two parties have been quite logically the following: the basic research and the development of new methods belongs to the university or state research organizations, whereas the practical production and marketing are carried out by the industry.

Another reason for our particular interest in biological control is the raising costs of developing new chemicals. The ever increasing toxicological requirements and resistance problems make biological control a more interesting alternative. In this kind of situation I believe it is clear that if the company wants to stay in business, it cannot afford to keep out of biological control.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE
INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

GREENHOUSE WHITEFLY CONTROL OF AN INTEGRATED REGIMEN BASED ON ADULT TRAPPING AND NYMPHAL PARASITISM

Ralph E. Webb & Floyd F. Smith

Science and Education Administration, USDA
Florist and Nursery Crops Laboratory
Beltsville, Md 20705
U.S.A.

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 235-246

GREENHOUSE WHITEFLY CONTROL OF AN INTEGRATED REGIMEN BASED ON ADULT TRAPPING AND NYMPHAL PARASITISM

Ralph E. Webb & Floyd F. Smith

Summary

We used sticky yellow boards in trapping tests against greenhouse whitefly adults. In one test, it took only 10 days to trap out newly established infestation of whitefly adults although continual reinfestation from outside prevented complete elimination. Meanwhile, naturally introduced populations of the parasite Encarsia formosa effectively built up on the progeny of the trapped-out whitefly adults despite the presence of the yellow board traps. Yellow sticky board trapping is therefore compatible with the use of this parasite in an integrated control regimen.

We obtained similar results when we placed the yellow board traps among tomato plants bearing established whitefly populations. Whitefly adults that emerged from nymphs present at the beginning of the test left the plants on which they had developed soon after emergence and were quickly caught on the yellow boards. Again the Encarsia population rapidly built up to overwhelming numbers, despite the presence of the traps.

In a third test, we established that narrow yellow sticky boards running the length of the bench effectively trapped out populations of whitefly adults. Moreover, most released whitefly adults were captured close to the point of release rather than dispersing over the greenhouse.

Finally, a practical test in a small commercial greenhouse demonstrated that sticky yellow panels can effectively protect uninfested plants, in this case geranium cuttings, from greenhouse whitefly infestation by intercepting adults migrating from nearby infested plants.

Introduction

The strong preference of greenhouse whiteflies, *Trialeurodes vaporariorum* (Westwood), for yellow and yellow-green was first noted almost 60 years ago by Lloyd (1921) who reported that different numbers of the adults became stuck to adhesives on containers holding solutions of various colors. More recently, laboratory investigations with an apparatus that produces light of various wave-lengths showed that more of these adults responded to light in the yellow-green region of 520-610 nm (Vaishampayan, 1973; Vaishampayan et al., 1975a, 1975b) and that host-plant selection was largely, if not exclusively, a response to color. Also MacDowall (1972) used monochromatic light and found the highest attractancy to whiteflies at 540-550 nm. In addition, Kring reported (1969, unpublished) that both the greenhouse whitefly and its common parasite *Encarsia formosa* (Gahan) were attracted to yellow and that whiteflies could be trapped on sticky colored stakes.

As a result of Kring's report, we painted cardboard squares (25 cm on a side) with Rustoleum Yellow no. 659 [1)] and coated them with Tack Trap [1)], a sticking agent; these we suspended on wires or attached to stakes among experimental plants to reduce or prevent unwanted whitefly infestations that would interfere with tests against other insects. Later, when these cardboard traps became distorted from use, we replaced them with painted fiberboard squares. This technique was used so successfully for several years that it recommended itself as a practical means of controlling existing whitefly infestations in older crops and preventing infestations in new plants. We also felt that such trapping might have an effect on the control provided by *Encarsia formosa*. An integrated regimen of this type might be useful in small greenhouses where other methods

[1)] Mention of a commercial product in this paper does not constitute endorsement by the authors or the United States Department of Agriculture. Rustoleum 659 Yellow is produced by the Rust-Oleum Corp., Evanston, Ill. 60204. Tack Trap is a trade name of Animal Repellents, Inc., Griffin,Ga 30223. Stickem Special is a trade name of Michel and Pelton Co., Emeryville, Cal. 94608. Tanglefoot is manufactured by the Tanglefoot Company, Grand Rapids, Mich.

of controlling whiteflies are ineffective or difficult to attain, where operators are averse to the use of chemicals for pest control, or where operators wish to assess levels of whitefly populations before release of parasites. Studies were therefore initiated in 1978.

Methods and results

Experiment 1. Trapping whiteflies from a 'newly established' infestation

Eight tomato plants were placed in a 3 x 4 m greenhouse, with a 1.2 m wide centre bench and 2 side benches 0.8 m wide. Then 2400 whitefly adults from a source colony were released in the house and allowed to settle for 2 days. On day 1 of the test, 8 additional (uninfested) tomato plants were arranged alternately with the infested plants to give a 4 x 4 arrangement, and 12 sticky yellow board traps were interspersed among the plants so the tops of the boards were level with the top of the plants. Counts made just before the boards were put in place revealed 2565 adults on the plants. The number of whiteflies caught on the traps were determined at intervals for 35 days, and the adults on the plants were counted daily for the same period.

The results are shown in Figure 1 as cumulative trap catches, but numbers on the plants represent daily counts. Thus, 643 adults were found on the plants on day 3 and 174 on day 6. For example, from day 10 to day 23, the number of adults on the 16 plants held steady at about 100; meanwhile the cumulative trap catches increased by approximately this same number each day, a result of an influx of about 100 whitefly adults each day through the greenhouse ventilators. (Although many of these immigrating whiteflies were quickly caught on the boards, all could not be trapped). On day 23, the second generation whiteflies began emerging from the progeny established before the parents were trapped out. A count on day 27 indicated that the adult population in the house had risen to 933. However, these adults were quickly trapped out. By day 35 about 10.000 whiteflies had

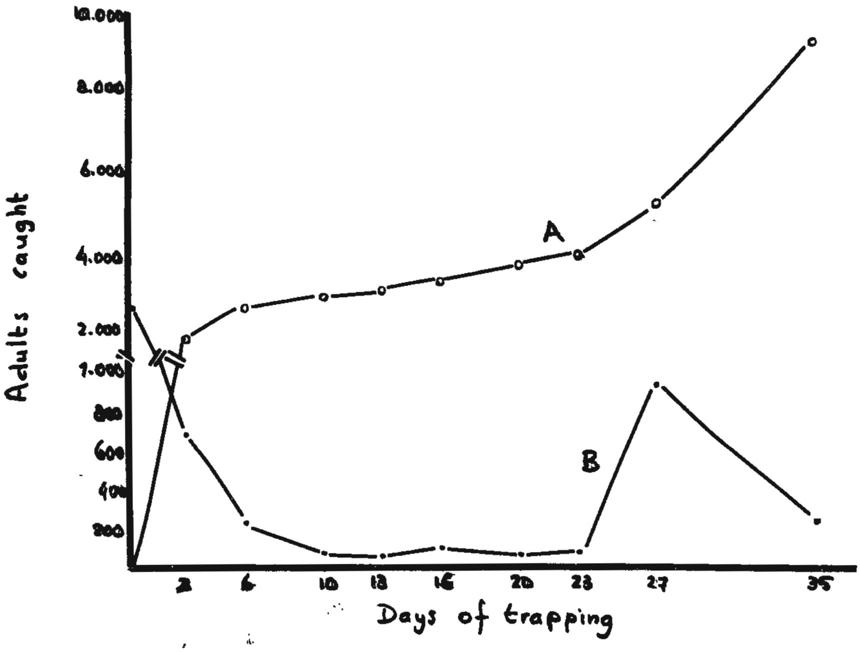


Figure 1. Test 1: yellow sticky board trapping in a newly established infestation. A) Cumulative numbers of adult whiteflies caught on yellow boards on indicated dates. B) Numbers of adult whiteflies found on tomato plants on indicated dates.

been trapped on the boards, but only 244 adults remained on the plants. Numbers of this second generation would have been far higher except that *Encarsia* parasites migrating in from neighbouring greenhouses had avoided the yellow traps and parasitized about 95% of the whitefly scales. Relatively few whitefly adults escaped the traps and reached the uninfested plants from the infested plants. This aspect of the test will be more fully discussed in a later paper.

Experiment 2. Whitefly trapping and Encarsia parasitism in an established infestation

Tomato plants already heavily infested with whiteflies in all stages were placed 4 each in 4 rows in the same greenhouse as used in experiment 1. In this case, a yellow board was placed between each 2 plants in a row, 3 boards per row. This procedure was otherwise as before, except that leaf samples were taken from one plant from each row and the percentage of whitefly immatures infested with *Encarsia* was determined.

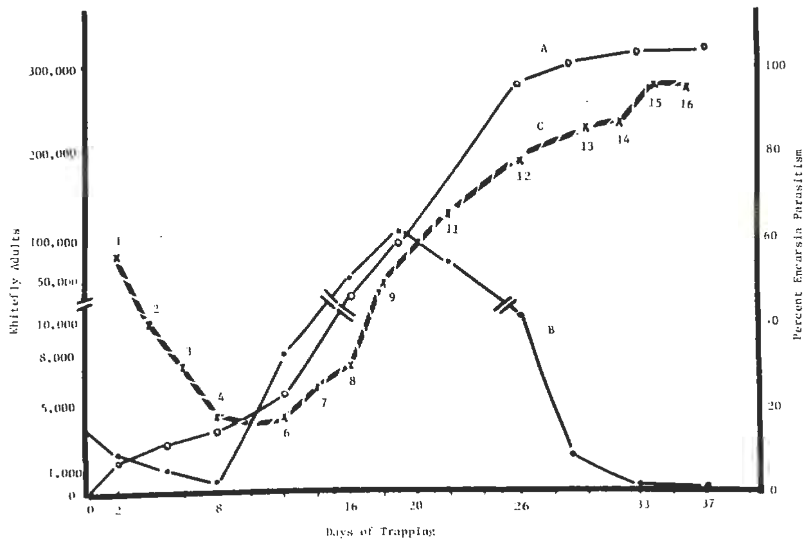


Figure 2. Test 2: yellow sticky board trapping in a well--established infestation. A) Cumulative numbers of adult whiteflies caught on yellow boards on indicated dates. B) Numbers of adult whiteflies found on tomato plants on indicated dates. C) Percent *Encarsia* parasitism on leaves 1 (bottom) - 16 (top) (see right margin for percentages).

Numbers of whiteflies captured on yellow boards recorded cumulatively during a 37-day test period are reported in Figure 2. Between 8 and 20 days after the test began, the numbers of young adults that emerged from nymphs (number counted on plants) nearly equaled the number captured on the traps. Then numbers of whiteflies on plants declined until only 140 were counted on day 37, though about 300.000 were trapped. The percentage of *Encarsia* -infested whitefly immatures was 58 at the beginning of the test, dropped to 18 on day 10, and increased to 97 on the last day. As numbers of available whitefly nymphs became lower, sizable numbers of adult parasites were captured on the boards. This was interpreted as searching for a suitable host rather than a strong response to yellow.

Experiment 3. Trapping whiteflies on narrow yellow sticky bars

In 1979 we conducted a two-month study in the same greenhouse to determine the dispersal of whiteflies from the point of release to other plants in the same row, the efficiency of trapping adults on narrow yellow sticky boards suspended between rows of tomatoes, the buildup of *Encarsia* on existing whitefly nymphs, and the increase and decline of an induced whitefly population. Over a 5-day period (February 6-11), 6.000 adult whiteflies aspirated from our source colony into 4 vials were released on the first tomato plant in each of 4 rows of 6 uninfested plants growing in 8-liter containers. A 3.2 m by 12.5 cm sticky yellow bar was then positioned horizontally between the two rows on the center bench and along the outside of the single rows on the side benches. Whiteflies trapped on the boards near the plants in the row could therefore be counted and establishment and subsequent movement from the point of release could be documented.

During the first 14 days, about 62% of the released adults were captured near the point of release (Figure 3), but later distribution was more uniform on all plants in the rows. The last count reflected numbers of progeny of the released adults.

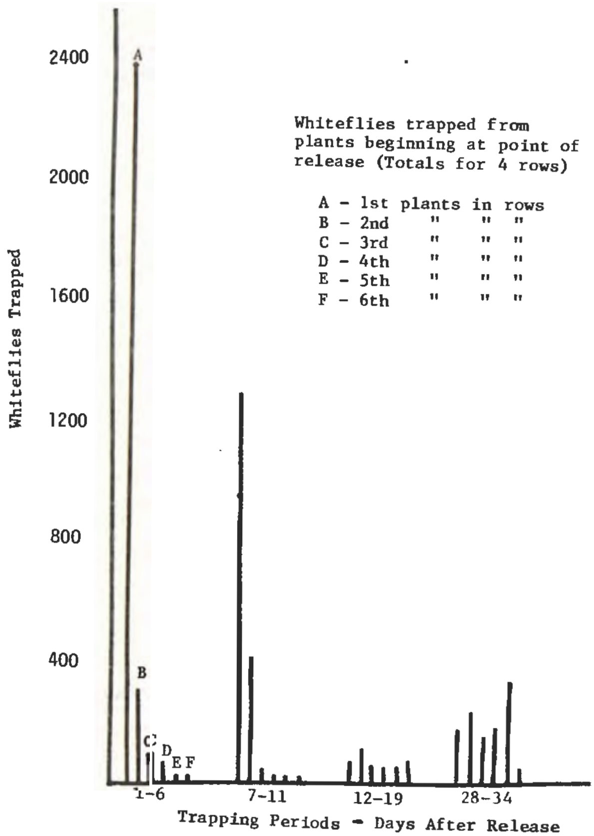


Figure 3. Test 3: numbers of whiteflies trapped on sections of sticky yellow bars placed in horizontal position between rows of tomato plants to show dispersal after release. A) Plants close to release point. F) Plants most far from release point.

Also, a sample of 40 middle leaves selected at random from all 24 plants and examined in the laboratory showed a total of 2142 whitefly immatures with 0 eggs, 6 live nymphs, 10 unemerged pupae, 145 emerged pupae, 342 dead nymphs, and 1538 (72%) nymphs parasitized by *Encarsia*.

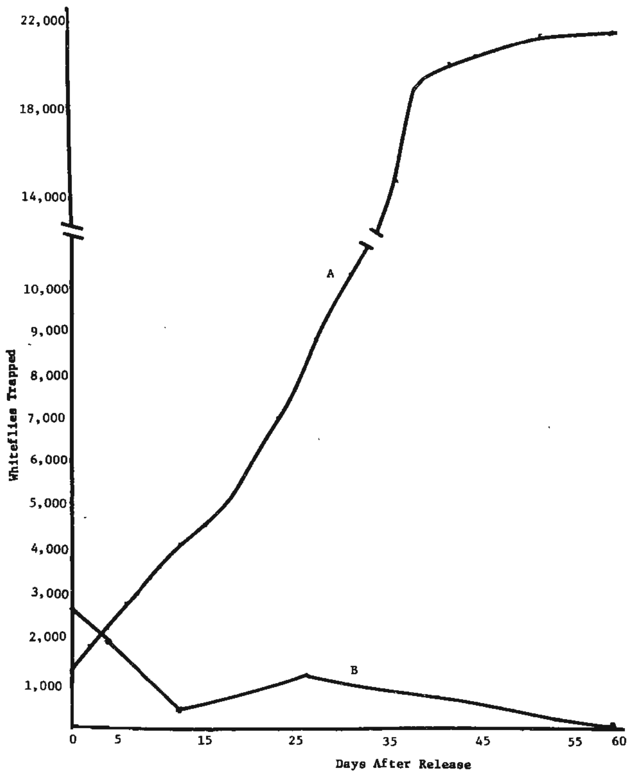


Figure 4. Test 3: yellow sticky bar trapping in a newly established infestation. A) Cumulative numbers of adult whiteflies caught on yellow bars on indicated dates. B) Numbers of adult whiteflies found on tomato plants on indicated dates.

The captures of whiteflies on the four boards over the 60-day period following release of adults February 6-11 are shown graphically in Figure 4. At the end of 4 days, 54.7% of the adults were found on traps and 45.2% on plants. Not all 6.000 introduced adults were recovered, since at least some adults were found in condensed moisture on the greenhouse glass. Then as progeny of the introduced adults reached maturity, the numbers of young adults trapped increased rapidly. These new adults apparently leave the plants in search of new hosts because virtually all of them were trapped as they emerged. At the end of the experiment 21.537 adults had been trapped and 40 living adults were found on the plants.

Experiment 4. Control in a commercial greenhouse

Through the cooperation of S.A. Gill, Maryland Extension Service, arrangements were made in March, 1979 to conduct a trapping experiment in a commercial plastic covered greenhouse (7 x 25 m). This greenhouse contained 2 center benches 1.3 m wide and 2 side benches 1 m wide and was used for growing a wide variety of foliage plants, house plants, and vegetable plants. Sticky yellow square board traps were suspended at about 3-m intervals above the plants on each of the two center beds which included fuchsias, geraniums, and impatiens, all with well established populations of whiteflies. The side benches held younger uninfested plants, and above the susceptible geranium plants a separate yellow sticky bar 12.5 cm x 3.2 m was suspended to trap whiteflies coming to them. For details, see Gill (1979). Over a 2-month period approximately 4800 whitefly adults were trapped from the center beds, and the infestations were reduced to the point that only 3 adults were trapped per week. No *Encarsia* was present during the course of the experiment. On the board above the young geraniums on the side bench, 384 adults were trapped, but no eggs, nymphs or adults were found on the plants beneath the board. Our effort to prevent whiteflies from becoming established on new uninfested plants was therefore successful. The strong attractancy of whiteflies to yellow led to their elimination before they became established on the new hosts.

Discussion

Kring (1969, unpublished) noted that *Encarsia formosa* was attracted to yellow in flight chamber tests. However, Vaishampayan (1973), in studies of spectral sensitivity of *E. formosa* , found that this wasp did not show any significant response to colours and seemed insensitive to light. Ledieu (1977) showed that *Encarsia formosa* adults located isolated colonies of whiteflies within a few minutes in an otherwise uninfested greenhouse crop. The parasites were similarly attracted to whitefly scales or to honeydew, probably because of some specific volatile substance that is produced by the whiteflies. In our greenhouse tests, *Encarsia* adults were rarely captured on the yellow sticky traps at the beginning of the trapping period when there was a balance between the number of parasites and host immatures. However, as the adult whiteflies were trapped out, and the number of nymphs and pupae that remained unparasitized declined, *Encarsia* adults actively searched for hosts, and large numbers were captured on the boards. We are uncertain whether this resulted from random searching and landing or from a change in their response to yellow when hosts were scarce.

As noted, MacDowall (1972) suggested the use of light traps. Likewise, Vaishampayan (1973) and Vaishampayan et al. (1975b) found that whiteflies were attracted to green or near ultraviolet light and suggested that phototaxis could be employed in integrated control programmes for the greenhouse whitefly. However, in these studies behaviours in natural versus artificial light were not compared. On the other hand, Lloyd's observations (1921) were based on colour response of whiteflies to yellow in natural daylight, as were Kring's (1969) trapping studies of whiteflies on yellow sticky stakes and Moericke's experiments (1969) though these latter observations were translated to wave lengths. In fact, the yellow pan traps Moericke used for capturing aphids led naturally to sticky yellow boards for capturing whiteflies.

Our studies of whitefly attractancy at Beltsville were conduced in glass- or polyethylene-covered greenhouses. We found that the adults were more active at higher temperatures (25°C or above) than at lower temperatures (20°C or below). They flew little in air currents resulting from ventilating fans; and they responded to the yellow colour in bright sunlight as well as on dull cloudy days, even during twilight periods and cloudy winter days. Light intensity was not measured during these tests. Also, we did not investigate nighttime response to light traps, but our observations indicate that whiteflies are essentially diurnal in their colour attractancy.

Tack Trap, the coating we used as sticking agent, is a synthetic resinous adhesive used for many insect traps. When we diluted Tack Trap with an equal volume of Varsol, a petroleum distillate, the result was a thinner varnish-like product that could be applied with a brush without heating. Some lots of Tack Trap are more fluid than others and require correspondingly less thinning agent for application. The sticking agent continued to efficiently trap whitefly adults for several weeks and could be easily removed with Varsol and rough toweling and then reapplied. Stickem Special approaches Tack Trap in efficiency but was more difficult to handle. We also conducted tests with white medicinal mineral oil and heavy motor gear oil. They were initially quite efficient as trapping agents, but lost their residual tackiness after a week. Ineffective materials tested included a petroleum jelly and Tanglefoot, a resinous product used to trap many insects.

<u>References</u>

Gill, A., 1979. Controlling whiteflies with trap boards. Insect and Disease Notes, Cooperative Extension Service, 600 S. Frederick Ave., Gaithersburg, Md. 20760.

Kring, K., 1969. Trapping whiteflies and aphid parasites in a greenhouse. 41st Ann. Meeting, Eastern branch, Ent. Soc. Am. (not published).

Ledieu, M.S., 1977. Ecological aspects of parasite use under glass. Pest management in protected culture crops, ARS-NE-85.

Lloyd, L. 1921. Notes on colour tropism of Asterochiton (aleurodes) vaporariorum westwood. Bull. Ent.Res. 12: 355-359.

MacDowall, F.D.H., 1972. Phototactic action spectrum for whitefly and the question of color vision. Can. Ent. 104: 299-307.

Moericke, V., 1969. Host plant specific behavior by Hyalopterus pruni (Aphididae). Entom. Exp. Appl. 12: 524-534.

Vaishampayan, S., 1973. The spectral sensitivity of the greenhouse whitefly Trialeurodes vaporariorum Westwood and its biological significance in host selection. Ph.D. dissertation Univ. of Ill. (unpublished), 179 p.

Vaishampayan, S.M., M. Krogan, G.P. Waldbauer & J.T. Woolley, 1975a. Spectral specific responses in the visual behavior of the greenhouse whitefly Trialeurodes vaporariorum (Homoptera Aleyrodidae). Entom. Exp. Appl. 18: 344-356.

Vaishampayan, S.M., G.P. Waldbauer & M. Kogan, 1975b. Visual and olfactory responses in orientation to plants by the greenhouse whitefly, Trialeurodes vaporariorum (Homoptera Aleyrodidae). Entom. Exp. Appl. 18: 412-422.

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE
CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES
SECTION REGIONALE OUEST PALEARCTIQUE

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS
WEST PALEARCTIC REGIONAL SECTION

PROGRESS REPORT ON DEVELOPMENT AND APPLICATION OF INTEGRATED PEST CONTROL IN GLASSHOUSES IN THE NETHERLANDS WITH AN INDICATION ABOUT LIMITING FACTORS

J. Woets[1], P.M.J. Ramakers[2] & J.C. van Lenteren[3]

[1]Glasshouse Crops Research Station, Naaldwijk
[2]Research Institute for Plant Protection, Wageningen
[3]Dept. of Ecology, University of Leiden, Leiden

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES, PROCEEDINGS OF THE FOURTH MEETING

BULLETIN S.R.O.P. / W.P.R.S. 1980 III / 3, 247-257

5926

PROGRESS REPORT ON DEVELOPMENT AND APPLICATION OF INTEGRATED PEST CONTROL IN GLASSHOUSES IN THE NETHERLANDS WITH AN INDICATION ABOUT LIMITING FACTORS

J. Woets, P.M.J. Ramakers & J.C. van Lenteren

Introduction

Since the last meeting of the working group on integrated control in glasshouses (Antibes, France, 1976) we have been working on the following aspects:

1. Greenhouse whitefly (*Trialeurodes vaporariorum* (Westwood))
   - 1.1 development of biological control in cucumber
   - 1.2 development of biological control in gerbera
   - 1.3 searching for new parasites or other *Encarsia* strains that might parasitize whitefly effectively at low glasshouse temperatures
2. Tomato leafminer (*Liriomyza bryoniae* Kalt.)
3. Aphids (*Myzus persicae* Sulzer)
4. Onion thrips (*Thrips tabaci* Lind.)

(2–4: Development of biological control)

1. Greenhouse whitefly (*Trialeurodes vaporariorum* (Westwood))

Differences in degree of success with biological control of the whitefly in different crops forced us to study the relation between host plant - phytophagous insect - entomophagous insect (Woets, 1973). The first results of this study were reported at the Antibes meeting (Woets & van Lenteren, 1976). As far as the relation between phytophagous insect (the whitefly) and the host plants are concerned, we found the following. Host plants are selected after landing on the plant (Verschoor-van der Poel & van Lenteren, 1978). Mechanical barriers do not prevent whitefly adults or larvae from feeding on a host plant, neither is the distance between cuticle and vascular tissue too large, so the host-plant selection is apparently caused by chemical differences between the host plants (van Lenteren et al., 1977). Host-plant selection of the flies strongly reflects host-plant quality for the first four host plants we tested, that is for eggplant (*Solanum* *melongena* L.), cucumber (*Cucumis sativus* L.), tomato (*Lycopersicum esculentum* L.) and sweet pepper (*Capsicum annuum* L.) (van Boxtel et al., 1978; van de Merendonk & van Lenteren, 1978). Recently the same experiments were repeated for three other plants, melon (*Cucumis melo* L.), gherkin (*Cucumis sativus* L.) and gerbera (*Gerbera jamesonii* Hook). Within the Cucurbitacaeae and Solanaceae the general picture remains the same: a high oviposition frequency correlates with a high total number of eggs, a long life span, a high rate of development and a low mortality of developmental stages (van Sas et al., 1978). The only plant for which this correlation was not found is gerbera: certain aspects measured indicate a good quality (life span, total number of eggs), whereas others suggest a bad quality (oviposition frequency, rate of development and mortality of developmental stages). These results showed us that we cannot simply use a host-plant selection test to obtain an indication about the quality of the plant. Perhaps a strong correlation between all aspects will only be found at tests with plants belonging to small systematic units. Reliable information about quality may be obtained with a test in which oviposition frequency and mortality of developmental stages are combined.

To estimate the success of whitefly control by *E. formosa*, the data of oviposition frequency and life span were transformed to simple lines from which the potential rate of development and generation time can be calculated. Estimated from this figure we would expect biological control of the pest to be easiest on sweet pepper and most difficult on eggplant. Part of the field data do support this conclusion indeed: control is easy on sweet pepper, tomato and melon, difficult on eggplant, cucumber and gherkin. We found, however, some exceptions. Control on eggplant, for example, proved to be easier than on cucumber where almost every biological control trial ended in a failure, although whitefly populations develop faster on eggplant (in both cucumber and eggplant a much higher number of parasites was introduced per plant than in the case of tomato). There has to be at least one other factor than influences the biocontrol result: apparently either the host plant or the host influences the parasite differently.

The relation between the parasitic wasp *Encarsia formosa*, its host the greenhouse whitefly, and the host plants was also studied. Data about host-habitat searching, host-searching and acceptance of hosts have been discussed at the previous meeting in 1976 (Woets & van Lenteren, 1976; van Lenteren, 1976a, 1976b; Nell et al., 1976; van Alphen et al., 1976).

1.1 Development of biological control of whitefly in cucumber

During the observations on host finding and host acceptance behaviour, we saw that the leaf structure of the plant strongly influenced the walking speed and pattern of *Encarsia formosa*. We therefore measured walking speed and pattern on the leaves of various plant species (Hulspas-Jordaan & van Lenteren, 1978). Of the plants we used, the hairy cucumber and gherkin both have large and stiff hairs on the leaves, while tomato and gerbera have much smaller hairs. Eggplant has relatively few, but large and stellate hairs. The hairless cucumber and sweet peper have no hairs at all. Highest walking speeds were reached on the smooth leaves and walking speed is inversely proportional to the amount of hairiness.

These results support the hypothesis that the structure of the leaf surface influences the walking speed and therefore the parasitization efficiency. The data may explain why the control results on cucumber are worse than on eggplant, though whitefly develops faster on eggplant. In comparison with the situation on eggplant, the wasps are much more hindered by the stiff hairs on cucumber leaves, that reduce their walking speed more and thus diminish their parasitization efficiency more drastically. This effect is strengthened by the higher amount of honeydew that is retained on leaves with large hairs than on smooth leaves. On a leaf with a lot of honeydew, the wasps spend much time preening their bodies, which become covered with honeydew. This time cannot be used for searching for hosts and so the parasitization efficiency will be more reduced than estimated from walking speed data only.

The practical implications of these results will be clear. It is very probable that biological control results can be improved by using plant varieties with few or without hairs. De Ponti recently got a hairless cucumber variety from Leningrad and our measurements show that on this variety *E. formosa* walks 3.5 times as fast as on the usual hairy leaves. A glasshouse experiment showed that the parasitization efficiency is about 20% higher on this hairless variety.

Some more glasshouse tests have to be done to show that 'smooth' leaves alone increase the parasitization efficiency on cucumber sufficiently to obtain reliable control. If not, it will be necessary to check whether there are cucumber varieties that are less suitable for the whitefly. The solution of this problem will make biological control of whitefly possible in this second largest dutch glasshouse crop.

1.2 Development of biological control of greenhouse whitefly on gerbera

Gerbera gives some opportunities for biological control of several leaf pests, because only flowers are marketed. According to oviposition (245 eggs per female), life span of the females (41 days) and developmental time (32 days) *Gerbera jamesonii* seems to be a good host plant for greenhouse whitefly, as good as cucumber. Nevertheless there is a very high mortality of pre-adult stages (60%) (van Sas et al., 1978). So host-plant quality of gerbera proves to be as bad as that of tomato.

We started two trials to control greenhouse whitefly in a common gerbera crop situation. In both cases *Encarsia* reached good parasitization percentages, but in the mean time numbers of whitefly larvae increased so much that a lot of honeydew was secreted and development of sooty moulds was serious. Within two months of the start the pest population escaped from sufficient control by *Encarsia formosa*.

1.3 Searching for new whitefly parasites or other Encarsia formosa strains

A future problem will be the continuation of whitefly biological control on tomatoes. Because of high energy consumption (natural gas) of glasshouse crop production, much research was done by plantbreeders to develop varieties that produce sufficient fruit at glasshouse temperatures lower than those used now. (In Japan tomato crops are already grown at lower temperatures). With these lower temperatures, *Encarsia formosa* will not be able to keep the whitefly at low population levels. To cope with this problem we did collect and will compare the parasitization efficiency of 'new' whitefly parasites and strains of *E. formosa*. This work is done in cooperation with our English colleagues (for a survey of this problem see Vet et al., 1980).

2. Tomato leafminer (*Liriomyza bryoniae* Kalt.)

Chemical control of leafminers makes biological control of the whitefly impossible. At present leafminer pests are more frequent than before, both in chemically and integrated controlled tomato houses. Leafminer pests can be caused by pupae that survive in the soil from one growing season to another, if no proper annual soil desinfection is done.

Three parasites occur quite common 'spontaneously' in Dutch glasshouses. These are two Braconidae, *Opius pallipes* Wesmael (Opiiniae) and *Dacnusa sibirica* Telenga (Alysiinae), and one Chalcididae, *Diglyphus isaea* Walker (Eulophidiae) and we decided to study if one of these parasites could keep leafminers at low density levels and then to develop mass rearing and introduction programmes.

Laboratory experiments showed that the Braconid parasites *Opius* and *Dacnusa* are promising candidates for biological control: their developmental period from egg to adult is shorter than that of the host, adult life span is about as long and egg production is also about the same as that of the host. Also, mass production is not difficult, but probably expensive.

Before a decision about which parasite to choose can be made, a test under 'field conditions' has to be done, to measure the parasite's dispersal and host-finding capability. Glasshouse tests are in progress in which the parasitization efficiency of *Dacnusa sibirica* and *Opius pallipes* are compared.

This research is described in more detail by Hendrikse et al. (these proceedings).

3. Aphids (*Myzus persicae*, *Aphis gossypii*, *Macrosiphum euphorbiae*)

We compared *Aphidius matricariae* Hal. (Scopes, 1970) and *Aphidoletes aphidimyza* (Rond.) (Bondorenko, 1975) as biological control agents of aphids. Discrimination between parasitized and unparasitized hosts by *A. matricariae* was proved in laboratory experiments ('t Hart et al., 1978). In glasshouse tests *A. matricariae* effectively controlled *Myzus persicae* in winter and spring; in summer aphid control was disturbed by hyperparasites (Alloxystinae and Ceraphronidae). From March onwards *A. aphidimyza* can be used in heated glasshouses against all aphids occurring on sweet pepper, cucumber, tomato and eggplant.

4. Onion thrips (*Thrips tabaci* Lind.)

For integrated control of *T. tabaci* tetrachlorvinphos was tested. At low concentration (1/3 of normal dose) it gave excellent thrips control; one spray can replace several treatments with diazinon, for example. Even at normal concentration it had no noticeable effect on *Phytoseiulus persimilis* in the glasshouse. For biological control of *T. tabaci*, see Ramakers (these proceedings).

Future outlook

Research problems are mentioned above and also by Ramakers and Hendrikse et al. (these proceedings). Our aim is to develop as many biological control methods as possible against greenhouse pests, mainly to prevent and overcome problems due to resistance against insecticides. In developing biological control methods, we concentrate our efforts to develop complete biological control schemes per crop, because if control of one pest remains dependent on the use of pesticides, the future of biological control of any pest in that crop remains uncertain. The positive attitude of growers towards the use of biocontrol methods is an important factor for our continuation. It is not due to them that the

acreage on which biocontrol is applied does not increase further (Table 1.) .Growers ask for new parasites and predatores before we can provide the knowledge and reliable application.
It are the problems at the administration level that are discouraging.

From the long list of problems (1.1 to 4) one can conclude that research is the first limiting factor in the progress of biological control. The topmen of several governmental organisations are saying that investigations on and promotion of biological control techniques are very important.
Despite that, the actual situation is that only a few workers are involved with this subject in vegetable and fruit growing.

It is not the production of natural enemies which limits the actual possibilities of application. The Dutch producer of natural enemies delivered *Aphidius matricariae* as soon as it seemed profitable to do trials in practice.
He cooperated with us on leafminer problems and already started to produce *Dacnusa sibirica* . Governmental support should be given to producers of beneficial insects as a financial guarantee during the first years that a new natural enemy is tried in practice. It will further be necessary to help these producers in their search for natural enemies, in developing mass-production schemes, introduction methods and guidance programs.

The second limiting factor concerns the situation in the area of information and extension. There is a governmental committee of agriculturists and toxicologists that recommends the Ministries of Agriculture and Public Health about legislation of pesticides. There are well-known channels for an input of data to that committee from plant protection institutes. There are also intensive formal and informal exchanges of information between plant protection institutes, agricultural research stations and the agricultural extension service. The channels to and from the committee are not used for information about alternative control methods, because these do not have to be submitted to the legislation procedures of the Ministries of Agriculture and Public Health. So information and discussion about alternatives for chemicals are not included in the work of the advising committee. As a result many people who are responsible for the plant protection policy are well-informed about chemical control possibilities, but not about alternatives. Many of them are still crusted with prejudices against biocontrol. As a result the common extension officers, as the practical officials who meet the growers, speak too often about chemical control as the only way of plant protection. We see a strong need for the advising committee of the government to include in their recommendations data on side-effects of pesticides on natural enemies. The gap between the knowledge about chemical control and biological control would then become less. When the committee would collect the data about all control methods (both chemical and alternative) it should be easy to consider whether a new pesticide really needs to be legislated, if reliable alternatives are already available.

It is well-known that vegetable growers apply chemicals which only have a legislation in ornamentals because of long-lasting effects. In sweet pepper and cucumber a quite persistent acaricide which has no legislation for use in these crops, is frequently used to control spider mite. Better control by governmental employees would cause a decrease of misuse and result in a better chance for application of *Phytoseiulus*.

All biological control research and extension work is done by governmental organisations. Other state organisations provide legislation for pesticides and check correct application by growers. This strong governmental influence on all these aspects makes it possible to develop an active policy to develop biological control by

1) organising and stimulating biological control research and extension,
2) changing the pesticides legislation policy
3) checking the illegal use of pesticides.

Table 1 Acreage (in ha) of the three most important glasshouse food crops in the Netherlands in which biological control is applied (non-heated houses excluded). Total acreage in the main cropping period, the acreage and percentage of successful biological control of greenhouse whitefly by *Encarsia formosa* (in tomato) and of two-spotted spider mite by *Phytoseiulus persimilis* (in cucumber and sweet pepper)

	TOMATO			CUCUMBER			SWEET PEPPER		
	total	*Enc.*	%	total	*Phyt.*	%	total	*Phyt.*	%
1969	2200	-	-	860	25	2	-	-	-
1970	2380	-	-	870	200	25	-	-	-
1971	2430	4	-	750	75	10	70	-	-
1972	2290	20	1	840	100	12	75	-	-
1973	2040	120	5	790	150	20	150	10	7
1974	2090	400	20	785	150	20	160	12	10
1975	2060	500	25	780	200	25	160	15	10
1976	2040	600	30	720	300	40	160	20	12
1977	2090	550	25	770	350	45	175	30	15
1978	2000	530	25	750	400	50	180	40	20
1979	2050	560	25	720	400	55	180	40	20

References

Alphen, J.J.M. van, H.W. Nell & L.A. Sevenster-van der Lelie, 1976. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). VII. The importance of host feeding as a mortality factor in greenhouse whitefly nymphs. Bull. O.I.L.B./S.R.O.P. 1976/4: 165-169.

Bondarenko, N.V., 1975. Use of aphidophages for the control of aphids in hothouses. VIII Int. Plant Prot. Congr., Moscow.

Boxtel, W. van, J. Woets & J.C. van Lenteren, 1978. Determination of host-plant quality of eggplant (Solanum melongena L.), cucumber (Cucumis sativus L.), tomato (Lycopersicum esculentum L.) and paprika (Capsicum annuum L.) for the greenhouse whitefly (Trialeurodes vaporariorum (Westwood)) (Homoptera: Aleyrodidae). Meded. Fac. Landbouww. Rijksuniv. Gent. 43: 397-408.

Hart, J. 't, J. de Jonge, C. Collé, M. Dicke, J.C. van Lenteren & P. Ramakers, 1978. Host selection, host discrimination and functional response of Aphidius matricariae Hal. (Hymenoptera: Braconidae), a parasite of the green peach aphid, Myzus persicae (Sulz.). Meded. Fac. Landbouww. Rijksuniv. Gent 43: 441-453.

Hulspas-Jordaan, P.M. & J.C. van Lenteren, 1978. The relationship between host-plant leaf structure and parasitization efficiency of the parasitic wasp Encarsia formosa Gahan (Hymenoptera: Aphelinidae). Meded. Fac. Landbouww. Rijksuniv. Gent. 43: 431-440.

Lenteren, J.C. van, H.W. Nell, L.A. Sevenster-van der Lelie & J. Woets, 1976a. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). I. Host finding by the parasite. Ent. exp. appl. 20: 123-130.

Lenteren, J.C. van, H.W. Nell, L.A. Sevenster-van der Lelie & J. Woets, 1976b. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). III. Discrimination between parasitized and unparasitized hosts by the parasite. Z. angew. Ent. 81: 377-380.

Lenteren, J.C. van, J. Woets, N. van der Poel, W. van Boxtel, S. van de Merendonk, R. van der Kamp, H. Nell & L.A. Sevenster-van der Lelie, 1977. Biological control of the greenhouse whitefly Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae) by Encarsia formosa Gahan (Hymenoptera: Aphelinidae) in Holland, an example of successful applied ecological research. Meded. Fac. Landbouww. Rijksuniv. Gent. 42: 1333-1342.

Merendonk, S. van de & J.C. van Lenteren, 1978. Determination of mortality of greenhouse whitefly, Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae) eggs, larvae and pupae on four host-plant species: eggplant (Solanum melongena L.), cucumber (Cucumis sativus L.), tomato (Lycopersicum esculentum L.) and paprika (Capsicum annuum L.). Meded. Fac. Landbouww. Rijksuniv. Gent 43: 421-429.

Nell, H.W., L.A. Sevenster-van der Lelie, J.C. van Lenteren & J. Woets, 1976. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). II. Selection of host stages for oviposition and feeding by the parasite. Z. angew. Ent. 81: 372-376.

Sas, J. van, J. Woets & J.C. van Lenteren, 1978. Determination of host-plant quality of gherkin (Cucumis sativus L.), melon (Cucumis melo L.) and gerbera (Gerbera jamesonii Hook) for the greenhouse whitefly, Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae). Meded. Fac. Landbouww. Rijksuniv. Gent. 43: 409-420.

Scopes, N.E.A., 1970. Control of Myzus persicae on year-round chrysanthemums by introducing aphids parasitized by Aphidius matricariae into boxes of rooted cuttings. Ann. appl. Biol. 66: 323-327.

Vet, L., J.C. van Lenteren & J. Woets, 1980. The parasite--host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). IX. A review of the biological control of the greenhouse whitefly with suggestions for future research. Z. angew. Ent. (in press).

Woets, J., 1973. Integrated control in vegetables under glass in the Netherlands. Bull. O.I.L.B./S.R.O.P. 1973/4: 26-31.

Woets, J. & J.C. van Lenteren, 1976. The parasite-host relationship between Encarsia formosa (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Homoptera: Aleyrodidae). VI. The influence of the host plant on the greenhouse whitefly and its parasite Encarsia formosa. Bull. O.I.L.B./S.R.O.P. 1976/4: 125-137.