IOBC/WPRS

Working Group "Integrated Control Glasshouses"

OILB/SROP

Groupe de Travail "Lutte intégrée en Cultures sous Verre"

Proceedings of the Workshop

"IPM in Greenhouse Ornamentals"

at

Cambridge, (United Kingdom)
8-11 September 1992

Edited by L.R. Wardlow & J.C. van Lenteren

IOBC/WPRS Bulletin
Bulletin OILB/SROP Vol. 16(8) 1993

PREFACE

Following the meeting of the working group in Budapest in 1987, a workshop on IPM in ornamentals was held at Aalsmeer in December of that year. This meeting gave an impetus to the expansion of IPM in ornamentals and resulted in many contributions on this subject to the next full meeting of the Group in Copenhagen in 1990. It was agreed that another workshop on ornamentals should be held in the United Kingdom during 1992. Consequently, this meeting was convened at Trinity College, University of Cambridge.

The aims of the workshop were to:

(i) review the latest research in IPM on ornamentals;
(ii) to identify gaps in the research programme;
(iii) to recommend future action.

The workshop agenda was divided into sections, each with a chairman and secretary (see Summary section).

Delegates also spent one afternoon visiting glasshouse nurseries and a garden centre in the Lea Valley area of Hertfordshire.

Although the workshop was poorer for the absence of J.C. van Lenteren who convenes the activities of the group, delegates agreed that it had been very useful and was enhanced by the superb domestic and technical facilities offered in the academic and historic atmosphere of the University. Trinity College was founded by the English king, Henry VIII who, ironically, was not famous for practising biological control.

Convenors:-
L R Wardlow
J Bennison
J Buxton

CONTENTS

List of participants

Name	Address
Aagesen, J.	Christian Hansen Biosystems, 10-12 Boge Alle, DK 2970, Horsholm, Denmark
Albert, R.	Landesanstalt für Pflanzenschutz, Reinsburgstrasse 107, 7000 Stuttgart, Germany
Altena, K.	Koppert BV, PO Box 155, 2650 AD Berkel en Rodenrijs, The Netherlands
Baker, R.H.A.	Central Science Laboratory, MAFF, Hatching Green, Harpenden, Hertfordshire, United Kingdom
Baranowski, T.	Akademia Rolnicza, Katedra Metod Ochrony Roslin, ul Dabrowskiego 169.71 60-594 Poznan, Poland
Beck, N.G.	Crop and Food Research, Mount Albert Research Centre, Private Bag 92169, Auckland, New Zealand
Bennison, J.	ADAS, Government Buildings, Chequers Court, Huntingdon, Cambridgeshire, United Kingdom
Berlinger, M.J.	Gilat Regional Experiment Station, Mobile Post, Negev 2, 85-280 Israel
Bertaux, F.	GRISP-INRA, BP 1078, 06606 Antibes, France
Brødsgaard, H.F.	Department of Pest Management, Research Centre for Plant Protection, Lottenborgvej 2, DK-2800 Lyngby, Denmark
Brough, W.	ADAS, Crown House, Maidstone, Kent, United Kingdom
Buxton, J.H.	ADAS, Woodthorne, Wolverhampton, United Kingdom
Cheek, S.	Central Science Laboratory, MAFF, Harpenden Laboratory, Hatching Green, Harpenden, Hertfordshire, United Kingdom
Cooper, S.	English Woodlands, Hoyle Depot, Graffham, Petworth, West Sussex, United Kingdom
Copland, M.	Department of Biochemistry and Biological Sciences, Wye College, University of London, Wye, Ashford, Kent, United Kingdom
De Courcy-Williams, M.	Horticulture Research International, Worthing Road, Littlehampton, West Sussex, United Kingdom
De Goey, J.W.F.M.	IKC-afd Bloemisterij, Linnaeuslaan 2a, 1431 JV Aalsmeer, The Netherlands
De Jaeger, K.	State University of Leiden, Department of Biology, Kaiserstraat 63, POB 9516, 2300 RA Leiden, The Netherlands
Enkegaard, A	Plantevaernscentret, Afdeling for Hordbrugszoologi, Lottenborguej 2, DK-2800, Lyngby, Denmark
Finlay, R.	Horticulture Research International, Efford Experimental Station, Lymington, Hampshire, United Kingdom
Foster, C.	Jodrell Glass, Royal Botanical Gardens, Kew, Richmond, Surrey, United Kingdom
Fransen, J.J.	Research Station for Floriculture, Linnaenslaan 2a, 1431 JV Aalsmeer, The Netherlands
Frey, D.E.	Federal Research Station, Laboratory 4, CH-8820, Wädenswil, Switzerland

List of participants continued

Gouge, D.	University of Reading, Department of Agriculture, Spur E, Early Gate, PO Box 236, Reading, Berkshire, United Kingdom
Guldemond, A.	IP0-DLO Research Institute for Plant Protection, Binnenhaven 12, PO Box 9060, NL-6700 GW, Wageningen, The Netherlands
Helyer, N.	Horticulture Research International, Worthing Road, Littlehampton, West Sussex, United Kingdom
Hoyle, E.	ADAS, Government Buildings, Epsom Road, Guildford, Surrey, United Kingdom
Jacobson, R.	Bunting Biological Control Limited, Great Horkesley, Colchester, Essex, United Kingdom
Lindquist, R.	Ohio Agricultural Research Centre, Wooster, OH 44691, USA
Lindquist, I.	Agricultural Research Centre, Institute of Plant Protection, SF-31600 Jokioinen, Finland
Lofts, C.	National Pest Control Limited, Barnham, West Sussex, United Kingdom
Marris, G.	Central Science Laboratory, MAFF, London Road, Slough, Berkshire, United Kingdom
Nedstam, B.	Swedish Board of Agriculture, PO Box 44, S-23053 Alnarp, Sweden
Oetting, R.	Department of Entomology, Georgia Experimental Station, Griffin, Georgia 30223, USA
Piatowski, J.	Instytut Ochrony Roslin, Miczurina 20, 60-318 Poznan, Poland
Ravensberg, W.	Koppert Biological Systems, Veilingweg 17, 2651 BE, Berkelen Rodenrijs, The Netherlands
Rossebo, A.K.	as Plantevern-Kjemi, Huggenes Gard, 1580 Rygge, Finland
Sana, A.	Biolab, Centrale Ortofrutticola, Centro Servizi Avanzatiper Agricoltura, Via Masiera Prima 1191-47020, Martorano, Cesena Fo, Italy
Sautter, H.	Sautter und Steppper GmbH, Biologischer Pflanzenschutz, Rosenstrasse 19, D-7403 Ammerbuch 5 (Altingen) Germany
Saynor, M.	ADAS, Block A, Government Buildings, Coley Park, Reading, Berkshire, United Kingdom
Schmidt, M.	Federal Research Station, Laboratory 4, CH-8820 Wädenswil, Switzerland
Simon, E.	Hodmezovasarhely, PO Box 99, Rarosi u 102, 6800 Hungary
Steiner, M.	Alberta Environmental Centre, Bag 4000, Vegreville, Alberta, Canada
Stenseth, C.	Stratens Plantevern, Ardeling Skadedyr, Fellesbygget, N-1432 AAS, Norway
Sütterlin, S.	Department of Entomology, PO Box 8031, 6700 EH Wageningen, The Netherlands

List of participants continued

Van Dijk, M.J.	Department of Population Biology, State University of Leiden, PO Box 9516, 2300 RA Leiden, The Netherlands
Van Dijken, F.R.	CPRO-DLO, PO Box 16, 6700 AA Wageningen, The Netherlands
Van Houten, Y.M.	Department of Pure and Applied Ecology, University of Amsterdam, Kruislaan 302, 1092 SM Amsterdam, The Netherlands
Van Rijn, C.J.	Universit of Amsterdam, Department of Ecology, Section of Population Biology, Kruislaan 302, 1092 SM Amsterdam, The Netherlands
Walker, P.	Biological Crop Protection, Acorn Cottage, Chapel Lane, West Wittering, Chichester, West Sussex, United Kingdom
Wardlow, L.R.	ADAS, Olantigh Road, Wye, Ashford, Kent, United Kingdom
Williams, E.C.	Central Science Laboratory, MAFF, Hatching Green, Harpenden, Hertfordshire, United Kingdom
Woodhams, J.	Jodrell Glass, Royal Botanical Gardens, Kew, Richmond, Surrey, United Kingdom

RESEARCH REPORTS

DEVELOPMENT OF BIOLOGICAL CONTROL IN ORNAMENTALS

R. Albert[1], H. Schneller[1], and H Sautter[2]

[1]Landesanstalt für Pflanzenschutz, Stuttgart
[2]Sautter und Stepper GmbH, Ammerbuch 5

Abstract

Biocontrol in greenhouse ornamentals is developing well in the State of Baden-Württemberg in south west Germany. In 1989 beneficials were used on 3.4 ha, in 1990 on 6.0 ha and in 1991 on more than 9 ha with ornamentals. Altogether 13 beneficial arthropod and nematode species have been used by the growers.

Biocontrol in ornamentals started in 1987 with one experiment in an *Euphorbia pulcherrima* stand. Poinsettias are still the most important culture for biocontrol. It could be shown in many experiments that biocontrol is possible with nearly all ornamental plant species. But some problems still exist, ie. too low relative air humidity for *Phytoseiulus persimilis* and *Amblyseius* species in the summer or too low temperatures for *Encarsia formosa* and other species in winter time.

The following strategy was proposed: a high degree of hygiene before the crop is started and during the season. Biocontrol should have priority over chemical control. A regular, often weekly, introduction of beneficials against the main pest species is necessary. Beneficials against the minor pest species should be introduced when inevitable. Weekly monitoring of the stands is important.

A questionnaire was sent out to growers using beneficials in their crops. The results of the questionnaire are given below.

Introduction

During the joint meeting of the IOBC-WPRS- and EPRS- groups in Budapest in 1987 it was decided to develop biological control systems for ornamental plants.

In Western Germany the development of biocontrol was especially important for host plants of whitefly species (*Bemisia tabaci* and *Trialeurodes vaporariorum*) under glass, because powerful pesticides against these pest species have no registration here (table. 1). The number of insecticide applications in ornamental stands with whiteflies is very high and can be up to twenty in a season. In ornamental crops that are attacked by other pest species like *Frankliniella occidentalis*, *Liriomyza trifolii*, *L. huidobrensis* or *Tetranychus urticae* the situation is less bad, because effective insecticides are registered.

Methods

A number of experiments have been started in commercial nurseries since 1987 in Baden-Württemberg, a state in south west Germany with about 10 million inhabitants. For these experiments the following strategy was chosen:

(a) **Biocontrol should have priority over chemical control**, as long as no harm to the plant stand can be expected,

(b) **A regular, part weekly introduction of beneficials** especially in heated houses and in the summer against the main pests is easily understood and handled by the grower. This is also a sort of insurance for the experimenter, in

the case, that chemical residues are present on the plants, in the soil or the construction of the glasshouse at the start of the crop. With the regular introductions of the beneficials against the main pests the beneficials will sooner or later survive and start with the biocontrol. In summer time some beneficials are short lived at high temperatures, the regular introduction solves this problem too.

(c) **Weekly monitoring** of the stands is necessary to get interpretable data, find minor pest species and to win growers confidence.

(d) **Beneficials against minor pest species should be introduced only when necessary,** to save costs.

The possibilities of biocontrol in ornamentals have been published by the authors in several papers (Albert und Sautter, 1989, Albert *et al*, 1990, Albert und Schneller, 1989, Albert, 1990, Albert and Schneller, 1991). In these papers we suggest to use one *Encarsia formosa* per three plants per week in poinsettias, hibiscus and *Begonia* against *B. tabaci* and one *E. formosa* per ten plants per week against whiteflies in other cultures. Sometimes higher numbers of *E. formosa* can be necessary. To receive information on the use and the results of biocontrol in the nurseries, a questionnaire has been sent to growers who bought beneficials for ornamentals. Some results of the questionnaire are given below.

Results

Bemisia tabaci is up to now found in numbers only on poinsettias, hibiscus and *Begonia*. The other plant species are attacked by *Trialeurodes vaporariorum* only. The biocontrol of this species with *E. formosa* normally gives very good results, when the density of the pest is not too high at the beginning of the experiment and the plants were free of pesticide residues. *E. formosa* was able to finish the *T. vaporariorum* attack on poinsettias, *Lantana*, *Verbena* and most of the *Fuchsia* varieties completed. On *Geranium grandiflorum*, *E. formosa* parasitised only some of the juveniles of the whitefly.

In most nurseries *B. tabaci* is the only whitefly species found on poinsettias. The possibility for a biocontrol of *B. tabaci* on poinsettias was first published in 1989 (Albert und Sautter, 1989). The biocontrol of *B. tabaci* with *E. formosa* varied from not sufficient to too good in our experiments. This is due to the fact that *B. tabaci* cannot be completed eradicated from the plants by *E. formosa* in the three to four months of the poinsettia production time.

To get more information about the practical biocontrol in greenhouses the questionnaire was set out to 120 growers in 1990 and 150 in 1991, who bought beneficials for ornamentals. The production size of the nurseries various from 500 m² to 7 ha and the number of poinsettias with biocontrol from 1,000 to 160,000 plants. The main problems in poinsettia stands in 1990 were the whitefly species followed by sciarid flies and *F. occidentalis* by fungal diseases in 1991.

In 1990 the results of the regular *E. formosa* introduction were in more than 70% of the stands better or equal than that of the chemical control. In less than 20% was it worse. In 1991 the result of the *E. formosa* use was much better. Over 80% received very good and good results, more than 10% satisfying and sufficient results and only 7% bad results (fig. 1). The results of the biocontrol of sciarid larvae are less good. But this led to an extreme reduction in pesticide use (fig. 2). In both years more than half of the nurseries did not use

any insecticides at all. In the rest of the nurseries the use of insecticides was reduced to less than two applications.

Fig. 1: Results of the introduction of beneficials in the poinsettia stands

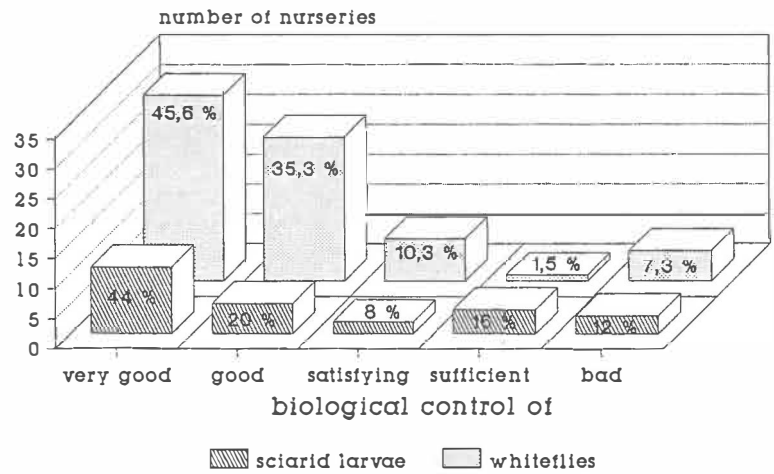
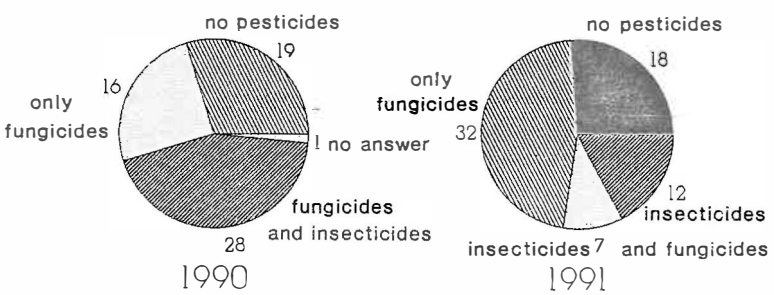


Fig. 2: *E. formosa*-introduction and use of pesticides in the poinsettia stands



The growers who had answered the questionnaire tried biocontrol also in ten other cultures in 1990 and in 23 in 1991 (Tab. 2). Biocontrol was successful in most of the cultures. The exceptions were in 1991 *Croton*, *Gerbera*, *Lantana*, *Saintpaulia* and *Verbena*. Especially the biocontrol in *Gerbera* is difficult because of the sometimes unheated glasshouses in winter time, the sometimes already high density of the whitefly at the beginning of the biocontrol and the residues of pesticides on the plants, in the soil and the glasshouse construction. Because of the great number of pest species attacking *Gerbera* (whitefly, spider mites, aphids, thrips, broad mites, leafminers, bugs and slugs) the biological control can be expensive.

Beneficial arthropods have been used in ornamental crops in Baden-Württemberg in the year 1989 on 3.4 ha, in 1990 on 6 ha and in 1991 on more than 9 ha. Thus biocontrol in ornamentals is developing well in the south of Germany. Exact data for Germany do not exist, but beneficials have been used in 1991 at least on 25 ha with ornamentals.

Discussion

The biological control of noxious arthropods in glasshouses with ornamental plants can be as successful as in vegetables. The regular introduction of beneficials against the main pests was especially successful in whitefly control. This method has been recommended to the growers and is already widely used. In Baden-Württemberg the biological control has been used in 1991 on more than 9 ha with ornamentals. In poinsettias the costs for biological control can be the same as for chemical control. Biocontrol in cultures with more than one main pest species like *Gerbera* is difficult because different main pest species require the regular introduction of some beneficials, thus the costs are much higher than in a poinsettia stand. An integrated control system with an introduction of beneficials against some pests and chemical control with pesticides harmless for the beneficials against other pests or the closure of the ventilation by netting can be a proper way to reduce the costs for a good control in difficult cultures.

Literature

Albert, R., 1990: Weiße Fliege in Gemüse- und Zierpflanzenkulturen unter Glas, GbGw 14, 677-681.

Albert, R. und Sautter, H., 1989: Schlupfwespen schützen Weihnachtsterne vor Weißer Fliege, Deutscher Gartenbau, 27, 1671-1673.

Albert, R., Sautter, H. und H. Schneller, 1990: Biologischer Pflanzenschutz in Poinsettien, GbGw, 15, 734-737.

Albert R., und Schneller, H., 1989: Biologische Schädlingsbekämpfung im Zierpflanzenbau, Med. Fac. Landbouww. Rijksuniv. Gent, 54/3a, 873-882.

Albert R. und Schneller, H., 1991: Bisherige Erfahrungen mit der biologischen Schädlingsbekämpfung in Zierpflanzenkulturen - I. Bekämpfung der Weißen Fliegen-Arten *Trialeurodes vaporariorum* und *Bemisia tabaci*, GbGw, 1, 10-15.

Table 1. Development of biological control in ornamentals

Pest Species	Powerful pesticide with registration for ornamentals in Germany (+) no registration (-)	biocontrol possible in combination with the pesticide
Frankliniella occidentalis	Mesurol flüssig (Methiocarb) (+)	+-
	Tamaron (Methamidophos) (+)	-
Bemisia tabaci	Applaud (Buprofezin (-)	+
Trialeurodes vaporariorum	hydrocyanic gas (-)	+
	Lannate 25-WP (Methomyl) (-)	-
	Pyrethroides (+)	-
Liriomyza trifolii	Vertimec (Abamectin) (+)	+-
L. huidobrensis		
Aphis gossypii	Pyrethroides (+),	-
	Bladafum II (Sulfotepp) (+)	+-

Table 2. Use of beneficials in other cultures of the 64(1990) und 59 (1991) nurseries

Cultures	1990		1991	
	number of successes	number of failures	number of successes	number of failures
Abutilon megapotanicum	0	2	-	-
Ageratum houstochianum	1	0	1	0
Alstroemeria	-	-	1	0
Amaryllis belladonna	-	-	1	0
Anisodontea capensis	0	1	1	0
Asparagus desiflorus	-	-	1	0
Begonia elatior - hybrids	1	0	1	0
Calceolaria - hybrids	1	0	1	0
Croton	-	-	0	1
Cyclamen	-	-	3	-
Dahlia - hybrids	1	0	1	0
Datura	-	-	1	0
Fuchsia - hybrids	7	3	14	0
Geranium	-	-	1	0
Gebera	-	-	4	5
Hibiscus rosa-sinensis	1	0	2	0
Impatiens walleriana	-	-	2	0
Lantana camara	5	0	6	2
Lysianthus	-	-	1	0
Pelargonium zonale - hybrids	-	-	3	0
Saintpaulia	-	-	1	1
Salvia uliginosa	1	0	-	-
Verbena	-	-	1	1
Viola	-	-	1	0
Zinnia	-	-	1	0

BEMISIA TABACI IN THE UNITED KINGDOM

R.H.A. Baker and S. Cheek
Central Science Laboratory, MAFF, Hatching Green, Harpenden, Herts AL5 2BD, UK

Summary

Since 1987, numerous introductions of the economically important whitefly pest, *Bemisia tabaci*, have been eradicated from the United Kingdom. Imported poinsettia cuttings were the primary source of infestation and statutory action was taken both to exclude and eradicate the pest. Although *B. tabaci* is capable of becoming established on a wide range of protected crops, outbreaks have been largely limited to poinsettia. Possible explanations for this are discussed. Comparisons with climatic conditions overseas suggest that, on field crops, populations are unlikely to reach levels high enough to cause direct damage or persist through the winter. The main threat posed by this pest is its ability to transmit viruses, particularly under glasshouse conditions.

Introduction

Bemisia tabaci (Homoptera, Aleyrodidae) is believed to pose a potentially serious threat to the horticultural industry in the UK due to its polyphagy and importance as a virus vector (Bartlett, 1922). A host range of over 500 plant species has been reported (Greathead, 1986) and, in a recent literature survey, Baker (unpublished) found 71 virus diseases recorded as being transmitted by this pest, *B. tabaci* shows a high degree of host-associated intraspecific variation and two distinct biotypes or strains have been identified - the cotton strain or biotype A and the poinsettia strain or biotype B (Bethke *et al*, 1991). In the early 1980's, $100 million crop losses due to virus diseases transmitted by *B. tabaci* occurred on cotton and vegetable crops in California (Duffus & Flock, 1982) and the first reports of damage to protected crops appeared in Israel (Berlinger, 1980) and Turkey (Uygan & Özgür, 1980). In 1986, *B. tabaci* was estimated to have caused $2 million losses to Florida poinsettia *Euphorbia pulcherrima*) growers when it invaded glasshouses for the first time (Hamrick, 1987). This development had a major impact on the poinsettia industry. In recent years, further major losses have occurred on tomatoes and other protected crops in Florida (Stanley, 1991) and in Californian field crops (Perring *et al*, 1991). These recent losses have been caused by biotype B, which, unlike biotype A, can produce physiological disorders (Cohen *et al*, 1992) and has enhanced polyphagy (Perring *et al*, 1991), fecundity (Bethke *et al*, 1991) and insecticide resistance.

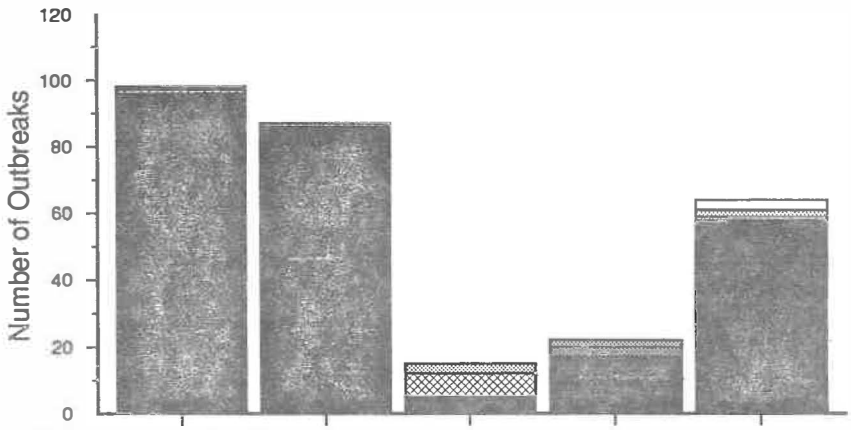
B. tabaci is a notifiable pest in the United Kingdom, with growers having a legal obligation to report any signs of infestation. Statutory action has been taken against this pest since the first commercial outbreak in 1987, both the prevent introductions and to eradicate outbreaks. This paper reviews the history of *B. tabaci* in the UK, outlines the measures taken to exclude and eradicate it and assesses the risk posed by biotype B to crops in the UK.

B. tabaci Outbreaks

Two short-lived populations of *B. tabaci* were found in 1943 (in a Kent wood) and 1980 (at the Royal Botanic Gardens, Kew), but the first commercial outbreak occurred in August 1987 on poinsettia imported from the Netherlands. The export of *B. tabaci* to Northern Europe from infested mother-stocks in the United States via the trade in poinsettia cuttings was the likely source of this and subsequent outbreaks. From 1987 to the end of 1991, 286 nursery outbreaks were detected and eradicated in England and Wales (Bartlett, 1992), 33 in Scotland and none in Northern Ireland. Electrophoretic examination of *B. tabaci* from the recent southern Californian outbreak, from various sites in the near and middle east and from

one poinsettia sample imported into the UK from the Netherlands were found to have identical enzyme banding patterns identifiable as biotype B (Byrne, pers. comm.). All outbreaks, except one on *Begonia*, were associated with the seasonal import of poinsettia cuttings for the Christmas market. Reflecting trade patterns, infestations of *B. tabaci* on the nursery have been traced from cuttings imported primarily from the Netherlands, but also from Germany, Israel, Denmark and Belgium (figure 1).

Import interceptions of *B. tabaci* have also been made on the following host plants: *Gypsophila*, *Lisianthus*, *Aster*, *Trachelium* and sweet basil from Israel, melokhia (*Corchorus olitorius*) from Cyprus, *Chrysanthemum* from the Canary Islands and from Holland, *Ipomoea* from Thailand and guava from Egypt. Infested consignments were destroyed or re-exported but these records indicate the potential of *B. tabaci* to colonise a wide range of hosts.



	1987	1988	1989	1990	1991
Netherlands	96	86	5	17	58
Germany	1	1	7		1
Denmark	1			3	
Israel			3	2	2
Belgium					3

Figure 1: The number and source of annual *Bemisia tabaci* outbreaks in England and Wales.

Exclusion and Eradication of *B. tabaci*

Preventing the entry of harmful organisms is a more effective plant quarantine strategy than attempting to eradicate after entry. Exclusion of an organism is largely achieved by legislation. *B. tabaci* has been listed as a quarantine organism in domestic import legislation in the UK since 1988. Pre-export requirements include freedom from the pest at the place of production, official inspections or treatment to ensure freedom from signs of the pest prior to the export of plant material. Continuing protection for the UK within the European Community from 1993 will be provided by a Protected Zone against *B. tabaci*.

In support of legislative measures, research is being undertaken at the Central Science Laboratory on the pre-transit treatments of poinsettia cuttings. Preliminary tests have been carried out to determine the phytotoxic effects of methyl bromide fumigation on rooted cuttings (Macdonald, unpublished). Results appear promising with little damage caused even

at a CTP (Concentration Time Product) of approximately 75 mg per litre hours. However, the future use of methyl bromide is uncertain, due to allegations of ozone depletion.

Despite measures taken to exclude *B. tabaci*, low levels of the pest have been introduced. In addition to early inspection by the Plant Health and Seeds Inspectorate, growers are also encouraged to check plants carefully on arrival at the nursery and are warned that since material could be carrying eggs that are difficult to detect, plants should continue to be monitored for several weeks (Cheek, 1992).

A full integrated control programme is required under statutory notice involving physical, cultural and chemical control methods. Where biological control is being practised at a nursery, this can be integrated into the treatment programme as inundative releases. *Encarsia formosa* is the only whitefly parasite commercially available in the UK at the present time but is not an efficient *B. tabaci* control agent. Extensive trapping both for monitoring and control and destruction of infested plants is required. Chemical control measures consist of space treatments (primarily nicotine and propoxur), systemic treatments with aldicarb (Temik) and foliar applications of teflubenzuron (Nemolt), soft soap (Savona) or a proprietary wetter. Bifenthrin (Talstar) has recently been added to the treatment schedules and buprofezin is under evaluation for approval in additional experimental treatment. Mycotal (*Verticillium lecanii*) has been useful in treating unrooted cuttings under cover where the high humidity promotes fungus development. At the end of the season, plants inspected prior to sale and only those found free from signs of the pest are released. Thorough clean-up and sterilisation of the glasshouse is required with the remaining poinsettia plants destroyed to ensure the eradication of any residual populations of *B. tabaci*.

The Development of *B. tabaci* in Protected Crops

With a host range of over 500 species (Greathead, 1986), many UK protected crops are potentially at risk from *B. tabaci*. However, accurate estimates of its ability to develop on these crops in UK glasshouse conditions cannot be made because, as yet, only two studies on the development rates of biotype B have been published. Cohen *et al* (1992) found that biotype B developed faster than biotype A on six host plants at 26° - 32°C and Fransen (1990) measured the development of *B. tabaci* imported into the Netherlands on poinsettia at two constant temperatures (20°C and 25°C). Gill (1992) states that biotype B is more cold tolerant but there appears to be little evidence. To obtain detailed predictions of development rates and thresholds, data recorded over a longer series of constant temperatures (as for *B. tabaci* on cotton (Butler *et al*, 1983) are required.

The Development of *B. tabaci* in Field Crops

Without direct knowledge of *B. tabaci*'s response to climatic conditions in the UK and with only poor knowledge of the environmental conditions limiting the development of biotype B, the threat posed to field crops in the UK can only be estimated by comparison with climatic conditions in areas where *B. tabaci* reaches its highest densities (Yuma, USA) and its overwintering limits (Adana, Turkey and Atlanta, USA). Temperatures at these sites were compared with climatic conditions at one site representative of southern UK (Southampton) using the climate matching facility in CLIMEX (Sutherst & Maywald, 1985), though figure 2 was drawn from original data.

Yuma, lies within a few miles of the Imperial Valley, California, where massive outbreaks of *B. tabaci* have occurred (Perring *et al*, 1991). Figure 2a compares conditions at Yuma and Southampton (Meteorological Office, 1972, 1980). Maximum temperatures at Yuma are consistently 15°C-20°C higher than maxima at Southampton and even the minimum temperatures approximate to maxima in the south of England. The peak period for *B. tabaci*

outbreaks in the Imperial Valley lies in August-September when temperatures average between 23°C and 40°C. Such conditions are unlikely to occur in the UK, and thus we are unlikely to see high population densities of *B. tabaci* on outdoor crops in the UK.

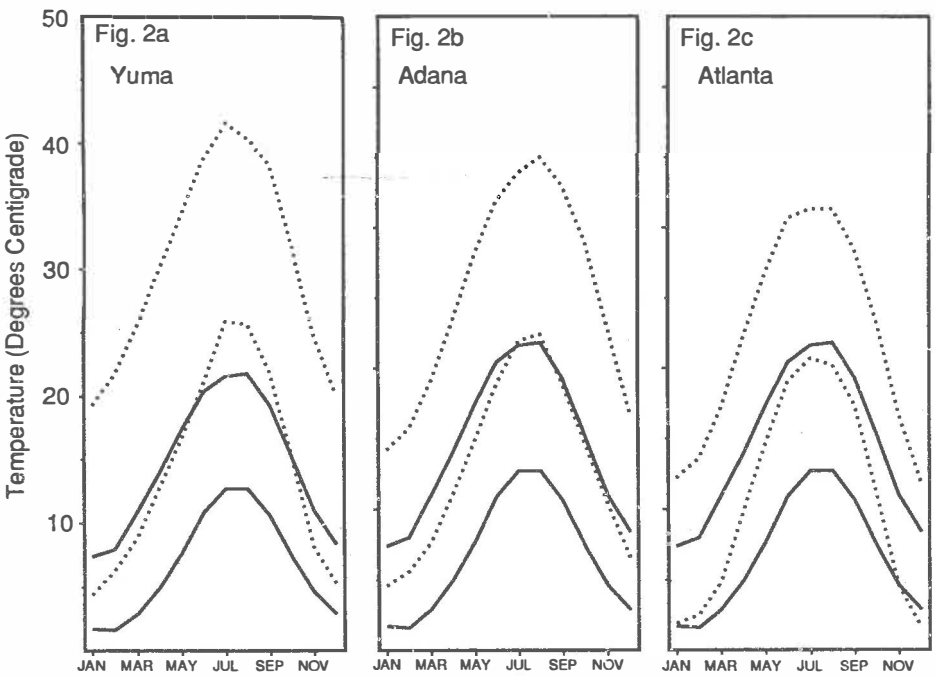


Figure 2a, 2b & 2c: The daily mean maximum and minimum temperatures for each month at Yuma (fig. 2a) in Arizona (USA), Adana (fig. 2b) in Turkey and Atlanta (fig. 2c) in Georgia (USA) are shown in dotted lines. In each graph they are compared to the same data for Southampton (UK) which are shown in solid lines.

Çukorova, in Turkey, is a flat plain at the extreme north-east corner of the Mediterranean Sea. Here, *B. tabaci* is an important pest of cotton and overwinters on *Cistus* in the foothills of the mountains which overlook the plain (Özgür, 1989). Flight activity and egg laying was virtually absent between December and March and the population was at its peak in August-September. Adana, lies within the overwintering area. Meteorological data were obtained from FAO (1987). Compared to Southampton (figure 2b), minimum winter temperatures are only 2-3 degrees higher at Adana, though maxima are 7 degrees warmer. Irrespective of winter survival, temperatures comparable to those when flight and egg-laying activity started in the spring at Çukorova do not occur until June/July in Southampton. Summer temperatures in southern England are much cooler than in southern Turkey.

Because winters are so variable, there is no strict geographical limit to areas where *B. tabaci* can overwinter. Broadbent *et al* (1989) confirmed that *B. tabaci* cannot overwinter outside in Canada. Oetting (pers. comm.) considered that central Georgia provided the effective northern limit for *B. tabaci* to overwinter in the USA. Fig. 2c compares temperatures at Atlanta (Meteorological Office (1980) and Southampton, UK. Minimum

temperatures are similar in winter, with maxima 2°-3°C higher in Atlanta suggesting that *B. tabaci* could survive some mild winters outdoors in southern England. However, summer temperatures are much higher in Georgia and, again, it would seem most unlikely that any substantial populations of this pest would be able to build up outdoors in the UK.

Several experimental studies confirm *B. tabaci*'s dependence of high temperatures for development. Butler *et al* (1983) found that, on cotton, the shortest development times occurred between 25° and 30°C. A linear regression of the reciprocal of the development times provides an estimated minimum development threshold of 10°C. Egg-laying only occurred above 19°C in India (Trehan, 1944). In Israel, egg development ceased at 12.5°C and the minimum threshold for larval development was 12°C (Avidov, 1956). In the Imperial Valley, California, the minimum threshold for development was estimated at 10°C for field populations (Zalom *et al*, 1985). These studies should now be repeated for biotype B.

Assessment of Pest Potential and Future Prospects

Although, all the outbreaks of *B., tabaci* have so far been eradicated in the UK, biotype B is clearly capable of establishing on a wide range of protected crops. Statutory action has ensured that population levels do not build up to high levels, thus minimising the opportunity for dispersal from poinsettia to alternative crops both under glass and outdoors in summer months. Costa *et al* (1991) showed that *B. tabaci* reared on pumpkin or cotton for 12-15 generations (nearly 1.5 years) preferred to stay close to and oviposit on the host they had been reared on and it is possible that a comparable association has developed with poinsettia, reducing the likelihood of other host plants being colonised. At present, the seasonal nature of the poinsettia industry enables complete sterilisation of the glasshouse to be carried out after destruction of any remaining plants at the end of the cropping season ensuring complete eradication of the pest. Future changes in the industry that jeopardise this practice will increase the risk that residual pest populations will be able to colonise alternative host plants.

Populations are unlikely to reach levels capable of causing direct damage, but it is the potential transmission of viruses such as tomato leaf curl and lettuce infectious yellows and the production of physiological disorders such as tomato misripening that represent the main threat to the horticultural industry. It is currently difficult to quantify this threat since biotype B's capacity to transmit viruses is unknown (Gill, 1992) and, in general, geminivirus transmission by *B. tabaci* may be sporadic (Brown, 1991).

It is therefore important that research continues both into pre-transit treatment measures to prevent the introduction of the pest and increasing our knowledge of biotype B's capacity to develop in the UK horticultural environment and transmit economically damaging virus diseases.

Acknowledgements

Thanks are due to the Plant Health and Seeds Inspectorate, colleagues at the Central Science Laboratory and Paul W. Bartlett, in particular, for their assistance in the preparation of this paper. We are also grateful to the Scottish Agriculture and Fisheries Department and the Department of Agriculture Northern Ireland for pest interception data and Oliver Macdonald for use of his methyl bromide fumigation results.

References

Avidov, Z. 1956. Bionomics of the tobacco whitefly (*Bemisia tabaci* Gennad.) in Israel. Ktavim, 7:25-41

Bartlett, P.W. 1992. Experience of polyphagous alien pests of protected crops in Great Britain EPPO Bull 22 (In press).

Berlinger, 1980. A yellow sticky trap for whiteflies: *Trialeurodes vaporariorum* and *Bemisia tabaci* (Aleyrodidae). Entomologia exp.appl.27:98-102.

Bethke, J.A., Paine, T.D. & Nuessly, G.S. 1991. Comparative biology, morphometrics and development of two populations of *Bemisia tabaci* (Homoptera: Aleyrodidae) on cotton and poinsettia. Ann. ent. Soc. Am. 84: 407-411.

Broadbent, A.B., Footit, R.G. & Murphy, G.D., 1989. Sweet potato whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), a potential insect pest in Canada. Can.Ent. 121: 1027-1028.

Brown, J.K. 1991. An update on the whitefly-transmitted geminiviruses in the Americas and the Caribbean Basin. FAO Plant Prot. Bull. 39: 5-23.

Butler, G.D., Henneberry, T.J. & Clayton, T.E. 1983. *Bemisia tabaci* (Homoptera: Aleyrodidae): development, oviposition and longevity in relation to temperature. Ann. ent. Soc. Am. 76:310-313.

Cheek, S. 1992. Keep the superbugs off our poinsettias. Grower, 118 (5): 20-22.

Cohen, S., Duffus, H.E. & Liu, H.Y., 1992. A new *Bemisia tabaci* biotype in the south-western United States and its role in silverleaf of squash and transmission of lettuce infectious yellows virus. Phytopathology, 82 (1): 86-90.

Costa, H.S., Brown, J.K. & Byrne, D.N. 1991. Host plant selection by the whitefly, *Bemisia tabaci* (Gennadius), (Hom., Aleyrodidae) under greenhouse conditions. J. appl. Ent. 112: 146-152.

Duffus, J.E. & Flock, R.A. 1982. Whitefly-transmitted disease complex of the desert Southwest. Calif. Agric. 26 (11/12):4-6.

FAO. 1987. Agroclimatological data for Asia. Volume 2. FAO Plant Production and Protection Series No. 25. FAO. Rome.

Fransen, J.J. 1990. Development of *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) on poinsettia and other pot plants grown under glass. Bull. SROP/WPRS, 13:61-63.

Gill, R.J. 1992. A review of the sweet potato whitefly in southern California. Pan-Pacific Ent. 68:144-152/

Hamrick, D. 1987. Research update. Grower Talks, 31;94.

Greathead, A.H., 1986. Host plants. In: Cock, M.H.W. (Ed.). *Bemisia tabaci* - a literature survey on the cotton whitefly with an annotated bibliography. CABI, FAO.

Meteorological Office. 1972. Tables of temperature, relative humidity, precipitation and sunshine for the world. Part III. Europe and the Azores. HMSO. London.

Meteorological Office. 1980. Tables of temperature, relative humidity, precipitation and sunshine for the world. Part I. North America and Greenland. HMSO. London.

Özgür, A.F., Sekeroglu, E., Ohnesorge, B & Göçmen, H. 1989. Studies on the population dynamics of *Bemisia tabaci* genn. (Homopt., Aleyrodidae) in Çukorova, Turkey, J. appl. Ent. 107; 217-227.

Perring, T.M., Cooper, A., Kazmer, D.J., Shields, C. & Shields, J. 1991. New strain of sweet potato whitefly invades California vegetables. Calif. Agric. 45(6):10-12.

Sutherst, R.W. & Maywald, G.F. 1985. A computerised system for matching climates in ecology. Agric. Ecosys. Environ. 13:281-299.

Stanley, D. 1991. Whitefly causes bleak times for growers. Agricultural Research, 39(1): 16-17.

Trehan, K.N. 1944. Further notes on the bionomics of *Bemisia gossypiperda* M & L, the white-fly of cotton in the Punjab. Indian J. agric. Sci. 14:53-63.

Uygun, N. & Özgür, F. 1980. [Identification of pests of glasshouse vegetables in the Idel and Adana Regions and the effects of endosulfan smoke tablets and pirimicarb on *Myzus persicae*.] Tirkiye Bitki Koruma Dergisi 4(3): 185-192 (in Turkish).

Zalom, F.G., Natwick, E.T. & Toscano, N.C. 1985. Temperature regulation of *Bemisia tabaci* (Homoptera: Aleyrodidae) populations in Imperial Valley cotton. J.econ. Ent. 78: 61-64.

IPM FOR CYMBIDIUM ORCHIDS IN NEW ZEALAND

N.G. Beck, P. Workman and N. Martin
New Zealand Institute of Crop and Food Research Limited
Mt Albert Research Centre
Private Bag 92169, Auckland, New Zealand

Introduction

In 1990-92, the New Zealand export cut flower industry was worth USD 14 million and is predicted to increase to USD 50 million by the year 2010. Cymbidium orchid exports account for half of this industry and are sold primarily to Japan, where extremely high quality demands include 10-12 perfect blooms per spike of 1 m length or more, and zero tolerance for the presence of or damage by insects or mites. Despite these rigorous demands, growers are rapidly uptaking an Integrated Pest Management (IPM) programme which incudes biological control. The successful targeting of a cut flower crop for IPM is indicative of the changing attitudes of New Zealand growers and the general public, both in terms of problems with increasing resistance in the insect pests and in general awareness of the dangers of indiscriminate pesticide use.

Physical environment

Located in the Southern hemisphere, New Zealand can supply off-season flowers to major markets in the Northern hemisphere. The main Cymbidium growing areas are in the northern half of North Island at a latitude of 34-48° with the majority of the growers centred within 150 km of Auckland. The temperate climate rarely reaches freezing in winter and summer highs average 30°C. The economic advantage of minimal heating and cooling costs is offset by the expense of flying flowers to distant markets.

Pest Problems

Disease problems are minor and generally are prevented through use of environmental and cultural controls, with minimal fungicide applications. Growers use multiple applications of pesticide between June and December to protect flowers from aphids, thrips and lepidoptera. Applications of pesticides may be weekly during peak flowering (Martin and Workman 1988 ab). Choice of pesticides is restricted to those not causing flower damage or leaving a powder deposit. Bumblebees which can pollinate the flowers and cause premature senescence are excluded by screening at all vents. Scale insects are controlled during the non-flowering period. Non-insect pests include spiders, snails (primarily the little bush snail, *Zonitoides arboreus*), and two mites, the mould mite(*Tyrophagus neiswanderi*) and two- spotted mite (TSM) (*Tetranychus urticae*).

TSM has been identified as the key pest in this crop. It is active year-round in orchid houses and its activity increases during the spring, in October and November, when flower picking is peaking. Detection of a single TSM, dead or alive, on an export bloom results in an entire shipment being fumigated by the importers, an expensive process paid for by the growers and which reduces flower quality. TSM is difficult to control with pesticides because it lives on the underside of the more dense foliage. To achieve good control of TSM growers need to apply four or more

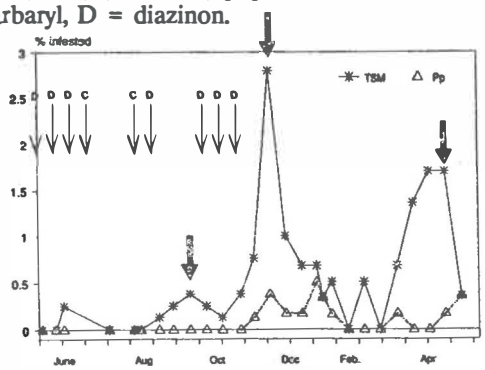
miticides each year at a rate of 0.5 - 1 l of liquid per meter of bench (Martin and Workman 1988a). Growers are restricted in the miticide they can use as several miticides are no longer particularly active against TSM (Georghiou 1981); others can cause phytotoxic damage to the flower or leave a long-lasting and visible residue. We proposed using seasonal innoculative releases of *Phytoseilus persimilis* to reduce TSM populations to non-economic levels.

Threshold and scouting trials.

We developed an IPM programme which revolved around the economic control of TSM by *P. persimilis* and controlled other pests by cultural, environmental, or chemical means (Martin 1987). Early observations indicated that TSM populations moved up into flower spikes only when population numbers on leaves reached a high density. Initial field-station trials in 1984 showed good control of TSM was achieved but more than one release of *P. persimilis* was required per season. All subsequent trials were in commercial Cymbidium houses. A scouting system was designed to monitor populations of both TSM and *P. persimilis* and to determine threshold levels of TSM, timing and quantity of *P. persimilis* introduced. The scouting system was simple so that it could be used by growers. Five young leaves were examined within every two to three metre section of row for TSM and *P. persimilis* and the presence/absence of both TSM and the predator were recorded. Thresholds were dependant upon the crop status: during flowering, the threshold in any one sampling unit was 40% infested, while during non-flowering periods the threshold was 60% infested in any one sampling unit. Other pests were controlled with pesticides (diazinon, carbaryl or pirimicarb) which were compatible with *P. persimilis*.

In a trial from May 1985 through to May 1986, sampling occurred fortnightly. When a colony build-up exceeded the threshold within a sampling area, a small release of *P. persimilis* (approximately 50 mature females) was made in that specific area. From May to October, 9 applications of diazinon or carbaryl were applied for control of insect pests (Figure 1). Three times during this year, small colonies of TSM exceeded the sampling threshold and the predator was released in September, November, and April (Figure 1). TSM populations were never found on more than 2.7% of the leaves sampled, and decreased within a week after introduction of the predator (Figure 1).

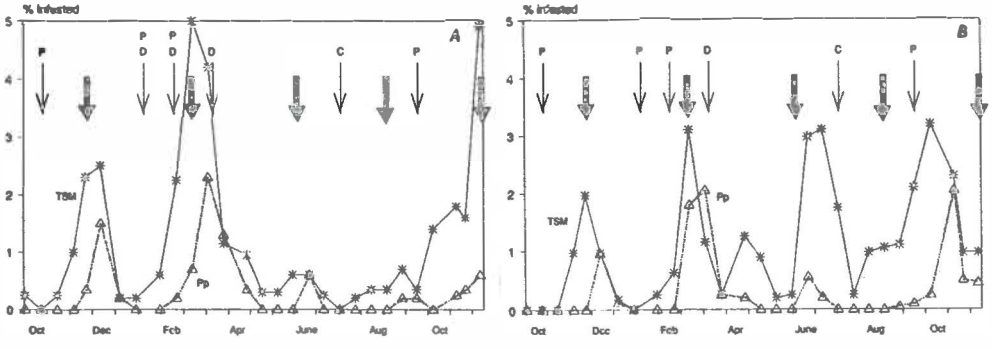
Figure 1. 1985-86. Small localised releases of *P. persimilis* (Pp) were made at location of two-spotted mite (TSM) (*T. urticae*) populations. Dark arrows = *P. persimilis* releases. C = carbaryl, D = diazinon.



This sampling technique involved examining 800 leaves each time and gave much information on population presence, movement, and size, but was very labour intensive and not practical for growers. TSM populations were observed to reach the action threshold approximately every three months.

In a trial from October 1986 through November 1987 in two separate greenhouses on one property, we made releases every three months at the rate of four predators per square meter (Figures 2AB). This corresponded to a minimum of 10 adult *P. persimilis* per sampling area. Timing of the initial release was determined by monitoring. TSM populations started to increase in late November (Figures 2AB). The first *P. persimilis* introduction was made the second week of December. The second calendar introduction coincided with the second population peak and the predator was able to quickly reduce the TSM populations. In one house, TSM populations remained relatively low until the following October when relatively large TSM populations were observed (4.9% of leaves sampled were infested) and the fifth predator introduction was made (Figure 2A). In the other house, TSM populations went through four distinct generations (Figure 2B). The second predator introduction coincided with peak TSM population, and rapidly reduced TSM populations to acceptable levels. The third introduction was made two weeks before TSM populations started to increase (Figure 2B). Both the predator and fenbutatin were applied at this time to reduce TSM populations during this crucial early flowering period. The fourth calendar introduction of the predator was made four weeks prior to TSM population increase (Figure 2B). This house was past peak bloom production at this time and the grower was able to allow some pest build-up while giving the predator time to bring pest populations down to acceptable levels.

Figure 2AB. 1986-87. Calendar releases of *P. persimilis* (Pp) for control of two-spotted mite (TSM) (*T. urticae*). A. TSM populations remained at low density after the initial two releases. B. The latter two releases were made prior to TSM population increases. Dark arrows = *P. persimilis* releases. C = carbaryl, D = diazinon, P = pirimicarb.



The results of these trials indicated that calendar applications of the predator were feasible, but that growers might have to resort to an application of a miticide which is compatible with the predator, as not all the calendar predator introductions would be made at the most appropriate time. However, timing of the first introduction of the predator is crucial, and does require some scouting for pest infestations.

Cymbidium orchid IPM programme.

At the present time, 9% of the 24 hectares of export Cymbidium orchids grown in New Zealand are using biological control. Most growers do not scout and rely on calendar introductions of the predator mite and occasionally supplement its control of TSM with compatible miticides. Of the growers who do scout, most do a cursory examination of "indicator" plants, those cultivars which are most susceptible to TSM. In addition, some growers who use the predator during the non-flowering period rely on chemical control only during the crucial flowering period. We supply growers with a detailed manual which gives control options for all the pests, including cultural, environmental, biological, and chemical techniques. Our grower base is expanding as more Cymbidium growers see the benefit to reducing their pesticide use by means of non-chemical techniques such as environmental controls and biological control agents despite the higher cost of using *P. persimilis* as compared to conventional miticides (Martin and Workman 1988b).

References

Georghiou, G. P. 1981. The occurrence of resistance to pesticides in arthropods, an index of cases reported through 1980. FAO of UN, Rome 1981. 172 pp.

Martin, N. A. 1987. Progress towards integrated pest management for greenhouse crops in New Zealand, pp. 111-115. *In* B. Nedstam, L. Stengard Hansen and J. C. van Lenteren (eds.), Combined working groups integrated control in glasshouses, EPRS/WBRS, Budapest, Hungary 26-30 April 1987.

Martin, N. A. and P. Workman. 1988a. Cymbidium Orchids - A Survey of Pest and Disease Control. *DSIR Entomology Division Report No. 9*, 32p.

Martin, N. A. and P. Workman. 1988b. The cost of integrated pest management for Cymbidium orchids. *Proc. 41st N. Z. Weed and Pest Control. Conf: 77-80.*

NURSERY VISITS DURING THE WORKSHOP

J.A. Bennison
ADAS, Chequers Court, Huntingdon, Cambs PE18 6LT, UK

Summary

Delegates of the IOBC workshop visited a pot plant nursery where IPM was demonstrated on Cyclamen and Poinsettia. A visit was also made to a cucumber nursery where an ADAS trial was demonstrated, using open rearing systems for improving aphid control by natural enemies.

1. Northfield Nursery, Chingford, Essex

The grower, David Harker, demonstrated his use of IPM on Cyclamen and Poinsettia:-

Cyclamen

Thrips: Western flower thrips were being successfully controlled by *Amblyseius cucumeris*, applied in bran at 50 /m²/week. No thrips damage was occurring to the flowers, despite blue sticky traps indicating the presence of adult *Frankliniella occidentalis*. Weekly counts of thrips on the traps between late July and early September had ranged between five and 30 per trap per week, with an average of 15.

Aphids: *Aphis gossypii* were being introduced by naturally occurring *Aphidius* spp. and by *Aphidoletes aphidimyza*, introduced at 1/m²/week. One fumigation of nicotine had been necessary to control an increase in aphids in early September, thereafter natural enemies maintained control.

Vine weevil: After the IOBC visit in late September, an infestation of vine weevil larvae was rapidly controlled by *Heterorhabditis* sp. nematodes. A preventive treatment of nematodes had not been applied, as the pest had not previously occurred on the nursery.

Poinsettia

Whitefly: As on many other nurseries in the UK, *Bemisia tabaci* had been imported on the cuttings. This pest is still a notifiable pest in the UK and the nursery was following the statutory eradication programme stipulated by the MAFF Plant Health and Seeds Inspectorate (PHSI). The schedule allowed the use of IPM so long as the programme was monitored by PHSI and ADAS. Aldicarb had been applied after potting, followed by *Encarsia formosa* at one per plant per week. Three applications of teflubenzuron were integrated into the control programme. At the time of the visit by IOBC delegates, small numbers of *B. tabaci* scales were evident on the plants, but the infestation was controlled by the end of the season. No parasitised whitefly scales were observed at any time; it was suspected that control by *E. formosa* was mainly by stinging the young scales.

In addition to the Cyclamen and Poinsettia crops, David Harker had used IPM successfully on a range of pot plant species earlier in the season. These included Geranium, Fuchsia, Marguerite, Impatiens and Begonia. This was the first year IPM had been used on the nursery and pests had been controlled more successfully than with the pesticide programmes previously used. With ADAS guidance, the grower and staff gained experience and confidence during the first year of IPM and next season, the use of IPM will be extended to a wider range of crops.

2. DTN Stubbins Nursery, Waltham Abbey, Essex

The grower, Sam Difrancesco, demonstrated successful biological control of *Aphis gossypii* by natural enemies, in an ADAS trial using open rearing systems. Cereal plants infested with *Rhopalosiphum padi* had been introduced at planting and used as open rearing systems for *Aphidius colemani* and *Aphidoletes aphidimyza*. Excellent control of *A. gossypii* was seen, with over 90% parasitism by *A. colemani*. The system demonstrated effective and economic biological control of aphids and has potential for use in sweet peppers and ornamental crops. Further details will be published in the IOBC Bulletin for the meeting of the Working Group "Integrated Control in Glasshouses", to be held in California, April 1993.

THE DEVELOPMENT OF AN IPM PROGRAMME FOR GREENHOUSE CROPS IN ISRAEL

Berlinger M.J.[1], Sarah Lebiush Mordechi[1], Dvora Fridja[1]
Raisa Chyzik[2], M. Klein[2], Y. Ben Dov[2], Y. Aharon[3]

[1]Entomology Laboratory, ARO, Gilat Regional Experimental Station, Mobile Post Negev 85-280, Israel
[2]Department of Entomology, ARO, The Volcani Center, Bet Dagan 50-250, Israel
[3]Besor Experimental Farm, ARO, Mobile Post Negev 85-400, Israel

Summary

Different screens aimed at the minimising of pest immigration were tested. In experiments conducted in high, walk-in screened tunnels, the immigrant populations of whiteflies, western flower thrips, serpentine leaf miner flies and aphids were significantly lower than outdoors and in most cases it was below the acceptable economic damage threshold. Preliminary results showed that the indoor pest populations must be controlled and this can be done in most cases by parasitoids or predators. However, against the other pests "safe" insecticides must be tested and integrated into this IPM system.

Introduction

In Israel flowers and vegetables are grown year round; outdoors in the summer and in greenhouses in the winter. When the outdoor crops are harvested at the end of the summer, the pests which have developed on them take off in search of new host plants, they penetrate into the greenhouses and attack the newly planted crops (Berlinger *et al* 1983). Most of the greenhouses are unheated and in these cases pest activity decreases during the cold winter months and increases again in March-April. Control measures are aimed accordingly, ie., in the autumn against the immigrating pests and the primary transmission of viruses, and in the spring against the pests which survived the winter and have started to build up an indoor population (Berlinger *et al* 1988).

The main greenhouse pests are the tobacco whitefly (*Bemisia tabaci*), the western flower thrips (*Frankliniella occidentalis*), the serpentine leaf miner (*Liriomyza trifolii*), aphids, red spider mites (*Tetranychus cinnabarinus*) and the russet mite (*Aculops lycopersici*) (Berlinger *et al* 1983).

Growers invest much time and money in controlling these pests and their success rate is usually poor. Covering the plants with Agryl® P17, an unwoven polypropylene sheet, was found to be very effective in preventing pests from immigrating into the greenhouses (Berlinger *et al* 1988). However, the high temperatures, which developed under this coverage, damaged the plants (Rilski *et al* 1984) and it was therefore necessary to test alternative coverings in order to allow maximum ventilation while minimising the penetration of pests. The use of woven screens of about 50 x 25 threads/inch, is a good mechanical control method which prevents pest penetration (Zipori *et al* 1988). Outdoor laboratory experiments, performed by stretching screen pieces over traps, made of plastic Petri dishes (9.5 cm) showed that in addition to the mesh, the colour of the screen plays an important role.

The purpose of this study was to test the possibilities of applying IPM systems for greenhouse crops through the use of mechanical control by screening together with

complementary control measures, biological control agents and specific insecticides when needed.

Materials and Methods

The treatments: (i) a white woven screen, 25 x 50 threads/inch; (ii) a white woven screen, 28 x 58 threads/inch; (iii) a gray woven screen, 25 x 54 threads/inch; (iv) loosely interlaced, 33% ventilation, aluminium coloured; (v) a white woven screen, 14 x 16 threads/inch; (vi) uncovered control.

The walk-in tunnels were 6.5 m wide, 2.5 m high at their peak, and 6 m long. Half the area was planted with Ageratum flowers especially aimed at assessing thrips, and the other half was planted with tomatoes, especially aimed at assessing whiteflies and their damage. Leafminers and spider mites were easily assessed on both crops.

The results were evaluated as follows (i) for *B. tabaci* by trapping and by assessing the number of virus infected tomato plants; (ii) for *T. occidentalis* by direct counting, and by extracting them from flower samples by a modified Berlees funnel; (iii) for adult *L. trifolii* and aphids by trapping; (iv) for *L. trifolii* larvae and for *T. cinnabarinus* by estimating their numbers per leaf.

The experiments were performed in two time phases according to the appearance of the pests. In each phase the suitable tests were performed; (i) in autumn the penetration of the pests through the screens and the damage caused by them, was studied; (ii) in spring various control measures were tested, ie., the use of biological control agents and the use of specific insecticides which can be integrated with biocontrol systems.

Results

1. First phase : October - December

Whiteflies - In the tunnels covered by one of the three woven, high density screens (i, ii, iii) the whitefly penetration and the primary virus spread were very low, ie., below the accepted economic threshold. No complementary control measures were necessary. The differences in the number of trapped whiteflies under these three screens were slight and insignificant. Under the low density screens (iv, v) the numbers of trapped whiteflies was too high. Even spraying with pyrethroids twice a week was insufficient in preventing economic damage.

Thrips - the number of thrips found under the three woven screens of high density (i, ii, iii) was 50% lower compared with their number outdoors although when tested in the laboratory the thrips penetrated through these screens. Under the loosely interlaced aluminium screen (iv) the thrips number was also reduced by 50%. It seems that in the field there are additional factors influencing thrips penetration behaviour.

Leafminer flies - Leafminer flies were practically only found under the loose white 14 x 16 woven screen (v) in even higher numbers than outdoors. Their appearance was soon followed by naturally occurring parasites, and by the end of this time phase leafminers were no longer found. Their population also did not recover in the following spring.

Spider mites - Spider mites did not appear during this time phase, neither in the screened tunnels nor in the uncovered treatment (Berlinger *et al* 1989).

2. Second phase: April - June

With the increasing temperatures "indoor populations" of similar densities built up under different screens. Accordingly, pest control trials could be performed independently of the type of screen.

Western flower thrips - Larvae of the predatory bug *Orius laevigatus* (Heteroptera: Anthocoridae) were released on the Ageratum flowers in mid April. The thrips population continued to increase for another month and peaked up to 37.3/sample. From that time on the thrips population decreased and in the beginning of July only 3.1/sample were found, compared with 3.3 bugs/sample. In the control plots the thrips population levelled up to 320/sample two months after the start of the experiment.

Red spider mites - The introduction of the predatory mite *Phytoseiulus persimilis*, reduced the red spider mite population. The predators were very active and spread out also into the control plots (Berlinger *et al* 1989).

Whiteflies, red spider mites and russet mites - Recently the parasitoid *Encarsia transvena* was received from Prof. D. Gerling (Tel Aviv University) but its introduction was too late in the season to evaluate its effectivity.

Spraying at high volume "Virol", a light summer oil, by means of a motorised back pack sprayer, controlled whitefly larvae, the russet mite and the red spider mites after a few repeated applications to a good extent, but the predatory mite, *Phytoseiulus persimilis* also disappeared from the sprayed plots.

In conclusion

Screening the greenhouses with a suitable screen to minimise primary pest immigration, is the basis for any IPM programme. However, some pest specimens succeed somehow to penetrate, despite all precautions and complimentary control measures must be applied to combat them. The herewith presented first results are very promising. Now the IPM system must be studied as a unity.

References

Berlinger, M.J., 1980. A yellow sticky trap for whiteflies; *Trialeurodes vaporariorum* and *Bemisia tabaci* (Aleurodidae). Ent. exp. & appl. 27:98-102.

Berlinger, M.J., Dahan, R. 1989. The importance of plant resistance in the epidemiology of whitefly-borne viruses, and the development of screening methods. pp. 239-248 in: S.K. Green (Ed.) Tomato and Pepper Production in the Tropics. International Symp. on Integrated Management Practices, AVRDC, Tainan, Taiwan.

Berlinger, M.J., Dahan, R., Cohen, S. 1983. Greenhouse tomato pests and their control in Israel. Bull. IOBC/WPRS 1983/VI/3: 7-11.

Berlinger, M.J., Dahan, R., Mordechi, S. 1988. Integrated pest management of organically grown greenhouse tomatoes in Israel. Applied Agric. Res. 3: 233-238.

Berlinger, M.J., Dahan, R., Mordechi, S., van Dijk, B. 1989. A suggested method to improve the biocontrol of red spider mites in greenhouse tomatoes by using indicator plants. pp. 117-128. in: R. Cavalloro, C. Pelerents, Integrated Pest Management in Protected Vegetable Crops. Proc. CEC/IOBC group meeting/Cabrils, 27-29 May, 1987. A.A. Balkema/Rotterdam/Brookfield/1989.

Rilski Irit, Berlinger, M.H., Dahan, R, Spiegelman, M. 1984. The effect of plastic covering and of removing one or two clusters, on the yield of glasshouse tomatoes. Hassadeh 64: 2008-2010 (in Hebrew with English abstract.

Zipori, I., Berlinger, M J., Dayan, E., Dahan, R., Shmuel, D., Mordechi, Sara, Aharon, Y., 1988. Integrated control of *Bemisia tabaci* in greenhouse tomatoes planted early in the season. Hassadeh 68: 1710-1713 (in Hebrew with English abstract.

LUTTE BIOLIGIQUE CONTRE LE THRIPS *FRANKLINIELLA OCCIDENTALIS* PERG. EN CULTURE DE ROSIER SOUS SERRE

F. Bertaux
Ministère de l'Agriculture - Service de la Protection des Végétaux - Groupement Régional d'Intérêt Scientifique et Phytosanitaire - 06606 Antibes

SUMMARY

Western Flower Thrips is one of the most important pests on roses in greenhouses. We have tried to use two species of *Orius* to control it. A first test in field was unsuccessful perhaps because of residues from pesticides. The second, in the laboratory, showed that *Orius laevigatus* could lay its eggs in the tissues of roses even in the presence of pelargonium where it was bred. But further studies must be done; and biological control will be very hard to manage on rose because of the nuisance of WFT even at low density and of the great difficulty to control other pathogens without pesticides.

RESUME

Le Thrips californien est l'un des plus importants ravageurs du rosier sous serre. Nous avons essayé d'utiliser 2 espèces de punaises du genre *Orius* pour le contrôler. Un premier essai en culture a été un échec peut-être à cause de résidus de pesticides. Le deuxième, en laboratoire, a montré que l'espèce *Orius laevigatus* pouvait pondre ses oeufs dans les tissus du rosier même en présence de *Pélargonium* sur lequel elle a été élevée. Mais les études doivent être poursuivies; et un contrôle biologique sera très difficile à cause d'une nuisibilité du Thrips même à faible densité et des grandes difficultés à contrôler les autres pathogènes sans pesticides.

INTRODUCTION

Le rosier est la plus importante culture ornementale sous serre en France. Jusqu'à ces dernières années, les principaux pathogènes de cette plante étaient bien contrôlés par des traitments chimiques, des techniques culturales (brumisation contre les acariens ou l'oïdium) et des choix variétaux (résistance ou tolérance à l'oïdium). Mais l'introduction en 1987 due Thrips californien *Frankliniella occidentalis* a bouleversé cet équilibre. En effect cet insecte s'est avéré particulièrement difficile à détruire du fait de sa biologie et de sa résistance partielle ou totale à de très nombreux insecticides (Immaraju *et al*, 1992). Les horticulteurs ont dû multiplier les traitements avec des produits souvent très toxiques, et, cependant, une moins bonne efficacité des certaines matières actives a semblé déjà apparaître.

Des études ont été entreprises pour développer une lutte biologique d'abord en cultures légumières avec des acariens prédateurs due genre *Amblyseius* puis des punaises due genre *Orius* dont les potentialités biologiques paraissaient plus élevées.

Des essais ont déjà été effectués sur concombre, fraise et poivron avec plusieurs espèces d'*Orius*: les travaux sont encore en cours et ont permis de préciser l'intérêt et les limites de cette lutte (Fischer *et al*, 1992).

Le but de notre travail a été de voir dans quelle mesure cette lutte était possible en culture de rosier sous serre tout en maîtrisant les autres pathogènes.

Nous présenterons l'étude que nous avons menée sous serre puis les résultats obtenus en labortoire.

I. ESSAI DE LUTTE SOUS SERRE:

Matériel et méthode:

L'essai a été entrepris sur une culture de rosier des plus de 10 ans en pleine terre, variété Sonia, dans une serre de 500 m², d'avril à juillet 1991. La conduite de taille était en continu pour disposer de fleurs pendant toute cette période.

Les traitements chimiques ont été réduits au minimum et complètement stoppés 1 mois avant le lâcher des *Orius* jusqu'à 1 mois après.

Plusieurs méthodes autres que chimiques ont été utilisées pour contrôler les différents pathogènes:

- des bassinages fréquents pour limiter le développement des acariens et de l'oïdium.
- des lâchers d'auxiliares: *Aphelinus abdominalis* contre les pucerons et *Phytoseiulus persimilis* contre les acariens.

Les comptages

Toutes les semaines, d'avril à juillet, des prélèvements de roses sont effectués dans la serre pour évaluer la population de thrips. Les fleurs sont cueillies au stade floraison; on prend deux fois dix fleurs correspondant aux deux moitiés de la serre. Elles sont aussitôt placées dans 2 berlèses (voir schéma).

Les Thrips sont dénombrés en distinguant les espèces ainsi que les larves, les mâles et femelles de *Frankliniella occidentalis*.

Lâchers d'*Orius*

Le lâcher a lieu le 14 mai. Ils proviennent d'un élevage de l'Inra d'Antibes (M. Millot).

Deux espèces sont utilisées:

Orius laevigatus : environ 2000 adultes lâchés dans les deux tiers de la serre.
Orius majusculus ; environ 1000 adultes lâchés dans le tier de la serre.

Un deuxième lâchér est fait le 3 juillet avec respectivement 1600 *Orius majusculus* et 1000 *Orius laevigatus*.

Les environ lâchérs ont été effectués tôt le matin sur les fleurs par petits foyers d'environ 100 individus à chaque fois.

Calendrier des interventions

LUTTE CHIMIQUE			LUTTE BIOLOGIQUE		
Date	Matière active	Pathogène	Date	Auxiliaire	Ennemi
23/03	Myclobutanil	Oïdium			
28/03	Pirimicarbe Pyriféno x	Pucerons Oïdium			
			3/04	Phytoseiulus-1 persimilis	Tétranyques
			5/04	Aphelinus abdominalis	Pucerons
11/04	Myclobutanil Dichlorvos	Oïdium Thrips Pucerons			
			16/04	Phytoseiulus-2 persimilis	Tétranyques
			30/04	Phytoseiulus-3 persimilis	Tétranyques
			9/05	Phytoseiulus-4 persimilis	Tétranyques
			14/05	Orius sp	Thrips
			16/05	Phytoseiulus-5 persimilis	Tétranyques
18/06 19/06 25/06 26/06	Pirimicarbe Cyhexatin Hepténophos Cyhexatin	Pucerons Acariens Pucerons Acariens			
			3/07	Orius sp.	Thrips

Résultat:-

Evolution des pathogènes

Oïdium: 3 traitements chimiques rapprochés avaient été effectués avant la mise en place de l'essai (myclobutanil, pyriféno x, myclobutanil).
Cependant, malgré des bassinages réguliers il apparaît et se propage rapidement à toute la serre fin mai.

Acariens: Les premiers foyers sont décelés dèclés dès le début avril. Un premier lâcher de *Phytoseiulus persimilis* est pratiqué assitôt; 4 autres suivront jusqu'en mai. Cependant cet auxiliare va s'installer très difficilement et très tardivement et les acariens vont se développer considérablement jusqu'à la fin de l'essai en provoquant des chutes importantes de feuilles et un blocage de la végétation malgré, aussi, les bassinages.

Pucerons: De fortes attaque sur jeunes pousses apparaissent début avril, près de l'entrée de la serre. Le lâcher d'*Aphelinus abdominalis* semble un échec et un traitement au dichlorvos doit être fait le 11 avril.

Ils disparaissent ensuite complètement. Ils se développent à nouveau en juin; un traitement au pyrimicarbe n'a pas d'effet et est suivi d'un traitement réussi à l'hepténophos le 25 juin.

Thrips: Les prélèvements hebdomadaires par berlèses montrent:

- la présence d'une seule espèce de thrips: *Frankliniella occidentalis.*
- une composition assez constante des populations avec une majorité d'adultes et de femelles, les mâles étant toujours présents mais en moyenne deux fois moins nombreux que les femelles.
- une croissance régulière et de plus en plus rapide des populations: 3 en moyenne par fleur le 4 avril; 7 le 7 mai; 10 le 4 juin et 85 le 25 juin.
- aucun *Orius* n'est trouvé dans les berlèses. Des visites régulières et des inspections minutieuses des fleurs en culture ont cependant permis de déceler la présence de quelques rares adults au niveau des zones de lâchers pendant 1 semaine après celui-ci. On ne retrouve plus ensuite ni adultes, ni larves.

EVOLUTION DES POPULATIONS DE THRIPS *FRANKLINIELLA OCCIDENTALIS* (Résultats des prélèvements de berlèses)

	COTE DROIT (10 fleurs)			COTE GAUCHE (10 fleurs)					Total Genera l	Moyenne /10 fleurs
Date de Prel.	Total Thrips	Femelles	Males	Larves	Total Thrips	Femelles	Males	Larves		
04/4	46	30	13	3	21	8	12	1	67	33,5
10/4	44	8	24	11	-	-	-	-	-	44,0
17/4	8	4	2	2	-	-	-	-	-	8,0
23/4	14	-	-	-	-	-	-	-	-	14,0
30/4	73	37		35	-	-	-	-	-	73,0
07/5	62	29	9	24	77	13	16	48	139	69,5
16/5	72	13	6	53	131	31	25	75	203	101,5
04/6	-	-	-	-	104	72	28	4	-	104,0
10/6	141	111	23	7	185	150	23	12	326	163,0
18/6	730	628	60	36	750	654	57	27	1480	740,0
25/6	905	636	219	50	807	530	210	67	1712	856,0
02/7	576	460	102	13	844	653	180	11	1420	710,0
09/07	1244	910	310	22	1305	930	350	25	2549	1274,5
16/7	1603	1233	380	90	2198	1562	556	80	3801	1900,0

Conclusion de l'essai sous serre:

L'utilisation des 2 espèces d'*Orius* pour lutter contre *Frankliniella occidentalis* sur la culture de rosier sous serre s'est avérée un échec. Il en reste à en déterminer la cause. En particulier il est intéressant pour l'avenir de cette lutte de savoir si c'est la plante cultivée, en l'occurence le rosier, qui ne convient pas pour le développement des *Orius* ou si ce sont les conditions culturales (résidus de pesticides par exemple) ou environnementales qui n'ont pas permis l'installation des *Orius*.
C'est l'objet de la deuxième partie de cette étude.

II OBSERVATIONS DES PONTES D'*Orius* SUR ROSIER

Cette étude a eu pour but de déterminer si le rosier es un bon support de ponte pour les *Orius*; s'il l'est, quelle est la partie de végétal qu'il préfère.

Matériel et méthode:
On dispose d'un élevage d'*Orius laevigatus* (M. Millot-Inra Antibes) élevé sur Pélargonium et se nourrissant d'oeufs d'*Ephestia kühniella* selon la technique décrite par Alauzet *et al*, 1990. Nous avons préparé 8 boîtes à l'intérieur desquelles nous avons disposé différentes parties du rosier associées ou non avec des feuilles de pélargonium:

1 ere boîte : pousses de rosier
2 eme boîte : fleurs de rosier
3 eme boîte : boutons de rosier
4 eme boîte : feuilles agées de rosier
5 eme boîte : feuilles de pélargonium
6 eme boîte : feuilles de pélargonium + boutons de rosier
7 eme boîte : feuilles de pélargonium + fleurs de rosier
8 eme boîte : feuilles de pélargonium + pousses de rosier

Dans chaque boite on dépose 30 *Orius* adultes: 10 mâles et 20 femelles ainsi que des oeufs d'*Ephestia*. La température est maintenue à 25°C. Tous les 3 jours, les fragments végétaux sont enlevés et les oeufs pondus à l'intérieur des tissus sont comptés.

Resultats:
POINTS D'*ORIUS LAEVIGATUS*
(Nombre d'oeufs comptés)

BOITES	1er comptage TO+2j	2eme comptage TO+6j	3eme comptage TO+9j	4eme comptage TO+13J	TOTAL	% du Pélargonium
ROSIER Pousses	27	69	72	63	231	30
ROSIER Fleurs	16	69	106	75	366	47
épanouies	14	165	86	30	295	38
- sépales	2	4	20	45	71	9
-pétales						
ROSIER Boutons	14	124	111	137	388	50
- sépales	12	108	79	114	315	40
- pétales	2	16	32	23	73	10
ROSIER Feuilles agées	39	16	11	14	80	10
PELARGONIUM	110	200	211	255	776	100
PELARGONIUM	28	220	121	122	491	63
+						
ROSIER Boutons	6	0	11	20	37	5
TOTAL	34	220	132	142	528	68
PELARGONIUM	35	147	129	82	393	51
+						
ROSIER Fleurs	1	64	10	6	81	10
épanouies						
TOTAL	36	211	139	88	474	61
PELARGONIUM	79	123	151	135	458	59
+						
ROSIER Pousses	15	72	35	23	145	19
TOTAL	64	195	186	158	603	78

On constate que le maxium d'oeufs dénombrés au bout de 13 jours correspond à la boïte contenant les feuilles de pélargonium; ce qui paraît logique car les *orius* ont été élevés sur ce même support végétal. Les pontes sont réduites de moitié sur les fleurs de rosier et sont localisées à la face inférieure des sépales, ainsi que sur les boutons. Elles sont plus faibles sur pousses (30%) et très réduites sur vieilles feuilles (10%).

Si les punaises *Orius* ont le choix, on s'aperçoit qu'elles pondent de préférence dans les tissus de pélargonium mais elles pondent cependant aussi en moindre quantité dans les tissus des fleurs et pousses de rosier.

L'éclosion et le développement des larves n'a pu être suivi car nous avons eu une forte mortalité généralisée dès l'éclosion à la suite d'une humidité élevée dans les boîtes et du développement de moisissure.

DISCUSSION - CONCLUSION:

La lutte biologique contre le Thrips *Frankliniella occidentalis* ne semble pas théoriquement impossible en culture de rosier sous serre à l'aide de punaises du genre *Orius*.

En effet le rosier paraît un bon support de ponte pour une espèce au moins. D'autre part sur la Côte d'Azur nous avons rencontré souvent en assez grand nombre ces punaises en été dans des fleurs de rosier en plein air.

L'échec que nous avons constaté pourrait être dû à l'effet répulsif ou toxique des résidus des nombreux pesticides appliqués sur la culture les années précédentes.

Cependant d'autres études devront être effectuées pour confirmer ces premiers résultats.

D'autre part, il sera aussi très difficile de maîtriser les autres pathogènes sans avoir recours aux traitements chimiques bien que des solution biologiques ou culturales existent.

Mais le seuil de nuisibilité du Thrips sur rosier est très bas (environ 5 Thrips par fleur) et les traitements apportent encore une solution satisfaisante. C'est pourquoi la lutte biologique sur rosier sous serre ne semble pas devoir se développer dans l'immédiat. Elle reste cependant une alternative à étudier pour l'avenir.

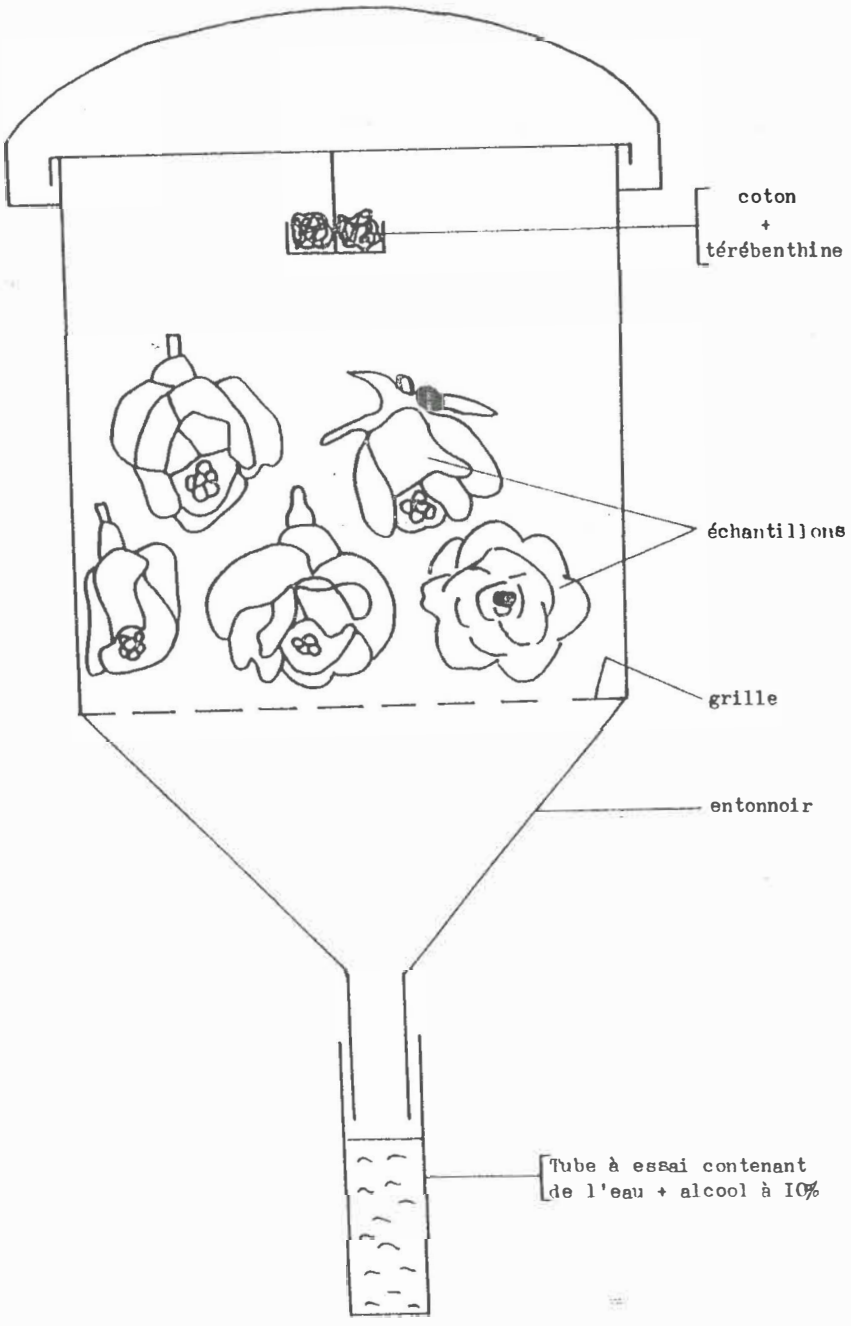
BIBLIOGRAPHIE:

ALAUZET C., BOUYJOU B., DARGAGNON D. et HATTE, M., 1990. Mise au point d'un élevage de masse d'*Orius majusculus* Rt. OILB/SROP Bull XIII (2) 118-122.

FISCHER, S., LINDER, Ch. et FREULER, J., 1992. Biologie et utilisation de la punaise *Orius majusculus* Reuter (Heteroptera, Anthocoridae) dans la lutte contre les Thrips *Frankliniella occidentalis* Perg. et *Thrips tabaci* Lind. en serre Revue suisse Vitic. Arboric. Hortic. Vol. 24/2: 119-127.

IMMARAJU, J., PAINE, T., BETHKE, J., ROBB, K. and NEWMAN, J., 1992. Western Flower thrips (Thysanoptera: thripidae). Resistance to insecticides in coastal California greenhouses. J. Econ., Entomol. 85: 9-14.

BERLESE


coton
+
térébenthine
échantillons
grille
entonnoir
Tube à essai contenant
de l'eau + alcool à 10%

MONITORING THRIPS IN GLASSHOUSE POT PLANT CROPS BY MEANS OF BLUE STICKY TRAPS

HENRIK F. BRØDSGAARD
Department of Pest Management, Research Centre for Plant Protection
Lottenborgvej 2, DK-2800 Lyngby, Denmark

Abstract
In 1988, blue sticky traps were used experimentally for detecting initial attacks and monitoring existing attacks by *Frankliniella occidentalis* in 30 glasshouse nurseries in Denmark. 40% of the growers had not previously found *F. occidentalis* in their nurseries. Out of the 24 cultures that were comprised by the investigation only five minor crops were free of attacks by this thrips during the whole period. The investigation also showed that the variation of catches in the course of the year and within the cultures was very great, but that the largest catches tended to occur in spring. An investigation of the correlation between a visually estimated degree of attack and catches on the blue sticky traps also showed great variation between the cultures. If the size of the thrips population on the plants is to be determined by means of sticky traps only, more information on the importance of the factors which affect the activity of the thrips, i.e. host plant, light influx, temperature, air circulation and the culture is needed. Even though these conditions have not yet been fully described, the blue sticky traps are still a very efficient tool for detecting initial attacks and monitoring population fluctuations.

Introduction

Since 1985, the western flower thrips (*Frankliniella occidentalis*) (Thysanoptera: Thripidae) has proved to be a very troublesome pest in almost all Danish glasshouse crops. This is, partly, due to the fact that this thrips species is very polyphagous (Brødsgaard, 1989a) and, especially, that it is very difficult to control by means of insecticides (Rasmussen & Jakobsen, 1987). Furthermore, the small size of *F. occidentalis* and its thigmotactic behaviour have made it difficult for growers to detect initial attacks and monitor ongoing attacks aimed at implementing more effective control and reduce risk of further spreading. Therefore, development of a monitoring method which helps growers to detect attacks by *F. occidentalis* is needed.

Previous investigations have shown that *F. occidentalis* has very great preference for sticky traps with a very particular blue hue, and that the thrips can be caught on the traps at very low densities in the glasshouses (Brødsgaard, 1989b). This provided the background for conducting two investigations in 1988, with the purpose of testing the efficiency of the blue sticky traps as a monitoring tool for *F. occidentalis*.

Materials and methods

In spring 1988, a large number of sticky traps (Riacryl 257 [Brødsgaard 1989b]) were produced at the Department of Pest Management and sold to interested growers. In each delivery a questionnaire was enclosed which the growers could complete with relevant information (crop species & C.V., prior experience with *F. occidentalis* attacks, pesticide use during three months before the investigation, dates of trap suspending and dismounting) and return together with the used sticky traps, which were then counted for thrips at the Department of Pest Management. On the basis of this information it was hoped to get an idea of the extent of the thrips problem and the usability of the traps in different crops.

Apart from this questionnaire survey, 11 nurseries with a total of six different pot plant crops and with different degrees of infestations with *F. occidentalis* were selected for a trial with the aim of finding a correlation between trap catches and population size of *F. occidentalis* in relation to host plants. The investigation took place over five weeks from week 33 to week 37, incl. In each nursery, two sticky traps were positioned at a distance of five m and five cm above the plants. The traps were changed weekly. On the day the traps were changed a visual assessment of the degree of attack was performed by the inspectors from the Government Plant Protection Service according to the current guidelines. Three degrees of attack were used: severe (S), weak (W) and no (N) attack. Concurrently with the sticky trap investigation the thrips were controlled by means of insecticides, which, normally, means spaying every four to seven days and a rotation between a broad spectrum of pesticides.

Results

A total of 30 growers with 23 different pot plant crops (Table 1) returned 324 sticky traps and the corresponding questionnaires in the period 16 April to 15 November. 60% of the growers had previously had attacks by *F. occidentalis*, whereas 40% had not previously found this thrips species. Most of the traps were suspended for 7 or 14 days and none of the growers, who had previously found

F. occidentalis in the nursery, let the traps hang for more than two weeks. Mean catches (± S.E.) of *F. occidentalis* per sticky trap in nurseries where thrips had previously been found was: 12.08 (± 2.1), and where thrips had not previously been found: 6.31 (± 2.7). There was no significant difference between these catches, however, due to the great variation within the groups.

The following pesticides (pooled in alphabetic order) were used during three months in the 30 nurseries: Afugan, Alar 85, Ambush, Birlane 24EC, Desis, Ekamet, Keltane E30, Lannate 20L, Lindan, Orthene 75SP, Phosdrin, Pirimor, Sumitan, Temik 10G, Thiodan and Vapona.

Figure 1 shows that there were considerable variations between catches in the course of the investigation period both in catches per trap and in the number of returned questionnaires. It can also be seen that the large catches are seen in spring (April-May).

Table 1 shows that only in the crops *Acalpha, Crossandra, Radermachera, Sinningia* and *Spathiphyllum* were no thrips attacks were seen during the investigation period and of these *Acalpha* and *Crossandra* are not recorded as host plants for *F. occidentalis*. It can also be seen that catches in the "cactus", which comprises a number of species, are far higher that those of the other crops. Between these two extremes there is no significant difference ($P > 0.05$) in catches between crops.

Table 2 shows that the variation of catches was considerable, both within the individual degrees of attack between crops and between the different crops within the same degree of attack.

Discussion

The questionnaire survey showed that in almost half the participating nurseries, *F. occidentalis* had never been found. But the growers concern for attacks, leading them to suspend blue sticky traps in the glasshouses, proved to be well-founded as only in 5 small crops of the 24 crops in total *F. occidentalis* was never found during the trial period. The great variation in catches over the period makes an evaluation of the seasonal variation of catches difficult; but there is a marked tendency to larger catches in spring. The reason for this may be that the control measures were intensified when the attacks had been detected on the first traps. This means that a more widespread use of blue sticky traps in order to register the beginning of the attack can make the control effort, both biological and chemical, more effective and result in an overall lower infestation pressure so that injuries on the crops will be avoided.

Only "cactus" deviated from the other crops with a higher daily catch. This does not indicate that the traps are more effective on "cactus" as the data obtained in this culture originates from only one nursery. It is more likely that the infestation pressure in this nursery was higher than in the other nurseries that participated in the investigation.

The efficacy test showed that there was a rather poor correlation between degrees of attack and weekly catch numbers within the individual crops. This may be due to a number of technical factors. First of all, the visual assessments gave a picture of the situation at the moment of assessment and the data were cumulated catches for a whole week. This means that pesticide sprayings were of greater importance for the visual assessment if they were carried out immediately before the visual assessment than if they were carried out earlier in the week. Furthermore, the visual assessment was conducted by different inspectors in different glasshouses, who, although they followed the same guidelines, probably could not make identical assessments. It may also reflect that the distribution of the thrips on the tables often is very aggregated. However, catches did not vary enough between traps suspended in the same week over the same tables at 5 m intervals to explain the entire variation by aggregated thrips distribution.

From the efficacy test it can also be seen that there was a clear difference between crops in catch numbers within the same degree of attack. This means that the same number of thrips on different crops resulted in different gradings of degrees of attack. The grading of a degree of attack is very much dependent on the structure of the plants and their susceptibility to thrips attacks because a visual assessment is influenced by how easily the thrips are detected in the crops. Furthermore, the size of the trap catches does not only depend on population size but also on thrips' activity. The activity is first of all dependent on the air temperature and the light influx, but as the experiments in the different crops were carried out simultaneously, these factors are estimated to be fairly similar. The level of activity also depends on the crop, the thrips being more willing to fly to the traps from

poor host plants than good host plants. Investigations should be performed to find correlations between catches and the actual population sizes on the plants for individual crops.

However, it is clear from the present investigation that, with visual assessments on the present crops, thrips infestations are most easily detected in *Saintpaulia* and with most difficulty in non-flowering *Schlumbergera*. This also is an indication of the very different damage thresholds between different ornamental crops.

The experience gained in 1988 with these trials shows that blue sticky traps is a very effective tool for early registration and monitoring *F. occidentalis* at very low densities. However, many questions still remain unsolved concerning a correlation between trap catches and the actual infestation pressure.

References

Brødsgaard, H.F. (1989a): *Frankliniella occidentalis* (Thysanoptera: Thripidae) - A new pest in Danish glasshouses. Tidsskr. Planteavl **93**: 83-91.

Brødsgaard, H.F. (1989b): Coloured sticky traps for *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in glasshouses, J. appl. ent. **107**: 136-140.

Rasmussen, A.N. & Jakobsen, J. (1987): [Chemical control of the western flower thrips *Frankliniella occidentalis* (Pergande) on *Saintpaulia* and *Gerbera*]. 4th Danish Plant Conference / Pests and diseases: 65-72. (Danish, English summary).

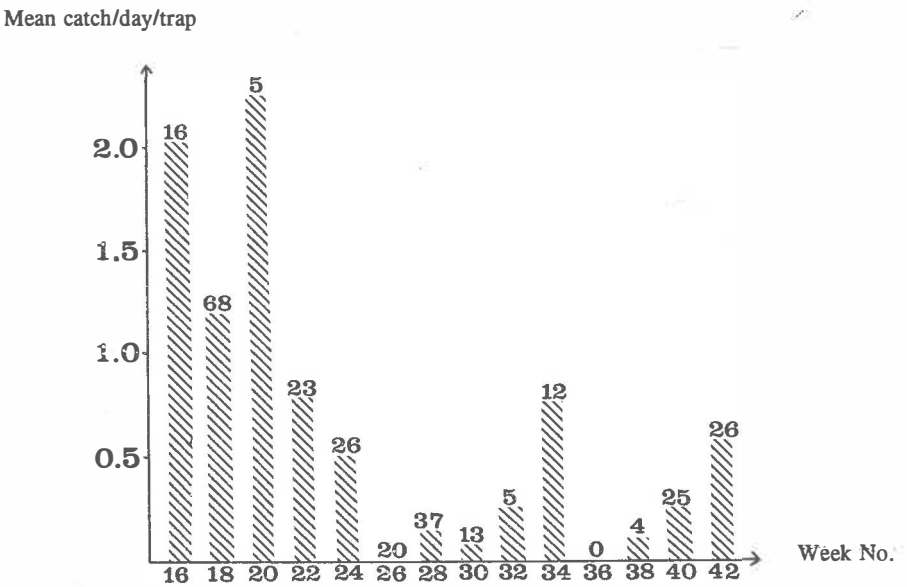


Figure 1. Mean catches per day per trap in the questionnaire survey during the trial period. The figures above the columns indicate the number of traps of the 2-week period in question. (Only part of the returned questionnaires were correctly filled out so that they could be used in this part of the investigation).

Table 1. Mean daily catch of the western flower thrips per trap for each pot plant crop.

Crop	Mean catch	S.E.	min. catch	max catch
Acalpha	0.00	0.00	0.00	0.00
Begonia	0.95	0.37	0.58	1.32
Chrysanthemum	2.26	0.55	0.00	7.08
Crassula	1.50	0.41	0.00	3.50
Crossandra	0.00	0.00	0.00	0.00
Dendranthema	0.37	0.19	0.00	1.20
Ficus	2.93	0.47	2.46	3.40
Fuchsia	3.09	0.95	1,44	5.25
Gerbera	1.47	0.58	0.00	4.93
Hibiscus	0.82	0.65	0.00	16.80
Cactus (misc. species #)	14.11*	7.08	0.50	89.50
Kalanchoë	0.32	0.20	0.00	13.14
Passiflora	3.74	0.18	3.38	4.00
Pelargonium	0.89	0.16	0.40	1.90
Plumbago	0.13	0.04	0.00	0.19
Pumila	0.03	0.02	0.00	0.17
Radermachera	0.00	0.00	0.00	0.00
Rosa	0.37	0.13	0.00	2.31
Saintpaulia	0.01	0.01	0.00	0.07
Scheffelera	0.04	0.04	0.00	0.13
Schlumbergera	0.67	0.25	0.00	7.08
Sinningia	0.00	-	0.00	0.00
Spathiphyllum	0.00	-	0.00	0.00

\# Schlumbergera was not included.

* Mean catches in the "cactus" were significantly higher than catches in the other crops ($P < 0.05$).

Table 2. Correlation between visual assessment of degrees of attack by *F. occidentalis* and weekly catches on sticky traps (S = severe; W = weak; N = no) on different ornamentals.

Crop	Degr. of attack	Mean catch	Max.	Min.	S.D.	S.E.
Cyclamen	S	43.50	43	44	0.71	0.50
Cyclamen	W	19.50	13	28	6.68	3.43
Cyclamen	N	39.71	0	207	72.21	19.30
Dendranthema	S	28.50	22	35	9.19	6.50
Dendranthema	W	34.50	11	53	17.86	8.93
Dendranthema	N	5.75	0	35	8.33	1.70
Saintpaulia	S	1.50	0	3	1.12	1.50
Saintpaulia	W	3.67	0	22	5.96	1.72
Saintpaulia	N	6.37	0	28	6.80	1.70
Capsicum	W	73.50	42	156	43.60	17.80
Schlumbergera	N	24.30	3	72	24.30	6.75
Chrysanthemum	N	3.20	0	6	2.14	0.68

INTEGRATED PEST MANAGEMENT IN AYR CHRYSANTHEMUMS

J H Buxton[1] and R. Finlay[2]

[1]ADAS, Wolverhampton, WV6 8TQ, United Kingdom
[2]HRI, Efford, Lymington, Hants, SO41 0LZ, United Kingdom

ABSTRACT

A range of treatments were tested on 5 plantings of AYR chrysanthemums at HRI Efford. Each treatment was in a separate compartment within the glasshouse and compartments were insect proofed to minimise the spread of mobile insects from one to another.

An 'overlay' of beneficial insects was used in all compartments to control pests such as aphid, leaf miner and spider mite which occurred on the crop.

The first two plantings were artificially infested with Western flower thrips one and three weeks after planting at the rate of 1 adult WFT per 5 plants. WFT spread naturally onto the remaining plantings in each compartment. Effectiveness of treatments was determined by country numbers of thrips on blue sticky traps weekly, by leaf and bud samples taken fortnightly and by flower assessments for thrips and flower quality at harvest. Numbers of WFT tended to increase from planting 1 to planting 5, regardless of treatment. The most effective treatment was *Amblyseius cucumeris* applied in bran at 100/m² every 2 weeks, although even this treatment gave acceptable flower quality for only the first two plantings.

The addition of weekly sprays of Nemolt (teflubenzuron) to *Amblyseius* as above reduced the level of control of WFT, although numbers of *Amblyseius* on the plant were not affected.

Weekly sprays of Nemolt alone had little effect on numbers of WFT.

Orius majusculus predatory bugs were introduced on three occasions to one compartment and appeared to reduce numbers of WFT for at least the first two plantings. After this time control was poor, and very few Orius were found during assessments of leaves, buds and flowers.

It is concluded that, at the level of introductions used, *Amblyseius cucumeris* is reasonable effective on WFT on AYR chrysanthemums, but is unlikely to give commercially acceptable control on its own. Improved control may result by using two biological control agents together, such as *Amblyseius* and predatory bugs. Future work at Efford will investigate this possibility, together with the use of WFT-resistant varieties.

OBJECTIVE

To evaluate *Amblyseius cucumeris*, alone or in combination with teflubenzuron (Nemolt), and also to evaluate *Orius majusculus* for the control of Western Flower Thrips in AYR chrysanthemums.

INTRODUCTION

The AYR chrysanthemum crop is one of the most important flower crops grown in the UK, and as many pests affect it (including thrips, aphids, spider mite and leaf miners) the usage of insecticides is normally high. Control of Western flower thrips, Frankliniella occidentalis, has become very problematical for growers, due to the rapid rate of increase of this pest and its ability to become resistant to many insecticides. (Higgins, 1992). Previous work (Buxton and Wardlow 1991) had shown that a combination of Amblyseius cucumeris and Mycotal could give good control of WFT in the winter period of the crop. In this trial, Amblyseius alone for the control of WFT or in combination with teflubenzuron (Nemolt), an insect growth regulator, was evaluated. Another compartment received no controls for WFT. The predatory bug Orius majusculus was tested in a separate compartment.

MATERIALS AND METHODS

a. Crop culture

Cuttings of the chrysanthemum varieties yellow and white Fresco were rooted in peat blocks under polythene and weaned off under shade netting. This variety was chosen for its resistance to TSWV (tomato spotted wilt virus). Fungicides for control of ray blight and Botrytis (Karamate and Rovral respectively) were applied during this period. Rooted cuttings were planted out in beds 1m wide x 16.2m long, one bed per compartment for each of 5 compartments (approximately 1000 cuttings per bed). This was repeated on 5 separate occasions at 3 week intervals from February to May.1992.

Planting dates were
Bed 1 - 11 February
Bed 2 - 2 March
Bed 3 - 24 March
Bed 4 - 14 April
Bed 5 - 5 May

The glasshouse environment was regulated using a Tomtech Computer to achieve compartment temperatures of 18°C day, venting at 21°C. Relative humidity was monitored, but not controlled. Each bed received two weeks of long days after planting, ten short days to flower. Harvesting was carried out on 6 May, 20 May, 11 June, 8 July and 27 July for plantings 1-5 respectively.

In order to provide a pollen source for the Orius bugs flowering pot plants (chrysanthemum variety Karma) were introduced at two weekly intervals to each compartment, from two weeks post planting to harvest.

b) Artificial infestation with WFT

Adult WFT were introduced to the first 2 plantings at the rate of 1 adult WFT per 5 plants 1 and 3 weeks post planting. It was assumed that WFT would spread naturally onto the remaining 3 plantings in each compartment.

c) 'Overlay' of beneficial insects

The details of the type and rates of beneficials used are shown in Table 1.

Table 1. Methods and rates of introduction of biological agents

Pest	Beneficial		Rate of Introduction
WFT	Amblyseius	mites	100/m² fortnightly distribute evenly
WFT	Orius	bugs	1/m², 2, 4, 6 weeks after planting distribute evenly
Leaf miner	Dacnusa Diglyphus	wasps	1/m² every 3 weeks distribute evenly
Aphids	Aphidus	wasps	1/m² every 3 weeks distribute evenly
Aphids	Aphidoletes	pupae	1/m² every 3 weeks put in vermiculite on capillary matting
Spider-mite	Phytoseiulus	mites	1/m² - distribute evenly

All beneficial insects were checked on arrival, and introductions were made in late afternoon/early evening of day on receipt and numbers distributed as accurately as possible over the crop. In addition, Vertalec sprays were used for control of aphids, one spray weekly for 3 weeks to each compartment at first sign of aphids.

d. Treatments

Compartment 1 — Untreated control - infested with WFT.

Compartment 2 — Amblyseius in bran @ 100/m² at planting and at two week intervals thereafter until colour. (6 applications in all). In addition spray Nemolt weekly from after planting. (8 applications in all, 500 ml per 1000 ltr of water).

Compartment 3 — Amblyseius in bran @ 100/m² at planting and at 2 week intervals thereafter until colour (6 applications in all).

Compartment 4 — Spray Nemolt weekly from 1 to 8 weeks after planting (8 applications in all, 500 ml per 1000 ltr of water, 2000 ltr per hectare).

Compartment 5 — Orius bugs at l/m², 3 introductions at 2, 4 and 6 weeks post planting.

ASSESSMENTS

1. Trap catches

Sticky blue traps (25 x 10cm) were positioned in the centre of each bed, at crop canopy level and counted and changed weekly.

2. Counts of pests and beneficial insects on leaves and flowers

a. 40 leaves/bed sampled at random every 2 weeks from planting.

b. 10 sprays of flowers sampled at harvest - numbers of thrips assessed by tapping (5 times onto white trays).

3. Flower quality assessment

The percentage unmarketable due to WFT was assessed.

Damage caused by other pests noted, eg capsid, at harvest.

RESULTS

Table 2 shows the numbers of adult WFT caught on blue sticky traps (1 per bed, ie 1 trap per 16 m² of crop). the counts are means of the weekly catches for each planting (n=9-12). Catches over 400 thrips per trap were recorded as a maximum of 400.

Table 2. Trap catches

Treatment	Planting Number				
	1	2	3	4	5
Untreated	193	304	338	400	400
Ambly + Nemolt	193	215	304	369	383
Ambly alone	72	166	216	330	352
Nemolt alone	145	223	302	370	387
Orius	81	94	226	327	344

The number of thrips increased rapidly on the untreated beds, reaching a maximum by planting 4. The compartment with Amblyseius at 100/m²/2 weeks had much lower catches of thrips for the first 3 plantings but after this numbers increased almost to the level of untreated beds. Weekly applications of Nemolt appeared to have little effect on thrip numbers, and the combination of Amblyseius and Nemolt was less effective than Amblyseius alone. The Orius compartment gave a similar level of control as Amblyseius alone.

Table 3 shows the counts of WFT (adults and nymphs combined) from 40 leaves per bed.

Table 3. Counts of WFT on leaves

Treatment	Planting Number					
	1	2	3	4	5	Overall Mean
Untreated	14	31.3	51.8	43.4	76.6	43.4
Ambly & Nemolt	18.6	12.0	10.0	40.0	34.2	23.0
Ambly alone	5.2	11.8	7.0	19.4	14.6	11.6
Nemolt alone	16.0	12.3	18.4	34.0	41.8	24.5
Orius	4.2	4.8	16.2	24.6	16.6	13.3
Mean by planting	11.6	14.4	20.7	32.3	36.8	

The leaf counts tended to mirror the trap catches, but numbers of thrips found on the leaves were much lower and never exceeded 2 per leaf even on the untreated beds. Again, Amblyseius alone was the best treatment in terms of reducing thrips numbers, followed by Orius. The reduction in thrips numbers continued moreover for all 5 plantings, unlike the trap catches, which tended to equalise out after planting 3. On the untreated plots severe silvering of the leaves was seen, as well as leaf scarring, which is the most normal type of damage caused by WFT. Visual differences could be seen between treatments, with Amblyseius alone showing much less silvering of the leaves on all plantings.

Table 4 shows the total number of adult and larval thrips extracted by beating the flower heads over a white tray. These counts are critical to the success of any treatment, as direct feeding damage by WFT on the petals leads to downgrading of the flowers. Presumably the number of thrips in flowers also reflects the levels on the crop during the vegetative phase, but WFT is strongly attracted to flowers and the speed of multiplication is increased when thrips have access to pollen (protein) as food as well as a carbohydrate source. (Van Rijn and Sabelis, 1992).

Table 4. Total number of WFT from 10 flower sprays (variety Fresco)

Treatment	Planting Number					
	1	2	3	4	5	Overall Mean
Untreated	268	284	339	239	266	279
Ambly & Nemolt	83	210	243	180	235	190
Ambly alone	84	108	175	176	270	163
Nemolt alone	169	232	382	234	408	285
Orius	90	165	337	96	160	170
Mean per planting	139	200	295	185	268	

The best treatment, Amblyseius alone, reduced the number of thrips per flower head for the first four plantings. After this, numbers of thrips in all treatments increased, leading to subsequent flower damage.

Table 5 shows the result of thrips damage to the flowers. All blooms were graded at harvest as either marketable or unmarketable.

Table 5. Quality of blooms at harvest (% unmarketable)

Treatment	Planting number				
	1	2	3	4	5
Untreated	73	99	100	100	100
Ambly & Nemolt	27	53	100	100	100
Ambly alone	11	29	88	98	99
Nemolt alone	36	60	100	100	100
Orius	9	25	98	99	90

Amblyseius alone, and Orius kept the damage to around 10% for the first planting, but by planting 2 the damage had increased to 25-30% and for later plantings damage was nearly 100%. The severity of the WFT attack on the crop is shown by the data for the untreated beds, where even the first planting had over 70% unmarketable.

Again, the addition of weekly sprays of Nemolt seemed to reduce the effectiveness of Amblyseius, and Nemolt alone had little effect on WFT damage after the first planting.

Counts of Amblyseius from 40 leaves sampled every 2 weeks are shown in Table 6.

Table 6. Amblyseius numbers on the crop

Treatment	Planting Number				
	1	2	3	4	5
Ambly & Nemolt	1.8	0.8	1.6	1.2	0.6
Ambly alone	1.8	0.3	1.0	0.6	1.0

Overall, there was little difference in the number of predators on the crop whether Nemolt was sprayed weekly or not. However, the performance of the predators was obviously affected, as the combined treatment was always inferior to Amblyseius alone in terms of WFT control. It is possible that the physical action of spraying the plant weekly may adversely affect the performance of the predator, without actually reducing the numbers on the crop.

DISCUSSION

The "overlay" of beneficial insects used in all compartments was successful except in the case of Myzus persicae and occasionally Aphis gossypii. Vertalec applications did give some control of these aphids, but not enough, and applications of Nicotine spray were needed on 2 occasions during the trial (25 April and 20 June). In future trials, improvements will be made to aphid control measures, including the use of "banker" plants, higher numbers of Aphidius parasites, and a different method of releases for Aphidoletes midges. No Aphidoletes were seen at any time, which was disappointing considering the number of releases made. Aphidius parasites were reasonably effective, especially against Myzus persicae, and the use of "banker" plants should improve this still further. This would then avoid having to spray Nicotine, which may adversely affect beneficial insects such as Amblyseius. Orius spp. can be effective against WFT in chrysanthemums. Fransen (1992) showed that high rates (approximately 50/m^2) of Orius insidiosis reduced flower damage from about 90% on untreated plots to 20% where Orius was introduced. These rates would be uneconomic in commercial use. However, it is possible that O. insidiosis is a more suitable predator than O. majusculus, which is sensitive to day length and goes readily into diapause at certain times of the year. In this trial, Orius majusculus were carefully placed on the plants in late afternoon, to minimise any dispersal, but were hardly ever recorded in subsequent assessments. It seems likely that Orius did not breed successfully in the compartment used. The use of flowering pot chrysanthemums as a pollen source for the Orius in this trial did not appear to have any great effect; counts of insects on the flowers only occasionally detected Orius. However, thrip counts on leaves, sticky traps and flowers indicated that the Orius predators were having some effect on WFT; indeed this treatment was second only to Amblyseius alone.

Sorensson and Nedstam (1992) evaluated Amblyseius and Orius insidiosus either alone or together for control of WFT on pot plants. They found that the combination of both predators was most effective. Future work at Efford will use the Amblyseius/Orius combination in an attempt to improve the effect on WFT.

Ramakers and Meiracker (1992) pointed out that Amblyseius only attacks the first two larval instars of WFT, whereas Orius and other predatory bugs can successfully attack all stages of WFT, including adult thrips. Moreover, predatory adult bugs can fly and so are more mobile than Amblyseius which can only move between plants when they are touching. However, they also found that Orius spp are only effective at appreciable thrips densities, unless there was also a pollen source available which serves as alternative food. In this trial, the Karma pot chrysanthemum seemed to have very little pollen, and may not therefore have helped Orius numbers to build up. In future work, an alternative plant such as sweet pepper, which produces much pollen, will be used in conjunction with Orius. The effect of Orius and Amblyseius together will also be evaluated: hopefully their effects will be complementary (Ramakers and Meiracker, 1992; Sorennsen and Nedstam, 1992). Amblyseius alone can give good results on chrysanthemum but very high numbers are needed. (Hessein and Parella, 1990).

CONCLUSIONS

1. Amblyseius cucumeris in bran, and to a lesser extent Orius majusculus gave some control of WFT but not at a level which prevented flower damage after the first two plantings.

2. Nemolt (teflubenzuron) was ineffective against WFT even after 8 weekly applications.

3. Application of Nemolt with Amblyseius reduced the predators effectiveness against WFT, although numbers of predators on the crop were not reduced.

ACKNOWLEDGEMENTS

Staff at HRI Efford did most of the assessments and organisation involved in this trial. Koppert B.V. Holland (Dr W Ravensberg) kindly supplied all the beneficial insects. This work was funded by the Ministry of Agriculture, Fisheries and Food.

References

Buxton, J.H. and Wardlow L. (1991). Two years trials work with IPM programmes on AYR chrysanthemums, OEPP/EPPO bulletin. Vol. 22, No. 3, pp 503-510.

Fransen J.J. (1992) Releases of Orius insidiosus against WFT on chrysanthemums. SROP/WPRS Bulletin, September 1992, Cambridge, England.

Guldemond, A. (1992) Preliminary results on density and incidence counts of aphids on cut chrysanthemums SROP/WPRS Bulletin, September 1992, Cambridge, England.

Hessein, N.E. and Parella, M. (1990). Predatory mites help control thrips on floriculture crops. California Agriculture, Nov/Dec, pp 19-21.

Higgins, C.J. (1992) Western flower thrips in greenhouses. Journal Economic Entomology 85, No 5, pp 1891-1903.

Sorensson, A. and Nestam, B (1992). Effect of Amblyseius cucumeris and Orius insidiosus on WFT in ornamentals. SROP/WPRS Bulletin September 1992, Cambridge, England.

Ramackers, P.M.J. and Meiracker, R.A.F. Vanden (1991) Biological control of WFT with predatory mites and pirate bugs: can two do better than one? Focus article, Annual Report 1991, DLO Institute of Plant Protection, Wageningen, Holland, pp 9-21.

THE BIOLOGY AND APPLICATION OF *ANAGRUS ATOMUS* (L.) HALIDAY

S Cooper

English Woodlands Biocontrol, Hoyle, Graffham, Petworth, West Sussex, GU28 0LR England

Summary

English Woodlands Biocontrol has for the past nine months been experimenting with the rearing of the parasite *Anagrus atomus* for the biological control of leafhoppers. The wasp has been used commercially since February 1992 and about 80% of output has been applied to salad crops rather than ornamentals.

The Pest

Several species of leafhopper (*Homoptera: Cicadellidae*) are found as pests on protected crops, the commonest being the glasshouse leafhopper *Hauptidia maroccana* (*Zygina pallidifrons*). Others include sage leafhopper, several species of the genus *Empoasca*, and strawberry leafhopper *Aphrodes bicinctus*. Although they are relatively minor pests they appeared to have increased in prevalence since specific biological controls for commoner pests have been applied, with the consequent reduction in insecticide application. Severe infestations of young long-season tomato plants can do economic and cosmetic damage to the foliage of ornamentals and herbs.

The Parasite

The mymarid wasp *Anagrus atomus* is found naturally in Britain and will invade glasshouses during the summer. It was first described in 1833 by Haliday and the only available paper on its biology seems to be one written in 1934 (MacGill, 1934).

The adult wasp is brown and about 0.6 mm long, wingspan also 0.6 mm. It runs actively on the leaf surface and flies readily when disturbed. Adult females can reproduce parthenogenetically, although males are also found. It appears to reproduce continuously through the year in suitable conditions.

Its eggs are laid, usually singly, in the leafhopper eggs in the leaf veins. The larvae when fully grown reach a length of about 0.7 mm, and the final instar larva and pupa are red, making it easy to see parasitised eggs in the leaf veins. The complete life cycle takes about 16-21 days in temperatures of 18-24°C.

Rearing methods

Anagrus are reared on cultures of *Hauptidia maroccana* bred either on dwarf beans (*Phaseolus*) or on tomatoes. Bean plant tissue is used for distribution to tomato growers for reasons of hygiene, but the leafhopper oviposits more readily on tomato. Attempts to rear *Anagrus* on sage leafhopper have so far been unsuccessful.

Day length does not seem to be critical for either pest or parasite, light/dark cycles ranging from 12/12 to 18/6 have been used. The temperature ranges from 15-28°C,

Initially, on the basis of the only available information, (Copland and Soeprapto) that the parasites were not very effective, pest and parasite were cultured together, but the numbers of leafhoppers declined over four months to levels such that the *Anagrus* harvest of about 500 per week could not be sustained. Separate cultures of leafhopper and parasite have now been set up.

Application in the field

Leaves bearing red parasitised eggs are harvested, packed immediately in damp tissue paper and sealed in polythene bags to prevent desiccation, for distribution by post. The grower is advised to place the leaves in a humid situation, eg., on rockwool blocks or among thick foliage, for two weeks to allow the adult parasites to emerge. The crop is subsequently monitored for the presence of red eggs, which are easy for the grower to recognise. Introduction rates have not yet been determined but as with all short-lived parasites which attack a specific stage of the host's life-cycle, weekly introductions for at least four weeks to achieve establishment are recommended.

The main demand would be likely to be in winter and spring, as natural infestations of *Anagrus* are found in the summer months.

The majority of orders have been from tomato growers, where establishment took place in all sites. Satisfactory control was achieved in about 40% of the area, in the rest high populations of both *Anagrus* and leafhopper resulted. On ornamentals *Anagrus* has been applied to Alstroemeria and to mixed crops with variable results incomplete at the time of writing.

As with *Encarsia* it is likely to be essential to introduce *Anagrus* as early if the life of the crop as possible to achieve satisfactory control. This year growers with the worst leafhopper problems were the most anxious to try the parasite and pest problems at several sites were too severe for the *Anagrus* to overcome completely. In 1993 it is envisaged that introduction will take place from the propagating stage wherever possible.

Future objectives

1. Production needs to be increased, particularly of the leafhopper.
2. Further information on the host species range is needed. English Woodland Biocontrol is keen to liaise with any interested IOBC members.
3. Application rates for different crops and pest species need urgent investigation.

Meanwhile *Anagrus atomus* is an effective biological control for a minor but widespread pest, and can be used throughout the year on a range of vegetable and ornamental crops under glass. The fact that *Anagrus* attacks the eggs of its host, before the nymphs cause feeding marks on the foliage, should make it particularly attractive to growers of ornamental crops.

References

COPLAND, M.J.W. and SOEPRAPTO, W., 1985. Biology of glasshouse leafhopper and its parasite in biological control, the glasshouse experience. Eds. Hussey and Scopes. P.58 et seq.

MacGILL, E.I., 1934. On the biology of *Anagrus atomus*. Parasitology 26: 57-63.

INFLUENCE OF HOST PLANT ON THE BIOCONTROL OF GLASSHOUSE MEALYBUG

M.J.W. Copland, H.A.S. Perera and M. Heidari
Department of Biochemistry and Biological Sciences,
Wye College, University of London, Ashford, Kent, TN25 5AH England

Summary
The main mealybug species and the predators and parasitoids currently available in the UK are described. While temperature and light are very important factors in biocontrol, the host plant determines the growth and fecundity of the mealybug. Host plant also influences parasitoid development and fecundity indirectly through the mealybug host and directly through the suitability of the plant surface for searching behaviour. Even in small cages of mixed plants different degrees of control are achieved on different plant species.

1. Introduction

There are three common mealybug species in temperate glasshouses in the UK. The citrus mealybug Planococcus citri (Risso) has the widest host range and fastest generation time. The obscure mealybug Pseudococcus affinis (Maskell) is a larger species with short tail filaments found commonly on Passiflora, commercial tomatoes, cacti and other ornamentals. The long-tailed mealybug Pseudococcus adonidum (L.) is more restricted in host range to hot-house exotic ornamentals. The first two species produce large characteristic egg masses which are protected from chemical control and allow rapid establishment through the migratory crawler stage (Copland et al., 1985).

We have worked at Wye with three parasitoids and two predatory coccinellids. Leptomastix dactylopii Howard, Leptomastidea abnormis (Girault), Anagyrus pseudococci (Girault) are all encyrtid parasitoids of P. citri. A small percentage of A. pseudcoocci will also develop in P. affinis although many are destroyed by encapsulation. None of these parasitoids will attack P. adonidum. L. dactylopii and A. pseudococci, which attack large mealybugs, require temperatures in the upper 20°Cs while L. abnormis, which attacks young mealybugs, is effective at temperatures in the lower 20°Cs (Copland and Tingle, 1988). Of the coccinellids, Cryptolaemus montrouzieri Mulsant and Nephus reunioni Fursch, are both easy to rear but only C. montrouzieri seems generally effective. Both adults and larvae attack all three species of mealybug but since eggs are laid preferentially into the mealybug ovisacs, control of P. adonidum is erratic.

However, this brief summary presents a too simplistic view of the complexity of the interaction between plant species, mealybugs and their beneficial control agents. While these three species of mealybugs have a wide host range they clearly differ in their ability to develop on different host plants. Peak mealybug populations coincide with periods of new growth, fruiting and flowering and host plant quality seems to be a major factor inducing mealybug outbreaks. Tingle and Copland (1988) showed that control of mealybugs varied greatly on different plants species and during different seasons. Temperature and light have important parts to play in promoting dispersal, feeding and searching efficiency and increasing the rate of egg production and larval development. The best control is achieved during the warm bright days of summer. Low light levels result in poor control during winter months even if temperatures are held high.

2. Approach

We have investigated the role of host plants using four approaches. The first method has been a comparison of mealybug growth on a selection of host plants chosen to represent a range of suitability (Perera & Copland, in press).

The second approach has been to modify host plant nutrition, for instance by varying nitrogen feeding or inducing water stress factors, and then measuring the growth of mealybug and parasitoids. The third technique has been to study the behaviour of beneficials searching on leaf surfaces from different plants (Heidari & Copland, in press). The last approach has been to measure control in cages containing a mixture of different host plants. Some data illustrating these main approaches are shown below.

3. Methods and Results

3.1 Host plant suitability

Host plants were chosen with a range of different physical morphology and secondary chemistry attributes. These were infested with mealybug crawlers and the rate of development, instar size and adult fecundity recorded. Adult mealybugs from these plants were used for parasitism studies by Anagyrus pseudococci. Some typical results are presented in Table 1.

Table 1. Influence of host plant on the mealybug Planococcus citri and its parasitoid Anagyrus pseudococci.

	n	Streptocarpus hybridus mean + s.d.			Aeschynanthus ellipticus mean + s.d.			Glycine max mean + s.d.		
P. citri										
development period (days)	5	53.0	a		39.0	b		35.0	c	
Adult body weight (mg)	80	2.0	a	0.1	1.9	a	0.2	3.5	b	0.09
total fecundity	25	268.8	a	7.9	195.1	a	7.3	474.0	b	11.7
A. pseudococci										
development period (days)	20	16.0	a	0.9	15.9	a	1.1	15.1	b	0.7
% adult emergence (†)	100	58.0	a	15.2	71.0	a	4.2	75.0	a	3.5
head width (mm)	15	0.51	a	0.04	0.50	a	0.03	0.64	b	0.02
longevity (honey fed)	20	29.7	a	4.0	29.6	a	2.1	33.5	b	4.2

Numbers in rows followed by the same letter are not significantly different at the 5% level. † tested after arc sine transformation.

P. citri performed in different ways on the three plant species illustrated. It took longest to develop on Streptocarpus and produced small, less fecund adults. On Aeschynanthus development was fast but individuals were small. Best development took place on Glycine and individuals were large and produced many eggs. Similarly Anagyrus developed faster and was larger and longer lived when parasitising these larger mealybugs.

3.2 Modifying host plant suitability

Well grown Streptocarpus hybridus plants were placed under three watering regimes representing well watered (unstressed), near the permanent wilting point (high stress) and an intermediate (medium stress) condition. The plants were infested with P. citri crawlers and growth parameters measured until adult. Adult mealybugs from the three regimes were used for parasitism studies by L. dactylopii. The results in Table 2 show that high water stress resulted in small, less fecund mealybugs which took longer to develop. Few L. dactylopii were able to parasitise these mealybugs and the resulting parasitoids took longer to develop, were small and shorter lived.

Table 2. Influence of water-stressed Streptocarpus plants on the mealybug Planococcus citri and its parasitoid Leptomastix dactylopii

	n	control mean + s.d.	medium stress mean + s.d.	high stress mean + s.d.
P. citri				
development period (days)	5	45.1 a 3.5	47.9 a 7.3	56.9 b 6.7
adult body length (mm)	25	3.3 a 0.12	3.0 a 0.01	2.1 b 0.07
total fecundity	25	284.5 a 14.0	275.2 a 16.9	112.9 b 9.8
L. dactylopii				
development period (days)	20	13.7 a 0.73	13.8 a 0.87	15.3 b 0.91
% adult emergence (†)	100	65.0 a 5.9	68.0 a 4.6	22.0 b 4.6
head width (mm)	15	0.54 a 0.04	0.55 a 0.06	0.35 b 0.03
longevity (honey fed)	20	37.3 a 5.1	38.8 a 9.8	31.2 b 3.2

Numbers in rows followed by the same letter are not significantly different at the 5% level. † tested after arc sine transformation

3.3 **Beneficial behaviour**

To study the effect of different host plant species on searching behaviour we have developed a computer program called MicroMeasure which allows the user to directly measure distances, speed, turning and other parameters from a video source. Table 3 illustrates searching parameters for adult N. reunioni on six host plant species.

The time allocated to various activities varies greatly depending on the leaf topography. N. reunioni was most active on the smooth leaved citrus, walking fast and turning to explore the surface. It was least interested in walking on Passiflora. Speed was greatly reduced on the hairy leaved tomato, potato and Streptocarpus while the sticky hairs on tomato resulted in most time spent preening.

Table 3. Searching behaviour of adult Nephus reunioni on six plant species over a 300 second period.

	Time Walking (s) mean + s.d.	Walking Speed (cm/min) mean + s.d.	Number Turns >90° mean + s.d.	Time Preening (s) mean + s.d.
Coffee	61.7 bc 11.7	57.9 b 4.2	5.9 ab 1.3	7.6 c 2.3
Passiflora	34.4 c 10.2	61.1 ab 6.3	4.3 b 1.8	10.5 c 3.7
Citrus	103.1 a 16.1	68.9 a 4.5	8.8 a 1.1	10.6 c 3.0
Tomato	61.8 bc 13.0	20.9 cd 2.5	6.8 ab 1.0	69.8 a 12.2
Potato	80.5 ab 13.1	28.0 c 2.3	6.5 ab 1.0	37.8 b 10.2
Streptocarpus	90.6 ab 20.8	15.1 d 1.3	3.8 b 0.9	13.4 c 5.0

Numbers in columns followed by the same letter are not significantly different at the 5% level.

3.4 Population regulation

Six large cages each containing five host plant species heavily infested with P. affinis were set up in the glasshouse. The mealybug populations on each plant were carefully counted (T1) and then the cages divided into three treatments having either no predators (C) or C. montrouzieri adults or N. reunioni adults added (P). After six weeks the mealybug populations were again counted (T2) on each plant and the percentage of mealybug destruction relative to the control cages shown in table 4 was calculated as follows:

$$\left(1 - \frac{T2P \times T1C}{T1P \times T2C}\right) \times 100$$

Table 4. Percentage of mealybugs destroyed by two predator species relative to uncontrolled populations on mixed plants in a caged system

	Cryptolaemus montrouzieri	Nephus reunioni
Streptocarpus	99.9 a	25.8 d
Citrus	100.0 a	97.9 ab
Potato	100.0 a	41.1 bcd
Passiflora	100.0 a	63.4 bc
Coffee	100.0 a	78.1 ab

Numbers followed by the same letter are not significantly different at the 5% level, after arc sine transformation.

While C. montrouzieri was effective on all plant species N. reunioni gave good control on citrus but acted poorly on hairy leaved Streptocarpus.

4. Discussion

Host plant defences have an important role in determining the species of pests and their rate of growth and reproduction. However these same defences may work directly to deter searching behaviour of beneficial insects or in the case of parasitoids result in small less fecund individuals. There is no simple universal biological control for mealybugs and success will vary depending on plant species, their nutritional status and at different times of year.

5. References

COPLAND, M.J.W., TINGLE, C.C.D., SAYNOR, M. & PANIS, A., 1985. Biology of glasshouse mealybugs and their predators and parasitoids. pp 82-86 In: Biological pest control: the glasshouse experience ed. N.W. Hussey & N.E.A. Scopes, Blandford Press, U.K., 240 pp

HEIDARI M & COPLAND, M.J.W., (in press). Host finding by Cryptolaemus montrouzieri a predator of mealybugs (Hom., Pseudococcidae). Entomophaga 37:

PERERA H.A.S. & COPLAND M.J.W., (in press). Effect of host diet on the biology of the mealybug parasitoids Anagyrus pseudococci and Leptomastix dactylopii. Biocontrol Science and Technology.

TINGLE C.C.D. & COPLAND, M.J.W., 1988. Effects of temperature and host plant on regulation of glasshouse mealybug (Hemiptera: Pseudococcidae) populations by introduced parasitoids (Hymenoptera: Encyrtidae). Bull. ent. Res. 78: 135-142

Amblyseius cucumeris (ACARI: PHYTOSEIIDAE) IN THE CONTROL OF WESTERN FLOWER THRIPS (*Frankliniella occidentalis*) ON CYCLAMEN

Michael de Courcy Williams
Horticulture Research International, Worthing Road,
Littlehampton, West Sussex BN17 6LP, England.

Summary

The results are presented of a biological control programme using *Amblyseius cucumeris* for the control of western flower thrips *Frankliniella occidentalis* on cyclamen. Sticky trap counts of thrips were compared with flower counts of adult and larval thrips and *Amblyseius* numbers. The influence of environmental conditions and cultural practice of the crop were examined. *Amblyseius* was found to disperse well on the crop. Thrips numbers were maintained below a damage threshold. A marked decline in thrips numbers to low levels was strongly correlated with environmental conditions. The role of *Amblyseius* in thrips control on ornamental crops needs to be further investigated in the light of more information on the pest status of thrips under different environmental conditions.

1. Introduction

Western fower thrips (WFT), *Frankliniella occidentalis* (Pergande), is an important pest of cyclamen. Although capable of feeding on the leaves it is primarily attracted to the flowers where it feeds preferentially on pollen and petal tissue. In a heavy infestation WFT can cause severe distortion and discolouration leading to spoiling of the flowers. In addition it is known to transmit tomato spotted wilt virus to cyclamen (Allen & Matteoni, 1988). The predatory mite *Amblyseius cucumeris* Oudemans has been widely used as a biological control agent of thrips on a broad range of protected crops. For ornamental crops biological control agents such as *Amblyseius* are used with inundative releases to provide an "Economic Overkill" (Wardlow, 1990). However, detailed published information on the dynamics of the interactions of *Amblyseius* and thrips are currently unavailable for most ornamental crops including cyclamen.

Pest monitoring in protected crops commonly involves the counting of pest numbers from sticky traps placed over the canopy of the crop. A combination of this information with that obtained from studies on the interactions of the pest and biological control agents can lead to a better understanding of their population biologies on the crop. The present study was initiated in order to investigate the interactions of pest and biological control agent for cyclamen.

2. Methods

The crop from which the data presented here was gathered consisted of 64,000 cyclamen plants (F1 hybrid Concerto & Zodiac series). These were grown in 13 cm pots on the ground on black capillary matting. The crop was watered from overhead onto the ground between the pots with especial care taken towards flowering. Young plants were brought in to the nursery during June. By week 31 (six to seven weeks later) the final pot spacing was into three seperate glasshouse chambers. Unit 1 of $3250m^{-2}$ contained 32,000 plants and units 2 & 3, both of $2000m^{-2}$, each contained 16,000 plants.

A regular programme of releases of *Amblyseius cucumeris* was commenced on week 31 to give approximately 5 mites $plant^{-1}$ $week^{-1}$. This was equivalent to between 40-50 mites m^{-2}. A commercial supply of *Amblyseius* (mixed with *Acarus*) in bran was used. The bran

mixture was broadcast onto the ground between the pots.

Regular counts of thrips over the crop were undertaken on yellow sticky traps (10 x 20 cm) commencing at week 31. Six traps were sited in unit 1 and four in each of units 2 and 3.

From week 35 onwards samples of flowers were taken to extract thrips and *Amblyseius* for counting in the laboratory. Each sample consisted of 20 flowers. Most of the petals were removed and the central portion of the flowers were placed in an acrylic container and transported back to the laboratory. A turpentine extraction method (Lewis, 1973) was used to drive the thrips and *Amblyseius* into a flask of 70% alcohol. The alcohol was filtered to trap any thrips and mites on filter paper. These were subsequently counted individually under a microscope. Thrips were distinguished into adults (winged) and larvae (instars 1-4).

Meteorological data was gathered from a nearby station (2 miles from the nursery) at HRI, Littlehampton. Solar radiation was recorded from a KIPP pyranometer and calculated to give a weekly average of a daily radiation reciept in Mega Joules m^{-2} day^{-1}. Maximum and minimum temperatures were similarly calculated as weekly averages of daily figures.

3. Results

Meteorological data are presented as graphs of solar radiation receipt and minimum and maximum temperatures for weeks 27-50 (figures a & b). Trap counts of thrips in each of the three units are presented as average daily trap counts for each week (figures c, f & i). Flower counts of thrips and *Amblyseius* are presented for a range of flower types as follows: in unit 1, Oberon (blue) and Rosamunde (pink with eye) (figures d & e); in unit 2, Finlandia (white) and Zodiac (pink with eye) (figures g & h) and for unit 3, Giselle (pink) (figure j).

The number of thrips caught on the traps in the larger unit (No. 1) rose steeply during the first month to a maximum of 28 thrips $trap^{-1}$ day^{-1} at week 36 (figure c). From this maximum there was a persistant decline to a low count of less than 2 thrips $trap^{-1}$ day^{-1} for weeks 41-47 culminating with a final zero count. The flower counts, from cultivars Oberon and Rosamunde, mirrored this pattern (figures d & e). There was a peak at weeks 36-37 of 8 thrips per flower (90% adult) followed by a decline to 1 thrips per flower (50% adult - Oberon & 100% adult - Rosamunde). Throughout this period the number of *Amblyseius* per flower was recorded at one mite to every five flowers in Oberon and 1-2 mites per flower for Rosamunde. Assuming a minimum of 5 flowers per plant this is equivalent to approximately one mite per plant for Oberon and approximately 5-10 mites per plant for Rosamunde.

A similar but less pronounced pattern was observed in the trap counts for units 2 and 3 (figures f & i). Flower counts from these units also followed the same general pattern of a peak in thrips numbers around week 37 followed by a decline towards week 43 (figures g,h & i). However, the peak in thrips numbers was lower (by a factor of two) in both the trap and flower counts of the two units when compared to unit 1.

For unit 2 the trap count of thrips reached a maximum of 12 thrips $trap^{-1}$ day^{-1} at week 36 (figure f). There was a steady decline thereafter to a zero count by week 43 at which point the crop had been marketed. Thrips numbers in the flowers of Finlandia were recorded at 7 thrips per flower (94% adult) at week 36 and dropped to 2 thrips per flower (14% adult) by week 43 (Figure g). For the Zodiac cultivar the thrips numbers in the flowers went from 3 thrips per flower (80% adult) in week 35 to 1 thrips per flower (33% adult) at week 43 (figure h). For the plants in unit 2 there was a pronounced but brief peak

at week 38 of larval thrips in the flowers of both Finlandia (9 thrips larvae per flower) and Zodiac (3 thrips larvae per flower). Numbers of *Amblyseius* were recorded at an average of 0.5 per flower for Finlandia and 0.3 per flower for Zodiac. Again this was roughly equivalent to 2.5 and 1.5 per plant respectively for Finlandia and Zodiac.

For unit 3 the trap count rose to a peak of 12 thrips $trap^{-1}$ day^{-1} at week 38 and declined sharply over the next 4-5 weeks to a zero count (figure i). The peak in thrips number here was two weeks later than experienced in the other two units. A mean of one thrips per flower was recorded in the flower samples of gisell over this period (figure j). A final zero count was recorded at week 43. The proportion of adult thrips in the sample dropped from 80% at week 36 to 22% at week 42. Numbers of *Amblyseius* were recorded in the flowers at an average of 0.9 mites per flower or approximately 4.5 mites per plant.

Between weeks 35 and 43 (indicated by vertical lines in figures a-j) there was a marked decline in solar radiation receipt and temperature. By week 43 the minimum required temperature of 12°C for cyclamen was reached. This period coincided with a decline in thrips numbers. The relationship between the meteorological data and thrips numbers was examined over this period by Spearman rank correlation. All comparisons of solar radiation and temperature were made with thrips numbers from both the trap and flower counts. Significant correlations (at or above 5% level) are given in table 1.

TABLE 1. Spearman rank correlation data for comparison of meteorological data with thrips numbers for weeks 35-43/45. ($P<0.01$ **; $0.01<P<0.05$ *).

Comparison	No. Observations	r_s	significance
SR vs trap counts (unit 1)	9	0.8500	**
SR vs trap counts (unit 2)	9	0.8333	**
SR vs trap counts (unit 3)	9	0.7667	**
MT vs trap counts (unit 1)	9	0.8833	**
MT vs trap counts (unit 2)	9	0.7333	**
MT vs trap counts (unit 3)	9	0.8000	**
SR vs total thrips (Oberon)	5	1.0000	**
SR vs adult thrips (Finlandia)	7	0.8289	*
SR vs adult thrips (Zodiac)	7	0.8214	*
SR vs adult thrips (Giselle)	7	0.8469	*
MT vs total thrips (Oberon)	5	0.9000	*
MT vs adult thrips (Oberon)	5	0.9000	*
MT vs total thrips (Rosamunde)	5	0.9000	*
MT vs adult thrips (Rosamunde)	5	0.9000	*
MT vs adult thrips (Finlandia)	7	0.8289	*
MT vs adult thrips (Zodiac)	7	0.8214	*
MT vs adult thrips (Giselle)	7	0.8469	*

SR= solar radiation, MT= maximum temperature.

4. Discussion

The susceptibility of cyclamen to WFT combined with the long term nature (5-6 months) of the crop necessitate an effective pest control programme. Cyclamen is grown to flower for the autumn and Christmas market. Therfore, the most susceptible part of the plant (the flower) is produced at a time of the year when insect activity is diminishing generally.

The crop is grown in cool well ventilated conditions with a minimum requirement of 12°C. These cultural requirements play an important role in pest control strategies for the crop.

In this study, despite an early increase in thrips levels, no detectable damage was noticed at any time. From a peak in thrips numbers during weeks 35-36 there was a decline to a consistently low or zero count at the time the crop was marketed. Good concordance was also noted between trap counts and flower counts (see figures c-j). Although *Amblyseius* was broadcast onto the ground between the pots the mites were consistently recovered from the flowers along with thrips (figures d, e, g, h, & j).

The dispersal ability of *Amblyseius* on the crop, the decline in thrips numbers and the absence of damage all indicate that successful control was achieved. The presence of some thrips without damage further indicate that there is a level of tolerance of the crop to WFT. However, the decline in thrips numbers are strongly correlated with changing meteorological conditions (table 1). The build up of thrips numbers coincided with a period of sustained high temperature (20-24°C) and solar radiation (16-22 MJ m^{-2} day^{-1}) during August (weeks 31-35). It is worth noting that the normal seasonal lag of about a month in the decline of temperature following that of solar radiation was not evident for the period under study.

Increasing plant bulk and the onset of flowering accompanied these environmental conditions. From week 35 onwards there was a steady seasonal decline in both recorded meteorological measurments of temperature and solar radiation receipt. During this period there was a decline in thrips numbers both on the traps and in the flowers of the crop. For the flower counts this association was most strongly evident in the decline in adult thrips numbers (see table 1). The number of larval thrips in the flower counts showed no significant correlations. The precise role of *Amblyseius* in the decline of thrips numbers under these environmental conditions needs to be further investigated.

The interplay of environmental conditions, the biology of the pest, biological control agents and their interactions on the crop are poorly understood for most ornamental crops. The influence of environmental conditions is a very important consideration in any integrated pest management strategy. An increased understanding of all these factors will promote the success of biological control methods for these crops.

5. Acknowledgments

I am very grateful to Fred Milbourn, the manager of Roundstone nurseries, for his interest & commitment to this work.

6. References

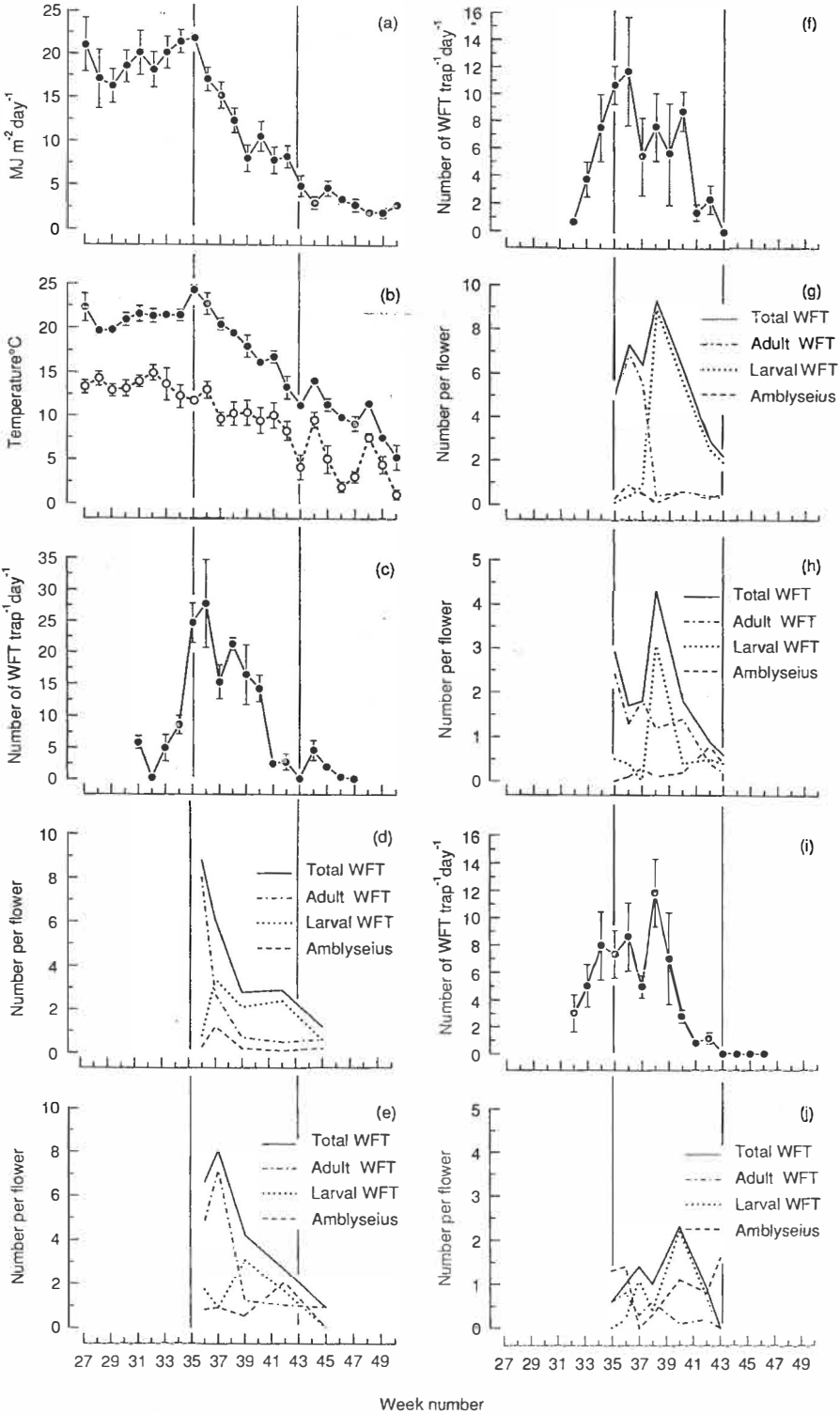
Allen, W.R. & J.A. Matteoni 1988 Cyclamen ringspot: Epidemics in Ontario greenhouses caused by the tomato spotted wilt virus. *Canadian Journal of Plant Pathology* **10:**41-46

Lewis, T 1973 *Thrips their biology, ecology and economic importance*. Academic Press, London & New York.

Wardlow, L.R. 1990 Integrated Pest Management in Protected Ornamental Crops. *SROP/WPRS/BULL.* **XIII/5:** 222-224.

Graphs of week number against: (a) solar radiation receipt; (b) maximum (●) and minimum (○) ambient temperature; trap counts of thrips in units 1 (c), 2 (f) and 3 (h) and flower counts of total, adult and larval thrips and *Amblyseius* numbers in the flower samples of Oberon (d), Rosamunde (e), Finlandia (g), pink Zodiac (h) and Giselle (j).

(overleaf)


(a)
MJ m-2 day-1
(b)
Temperature°C
(c)
Number of WFT trap-1 day-1
(d)
Number per flower
(e)
Number per flower
(f)
Number of WFT trap-1 day-1
(g)
Number per flower
Total WFT
Adult WFT
Larval WFT
Amblyseius
(h)
Number per flower
Total WFT
Adult WFT
Larval WFT
Amblyseius
(i)
Number of WFT trap-1 day-1
(j)
Number per flower
Total WFT
Adult WFT
Larval WFT
Amblyseius
27 29 31 33 35 37 39 41 43 45 47 49
Week number

SIZE AND FECUNDITY IN DACNUSA SIBIRICA TELENGA

Pat Croft and Mike Copland
Department of Biochemistry and Biological Sciences, Wye College, University of London, Ashford, Kent, TN25 5AH, United Kingdom

Summary
The relationship between size and the fecundity of the parasitoid *D. sibirica* was examined and found to be positively correlated. An influence on parasitoid size was the length of the puparium stage of the host *C. syngenesiae*.

1. Introduction

Fecundity is one of the biological parameters that can be used in assessing a parasitoids fitness (Bigler *et al*, 1987) and is usually positively correlated to the size of the parasitoid (Charnov *et al* ,1981; van den Assem *et al*, 1989).

In solitary parasitoids host size is determined by host quality as larger hosts contain more potential food than smaller hosts (Charnov *et al*, 1981; Jones, 1982). In idiobiontic species the host stage at oviposition represents a set food package (Askew & Shaw, 1986) and is easily measured. In koinobiontic parasitoids the relationship is not so obvious, as the development of the host continues after oviposition. Consequently host size can be measured either at oviposition or after the death of the host. However, host size at oviposition may not be indicative of final size due to subsequent environmental changes such as in host density or plant quality. The following experiment examined the relationship between size of the leafminer *Chromatomyia syngenesiae* Hardy (Agromyzidae: Diptera) and the parasitoid *D. sibirica* (Braconidae: Hymenoptera), and the influence of parasitoid size on its fecundity.

2. Materials and Methods

Potential Fecundity: Parasitized leafminer puparia, reared in a commercial insectary, were allowed to emerge at room temperature (18-22^{o}C) in sealed boxes, 70-80% r. h.. As female wasps emerged they were dissected in saline solution and the number of mature eggs counted. The corresponding hind tibia length for each wasp was also recorded as an estimate of female size.

Real Fecundity: Minkenberg (1990) describes *D. sibirica* as a synovigenic species which will emerge with less than a full complement of eggs; therefore potential fecundity may not reflect actual or real fecundity of the parasitoid (Leather, 1988) . Real fecundity, the actual number of offspring produced, was also recorded over a five day period to see if this estimation of fecundity and size agreed with the more crude potential fecundity estimation. Ten newly emerged wasps were selected comprising five large and five small females. The females were then left individually with males for a period of 24 h to ensure mating. The females were then placed in individual cages (60 by 40 by 50 cm). Each day for five days the females were given a fresh *Sonchus oleraceus* plant infested with approximately 200 leafminer larvae of 2nd and 3rd instars.

The cages containing the parasitoids were in a constant temperature room at 25+1^{o}C, 16:8 light:dark, light intensity 30 Wm^{2}. The females had access to 50% honey solution on filter paper. The plants were removed daily from the cages and kept at 20-22^{o}C. When the parasitised larvae pupated they were removed from the plants and placed in labelled containers, and kept in an incubator at 22+1^{o}C and 70-80% r. h., until the parasitoids emerged when they were counted and sexed. Analysis was carried out using ANOVA on a complete randomised block design.

Host size and *D. sibirica* size: Parasitized puparia were removed from the leaves of the plant *S. olereaceus* and the puparium length recorded. The puparia were kept in humid containers at room temperature (18-22^{o}C). The size of emerging parasitoids was recorded as hind tibia length and regressed against puparia length.

3. Results

Potential Fecundity: Fig. 1 shows that there is a positive relationship between the number of mature eggs in a newly emerged female parasitoid and her size ($p = <0.0001$).

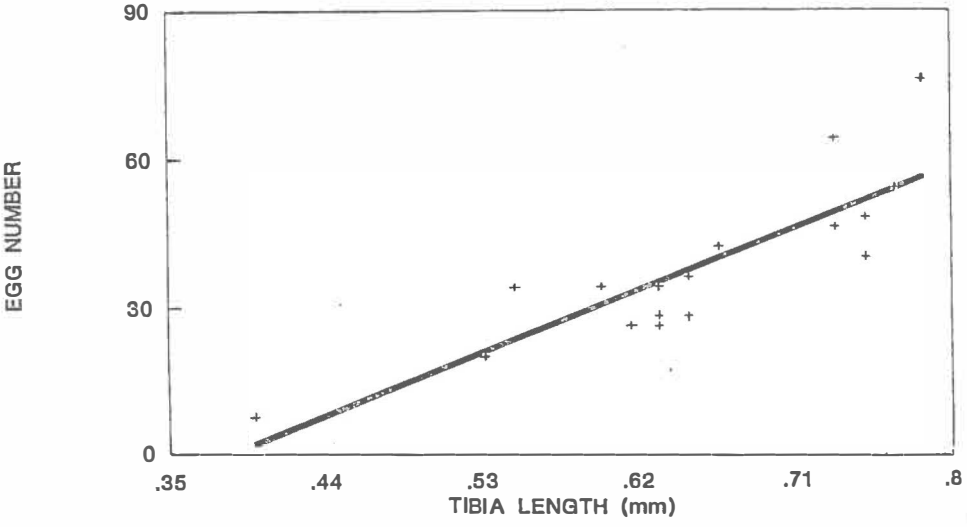


Fig 1. Relationship between number of mature eggs at emergence and tibia length in the parasitoid *D. sibirica*. Y = -52.9 + 139X, r^2 = 0.92, P = <0.0001.

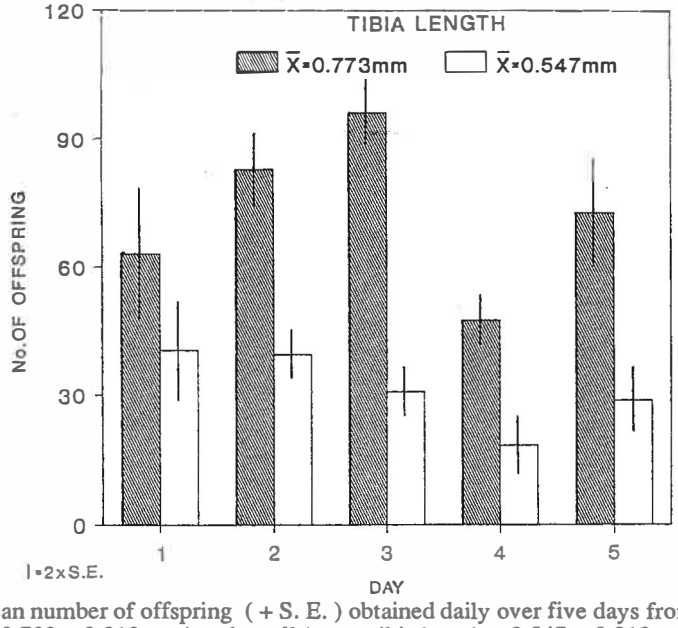


Fig 2. The mean number of offspring (+ S. E.) obtained daily over five days from large (mean tibia length = 0.733 + 0.013 mm) and small (mean tibia length = 0.547 + 0.013 mm) *D. sibirica*

Real Fecundity: Fig 2 shows the mean daily number of offspring counted for large females is greater than that recorded for small females (P = <0.05).

The Influence of Host Size on *D. sibirica:* Fig. 3 shows that parasitoid size increased linearly with host size although the variability is quite high. Host puparium volume or weight may

have given a better linear fit than puparium length, or some other aspect of host quality may be influencing parasitoid size.

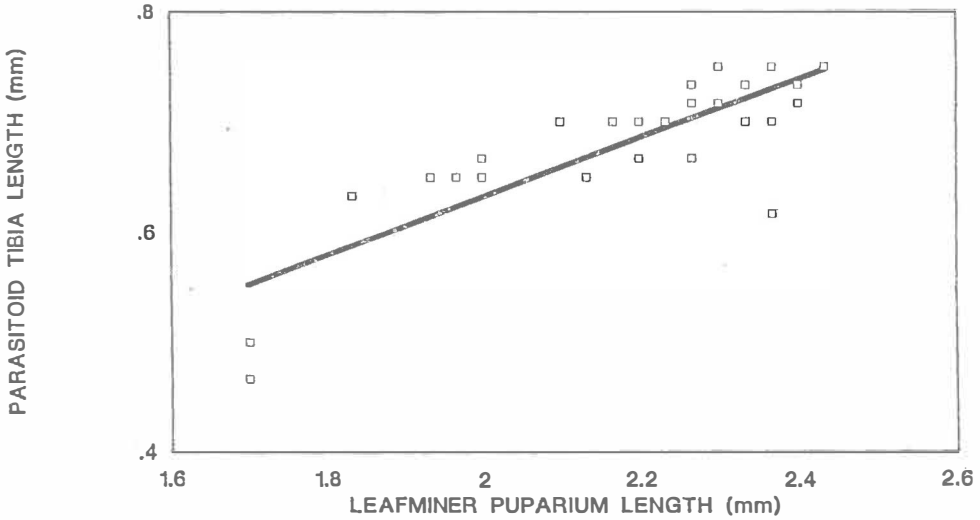


Fig 3. Regression of tibia length of female *D. sibirica* against the puparium length of the host *C. syngenesiae*. Y = 0.092 + 0.267X, r^2 = 0.48, P = <0.0001.

4. Discussion

Both the potential fecundity and the number of offspring recorded over five days were positively correlated to the size of the parasitoid. This relationship has been established for other parasitoid species (Chamov *et al*; 1981, Lui, 1985; van den Assem *et al*, 1989). However, there are examples where size and fecundity of parasitoids are not related; Minkenberg (1989) found that increased size of *Diglyphus isaea* (Walker) did not result in increased fecundity. Bigler *et al* (1987) also found for the egg parasitoid *Trichogramma maidis* Pintureau et Voegele when reared on the host *Ephestia* (=*Anagasta*) *kuehniella* Zell the females were larger but not more fecund than the smaller parasitoids reared from the host *Sitotroga cerealella* (Olivier).

The daily number of offspring recorded for *D. sibirica* was greater than the values obtained by Minkenberg (1990) at 22°C. Our higher temperatures therefore may have produced the higher fecundity. Minkenberg (1990) found that increasing temperature increased the fecundity of *D. sibirica*. In our experiment *D. sibirica* were provided with honey whereas in Minkenberg (1990) the wasps were not fed. Nedstam (1983) recorded that honey fed *D. sibirica* had controlled *L. bryoniae* better than non-fed parasitoids. The number of leafminer available for the parasitoid may also account for the disparity in results. We provided more than twice the number offered by Minkenberg (1990). Additionally parasitoids reared on *C. syngenesiae* may be more fecund than when the host is *L. bryoniae*: Minkenberg (1990) working with *D. sibirica* reared on *L. bryoniae* found at 25°C the total fecundity over a period of 4-15 days was 14-92 eggs, values that are lower than the mean numbers of offspring obtained in the present experiment over a period of five days. It is possible therefore that host quality influenced parasitoid fecundity. Gautam (1986) also found that longevity and fecundity of the parasitoid *Telenomus remus* Nixon was effected by different species of noctuid hosts.

An irregular pattern of offspring numbers was produced daily by each parasitoid over five days. In a study where the number of eggs oviposited by females were monitored throughout the life of the wasps the numbers of eggs produced where of a similar pattern and may be a result of fluctuating numbers of available mature eggs within the ovary as suggested in Walter (1988).

To determine the influence of host size on parasitoid size the final stage of the host, the puparium, was measured and was found to be positively correlated to size in *D. sibirica*.

Development of *D. sibirica* larval stages are delayed until the host puparium is formed. The puparium in this regard can almost be considered a 'set meal' to the parasitoid as found with hosts of idiobiontic species. Lui (1985) also found the width of the final mummy stage of the aphid *Hyperomyzus lactucae* (L.) positively correlated with the size of the koinobiontic parasitoid *Aphidius sonchi* Marshall. Nealis *et al* (1984) found that initial host size positively correlated with koinobiontic parasitoid size. Wright & Kerr (1988) found that size of both the initial and final stages of the scale host positively effected the size of the parasitoid *Encyrtus saliens* Prinsaloo & Annecke.

D. sibirica therefore would seem to be effected by host quality in a similar linear pattern as idiobiontic parasitoids. Such findings about host and parasitoid quality are useful to optimise or predict parasitoid fitness. However, Sequeira & Mackauer (1992) suggest that parasitoid development time may be a more important aspect of overall parasitoid fitness than body size or fecundity for some parasitoid species.

Acknowledgement

This work was supported by the Science and Engineering Research Council, U.K.

5. References

ASKEW, R. R. and SHAW, M. R., 1986. Parasitoid communities: their size, structure and development. pp. 225-264 *in*: *Insect Parasitoids*. Waage, J. and Greathead, D. Academic Press, London.

ASSEM, VAN DEN J.; VAN LERSEL, J. J. A.; LOS-DEN HARTOGH, R. L., 1989. Is being large more important for female than for male parasitic wasps? *Behaviour*. 108: 160-195.

BIGLER, F.; MEYER, A.; BOSSHART, S., 1987. Quality assessment in *Trichogramma maidis* Pintrureau et Voegele reared from eggs of the factitious hosts *Ephestia kuehniella* Zell. and *Sitotroga cerealella* (Olivier). *J. appl. Ent.* 104: 340-353.

CHARNOV, E. L.; LOS-DEN HARTOGH, R. L.; JONES, W. T.; VAN DEN ASSEM, J., 1981 Sex ratio evolution in a variable environment. *Nature, Lond.* 289: 27- 33.

GAUTAM, R. D., 1986. Influence of different noctuid hosts on the parasitization by *Telenomus remus* Nixon (Scelionidae: Hymenoptera). *J. Ent. Res.* 10: 70-73.

JONES, W. T., 1982. Sex ratio and host size in a parasitoid wasp. *Behav. Ecol. Sociobiol.* 10: 207-210.

LEATHER, S. R., 1988. Size, reproductive potential and fecundity in insects: things aren't always what they seem. *Oikos*. 51: 386-389.

LUI, S. S., 1985. Development, adult size and fecundity of *Aphidius sonchi* reared in two instars of its aphid host, *Hyperomyzus lactucae*. *Entomologia exp. appl.* 37: 41-48.

MINKENBERG, O. P. J. M., 1989. Temperature effects on the life history of the eulophid wasp *Diglyphus isaea*, an ectoparasitoid of leafminers (*Liriomyza* spp.), on tomatoes. *Ann. appl. Biol.* 115: 381-397.

MINKENBERG, O. P. J. M., 1990. On seasonal inoculative biological control. Ph. D. Thesis. Netherlands.

NEALIS, V. G.; JONES, R. E.; WELLINGTON, W. G., 1984. Temperature and development in host-parasite relationships. *Oecologia*. 61: 224-229.

Nedstem, B. (1983) Control of *Liriomyza bryionae* by *Dacnusa sibirica*. *SROP WPRS Bulletin*. 5: 26-29.

SEQUEIRA, R. and MACKAUER, M., 1992. Covariance of adult size development time in the parasitoid wasp *Aphidius ervi* in relation to the size of its host, *Acyrthosiphon pisum*. *Evol. Ecol.* 6: 34-44.

WALTER, G. H., 1988. Activity patterns and egg reproduction in *Coccophagus barletti*, an aphelinid parasitoid of scale insects. *Ecol. Ent.* 13, 95-105.

WRIGHT, E. J. and KERR, J. D., 1988. Host/parasitoid interactions and relative suitabilities of two host species of the soft scale parasitoid *Encyrtus saliens*. *Entomologia exp. appl.* 48: 51-59.

THE INTERACTION BETWEEN LIRIOMYZA TRIFOLII AND DIFFERENT CHRYSANTHEMUM CULTIVARS

Marinke J. van Dijk, Jan de Jong,
Jacques C.M. van der Knaap & Ed van der Meijden.

Dept. of Population Biology, University of Leiden
P.O. Box 9516, 2300 RA Leiden, The Netherlands

Abstract

A detailed analysis of the impact of resistance to Liriomyza trifolii in chrysanthemum was made. Three different experiments were used to seperate non-preference effects in choice situations from oviposition and antibiosis to larval development. Non preference was found, as well as reduced oviposition. When comparing survival in the different larval stages, only the first and second larval stage were influenced by resistance. Since these different effects of resistant plant genotypes occur in different cultivars, resistance can be improved by combining oviposition reducing factors with factors reducing larval survival.

Introduction

As a first step in breeding for resistance one needs to know whether resistance to the pest insect involved is present within the genetic variation of the crop. This has been studied extensively by several workers for chrysanthemum and the serpentine leafminer fly Liriomyza trifolii (Webb & Smith, 1969, Alverson & Gorsuch, 1982, De Jong & van de Vrie, 1987). These studies usually focused on differences in overall measures for resistance such as number of large (third instar) mines or pupae per plant in a choice situation. In this kind of experimental designs it is difficult to tell apart the seperate contributions of host plant effects on oviposition choices, adult mortality and larval survival. Of course they certainly were useful in the assessment of the potentials for breeding leafminer-resistant chrysanthemums. There turned out to exist huge variation within existing commercial cultivars, and therefore the potential was clearly there.

To set up breeding programs for insect resistance, however, needs more information than just the knowledge that genetic variation for the trait is present. It is important to know if different mechanisms exist and whether they can be combined to yield a stronger resistance. Therefore a program was started to analyse these mechanisms. As a first step a detailed analysis of the interaction between the leafminer and different chrysanthemum cultivars was needed. In this talk the results of this first step will be discussed. Further steps in this program involve:

* the analysis of morfological and chemical plant properties influencing resistance,
* the assessment of the importance of environmental factors in the expression of these mechanisms, and
* an analysis of the genetical make up of these plant properties.

Resistance can be complete (no damage) or partial (some damage, but less than on a susceptible plant). It can be antixenotic (e.g. causing avoidance behaviour in the herbivore: this is also called non-preference) or antibiotic (causing death of adult or larval stages of the herbivore). Resistance can influence the adult stage of the herbivore, or the larval stage, or both.

In order to make out which types of resistance occur in this particular plant-insect interaction, three different experiments were set up. The first one was designed to measure non-preference, the second one to measure direct effects of plant quality on oviposition, and the third one to measure antibiosis to larval development.

Non preference

Non-preference was measured by offering a mixed population of plant genotypes, with 30 genotypes each replicated ten times. (for details see Van Dijk, De Jong, Van der Knaap & Van der Meijden in prep.). Total number of mines was counted on each plant as a measure for the number of eggs laid. This is possible, because no significant differences in egg hatching exist between genotypes (as will be shown later). As is clear from the range in total numbers of mines in figure 1, the distribution of total number of mines over genotypes was far from random. Some were clearly avoided, while others were preferred. Interestingly, no significant relation existed between preference by the ovipositing female and subsequent larval survival (fig 1). The female chooses not always the genotypes that are best for her progeny. Whether the non preference traits shown here are of any use to the breeder depends on the customers he has to satisfy. It could be of use when a large variety of cultivars is grown intermixed (which is the case in Great-Britain) but would be less profitable in monocultures of one cultivar (as is quite common in Dutch greenhouses).

Oviposition in a no choice situation

The direct effect of six genotypes on oviposition was measured in a no-choice experiment, using ten plants per genotype in two series. Per plant, four pairs of one day old flies were left together with the plant for two days. After that plants were harvested and eggs counted.
The results are given in figure 2. In the first series the differences in number of egss seem quite clear. Cultivar A is least suitable for oviposition while cultivar F is the most suitable one. However in the second series the ranking order of cultivars changes. Therefore differences in oviposition show little consistency. The absolute difference between the two series is caused mainly by a difference in fly quality; in the first series 17 % of the females were still alive after two days, while in the second series 51 % was still alive. Especially the second series showed very little variation in fly survival between plant genotypes. The difference in oviposition between A and F found here can thus not be explained by an antibiotic effect on the adult female. It must therefore be attributed to for instance repellence or inferior food quality hindering egg development in the female fly. So oviposition differences are on far less clear in no choice situations compared to choice situations. As will be shown in the next experiment, larval survival has a much more dramatic effect, and since

this experiment shows little consistency, suitability for oviposition in no choice situations seems a difficult and not very important trait to work with for a breeder.

Resistance and larval survival: antibiosis effects

Antibiosis to the larvae was measured using six other plant genotypes in a similar no-choice experiment, this time using two pairs of flies for one day to avoid over-crowding and synchronize development. Five plants per genotype were allowed to develop first instar mines and were then harvested and examined for first instar larvae and unhatched eggs. In another ten plants per genotype larvae were allowed to develop into third instar, after which plants were put in plastic bags to collect pupae. Numbers of larvae from each instar per leaf were recorded daily.
As is shown by figure 3, large differences exist between the tested plant genotypes with respect to proportion of eggs surviving to pupa stage. As is shown by figs. 4 to 6, these differences are not caused by differences in egg hatching, but mainly by differences in survival in the first larval instar, with additional differences in survival in the second larval instar. Third instar larvae in all cultivars all survived to the pupa stage. Next to this, as is shown in fig 7, the number of days needed to reach third larval instar is clearly increased in the genotypes showing reduced larval survival.

Conclusion

It is clear from these results that resistance works in different developmental stages of the fly. It clearly affects fly preference, it effects number of eggs laid in a no choice experiment to some extent, and it drastically influences survival of first and second instar larvae and developmental time. As is already shown in figure 1, these effects are not always combined in one genotype. While some chrysanthemum cultivars are unattractive for oviposition, others reduce larval survival. Therefore it seems useful to try and combine the different plant properties causing these effects, in order to obtain even stronger resistance to Liriomyza trifolii in chrysanthemum. Since in chrysanthemum very little leafminer damage is acceptable, a strong oviposition reducing type of resistance with high first instar mortality would be the best aim at this moment.

References

ALVERSON, D.R. & C.S. GORSUCH (1982): Evaluation of chrysanthemum cultivars and insecticides for control of damage by a leafminer, Liriomyza trifolii. J.Econ. Entomol. **75**: 888-891.

DE JONG, J. & M. VAN DE VRIE (1987): Components of resistance to Liriomyza trifolii in Chrysanthemum morifolium and Chrysanthemum pacificum. Euphytica **36**: 719-724.

VAN DIJK, M.J., J. DE JONG, J.C.M. VAN DER KNAAP & E. VAN DER MEIJDEN (in prep): Analysis of resistance to Liriomyza trifolii (Burgess) in Chrysanthemum (Dendranthema grandiflora Tzvelev).

WEBB, R.E. & F.F. SMITH (1969): Effect of temperature on resistance in Lima bean, Tomato and Chrysanthemum to *Lyriomyza munda* (= *L. trifolii* pers. comm. Webb). J.Econ. Entomol **62** (2): 458-462.

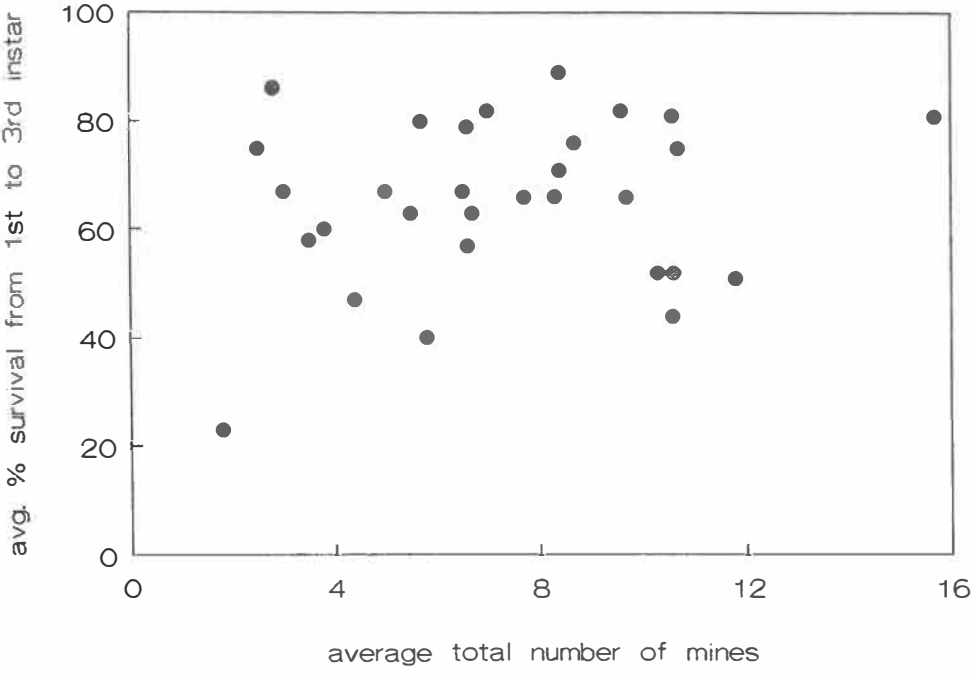


Fig. 1: Relationship between total number of *L. trifolii* mines (preference) in a choice experiment with 30 chrysanthemum genotypes and larval survival from first to third instar. (r = 0.19, n.s). Pooled standard error of total number of mines is 1.7; F-ratio (ANOVA) = 3.588, significance level < 0.0001).

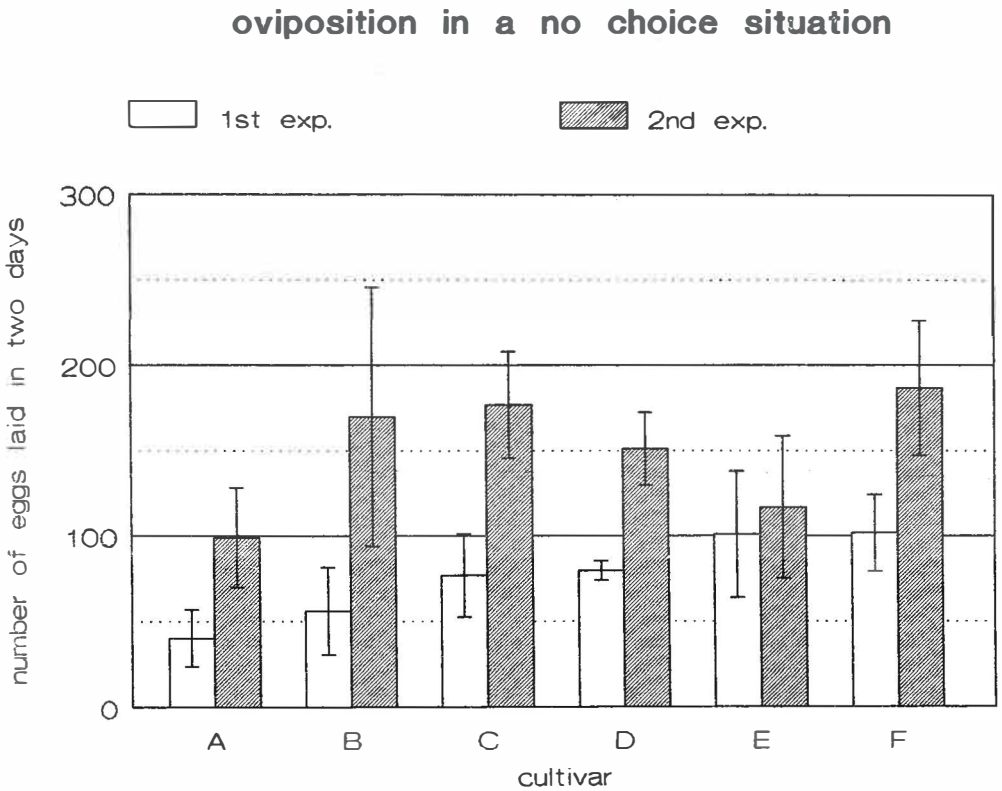


Fig. 2: Oviposition in a no choice experiment with six genotypes. Averages and confidence limits. Two series with each five plants per genotype, tested one week apart. Adult female survival was on average 17% in the first and 51% in the second series.

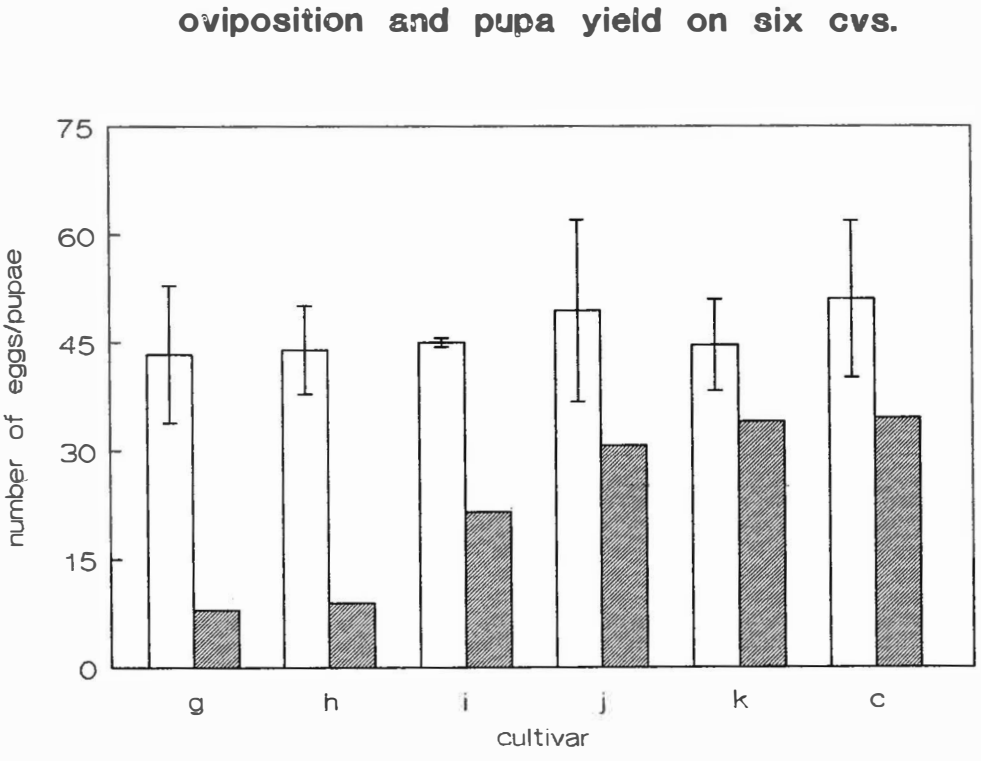


Fig. 3: Number of eggs laid (with s.e.) and number of pupae produced on six genotypes in a no choice experiment.

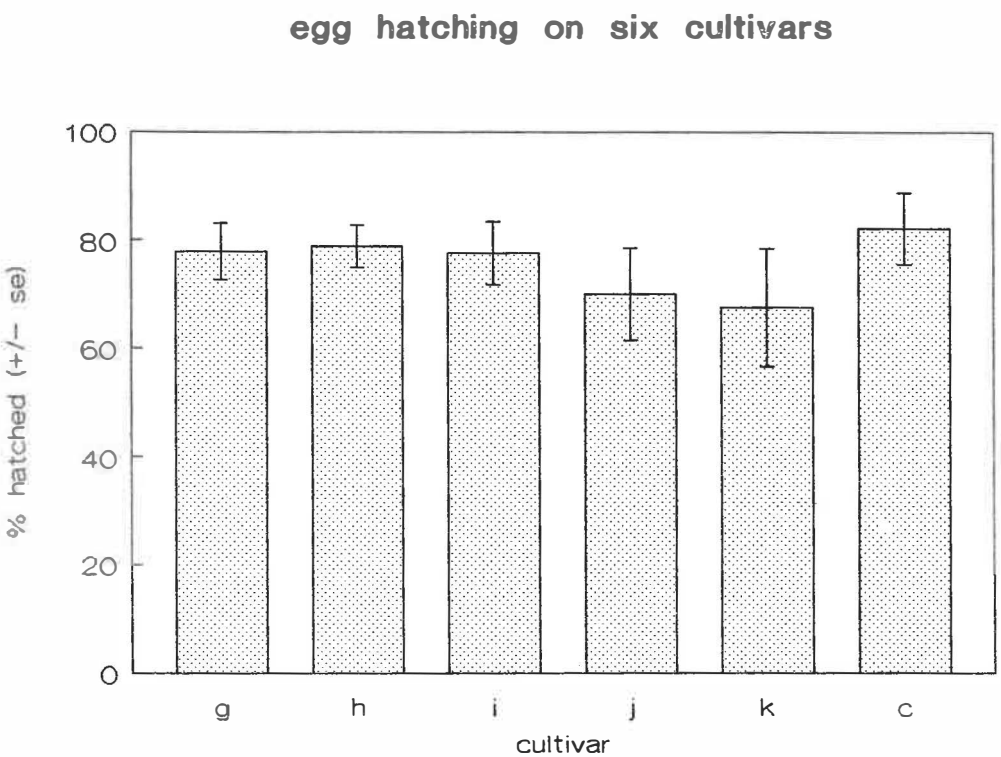


Fig. 4.5.6: Survival in the egg stage, the first instar and the second larval instar of *Liriomyza trifolii* on six chrysanthemum genotypes. Averages and standard errors.

Fig. 5 survival in first instar on six cvs.

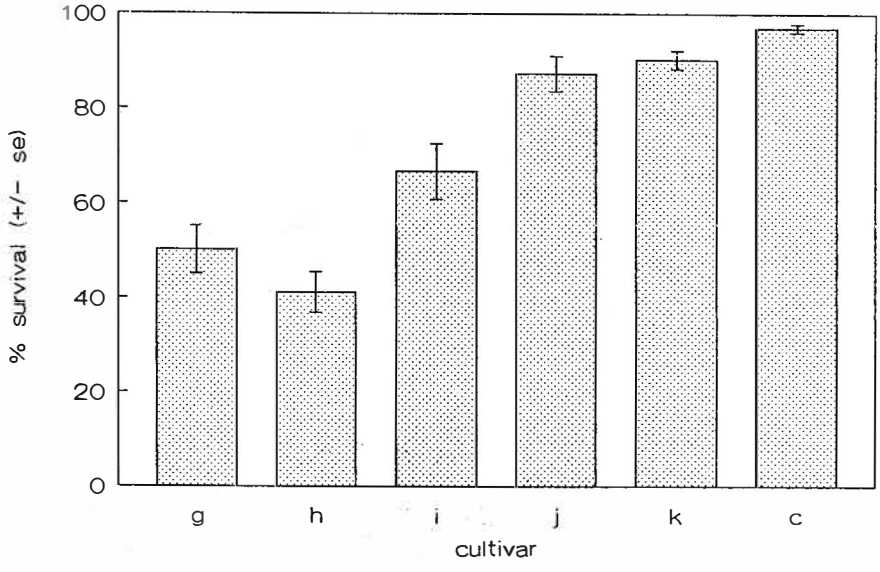
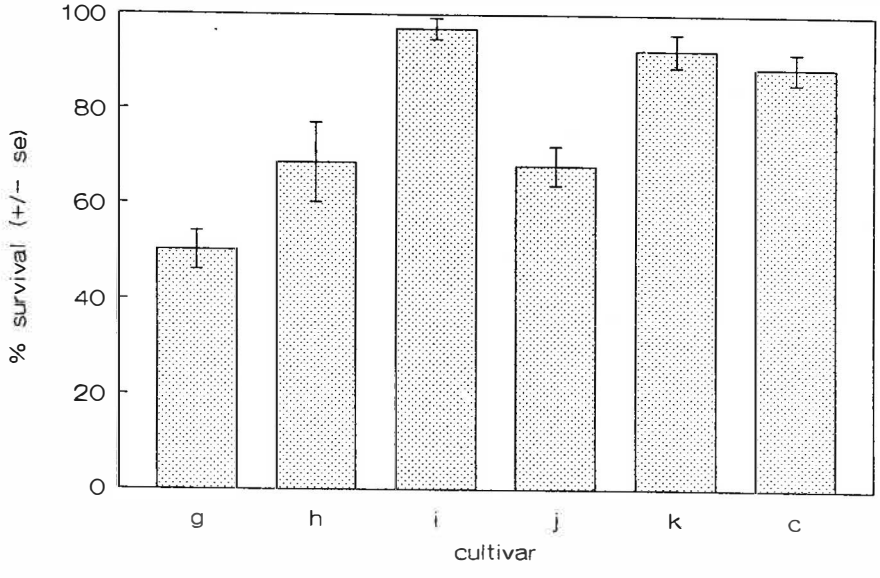


Fig. 6 survival in second instar on six cvs.



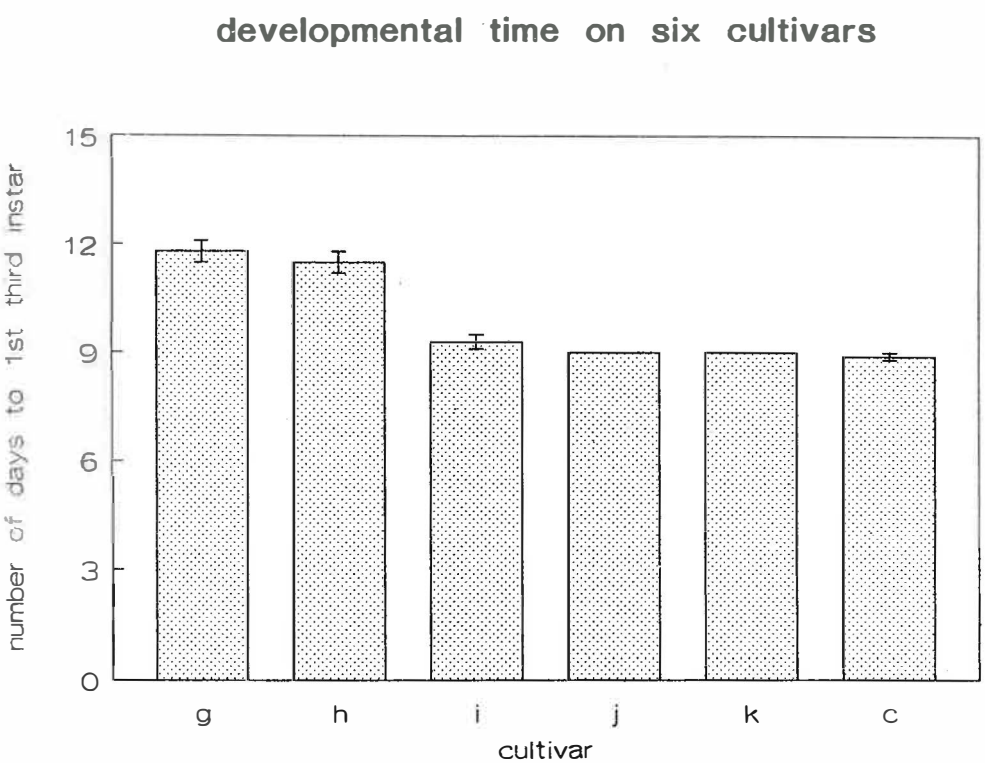


Fig. 7: Average number (and s.e.) of days needed to reach the third instar for larvae of *L. trifolii* on six chrysanthemum geneotypes.

THE BIONOMICS OF THE COTTON WHITEFLY, *BEMISIA TABACI* AND ITS PARASITOID, *ENCARSIA FORMOSA* ON POINSETTIA.

ANNIE ENKEGAARD,
Department of Pest Management, Research Center for Plant Protection,
Lottenborgvej 2, DK-2800 Lyngby, Denmark

Summary

The temperature-dependency of the following basic biological parameters of *Bemisia tabaci* infesting Poinsettia was investigated by laboratory experiments: developmental time for the eggs and the egg-to-adult phase, juvenile mortality, adult female lifespan, preoviposition period, age-specific fecundity and sex-ratio. In addition, lower temperature thresholds for juvenile and adult development and for oviposition were estimated. The investigations provided estimates of the net reproductive rate, the intrinsic rate of increase, the mean generation time and the doubling time. The basic biological characteristics (adult longevity, developmental time, juvenile mortality, net reproductive rate, intrinsic rate of increase, mean generation time, doubling time) of *Encarsia formosa* parasitizing *B. tabaci* on Poinsettia was likewise investigated by laboratory experiments at different temperatures. Lower temperature thresholds for adult and juvenile development was estimated. In addition, the temperature-dependent functional response of the parasitoid towards fourth instar larvae of *B. tabaci* was investigated.

Introduction

By way of the intensive international trading with plants and plant parts, the subtropical and tropical pest, the cotton whitefly, *Bemisia tabaci* Genn. (Homopt.: Aleyrodidae), has recently spread to temperate regions of the world where it in many places has become established as a serious pest in glasshouses, especially on ornamentals. The cotton whitefly is diffucult to control with chemicals, and development of biological control is needed. A prime candidate for biological control is the parasitoid *Encarsia formosa* Gahan (Hymenopt.: Aphelinidae), used succesfully against the greenhouse whitefly (*Trialeurodes vaporariorum*) for many years and readily available commercially.

The present study was undertaken to provide detailed information on basic biological characteristics of *B. tabaci* and of *E. formosa* parasitizing this whitefly species under the conditions prevailing in temperate glasshouses. Poinsettia was chosen as a model host plant for the study as this is the glasshouse crop most frequently attacked by *B. tabaci* in temperate regions. For additional details to this condensed presentation, see Enkegaard (1992a, 1992b, 1992c).

Materials and methods

All experiments were conducted on young Poinsettia plants (cv. Angelica) in climate cabinets at 3 or 5 constant temperatures in the range of 16°C to 28°C, with 60-80% r.h. and L16:D8 photoperiod. For further details on stock cultures, experimental procedures and processing of data see Enkegaard (1990, 1992a, 1992b, 1992c).

Results and discussion

The biological characteristics of *B. tabaci* on Poinsettia are shown in Table 1 and those of *E. formosa* parasitizing *B. tabaci* is shown in Table 2. Increasing temperature resulted for both whitefly and parasitoid in shorter developmental times, adult longevities and - for the whitefly - preoviposition periods, lower immature mortality and higher fecundity. This was reflected in a decrease in mean generation time and doubling time as well as in an increase in the multiplication rate per generation (R_0) and intrinsic rate of increase (r_m).

B. tabaci was able to survive and reproduce on Poinsettia at temperatures between 16° and 28°C. However, in spite of the fact that none of the two extreme temperatures constituted

a limit to growth of *B. tabaci* populations, the reproductive capacity and survival were greatly reduced at temperatures below 20°C, especially at 16°C which was on the borderline for a positive population increase.

Based on the results of immature development and mortality, Poinsettia seems to be a less suitable host to *B. tabaci* than cotton and eggplant, although the total number of eggs laid per female falls within the same range for the three host plants (Butler *et al.*, 1983; von Arx *et al.*, 1983; Horowitz *et al.*, 1984; Coudriet *et al.*, 1985; Sharaf *et al.*, 1985). Tomato, on the other hand, gives results on developmental time more similar to the ones obtained on Poinsettia (Coudriet *et al.*, 1985). Fecundity on tomato is somewhat lower than on Poinsettia (Sharaf & Batta, 1985), but this is counterbalanced by tomato being more supportive for the development of the juvenile stages (Sharaf *et al.*, 1985). Tomato must therefore be considered to be intermediate between cotton and eggplant on one hand and Poinsettia on the other with respect to host suitability to *B. tabaci*.

E. formosa exhibited a functional response of Type II to fourth instar larvae of *B. tabaci* (Fig.1.). The observed changes with temperature were most likely due to a general reduction in activity of the parasitoids as well as reduced rate of oogenesis with decreasing temperature (Kajita & Lenteren, 1982). The data was described by the model for a randomly searching parasitoid (e.g. Hassell, 1978):

$$N_a = N_t \left(1 - e^{-\left(\frac{a' S P_t}{1 + a' T_h N_t}\right)}\right) \qquad (1)$$

where N_a is the number of parasitized hosts per leaf, N_t the density of hosts per leaf, P_t the density of parasitoids (here = 1), a' the searchrate, S the total time available for search (here the 16 hours with light) and T_h the handlingtime. The minimum threshold for oviposition of *E. formosa* was obtained by plotting the inverse of handlingtime against temperature giving a straight line intercepting the x-axis at ca. 15°C. This threshold was used in an extended model describing the functional response with temperature incorporated as a paramter, i.e. $1/T_h = d \cdot (T - 15)$, where d is a constant and T is the temperature to which the parasitoids were exposed. Attempts were made to fit the extended model with a' expressed as various functions of temperature. The model giving the best fit was, however, one in which a' was independent of temperature:

$$N_a = N_t \left(1 - e^{-\left(\frac{a' S P_t}{1 + a' N_t / (d (T - 15))}\right)}\right) \qquad (2)$$

The estimated parameters are shown in Table 2. From the model estimated handling times of 1.54, 2.86 and 20.0 hours were obtained at 28°C, 22°C and 16°C, respectively. The maximum number of hosts that one *E. formosa* is able to parasitize at the three temperatures is thus 10.4, 5.6 and 0.8 larvae per day (with a 16 hours light period). The handling times include numerous activities, such as locating and parasitizing the host, cleaning and resting, and are therefore much higher than the actual time used by *E. formosa* to parasitize a host. The noted handling times also include puncturing activity not leading to actual parasitization.

The functional response of *E. formosa* exhibited towards *B. tabaci* at higher temperatures was of similiar type (Type II) and with search rate and handling time being of approximately the same magnitude as shown towards *T. vaporariorum* (Yano, 1987; Fransen and Montfort, 1987 (estimated from their data)). The similarity of the functional response indicates

that *E. formosa* in a biological control situation has the potential for controlling *B. tabaci* to the same extent as it controls *T. vaporariorum*.

The biology of *E. formosa* parasitizing *B. tabaci* was found to be very similiar to the biology on *T. vaporariorum* with respect to adult longevity and juvenile development (Burnett, 1949; Stenseth, 1975; Nechols & Tauber, 1977; Osborne, 1982; Madueke & Coaker, 1984). The same applied to the parasitoid's oviposition rate (Vianen & Lenteren, 1986). The juvenile mortality, however, was higher when *E. formosa* develops on *B. tabaci* than on *T. vaporariorum* (Arakawa, 1982; Nechols & Tauber, 1977). Thus, the whitefly host species seems to have a strong influence on the parasitoid's chances for surviving through the juvenile stages, even though the developmental time of those parasitoids that succeed in completing the development is unaffected by the whitefly host.

Although the value of r_m for *E. formosa* was rather low at 16°C, this temperature was not near the limits for a positive population increase in the parasitoid population. Albeit the values of r_m are low for the parasitoid when *B. tabaci* serves as host instead of *T. vaporariorum* (Arakawa, 1982), they are well above the values of r_m of *B. tabaci* itself at all temperatures in the range of 16° to 28°C (Table 1 and 2). Thus, when temperature is within the range of 16°C-28°C, which is normally the case for Poinsettia crops in temperate regions, the possibility for using *E. formosa* to control infestations of *B. tabaci* seems to be very good when jugded from the capacities for population increase - even at low temperatures where the population development of the parasitoid is slow. It must be kept in mind, however, that the values of r_m for *E. formosa* are based on the maximum oviposition rate - a rate that is realised only when a surplus of host is available. If the density of whitefly larvae becomes low, the full reproductive potential of the parasitoid will not be attained.

Adult *E. formosa* was found to be unable to survive at temperatures below 11°C. This was in contrast to the adult *B. tabaci* that could withstand temperatures down to 8°C. Thus, although the juvenile development of the whiteflies is hampered at these low temperatures, the whitefly population will be able to persist and subsequently resume population development, when temperature increases. In a biological control situation reintroduction of parasitoids after periods with low temperature will therefore be necessary.

At the lowest temperature the difference in developmental time of pest and parasitoid is very large. Therefore, if the whitefly population is highly synchronized, as is usually the case at the start of the season, it will be difficult for newly emerged parasitoids to survive until suitable larval stages of the whitefly start to appear. In this situation repeated introductions of *E. formosa* will be necessary.

A further point relevant to practical control situations is the pronounced influence of temperature on the efficiency of *E. formosa*. The reduction in the performance of *E. formosa* with decreasing temperature will result in a reduction in parasitization. Thus, in ornamentals produced by a process including periods of low temperature during day light hours, the number of parasitoids to be released in the culture must be increased accordingly to ensure a sufficient degree of parasitization.

References Cited

Arakawa, R., 1982. Reproductive capacity and amount of host feeding of *Encarsia formosa* Gahan (Hymenoptera, Aphelinidae). Z. Ang. Ent. 93, 175-182.

Burnett, T., 1949. The effect of temperature on an insect host-parasite population. Ecology 30, 113-134.

Butler, G.D., T.J. Henneberry & T.E. Clayton. 1983. *Bemisia tabaci* (Homoptera: Aleyrodidae): Development, Oviposition and Longevity in Relation to Temperature. Ann. Entomol. Soc. Am. 76: 310-313.

Coudriet, D.L., N. Prabhaker, A.N. Kishaba & D.E. Meyerdirk. 1985. Variation in developmental rate on different hosts and overwintering of the sweet potato whitefly, *Bemisia tabaci* (Homoptera:Aleyrodidae). Environ. Entomol. 14: 516-519.

Enkegaard, A. 1990. Age-specific fecundity and adult longevity of the cotton whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae) on Poinsettia (*Euphorbia pulcherrima*) at different temperatures. Bull. O.I.L.B/S.R.O.P. 1990 XIII/5: 51-54.

Enkegaard, A. 1992a. Bionomics of and interactions between the cotton whitefly, *Bemisia tabaci* GENN. (Homoptera: Aleyrodidae) and its parasitoid, *Encarsia formosa* GAHAN (Hymenoptera: Aphelinidae) on Poinsettia in relation to biological control. Unpub. Ph.D. dissertation. University of Copenhagen.

Enkegaard, A. 1992b. *Encarsia formosa* parasitizing the cotton whitefly, *Bemisia tabaci* on Poinsettia: Bionomics in relation to temperature. Ent. Exp. Appl. (in press).

Enkegaard, A. 1992b. Temperature dependent functional response of *Encarsia formosa* parasitizing the cotton whitefly, *Bemisia tabaci* on Poinsettia. Ent. Exp. Appl. (in press).

Fransen, J.J & M.A.J. van Montfort, 1987. Functional response and host preference of *Encarsia formosa* Gahan (Hymenoptera, Aphelinidae), a parasitoid of the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Homoptera, Aleyrodidae). J. Appl. Ent. 103, 55-69.

Hassell, M.P., 1978. The dynamics of arthropod predator-prey systems. Princeton Univ. Press, Princeton, New Jersey.

Horowitz, A.R., H. Podoler & D. Gerling. 1984. Life table analysis of the tobacco whitefly, *Bemisia tabaci* (Gennadius) in cotton fields in Israel. Acta Ecol./Ecol. Applic. 5: 221-233.

Kajita, H. & J.C. van Lenteren, 1982. The parasite-host relationship between *Encarsia formosa* (Hymenoptera, Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera, Aleyrodidae). XIII. Effect of low temperatures on egg maturation of *Encarsia formosa*. Z. Ang. Ent. 93, 430-439.

Madueke, E-D.N. & T.H. Coaker, 1984. Temperature requirements of the white fly *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) and its parasitoid *Encarsia formosa* (Hymenoptera: Aphelinidae). Entomol. Gener. 9 (3), 149-154.

Nechols, J.R. & M.J. Tauber, 1977. Age-specific interaction between the greenhouse whitefly and *Encarsia formosa*: Influence of host on the parasite's oviposition and development. Environ. Entomol. 6(1), 143-148.

Osborne, L.S., 1982. Temperature-dependent development of greenhouse whitefly and its parasite *Encarsia formosa*. Environ. Entomol. 11, 483-485.

Sharaf, N. & Y. Batta. 1985. Effect of some factors on the relationship between the whitefly, *Bemisia tabaci* Genn. (Homopt., Aleyrodidae) and the parasitoid *Eretmocerus mundus* Mercet (Hymenopt., Aphelinidae). Z. Ang. Ent. 99: 267-276.

Sharaf, N.S., A.M. Al-Musa & Y. Batta. 1985. Effect of different host plants on the population development of the sweetpotato whitefly (*Bemisia tabaci* Genn.; Homoptera: Aleyrodidae). Dirasat XII (6): 89-100.

Stenseth, C., 1975. Temperaturens betydning for utviklingen av snyltevepsen *Encarsia formosa*. Gartner Yrket, 65 (21/2), 136-139.

Vianen, A. van & J.C. van Lenteren, 1986. The parasite-host relationship between *Encarsia formosa* (Hymenoptera, Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera, Aleyrodidae). XV. Oogenesis and oviposition of *Encarsia formosa*. Z. Ang. Ent. 102, 130-139.

von Arx, R., J. Baumgärtner & V. Delluchi. 1983. Developmental biology of *Bemisia tabaci* (Genn.) (Sternorrhyncha, Aleyrodidae) on cotton at constant temperatures. Bull. Soc. Entomol. Suisse 56: 389-399.

Yano, E., 1987. Population responses of *Encarsia formosa* to the greenhouse whitefly and their role in population dynamics of whitefly-*E. formosa* system. Bull. O.I.L.B/W.P.R.S 1987/X/2, 193-197.

Table 1. Biological characteristics of *B. tabaci* on Poinsettia and their temperature-dependency, as well as lower temperature thresholds (T_0) and mean developmental times in day-degrees (°D) for different life stages.

	16°C	19°C	22°C	25°C	28°C
Developmental time (days ± S.E.)					
Egg-stage	34.3 ±0.33	17.6 ±0.09	12.7 ±0.12	10.5 ±0.14	7.8 ±0.06
Egg-adult	137.2 ±2.85	66.8 ±0.38	38.7 ±0.26	31.9 ±0.35	23.2 ±0.17
Developmental rate (y), rel. temperature (T)					
Egg-stage		$y = -0.095 + 0.0079 \cdot T$,		$r = 0.997$	$P < 0.01$
				$T_0 = 12°C$	°D = 126.2 (±0.5)
Egg-adult		$y = -0.043 + 0.0031 \cdot T$,		$r = 0.996$	$P < 0.01$
				$T_0 = 14°C$	°D = 327.2 (±1.3)
% Mortality (± S.E.)					
Egg-stage	19.3 ±1.52	9.2 ±1.03	2.1 ±0.51	1.0 ±0.32	2.8 ±0.62
Egg-adult	95.0 ±0.50	60.4 ±1.41	60.6 ±1.26	39.3 ±1.11	6.1 ±0.75
Relation with temperature					
Egg-stage		$\sin^{-1}\sqrt{pe} = 0.808 - 0.026 \cdot T$, (pe: prop. egg-mortality)		$r = 0.851$	$P = 0.068$
Egg-adult		$\sin^{-1}\sqrt{pa} = 2.567 - 0.079 \cdot T$, (pa: prop. egg to adult mortality)		$r = 0.959$	$P < 0.01$
Preoviposition period (days ± S.E.)	4.3 ±0.67	-	3.0 ±0.11	-	2.2 ±0.1
Adult longevity (days ± S.E.)	50.8 ±3.99	-	21.8 ±1.60	-	16.0 ±0.85
Developmental rate (y), rel. temperature (T)[1]		$y = -0.021 + 0.0027 \cdot T$,		$r = 0.937$	$P < 0.001$
				$T_0 = 7.8°C$	°D = 350.3(±16.0)
Sex-ratio (f) (♀/(♀+♂)) (± S.E)	-	0.60 ±0.03	0.63 ±0.03	0.69 ±0.04	0.76 ±0.02
Relation with temperature		$\sin^{-1}\sqrt{f} = 0.49 + 0.0196 \cdot T$,		$r = 0.903$	$P < 0.0001$
Age-specific fecundity, temperature-dependent (F_x, eggs/day/♀)	$F_x = (\alpha + \beta T) \times e^{-(\delta + \epsilon T) x}$				
	$\alpha = -1.677 \pm 0.156$	$\beta = 0.120 \pm 0.009$	$\delta = 0.024 \pm 0.014$	$\epsilon = 0.002 \pm 0.001$	
	$T_0 = -\alpha/\beta = 14°C$			Max. eggs/day/♀ at 125°D,	
No. eggs/♀ up to average lifespan	$F(T)_{avr} = \int_0^y (\alpha + \beta T)\, y\, e^{-(\delta + \epsilon T) y}\, dy$,				
predicted	60.2	-	90.9	-	96.3
Max. no. eggs/♀	$F(T)_{max} = \int_0^\infty (\alpha + \beta T) \times e^{-(\delta + \epsilon T) x}\, dx$				
predicted	77.5	-	208.3	-	263.0
	T is temperature; x is age of ♀; y is avr. ♀ lifespan; α, β, δ, ϵ are constants				
Population parameters					
R_0	1.238	11.503	17.979	42.834	57.624
r_m (days-1)	0.0012	0.0277	0.0562	0.0872	0.1263
Generation time (days)	169.12	88.24	51.41	43.09	32.10
Doubling time (days)	550.12	25.04	12.33	7.95	5.49
Relation with temperature					
r_m		$r_m = -0.167 + 0.0103 \cdot T$,		$r = 0.997$	$P < 0.001$

[1] Based on adult longevity for whiteflies reared on Poinsettia and for whiteflies reared on tobacco, for details see Enkeggard, 1992a.

Table 2. Biological characteristics of *E. formosa* parasitizing *B. tabaci* on Poinsettia and their temperature-dependency; the lower temperature thresholds (T_0) and mean developmental times in day-degrees (°D) for different life stages; and the parameters and R-values for the model (2) describing the functional response of the wasps towards 4th instars of *B. tabaci*.

	16°C	22°C	28°C
Developmental time (days ± S.E.)			
Egg-adult	72.8 ±0.86	25.3 ±0.30	14.0 ±0.17
Developmental rate (y), rel. temperature (T)			
Egg-adult	$y = -0.064 + 0.0048 \cdot T$,	$r = 0.998$ $T_0 = 13.3$°C	$P = 0.04$ °D = 207.4 ±1.66
% Mortality (± S.E.)			
Egg-adult	52.0 ±4.51	30.1 ±3.71	31.4 ±3.14
Adult longevity (days ± S.E.)	30.1 ±2.49	15.2 ±0.91	9.2 ±0.78
Developmental rate (y), rel. temperature (T)			
	$y = -0.07 + 0.006 \cdot T$,	$r = 0.997$ $T_0 = 11$°C	$P = 0.0001$ °D = 162.9 ±7.94
Functional response			
temperatur-dependent model (2)	a' (leaf·hour^{-1}) (±S.E.) 0.033 ±0.005	d (hour·°C)$^{-1}$ (± S.E.) 0.05 ±0.005	R^2-value 0.956
Fecundity			
Max. no of eggs/♀/day (from model (2))	0.8	5.6	10.4
Population paramters			
R_0	11.788	60.497	66.193
r_m (days^{-1})	0.0279	0.1303	0.2388
Generation time (days)	90.30	33.08	19.02
Doubling time (days)	24.84	5.32	2.90
Relation with temperature			
r_m	$r_m = -0.254 + 0.0176 \cdot T$,	$r = 0.999$	$P = 0.011$

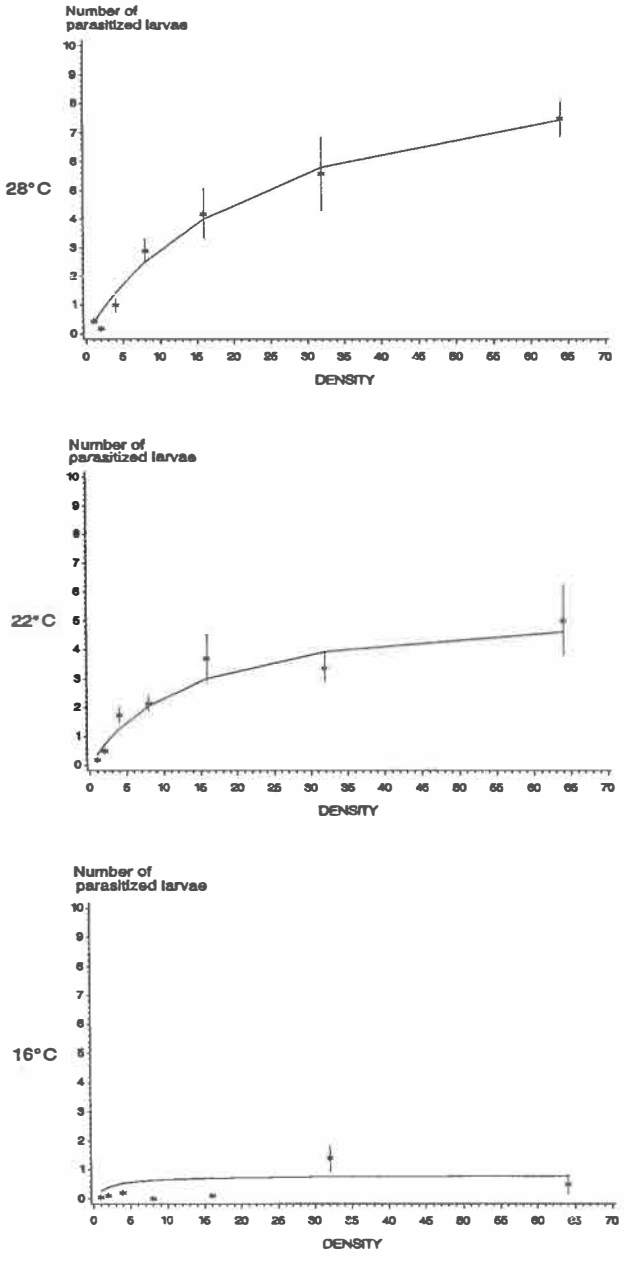


Fig. 1. Functional response of *E. formosa* expressed as the number of parasitized larvae in relation to density (fourth instar larvae/leaf) of *B. tabaci* at 28°C, 22°C and 16°C. The results are from laboratory experiments with a 24-hours exposure (16 hours with light) of infested leaves to the parasitoids. The curves were obtaines by applying model (1) to the data.

The minute pirate bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), as a predator of western flower thrips, *Frankliniella occidentalis* (Pergande), in chrysanthemum, rose and Saintpaulia.

Joanne J. Fransen, Menno Boogaard & Jan Tolsma

Research Station for Floriculture, Linnaeuslaan 2A, 1431 JV Aalsmeer, the Netherlands.

*The western flower thrips, **Frankliniella occidentalis**, has become a major pest in many ornamental crops over the last eight years. One of the natural enemies being studied for control of this pest is the minute pirate bug **Orius insidiosus**. Experimental releases of the predators resulted in reduction of thrips numbers in chrysanthemum and Saintpaulia, but not in roses. The predators in the nymphal and adult stage were found in the flowers but in very low numbers in roses compared with the other ornamentals.*

Introduction

Among the predators known to attack western flower thrips (WFT) are several *Orius* species. Herring (1966) stated that these anthocorids have been observed on a wide range of ornamentals as well as on cotton, potatoes, corn, peppers and soybeans. *Orius majusculus*, one of the species endemic to Northern Europe, *O. albidipennis*, found in Southern Europe, *O. tristicolor* and *O. insidiosus*, reported from North America, are being considered for biological control of (WFT). From 1989 onwards research is being carried out in the Netherlands on the introduction of *O. insidiosus* in ornamental and vegetable crops. This predator is easy to rear and the diapause response to short daylength is less compared with the endemic species *O. majusculus* (Ramakers & Meiracker, 1992). *Orius insidiosus* is a polyphagous predator preying on thrips larvae as well as adults (Isenhour & Yeargan, 1981) whitefly, mites (McCaffrey & Horsburgh, 1986), aphids and lepidopteran eggs.

Experimental releases of *O. insidiosus* were carried out in the two cut flowers chrysanthemum and rose, and the pot plant Saintpaulia. A concise report of some results is presented here in which the effect of the host plant is illustrated.

Materials and methods

Chrysanthemum: The predators (see for rearing Beekman *et al.*, 1991) were released in a greenhouse compartment with chrysanthemum cv 'Pink Pompon', being a susceptible cultivar, and in a compartment with chrysanthemum cv 'Daymark', a medium resistant cultivar. Experiments were carried out in a crop growing from September to December (exp. 1) and in a crop growing from January to April (exp. 2). The 'high density' treatment consisted of plots (66 plants per plot) in which one thrips/two plants were released and one predator/plant (exp.1) or one predator/two plants (exp. 2). The 'low-density' treatment consisted of a release of one thrips/11 plants and afterwards one predator/11 plants. In total four releases of predators were carried out at two-week intervals. In every compartment two rows of plots were kept untreated. From four plots in every treatment at harvest time six flower branches were sampled. All the flowers were washed in 50% alcohol and thrips and predator numbers were counted.

Saintpaulia: In November and December 1991 releases of *O. insidiosus* were carried out in Saintpaulia cv 'Colette'. There were flower buds and an occasional flower present at the start of the experiment. WFT was found in the flowers at the start of the experiment (week 45), but extra thrips was introduced at a rate of one per plant (week 46). The experiment lasted until the first week of January. Different release strategies were used in plots consisting of a table with 200 plants each: (a) no predators were released; (b) one predator/plant/week was introduced (in total seven predators/plant); (c) one predator/two plants/week (in total 3.5 predators/plant); (d) one predator/plant/two weeks (in total 4 predators/plant). The final count of thrips and predators was made from washings in 50% alcohol of 100 flowers per treatment.

Rose: The population of WFT was monitored in a two-year old rose crop cv 'Frisco' (60 m^2, grown on rockwool) in 1991. Once a week one predator/plant was released. The flowers were harvested regularly (numbers per week ranged from about 20 early in spring to over 100 in summer) and they were all washed in 50% alcohol. Numbers of thrips larvae and adults and *O. insidiosus* nymphs and adults were counted. During the year the population of thrips increased and in week 21, 22 and 23 in total six applications of *Verticillium lecanii* (Mycotal®) were carried out. This resulted in a reduction of thrips, but recovery of the population was observed and at week 28 and 29 three applications of flufenoxuron (Cascade®) were carried out. From week 14 onwards in total 16 Gerbera flowers were introduced to provide additional pollen. The flowers were renewed every two weeks, from week 30 onwards every week. Also the Gerbera flowers were washed in 50% alcohol and thrips and *O. insidiosus* numbers were counted.

Results and discussion

The results in Table 1 show that WFT populations on the medium resistent chrysanthemum cultivar Daymark develop to a lower extent compared with the populations on the susceptible cultivar Pink Pompon. The number of damaged plants was also less in the resistent cultivar. Also the number of damaged plants in the treated plots was lower than in the untreated plots (Fransen & Tolsma, in press). In the second experiment the numbers of WFT in the plots with low-density releases of the predator were not different from the numbers in the untreated plots. This is probably due to the difference in season (higher temperatures and use of black-outs in exp. 2) and a difference in (natural) infestation level between the plots. On some occasions *O. insidiosus* spread to the untreated plots which were separated form the other plots by a concrete path 3-4 m^2 wide. In the first experiment more predators were found in the plots with low-density releases. This may be explained by assuming that the WFT population in the high-density plots was almost eradicated and the predators migrated to other thrips infested plots. In the second experiment WFT numbers generally were higher, and highest predator numbers were found in the high-density plots.

In Saintpaulia control of WFT was also achieved (Table 2). However, the release of a total of seven predators per plant did not result in the lowest thrips numbers, but best results were obtained by the introduction of one predator per two plants per week. Again *O. insidiosus* was found in the flowers. It was observed, also in other experiments, that some thrips may still be present, but the typical thrips damage being pollen scattered over the petals, was absent in the treated plots.

The numbers of WFT in rose flowers were very high in contrast to the numbers of predators (Figure 1 and 2). Hardly any *O. insidiosus* was found in the rose flowers whereas the predators were present in the few Gerbera flowers distributed over the glasshouse. Thrips number were higher in the Gerbera flowers round week 20 but these flowers were kept in the greenhouse for 14 days which is longer than the perios from rose bud to flower ready for harvest. The thrips numbers were about the same in both flowers after week 30. The predator numbers, however, were still higher in the Gerbera flowers than in the rose flowers. Application of *Verticillium lecanii* had some effect but the application of the chemical flufenoxuron gave a higher reduction.

Table 1. The mean number of thrips (adults and larvae) and *O. insidiosus* (adults and nymphs) per flower branch after sampling six flower branches from four plots per treatment for the susceptible chrysanthemum cultivar Pink Pompon and the medium resistent cultivar Daymark.

	mean # thrips/ flower branch		mean # *Orius*/ flower branch	
treatment	exp.1	exp.2	exp.1	exp.2
Pink Pompon				
untreated	8.8	7.4	0.00	0.13
low density[1]	1.0	11.7	0.70	0.42
high density[2]	0.7	4.6	0.29	0.80
Daymark				
untreated	4.8	1.7	0.33	0.00
low density[1]	1.1	1.6	0.88	0.16
high density[2]	0.0	1.3	0.41	0.25

[1]:1 thrips/11 plants; 4 *O.insidiosus*/11 plants
[2]:1 thrips/2 plants; 4 *O.insidiosus*/plant (exp. 1) or 2 *O.insidiosus*/plant (exp. 2)

Table 2. Mean numbers of western flower thrips and *O. insidiosus* in Saintpaulia flowers (n=100) (a: no predators; b: 7 predators/plant; c: 3.5 predators/plant; d: 4 predators/plant).

week no.	mean # thrips/flower treatment: a	b	c	d	mean # *Orius*/10 flowers treatment: a	b	c	d
52	11.6	4.9	2.6	5.1	0.0	1.4	1.2	0.6

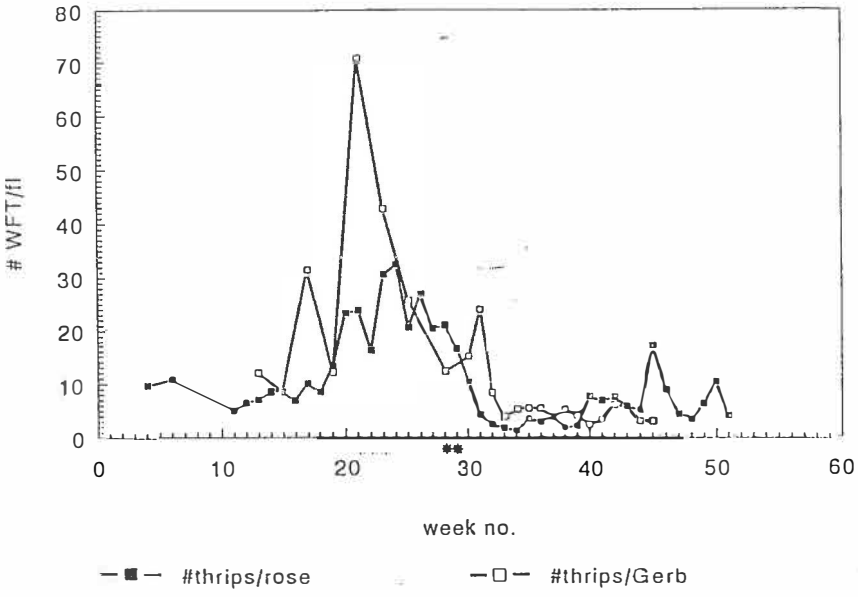


Figure 1. Mean number of western flower thrips larvae and adults per rose and Gerbera flower per week (*: application of *Verticillium lecanii* in week 21 to 23; application of flufenoxuron in week 28 and 29).

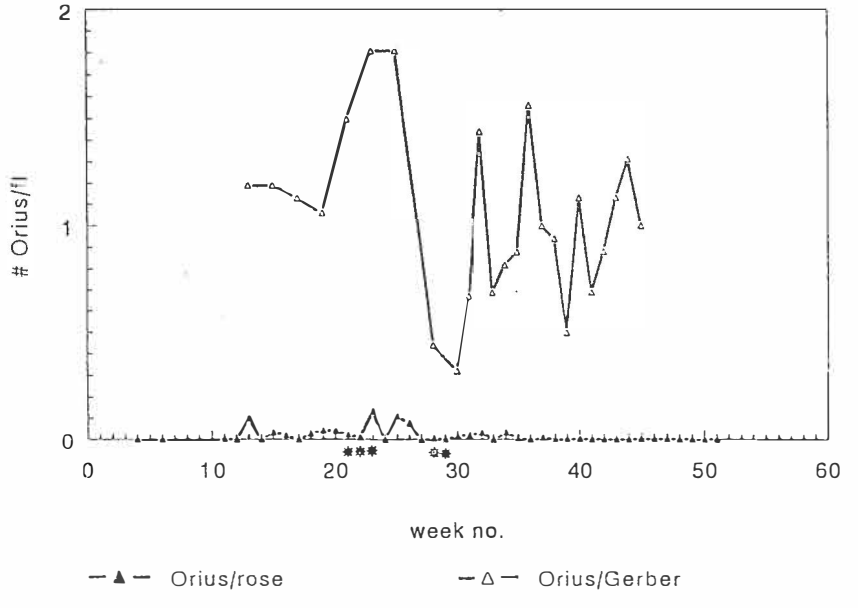


Figure 2. Mean number of *Orius insidiosus* nymphs and adults per rose and Gerbera flower per week (*: see Figure 1)

Orius insidiosus was successful in suppressing WFT populations in Saintpaulia and chrysanthemum. Introduction strategies have to be considered in relation to the growing period and the harvest regime. Keeping thrips populations at a low level will depend on the efficiency of the searching behaviour of the predator and their capacity to establish a population.

Alternative prey or pollen as an additional food source may help to establish the predator, as was observed in a sweet pepper crop (Meiracker & Ramakers, 1991). However this was not observed in the rose crop in addition of Gerbera flowers. Host plant resistance in combination with biological control appears to be successful in chrysanthemum. Comparison of the results of the releases of *O. insidiosus* in chrysanthemum, Saintpaulia and rose show that there is a host plant effect present. Differences in behaviour on chrysanthemum and rose have been reported by Beekman et al. (1991) and the phenomenon of host plant effect is subject of further research.

References

Beekman, M., Fransen, J.J., Oetting, R.D. & Sabelis, M.W., 1991. Differential arrestment of the minute pirate bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), on two plant species. Med. Fac. Landbouww. Rijksuniv. Gent, 56/2a: 273-276.

Fransen, J.J & Tolsma, J., 1992. Releases of the minute pirate bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), against western flower thrips, *Frankliniella occidentalis* (Pergande), on chrysanthemum. Med. Landbouww. Rijksuniv. Gent, *in press*.

Herring, J.L., 1966. The genus *Orius* of the Western hemisphere (Hemiptera: Anthocoridae). Ann. Entomol. Soc. Am. 54: 1093-1109.

Isenhour, D.J. & Yeargan, K.V., 1981. Predation by *Orius insidiosus* on the soybean thrips, *Sericothrips variabilis*: effect of prey stage and density. Environ. Entomol. 10: 496-500.

McCaffrey, J.P. & Horsburgh, R.L., 1986. Biology of *Orius insidiosus* (Heteroptera: Anthocoridae): a predator in Virginia apple orchards. Environ. Entomol. 15: 984-988.

Meiracker, R.A.F. van den & Ramakers, P.M.J., 1991. Biological control of the western flower thrips, *Frankliniella occidentalis*, in sweet pepper, with the anthocorid predator *Orius insidiosus*. Med. Fac. Landbouww. Rijksuniv. Gent 56/2a: 241-249.

Ramakers, P.M.J. & Meiracker, R.A.F. van den, 1992. Biological control of western flower thrips with predatory mites and pirate bugs: can two do better than one? Annual Report 1991, Institute of Plant Protection, Wageningen, the Netherlands, 9-21.

DAMAGE THRESHOLD LEVELS FOR WESTERN FLOWER THRIPS, *FRANKLINIELLA OCCIDENTALIS* (PERG.) (THYSANOPTERA: THRIPIDAE) ON ORNAMENTALS

J.E. Frey, Swiss Federal Research Station
for Fruit-Growing, Viticulture and Horticulture,
CH - 8820 Wädenswil, Switzerland

Summary
Damage threshold levels of Western Flower Thrips *Frankliniella occidentalis* Perg. populations on nine ornamental plant species were established (Begonia, Chrysanthemum, Gerbera, Impatiens, Poinsettia, Rosa, Saintpaulia, Sinningia, Streptocarpus). Blue sticky traps were used for population monitoring. They were changed weekly over a period of up to 30 months and for each week the damage caused by Western Flower Thrips was assessed. The evaluated threshold levels are mainly dependent on plant species and on temperatures. Three different damage thresholds could be determined: a low density level of 5-10 thrips caught per trap per week for very susceptible or highly attractive plant species, a medium density level of 18-30 thrips/trap/week for most of the tested plant species, and a high density level of above 40 thrips/trap/week for few plant species that seem to be rather resistant to thrips attack.

1. Introduction

One of the primary goals of integrated pest management is to reduce pesticide use as much as possible. This is only possible if the pest population densities are monitored. For Western Flower Thrips, blue sticky traps to an affordable price are commercially available. They are relatively selective, i.e., they do not trap many organisms other than thrips species, which is helpful in avoiding errors in counting the thrips. The use of sticky traps to monitor thrips population levels has many advantages which merit the expense of the traps as well as of the work necessary for handling and counting. They provide reliable information to the grower on the actual pest population density of the adults (Shipp and Zariffa, 1990) and also give important hints on the success of control measures including pesticide use. To be able to reduce the frequency of sprayings, the grower needs to know at which pest densities he has to do what. Therefore, trap suppliers and/or extension services should define damage threshold levels or tolerance levels. However, to my knowledge, tolerance levels for thrips population densities on ornamentals have so far not been described.

In this paper I report preliminary results on a study to establish damage threshold levels for Western Flower Thrips on nine species of ornamental plants using commercially available blue sticky traps.

2. Material and methods

Two different blue sticky traps were used to estimate thrips population densities in the greenhouses: Biopax blue® and, during the third year of the study, Rebell® blu. The difference in relative attractiveness between the two trap types was established by comparative trappings and the trap catches were adjusted accordingly.

The following plant species were studied: Begonia, Chrysanthemum, Gerbera, Impatiens, Poinsettia, Rosa, Saintpaulia, Sinningia, and Streptocarpus. One trap per plant species was placed 10 cm above the top parts. Trap density was in average circa 1 trap per 100m^2. The growers replaced the traps weekly and completed a form con-

taining information on the culture (e.g., temperature, relative humidity), on the present state of the plants, on plant protection measures taken during the week, and a quantitative assessment (% loss) of the thrips damage. The thrips on each trap were counted under the binoculars and the numbers were entered in a database together with the corresponding information on the culture.

For data analysis, the weekly reports were sorted in two groups: (1) "damage reported" vs. (2) "no damage reported". Box plots were used to analyse the variation in thrips catches within the two groups. Damage thresholds were defined as the 10th percentiles of the numbers of trapped thrips per week in those cases where damage was reported.

3. Results

The average number of trapped thrips was always higher in the group "damage reported" than in the group "no damage reported". Similarly, the average temperature of the group "damage reported" was 1.4°C higher than that of the group "no damage reported" ($P<0.01$, two-tailed t-test) suggesting that threshold levels probably are temperature-dependent. Figure 1 shows one example of the box plots.

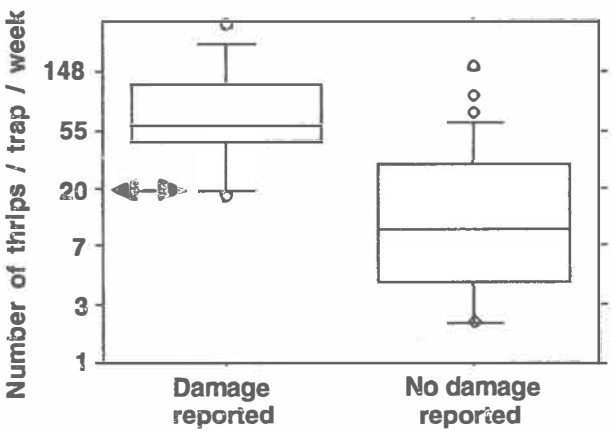


Fig. 1. Variation of the number of thrips caught weekly on blue sticky traps on chrysanthemum as separated in the two groups "damage reported" and "no damage reported".

The nine plant species analysed can be grouped into three threshold classes according to the 10th percentile values of the weeks with reported thrips damage representing the damage threshold levels (Tab. 1).

Tab. 1. Classification of plant species in three classes of threshold levels according to 10th percentiles of the number of thrips caught on blue sticky traps per week with reported damage.

Damage threshold level	No. of thrips/trap/week	Plant species
low	<10	Saintpaulia, Streptocarpus
medium	18 - 30	Chrysanthemum, Gerbera, Impatiens, Rosa, Sinningia
high	>40	Begonia, Poinsettia

The presented values are preliminary because they were calculated from the pooled data over the entire observation period. After study termination, they will be analysed according to growing season, i.e., different states of cultures and temperature, which may result in variable tolerance levels adapted to culture, season or temperature, respectively, and phenology.

The populations of Western Flower Thrips are higher in summer than in winter (Fig. 2). This is partly due to the higher reproduction rate at elevated temperatures (Lublinkhof and Foster, 1977) and possibly also due to the more abundant availability of pollen (Trichilo and Leigh, 1988).

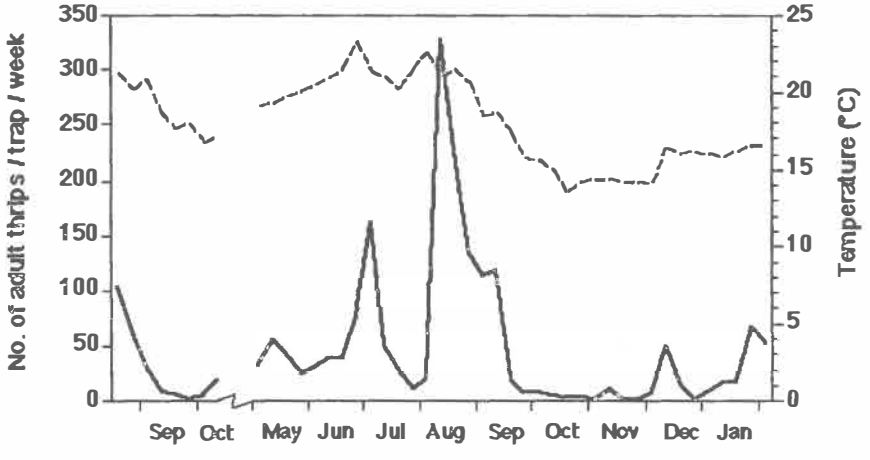


Fig. 2. Population dynamics of Western Flower Thrips on Chrysanthemum and average greenhouse temperature during the observation period (the depression in July was caused by the application of pesticides).

4. Discussion

Monitoring of insect pest populations is an important first step towards integrated pest management in greenhouses. In a first step, the information will help the grower to find the right time for pesticide application, to avoid unnecessary sprayings

and to select more efficient pesticides. In a second step it may allow the use of beneficials at least as long as the pest population levels are low.

The use of blue sticky traps is a valuable tool for monitoring adult Western Flower Thrips numbers in greenhouses (Brødsgaard, 1989b, and references therein). However, so far there has been no information on the tolerance levels of ornamental plants. Defining such tolerance levels may not be easy, since attractiveness of an optical trap always is only relative to that of the environment (Brødsgaard, 1989a) and possibly also depends on its exposure (Steiner, 1992). The results of the present study show, however, that it may at least be possible to give approximate threshold levels as guidelines. These levels would have to be adjusted for each individual greenhouse situation by the grower.

For most of the studied plant species, a number of 18-30 thrips caught per week on a single trap reflects a threshold level above which damage may occur. Because in many greenhouses more than one plant species is grown at the same time, higher population levels should probably not be tolerated even on the more resistant plant species. Thus, only for very susceptible plant species there is a need for lower tolerance levels. This may only be required at the most attractive, i.e., flowering stages, as e.g. Saintpaulia is a very poor host for Western Flower Thrips in the non-flowering stages (H. Brødsgaard, pers. comm.).

To validate the tolerance levels suggested in this paper, we will ask growers to follow them in their pest treatment plans and to report thrips density levels together with the information on the crop quality in the same way they did for the present study. Once the thrips population in a greenhouse has increased above the tolerance levels given in this paper, it should be reduced as fast as possible to avoid damage. This can not be done using beneficials or, e.g., growth inhibitors that usually need some time until they are effective. Therefore, under integrated pest management programmes thrips population density should be kept below these tolerance levels. The results of the follow-up study will help to formulate useful guidelines for Western Flower Thrips population monitoring.

Acknowledgements

I would like to thank B. Frutschi and his collaborators of the Kantonale Gartenbauschule Oeschberg, B. Frey, H. Hochstrasser, E. Höhn, S. Mazza and M.E. Schmidt for their contribution to this study, and M.P. Candolfi for his helpful comments on the manuscript. This project was supported in part by the Verband Schweizerischer Gärtnermeister VKB/ESG, the Migros Genossenschaftsbund and Credit Suisse CS.

5. References

BRØDSGAARD, H.F., 1989a. Coloured sticky traps for *Frankliniella occidentalis* (Thysanoptera: Thripidae) in glasshouses. J. appl. Ent. 107, 136-140.

BRØDSGAARD, H.F., 1989b. *Frankliniella occidentalis* (Thysanoptera: Thripidae) - a new pest in Danish glasshouses: A review. Tidsskrift for Planteavl 93, 83-91.

LUBLINKHOF, J. & FOSTER, D.E. 1977. Development and reproductive capacity of *Frankliniella occidentalis* (Thysanoptera: Thripidae) reared at three temperatures. J. Kansas Entomol. Soc. 50, 313-316.

SHIPP, J.L. & ZARIFFA, N. 1990. Developing a sampling program for Western Flower Thrips on greenhouse peppers. SROP/WPRS Bull. XIII/5, 194-197.

STEINER, M.Y. 1992. IPM for whitefly control in greenhouse poinsettias: Report on 1991 research trials at the Alberta Environmental Centre. Vegreville, Alberta T9C 1T4, Canada.

IPM AND EXTENSION IN FLORICULTURE IN THE NETHERLANDS

J.W.F.M. de Goey

Information and Knowledge Centre, Department of Floriculture, Aalsmeer, The Netherlands

Introduction

In the Netherlands the term IPM is not often used. The Dutch call it "Biological Control". But in fact this biological control is "integrated" in the day to day plant protection technique. The means available are attuned to the use of biological control agents. Slowly other "integrated" techniques are finding their way into normal pest control. Sticky traps are being used for "Scouting". Sometimes gauze is being used for keeping out insects. All in all this biological control is beginning to look more and more like real Integrated Pest Management.

All developments are taking place in the production of vegetables under glass. At the moment IPM is used on 2,500 ha. In floriculture the developments are slow, almost non-existent. IPM (including trials) is being used on not more than 25 ha. For the Government this is not enough and much energy is put into IPM-extension.

History

In the glasshouse cultures in Europe biological control was used before the Second World War. This control could have led to a speedy development and wide-spread application were it not for the arrival of chemical pesticides after the war. Chemical pesticides were cheaper and easier to use than biological agents. The use of chemical products spread unrestricted until the late sixties. In these years the disadvantages of chemical pesticides slowly became clear. The red spider mite (*Tetranychus urticae*) became resistant to the chemicals used in those days. Alternative methods had to be found. In the early sixties research already showed that it was possible to control the red spider mite by using the natural enemy, *Phytoseiulus*, a predatory mite. A widespread serious infection of greenhouse whitefly in 1971 led to research into biological control of this whitefly, and its natural enemy *Encarsia formosa* was found. It was not until 1973 that this predatory wasp could be used successfully against whitefly in greenhouses.

All these developments took place in greenhouse vegetable production. The restriction on the use of chemicals in vegetable crops in relation to residues led to research into alternative, non-chemical pest control. In edible crops a new awareness developed, linking good health and the use of chemical pesticides. In a later stage, when the permitted residue levels in the United States were lowered, this awareness was rewarded by economical advantages. Export of fruit-vegetables to the USA grew substantially.

In the case of floriculture there was no such awareness. There must have been growers who resented the use of chemicals, but a large number was more concerned about the presence of a pest or disease in their crop than a residue or effects on the environment. Alternative control methods were not considered until much later. If one chemical did not work more was used or an alternative, within the limits of the Pesticide Act. All this did not stimulate the awareness of the use of chemicals and its consequences. Even the Governmental Extension Service did not contribute anything on this point.

In glasshouse vegetable crops growers are by tradition quite open towards their fellow-growers. Exchanging experiences, even new inventions is quite common. This is not the case in floriculture. The flower and pot plant growers see each other more as competitors than as colleagues. A grower who discovers a new money-saving method will keep this to himself. This accounts for the slow introduction of new methods and techniques, including IPM and is a problem the extension service always had to deal with. At the moment everybody agrees that this attitude will have to change but old habits die hard.

Another important reason for the slow development of IPM is the existence of zero-tolerance. Some countries demand that some products are absolutely free of certain pests and diseases. In practice this means that everyone aspires to 100% disease and pest free products, even if there are no standards for their particular crops. This aspiration is stimulated by the auctions and trade. In trade the absence of pests and disease is accepted as normal quality and for flowers with some spots or an insect (even if innocent) the prices goes down. The auctions promote this "quality-standard" by introducing "green corners". A product will be given the qualification "green", not if it is produced environmentally safely but if it is 100% clean (but certainly not free of chemicals). To overcome this economical barrier is an enormous task for extension as well as Government. Constant pressure on trade and auction, educating quality controllers on the auctions, and political discussions with other countries are necessary in order to solve this problem.

Present situation

Keeping a crop free of diseases and pests, if at all possible, is a difficult task and results in a heavy input of crop protection chemicals. It is a well known fact that killing the last insect or the last spore requires an amount of chemicals outside all proportions (the law of diminishing returns). To many people decreasing the use of chemicals means allowing a slight infection of their crop. This means lower prices, so the incentive to use alternative methods is low. Growers only want to start trials when they are certain there is no financial loss.

In greenhouse vegetable production IPM is used on over 2,500 ha, in floriculture this is merely 25 ha. In the last few years there has been a growing interest in the use of IPM in floriculture. Application however is still not widespread. The reasons mentioned earlier are the cause of the growers' reluctance. Among the growers absence of a good knowledge of pests and disease in general is another reason. This also applies to the extension officers and other private advisers. Advice on pest control is given with the pesticide guide in hand and usually involve spraying.

It is often heard that practical developments are ahead of research. Exactly the opposite goes for IPM in floriculture. Research at the Research station of Floriculture at Aalsmeer and by the industry (Koppert) has shown that biological control of some pests is possible in at least a number of the most important crops. Yet there is little enthusiasm to apply biological control, even on an experimental basis, in spite of the many discussions about the effect of chemicals on the environment. Only in the last two years have experiments tentatively started. Certainly as long as the zero-tolerance (or the price policy in trade) exists, little or nothing will change.

Also the argument is given that research has not yet taken place on many crops. So it is impossible to begin because it is unknown how to begin. But this does not count as an argument! Certainly, if all problems have a standard solution the introduction will go faster. Yet the lack of research data and experience should not be a hindrance. The principles are known and the biological agents are available. With the help of colleagues with experience, the extension service, the supply industry and research, each grower could start his own experiment. It is impossible to ask research to investigate all the different crops in existence. Even if the money were available the manpower certainly is not. In the Netherlands over 700 different species of flower and pot plant are grown, each with their own number of varieties. Research on one crop would on average take two persons for two years for one pest. This would lead to 2,800 man years of research per pest, hence 100 researchers 28 years. According to the latest plan of the Government, IPM must be applied widely in floriculture by the year 2000, the year in which the use of a large number of pesticides will be forbidden.

Politics and trends

Under pressure of experts, environment activists and public opinion the Dutch Government has drawn up a Multi-year Crop Protection Plan. This plan aims to reduce the use of pesticides by over 50%, the dependence upon chemical pesticides, and the emission of chemicals into the environment. To reach these aims plans have been drawn up by experts for each sector. In two stages (up to 1995 and from 1995 - 2000) a large number of environment-critical applications of pesticides will be forbidden. Also the volume of pesticides used must be substantially lowered. Schemes to reach these aims have been designed. In floriculture the main solutions will be found in the field of artificial substrates and IPM. At the end of the period IPM must be an accepted and widely used method for most crops. The Dutch Government considers extension to be the most important instrument to reach the aims.

The extension service always used to play an important role in the introduction and spread of new techniques. But with the privatisation of the Dutch extension service the Government has lost this important instrument in steering development. The extension officer of the moment is much more concerned with the well being of the individual grower than with that of the industry as a whole. In case of uncertain situations the safest solution is chosen when growers and extension officers should be taking certain risks. This means a change in mentality and perhaps again more influence of the Government.

If by 1995 results should not meet expectations the Government will certainly issue compulsory measures such as prohibiting certain pesticides altogether, introducing taxes and requiring special spraying equipment.

Even consumers are beginning to take action. Only recently a Dutch consumer organisation issued a report about the use of pesticides in the ten most sold flowers. Four of these were cut flowers, the rest were bulb flowers. This report showed the high use of chemicals on rose and tulip, two consumer favourites. This consumer organisation advised the consumer not to buy these products but as it was the first protest of its kind it did not have much effect (yet). Also only production methods were considered and not whether the products were poisonous or not. These investigations and allegations will be occurring more often in future. In the Netherlands, flowers still have a friendly natural image, but more of these protests will certainly change this.

The sector is being forced by the Government and the consumer to reconsider its production methods and search for more environment-friendly production methods. Which of the two will exert the most pressure is difficult to predict. If the consumer should decide to boycott the product because of the damage done to the environment thus causing great financial losses, changes will take place quickly. It is feared that this will not go fast enough and that Government policy will have to be the first to bring about the changes. The sector will first resort to finding loopholes in the law and perhaps illegal practices. Only after a long period of protest will be sector abide by the regulations.

Future

The Dutch floricultural industry has to change its production techniques to more environmentally accepted methods. The Dutch Government is determined to execute its policy. In the long run the consumer will refuse flowers whose production harm the environment. One of the most obvious solutions is to use IPM extensively. Although the problem of the widespread use of chemicals and the importance of IPM is recognised by everyone, developments in the Dutch floricultural industry do not give rise to optimism about the future. In the coming eight years IPM must be commonly applied by most growers.

The task ahead for the Government is enormous. In the first place the level of knowledge of the extension service has to be raised substantially, if not, private advisers will take over their business and Government will lose its control completely. In the second place the knowledge of the growers has to be raised to the required level, in order for them to be able to work with IPM. Also all supplying industries and their advisers have to change their attitude towards IPM. An important task lies ahead for the auctions, although these are co-operatives they will have to create a better climate for environment friendly grown products and these products will have to be accepted by the trade. International trade demands will have to be amended so as not to lead to an excessive use of chemicals.

Only if the damage done to the environment is reduced to acceptable limits has the sector a chance to survive.

BIOLOGICAL CONTROL OF SCIARIDS IN ORNAMENTALS USING THE ENTOMOPATHOGENIC NEMATODE *Steinernema feltiae*.

DAWN H GOUGE & N G M HAGUE
Department of Agriculture, Reading University, U.K.

SUMMARY

The Sciarid fly *Bradysia* sp. is an economically important pest of glasshouse ornamentals in the U.K. Larvae damage seedlings and may even render mature plants unsaleable. The rhabditid nematode *Steinernema feltiae* was evaluated as a biological control agent under glasshouse conditions. Nematodes were applied directly into potted Fuchsias and as a result the numbers of adults trapped within the house was reduced by 73% in 9 weeks. Nematodes persisted well throughout the experimental period, and migrated throughout the growth media.

INTRODUCTION

Sciarids or fungus gnats commonly infest glasshouses and populations can rapidly increase to a level where serious plant damage may occur. Besides feeding on soil organic matter, fungi, and algae (Freeman, 1983), Sciarid larvae can cause serious damage to propagation material by feeding on roots and tunnelling into stems of cuttings (Binns, 1973). Sciarids also damage certain mature plants and are vectors of bacterial and fungal pathogens (Leath, 1969).

The use of insecticides has resulted in widespread insect resistance (White, 1981) and thus there is now an increased demand for a non-chemical alternative.

Steinernema feltiae is a rhabditid nematode occurring naturally throughout the British Isles, the nematodes being mutualistically associated with the pathogenic bacterium in the genus *Xenorhabdus*. Through inundative release, control of a broad range of pests can be achieved. The nematodes have a durable third stage infective juvenile (IJ3) which seeks out and kills insect hosts rapidly. The IJ3 stage can be stored, applied through normal spray equipment and can be mass-produced in fermenters. The IJ3 stage appears to be able to survive long periods of time in the soil (Kaya, 1991) and there is evidence for the recycling of nematodes in the soil.

Nematodes work well in cryptic environments in situations where chemical control agents fail. IJs are attracted to CO_2 and excretory products of the host larvae (Gaugler et al., 1980), they enter through natural body openings (Marcek et al.,1988) and invade the haemocoel where the *Xenorhabdus* is released from an oesophageal vesicle, the bacteria then cause septicaemia and death (Poinar & Thomas, 1966) of the Sciarid larvae. The nematodes feed on septicaemic tissues and reproduce within, when reserves are depleted (usually after a single generation in Sciarids) "dauer" larvae (the new IJs) form, and exit to the soil medium in search of a new host.

This paper presents the results of recent research using *S.feltae* as a biological control agent of Sciarids under glasshouse conditions.

MATERIALS AND METHOD

The *S.feltiae* isolate used in these experiments was found at the University of Reading and sent to Biosys, Palo Alto for formulation. The commercially formulated nematodes (isolate 244) were stored at 4°C for less than a week before use.

The experiment was done at a commercial nursery using the natural Sciarid populations (*Bradysia sp.*). Nematodes were applied to Fuchsias (Snow cap) grown individually in 8cm plastic pots, at a rate of 20,000 nematodes per pot (=780,000 nematodes per m^2) using a Brinkman hydraulic sprayer. Approximately 16560 plants were treated, and were arranged in a 23 bench glasshouse, with 720 pots per bench. The potting medium used was Fisons M2 (+ Phycote 3Kg per m^2), pH 4.49. No chemical pesticides were applied throughout the trial. All plants were top watered daily and the temperature range in the glasshouse was 20-24°C. When the nematodes were applied several 25ml samples of spray suspension were collected for evaluation of the nematode viability. Over the following 64 days the samples were evaluated bi-weekly as follows:

SCIARID EMERGENCE
a) Four pots taken at random from the glasshouse were caged and emerging adults caught and counted on suspended sticky traps.
b) Sticky traps were spaced at one per 36m^2 throughout the glasshouse, replaced bi-weekly and the adult Sciarids counted.

NEMATODE MOVEMENT AND PERSISTENCE
Three pots taken at random were divided into four levels: A - top 2cm, B - next 2cm, C - next 2cm, and D - bottom 2cm. Infective nematodes were extracted using exhaustive *Galleria* baiting.

The data obtained was subjected to ANOVA and tested for significance using Least significant mean tests.

RESULTS

Applying nematodes through a conventional sprayer did not affect nematode viability : 95% of the IJs were found to be alive in the spray suspension stored at 6°C for 24 hours after application.

The number of adult Sciarid flies emerging from the treated compost decreased over the experimental period by 73% (Fig.1) and there was a decrease in the numbers of flies caught on sticky traps above the crop by 92% (Fig.2).

Fig.1 The number of adult Sciarids trapped on sticky traps from caged plants.

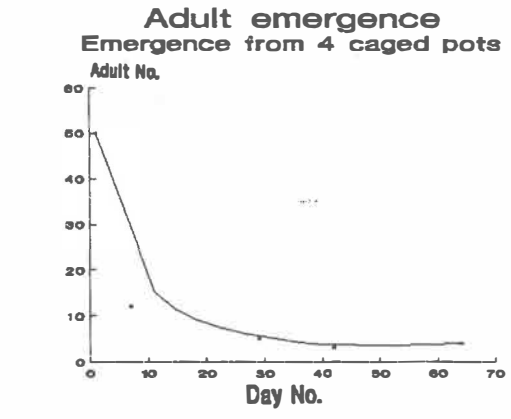
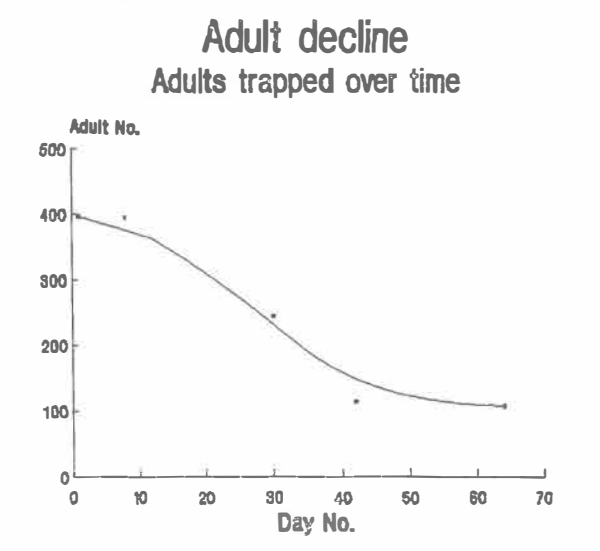


Fig.2 The decline in adult Sciarids monitored over 64 days in the glasshouse.



Nematodes rapidly disperse throughout the pots (Fig.3) and there is clear evidence that *S.feltiae* persists for at least 9 weeks within pots (Fig.4).

Fig.3 The persistence of nematodes over the 64 days of the experiment. S1, S2, S3, & S4 indicate the sample No. which is also referred to in Fig.4.

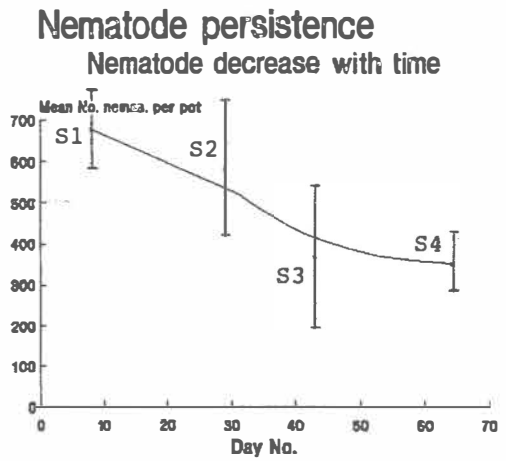
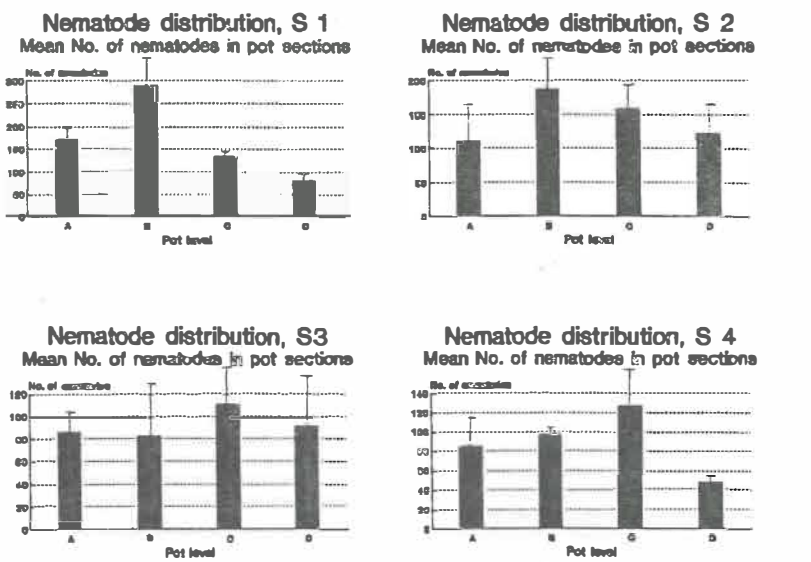


Fig.4 The number of nematodes recovered from different sections of the pots using an exhaustive *Galleria* assay.



DISCUSSION

The use of entomopathogenic nematodes in commercial glasshouses appears promising even though Cantelo, McDaniel & Thimijan (1977) described unsuccessful attempts to control Sciarids with *Steinernema feltiae*.

Results presented here indicate the rhabditid capacity to dramatically reduce fly populations even in the glasshouse itself where the ingress of flies from outside cannot be prevented. Pots removed from the glasshouse and caged in the laboratory ensured that the reduction in Sciarid emergence from pots was due to *S.feltiae* and not to changing factors within the glasshouse.

It is clear that infective nematodes are present in the soil throughout the experimental period. Either original IJs have remained viable in the growth medium or the nematodes are recycling through the host larvae. Research on persistence in soil is continuing.

Nematodes applied to the top of plant pots quickly distribute themselves throughout the pots. Thus, root damage is avoided.

To conclude *S. feltiae* can reduce the Sciarid population within the glasshouse to a low level which is satisfactory to the grower.

ACKNOWLEDGEMENTS

We thank Biosys,U.S.A. for supply of nematodes, and Mr. Brian Jeffries of Felbridge Nurseries for providing glasshouse facilities and his cooperation.

REFERENCES

BINNS, E.S., 1973. Fungus gnats (Diptera: Mycetophilidae, Sciaridae) and the role of mycophagy in soil: a review. Revue d' Ecologie et de Biologie du Sol 18: 77-90.

CANTELO, W.W., McDANIEL, J.S. & THIMIJAN, R.W., 1977. Research to reduce fly problems in the American mushroom industry. Pest Management in Protected Culture Crops. 15pp. Eds. SMITH, F.F. & WEBB, R.E. U.S.D.A.

FREEMAN, P., 1983. Sciarid flies, Diptera; Sciaridae. Handbooks for the identification of British insects 9, Part 6. 68pp. Royal Entomological Society of London.

GAUGLER, R., LEBECK, L., NAKAGAKI, B. & BOUSH, G.M., 1980. Orientation of the entomogenous nematode, *Neoaplectana carpocapsae* to carbon dioxide. Environ. Entomol. 8: 658.

KAYA, H.K., 1991. Effects of soil temperature, moisture, and relative humidity on entomopathogenic nematode persistence. J. Invert. Path. 57: 242-249.

LEATH, K.T. & NEWTON, R.C., 1969. Interaction of a fungus gnat, *Bradysia* sp. (Sciaridae) with *Fusarium* spp. on alfalfa and red clover. Phytopathology 59: 257-258.

MARCEK, Z., HAŇZAL, R. & KODRIK, D., 1988. Sites of penetration of juvenile steinernematids and heterorhabditids (Nematoda) into the larvae of *Galleria mellonella* (Lepidoptera). J. Invert. Path. 52: 477-478.

POINAR, G.O. & THOMAS, G.M., 1966. Significance of *Achromobacter nematophilus* Poinar & Thomas, (Achromobacteiaceae: Eubacteriales) in the development of the nematode, DD136 (*Neoaplectana* sp. Steinernematidae). Parasitology 56: 385-390.

WHITE, P.F., 1981. Chemical control of the mushroom Sciarid *Lycoriella auripila* (Winn.) Mushroom Science 11: 265-273.

PRELIMINARY RESULTS ON DENSITY AND INCIDENCE COUNTS OF APHIDS IN CUT CHRYSANTHEMUMS IN THE GREENHOUSE

J. Adriaan Guldemond
Research Institute for Plant Protection (IPO-DLO)
P.O.Box 9060, 6700 GW Wageningen, The Netherlands

Summary
Sampling of aphids (Aphis gossypii and Myzus persicae) in year-round cut chrysanthemums in the greenhouse was studied. It was shown that density can be estimated by incidence counts. Taylor's Power Law applied on the aphid data showed they had an aggregate distribution. The number of aphids on yellow sticky traps and density are not related. Monitoring aphids in chrysanthemums for a programme of supervised control can be achieved by incidence counts.

1. Introduction

The search for reduction of the use of pesticides in floriculture in The Netherlands has been stimulated by the intention of the Dutch gouvernment to curb its use. By 1995 a 47% reduction should be established, increasing to 64% in the year 2000 (Min. of LNV, 1990). The major part of this reduction is expected to be achieved in soil desinfectans and about a third in insecticides, acaricides and fungicides. The use of pesticides in year-round greenhouse chrysanthemums is with circa 35-90 kg active compounds/ha/year rather high (lowest and highest 20%, Vernooij, 1992), but there is a growing concern among and efford by growers to reduce the use of pesticides. Therefore, the growers association started in 1989 a project of supervised control in chrysanthemums in which a reduction in the use of pesticides of 54 and 28% in the first and second year, respectively, was obtained (Zwinkels, 1992).

In cut chrysanthemums various insect species are chemically controled, such as leaf miners (Liriomyza huidobrensis and L. trifolii), western flower thrips (Frankliniella occidentalis) , white flies (Trialeurodes vaporarium), beet army worm (Spodoptera exigua), spider mites (Tetranychus urticae) and various aphids (Cevat, 1991). Aphids are a problem due to the occurrence of resistance against several insecticides (especially in Myzus persicae and Aphis gossypii, Devonshire, 1989), the rapid rate of population increase (Dixon, 1985), and the production of honeydew which promotes the growth of fungi. Growth inhibition of chrysanthemums by aphids has not been found (Gurney, 1969).

An estimate of population density is a necessary measure in a model to predict population increase. On this basis information can be supplied to growers whether it is necessary to control an insect population. A difficulty of measuring population density of insects in commercial greenhouses is their low density, because little or no infection is tolerable. The distribution of aphids, e.g. random or clumped, determines how easily they are encountered during sampling, and what kind of a sampling programme has to be developed. It is much more convenient to estimate density by incidence (% of infested plants), and, therefore, the relationship between aphid density and incidence was studied. Finally, the relationship between aphid counts on yellow sticky traps and aphid density on the plants was assessed.

2. Methods

Between the end of April and the beginning of June 1992 two greenhouses in the area "het Westland" in the province of Zuid-Holland were sampled weekly for aphids. In one demonstration greenhouse (Denar) a compartment of 800 m^2 with supervised control and another with biological control were followed for 6 and 4 weeks, respectively. The chrysanthemums, cultivar Reagan, aged during the sampling from 3 to 8 and 4 to 7 weeks, respectively. Chemical control of aphids was necessary weekly in the chemically treated compartment. Aphids were counted weekly on three yellow sticky traps (Horiver) per compartment.

In the other commercial greenhouse plantings of chrysanthemums (345 m^2) of 3 and 6 weeks of age, respectively, were sampled during a period of 5 weeks. This resulted in sampling different plantings every week. The cultivars were Target (6x), Toon Hermans (3x) and Reagan (1x). Chemical control of aphids took place twice. One yellow trap was used per planting.

Plants were sampled using a grid pattern to cover as much of the planting as possible. At each sampling point six plants were sampled. Sampling took place

along the little paths which separate the flower beds, and along the bordering concrete path and the glass wall to avoid damage. In the Denar greenhouse sample sizes varied from 240 to 678 plants in the chemically treated compartment and from 42 to 180 in the compartment with biological control. In the commercial greenhouse sample sizes were 240 or 534 plants per planting. The sample size depended upon the infection and hence the handling time per plant because a fixed time per greenhouse was available. To speed up sampling the top of a plant was carefully examined for aphids. The lower parts were only examined when aphids were found on the top. This was allowed because A. gossypii and M. persicae infestation begins in the top and later a redistribution over the plant occurs in M. persicae (Wyatt, 1965 & 1969; Tamaki & Allen, 1969). Aphid species, morph (apterous or alate adult, larvae), numbers and position on the plant were recorded.

The relation between mean dendity (m) and sample variance (s^2)is an indication of the distribution of a species, e.g. when $s^2=m$ the distribution id random and when $s^2>m$ the distribution is clumped (Southwood, 1978). Taylor (1961) showed that a consistent relationship between mean density and sample variance could be described by $s^2=am^b$ for a great variety of plants and animals (Taylor et al., 1978). Log variance is plotted against log density and linear regression determines the relationship log s^2=log a+blog m. Zero values are excluded. The value of b is a species specific measure of aggregation, which also depends on the sample unit, and b>1 indicates that the population is aggregate (Taylor, 1961; Southwood, 1978).

3. Results & Discussion

Aphid species

The most common aphid species sampled was Aphis gossypii, which reached high density (9.6 aphids/plant) and incidence (55%) in the compartment with biological control; Myzus persicae occurred in lower densities of maximally 0.45 aphids/plant and an incidence of 15%. In all the chemically treated sampling localities densities were much lower, ranging from zero to 0.13 M. persicae/plant and 0.76 A. gossypii/plant. Analysis of the data is restricted to these two species and the total number of aphids, because the number of the other species found, Brachycaudus helichrysi, Macrosiphum euphorbiae and Aulacorthum solani were not sufficient to allow statistical treatment.

Blackman & Eastop (1984) reported 15 aphid species which occur regularly on chrysanthemum on a world wide scale. In The Netherlands 14 species have been recorded (Guldemond, unpublished).

3.1 Aggregation

Taylor's Power Law (Taylor, 1961) holds well for all aphids together, and Aphis gossypii and M. persicae (Figure 1). The slope is in all cases significantly (P=0.00000) different from b=0, and R^2 is 0.88 in M. persicae, 0.97 in 'all aphids', and 0.98 in A. gossypii. The coefficient b of Tayor's Power Law is greater than 1 in all cases, which indicates that the aphids have an aggregate distribution. A. gossypii has a higher coefficient (1.43 ± 0.08 s.e.) than M. persicae (1.13 ± 0.12) indicating that A. gossypii occurs more clumped.

A range of values from b=1.06 to b=1.75 is reported in 12 sampling situations for 6 aphid species (Taylor et al., 1978), and a more clumped distribution (b=1.95) was reported for Brevicoryne brassicae on Brussels sprouts (Wilson et al., 1983), which indicates that the values found in this study fall within the range for aphids. Comparison of b-values for M. persicae shows that this species is similarly aggregate on sugar beet (b=1.15) as chrysanthemum, and more aggregate on Brussels sprout (b=1.60) and on its primary (winter) host plant Prunus (b=1.36) (in Taylor et al., 1978; Wilson et al., 1983).

3.2 Incidence - density relationship

Densities found for M. persicae are all below 0.5 aphids/plant and the untransformed data show a linear relationship between incidence and density (Figure 2). The slope is significant at P=0.00000, and R^2=0.96. For 'all aphids' and A. gossypii values have been log10 transformed to obtain a linear relationship (Figure 2). The slopes are significant at P=0.00001. The R^2 is 0.93 and 0.90, respectively. Thus, aphid density can be estimated by incidence though one should be careful about the precise values obtained.

In A. gossypii two points are rather off the line, indicated by an "a" in Figure 2. This represents a situation where a great number of A. gossypii had just entered the greenhouse, settled on many different plants and had produced

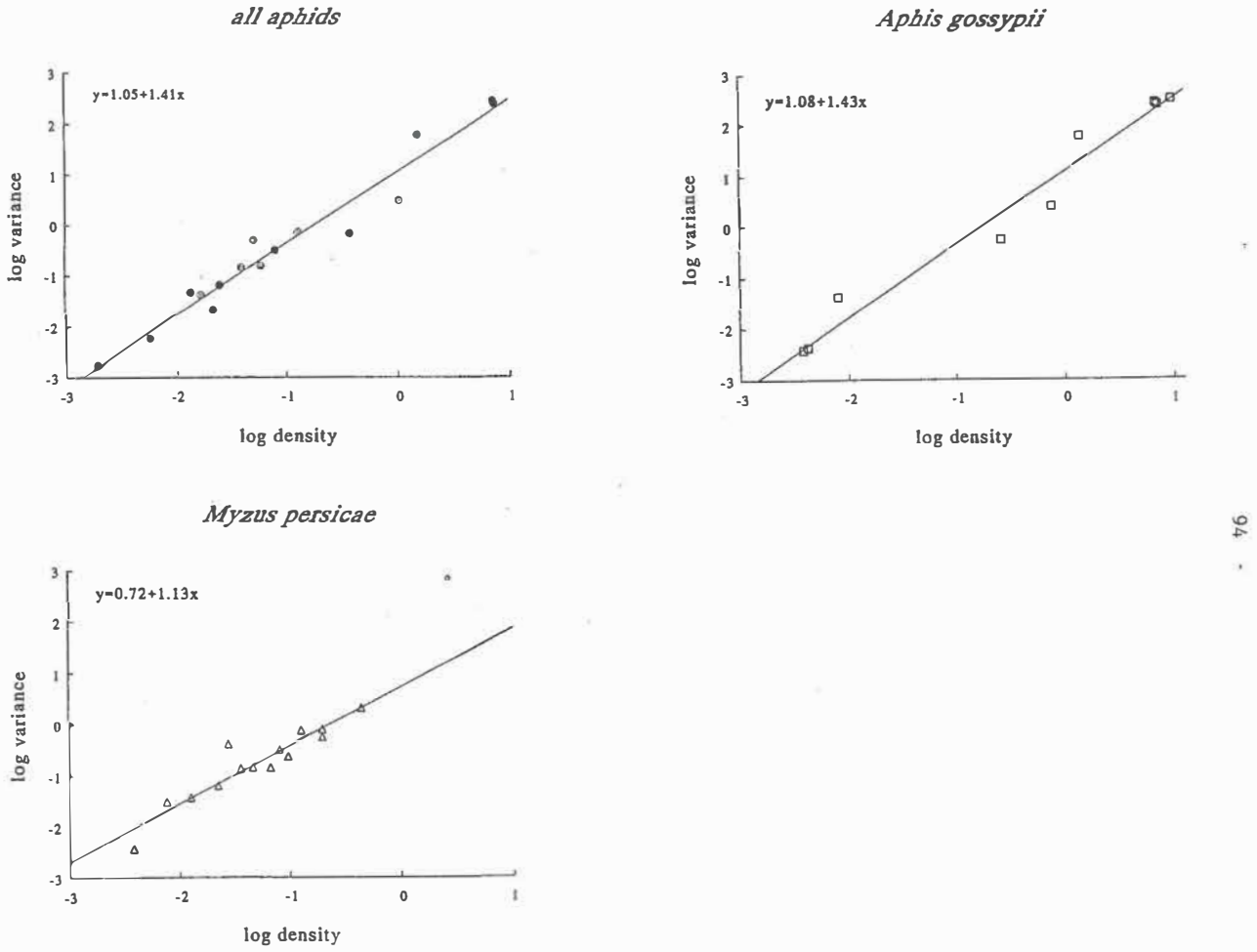


Fig. 1. Relationship of mean density and sample variance for aphids in chrysanthemums

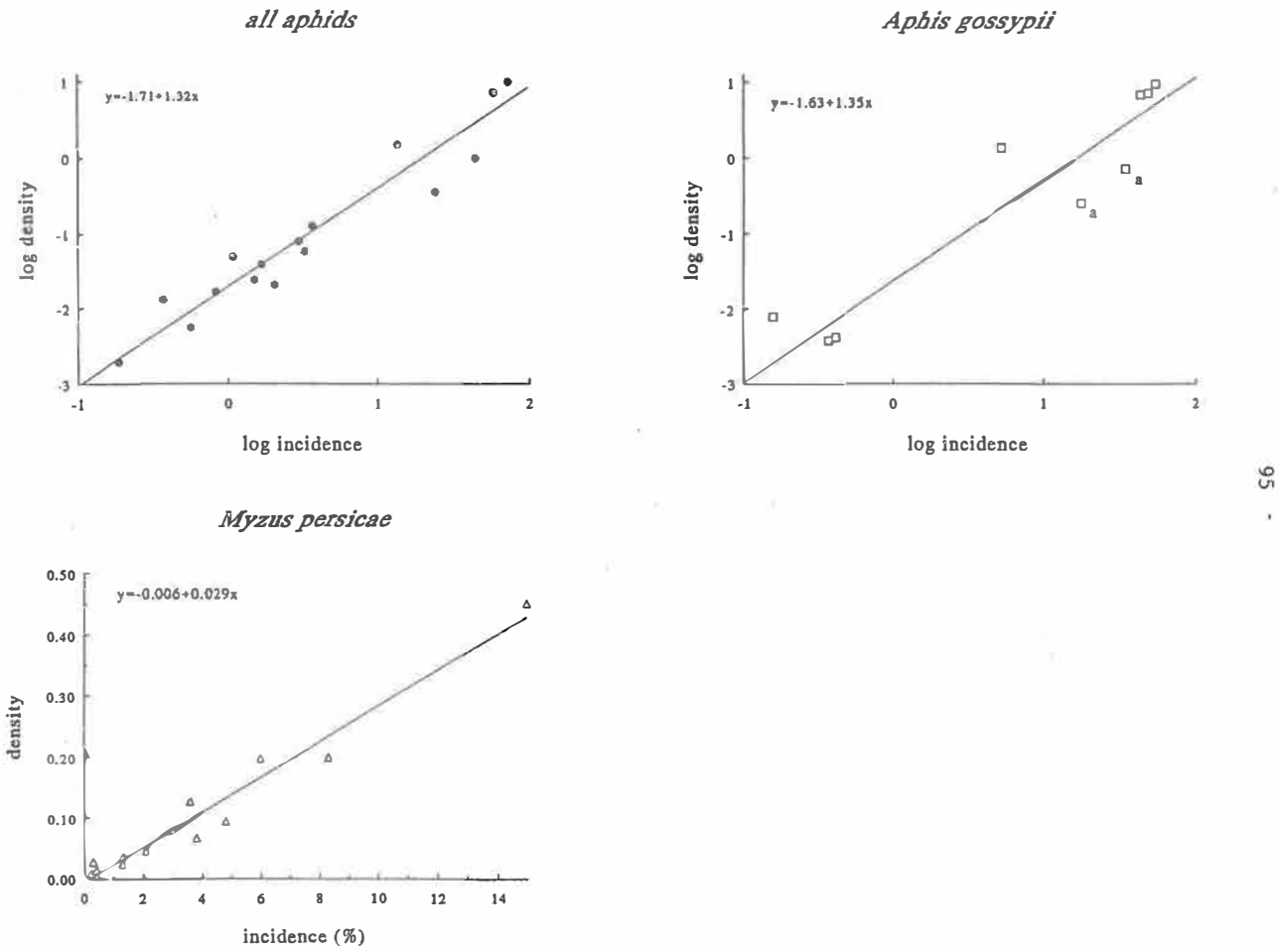


Fig. 2. Relationship of % incidence and mean density for aphids in chrysanthemums

until then only few offspring. Thus, the incidence is high, 34.4 and 17.9%, but the density is only 0.758 and 0.263, respectively. This is a nice example of the difficulties and dangers of estimating density by incidence: just after the invasion of a big number of aphids density is still low but incidence is high; after the aphids have reproduced for some time the density will have increased but the incidence only little or not. For supervised control this might be an advantage, because in such a case incidence gives early information for higher aphid densities in the near future (Daamen, pers. comm.)

Incidence counts of cereal aphids are used in the monitoring and forecasting programme EPIPRE, where the use of a dubble logarithmic scale resulted in a linear relationship between average number of aphids per tiller and percentage infested tillers (Rabbinge & Carter, 1984). In potatos incidence and density of Myzus persicae were related at low levels of infestation (Broadbent, 1948). Incidence-density (severity) counts were reviewed for fungal diseases by Seem (1984).

3.3 Yellow sticky traps

There is no relationship between the number of aphids counted on the yellow traps and aphid density in the chrysanthemums (Figure 3). This is not surprising because winged aphids are produced only if density is high enough to induce winged morphs by crowding (Dixon, 1985). This indicates that the number of winged aphids which can be caught with yellow sticky traps lags behind the total number of aphids in the chrysanthemums. Further, especially from late spring till autumn a large amount of the aphids which fly around outside the greenhouse are not able to reproduce on chrysanthemum. Some of these aphids eventually enter the greenhouse and are counted on the traps. It is obvious that these aphids are not particular relevant in forecasting aphid densities in the crop. When only aphid species that are able to infect chrysanthemum are counted, a more predictive relationship with incidence might be found.

The use of suction traps could be used to forecast the influx of species with a clear pattern of migration, such as M. persicae; for species that may have local eruptions because of their proliferation in a particular greenhouse, such as A. gossypii, the use of suction trap is probably not precise enough. The most accurate way of assessing aphid populations seems to be sampling in the chrysanthemums.

It is concluded that incidence counts of aphids are a reliable measure to estimate population density, and especially useful for a monitoring system for supervised control. The use of yellow sticky traps to measure aphid density, or even the presence of aphids in the greenhouse, is not reliable. Future research will focuss on the spatial distribution of aphids, and other insects, in the greenhouse and its consequences for a sampling programme for supervised control in chrysanthemums.

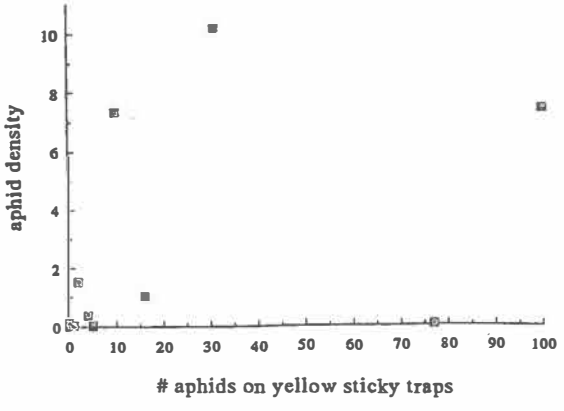


Fig. 3. Relationship of the total number of aphids on yellow sticky traps and mean aphid density in chrysanthemums ($n=20$)

Acknowledgement
The help of Theo van Daal with sampling is greatly appreciated. The hospitality of Daan de Kok, Peter van Emmerik and Wientze Pauzinga was a great help. Richard Daamen and Jan Theunissen gave useful comments on the manuscript. The study was funded by the GPP/MJPG programme of the Dutch gouvernment.

4. References

BLACKMAN, R.L. & EASTOP, V.F., 1984. Aphids on the world's crops. John Wiley & Sons, Chichester.

BROADBENT, L., 1948. Methods of recording aphid populations for the use in research on potato virus diseases. Ann. appl. Biol. **35**: 551-566.

CEVAT, H., 1991. Herkennen van ziekten en plagen in het gewas chrysant. NAKS.

DEVONSHIRE, A.L., 1989. Resistance of aphids to insecticides. In: Aphids. Their biology, natural enemies and control. (A.K. Minks & P. Harrewijn, Eds), vol 2C: 123-139. Elsevier, Amsterdam.

DIXON, A.F.G., 1985. Aphid ecology. Blackie, Glasgow.

GURNEY, B., 1969. Effect of Myzus persicae on the growth of chrysanthemum. Rep. Glasshouse Crops Res. Inst. p. 106.

MIN. of LNV, 1990. Meerjarenplan gewasbescherming. Rapportage Werkgroep Bloemisterij. Ministerie van Landbouw, Natuurbeheer en Visserij, The Hague.

RABBINGE, R. & CARTER, N., 1984. Monitoring and forecasting of cereal aphids in the Netherlands: a subsystem of EPIPRE. In: Pest and pathogen control - strategic, tactical and political models. (G.R. Conway, ed), 245-271. Wiley, Chichester/New York.

SEEM, R.C., 1984. Disease incidence and severity relationships. Ann. Rev. Phytopathol. **22**: 133-150.

SOUTHWOOD, T.R.E., 1978. Ecological methods. 2nd ed., Chapman & Hall, London.

TAMAKI, G. & ALLEN, W.W., 1969. Competition and other factors influencing the population dynamics of Aphis gossypii and Macrosiphoniella sanborni on greenhouse chrysanthemums. Hilgardia **39**: 447-505.

TAYLOR, L.R., 1961. Aggregation, variance and the mean. Nature **189**: 732-735.

TAYLOR, L.R., WOIWOD, I.P. & PERRY, J.N., 1978. The density-dependence of spatial behaviour and the rarity of randomness. J. Anim. Ecol. **47**: 383-406.

VERNOOY, C.J.M., 1992. Op weg naar een schonere glastuinbouw 2. Het gebruik van gewasbeschermingsmiddelen op praktijkbedrijven. Publ. 4.132, Landbouw-Economisch Instituut, LEI-DLO, The Hague.

WYATT, I.J., 1965. The distribution of Myzus persicae (Sulz.) on year-round chrysanthemums. I. Summer season. Ann. appl. Biol. **56**: 439-459.

WYATT, I.J., 1969. Factors affecting aphid infestation of chrysanthemums. Ann. appl. Biol. **63**: 331-337.

WILSON, L.T., PICKEL, C., MOUNT, R.C. & ZALOM, F.G., 1983. Presence-absence sequential sampling for cabbage aphid and green peach aphid (Homoptera: Aphididae) on Brussels sprouts. J. Econ. Entomol. **76**: 476-479.

ZWINKELS, N., 1992. Het verslag van het tweejarig NTS-gewasbeschermingsproject chrysant. NTS.

Potential of phytoseiid predators to control Western Flower Thrips in greenhouse crops, in particular during the winter period

Y.M. van Houten[1], P.C.J. van Rijn[1], L.K. Tanigoshi[1,2] & P. van Stratum[1]
[1] University of Amsterdam, Department of Pure and Applied Ecology, Section Population Biology, Kruislaan 302, 1098 SM Amsterdam, The Netherlands
[2] Permanent address: Washington State University, Department of Entomology, Pullman, WA 99164-6382, U.S.A.

Summary
The predatory mite, *Amblyseius cucumeris*, is used for biological control of Western Flower Thrips, *Frankliniella occidentalis*, in Dutch greenhouses. During winter, however, this predator fails to control the pest. Possible causes for this failure are (1) the predator females enter reproductive diapause, or (2) the predator's eggs are insufficiently resistant against low humidity conditions which, in practice, occur mainly in frost periods. A non-diapausing thrips predator that is tolerant to low humidities would improve control during the winter period.
In search for such a predator five phytoseiid species were selected, known to feed on thrips and originating from subtropical regions, where an ability to enter diapause is not a prerequisite for survival. In the laboratory a number of relevant features were investigated for these species, viz. *A. hibisci, A. degenerans, A. tularensis, A. scutalis* and *A. limonicus,* in comparison with *A. cucumeris*. Their potentials as a predator of Western Flower Thrips were assessed from the predation and oviposition rates on a diet of young thrips larvae. In addition, diapause incidence under short-day conditions and egg-hatching rate at different levels of humidity were investigated. The results show that *A. hibisci* and *A. degenerans* are good candidates for biological control of *F. occidentalis* under short-day and low-humidity conditions.

Introduction

Western Flower Thrips, *Frankliniella occidentalis* (Pergande), is one of the major pests in vegetable crops, such as cucumber and sweet pepper. Chemical control interferes with biological control of the other pests. Therefore, an effective biological control agent of *F. occidentalis* is needed.
The predatory mite, *Amblyseius cucumeris* (Oudemans), is produced commercially for biological control of *F. occidentalis* in various crops. However, it is not a very effective control agent in cucumber because large numbers of predatory mites have to be introduced repeatedly. In sweet pepper the predators are more successful and predator populations can be maintained throughout the season without reintroductions. This maintenance, which occurs even in absence of thrips, might be attributed to the presence of pollen as an alternative food source (Van Rijn & Sabelis, 1992). However, biological control on sweet pepper is less effective during winter (Morewood & Gilkeson, 1991). Preliminary experiments have demonstrated that *A. cucumeris* enters a reproductive diapause when introduced during winter (Morewood & Gilkeson, 1991; Van Houten, 1991). This may explain why *A. cucumeris* failed to become established in this period despite the presence of pollen.
Another factor that may affect the success of biological control during winter is relative humidity. In Dutch greenhouses, humidity levels decrease during frost periods, which may affect the egg hatching success of *A. cucumeris*. For phytoseiids, it was demonstrated that eggs are vulnerable to low humidity (see Dinh et al., 1988 and Bakker et al., 1992 for review). Moreover, these authors showed that there is a narrow humidity domain where hatch success drops from 100% to 0%.
In search for a thrips predator that could improve biological control in winter, five species of phytoseiid mites were selected, which were known as predators of thrips and which originated from subtropical regions, where diapause potentials are less likely to occur. In the laboratory we investigated a number of features of these species, viz. *A. degenerans* Berlese, *A. hibisci* (Chant), *A. tularensis* (Congdon), *A. scutalis* (Athias-Henriot) and *A. limonicus* Garman and McGregor, in comparison with *A. cucumeris*. Their potentials as control agent of

F. occidentalis were derived from the predation and oviposition rates, when young thrips larvae were used as prey. The relatively more voracious predators were further investigated for (1) predation on second-instar larvae, (2) ovipostion on a diet of sweet pepper pollen, (3) diapause incidence under short-day conditions and (4) egg hatching rate at different levels of humidity.

Materials and Methods

Amblyseius cucumeris was obtained from the Glasshouse Crops Research Station in Naaldwijk. *Amblyseius degenerans*, *A. hibisci*, *A. tularensis* and *A. scutalis* originated from insectary cultures of the University of California, Riverside, U.S.A. *Amblyseius limonicus* was collected in a cucumber greenhouse in Auckland, New Zealand.

Amblyseius degenerans, *A. limonicus* and *A. cucumeris* were reared on rectangular "arenas" made of black plastic. Wet tissue paper was wrapped over the edges of the arena, serving both as a barrier and as a water source. An additional barrier of Tanglefoot ® on the tissue paper prevented the mites from escaping. *Amblyseius hibisci*, *A. tularensis* and *A. scutalis* were reared on detached leaves of broad bean, *Phaseolus vulgaris* L., placed with the upper surface down on wet cotton wool. In all cases, pollen of the broad bean, *Vicia faba* L., was used as a food source.

Predation and oviposition rates were measured on disks of cucumber leaves (4.5 cm^2), placed with upper surface down on a water-saturated pad of cotton-wool, in a climate room at 25°C and 70% RH. The leaf disks were infested with 12 larvae of *F. occidentalis*. Preliminary experiments with *A. cucumeris* showed that at this prey density, the functional response is at its plateau level. This means that a small decrease in the number of living prey do not affect the predation rate. The larvae were either young first instars (0.5 - 0.6 mm) or young second instars (0.85 - 0.95 mm). One young gravid female predator was placed on each leaf disk. During three days, the predators were transferred daily to new leaf disks containing 12 freshly emerged thrips larvae. The old leaf disks were examined to record the number of predatory eggs and the number of dead thrips larvae.

The ability to reproduce on a diet of sweet pepper pollen was tested, using leaf disks as described above.

Diapause induction experiments were carried out on units identical to the rearing units. Cohorts of eggs, ranging from 0 to 24 h since oviposition, were placed under short day conditions (LD 10:14 photoperiod and TC 23°C:16°C thermoperiod), comparable with greenhouse conditions for sweet pepper during February. All experiments were carried out in photoperiod- and thermoperiod-controlled incubators. For the experiments on diapause, we supplemented the diet of pollen with ß-carotene, since some predatory mite species fed on broad bean pollen alone do not respond to photoperiod (Overmeer et al., 1989) or thermoperiod (Van Houten et al., 1987). Absence of egg production was taken as criterion for the occurrence of diapause. A sufficient number of males was present to inseminate all females.

The effect of humidity on egg mortality was tested at 25°C in closed plastic containers, in which desired humidity levels, namely 48%, 63%, 71% and 92%, were maintained by saturated solutions of different substances (Winston & Bates, 1960). Cohorts of eggs, ranging from 0 to 16 h since oviposition, were placed on plastic arenas inside the plastic containers. Three days later the number of desiccated eggs was counted to assess the fraction of eggs that hatched successfully.

Results and Discussion

We examined only some of the features important in evaluating candidates for biological control. Therefore, caution should be exercised in drawing conclusions. Small differences in predation and oviposition rates may not be conclusive, since differences in juvenile survival and searching efficiency (especially important at low prey densities) can modify the conclusions substantially. Nevertheless, the low predation and oviposition rates observed for *A. scutalis* and *A. tularensis* (Figure 1) are sufficiently low to warrant excluding these species from further research.

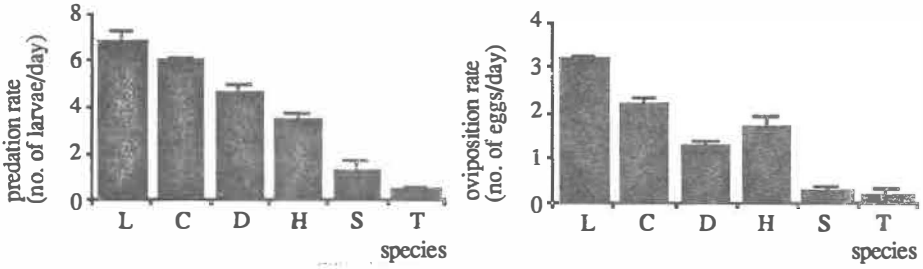


Figure 1: Daily predation and oviposition rate of six phytoseiid species (on day 2 and 3) on cucumber leaf disks (4.5 cm^2) with 12 first instar larvae of *F. occidentalis* at 25°C, (mean of 20 replicates ± SE). (L = *A. limonicus*, C = *A. cucumeris*, D = *A. degenerans*, H = *A. hibisci*, S = *A. scutalis* and T = *A. tularensis*)

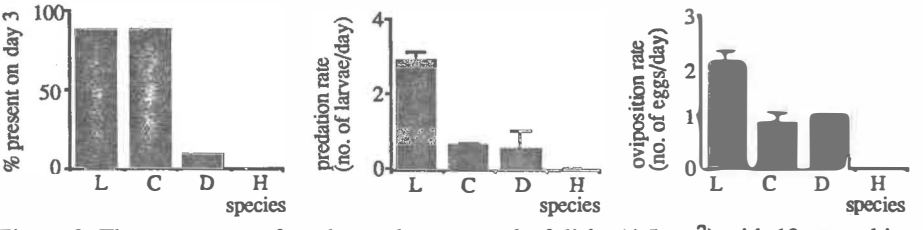


Figure 2: The percentage of predators that stay on leaf disks (4.5 cm^2) with 12 second instar larvae of *F. occidentalis* during a three days experiment and the predation and oviposition rate of the remaining predators at 25°C, (mean of 20 replicates ± SE). (L = *A. limonicus*, C = *A. cucumeris*, D = *A. degenerans*, and H = *A. hibisci*.)

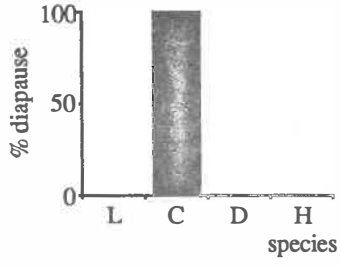


Figure 3: Incidence of diapause in four phytoseiid species under short-day conditions (LD 10:14 photoperiod and TC 23°C:16°C thermoperiod). (L = *A. limonicus*, C = *A. cucumeris*, D = *A. degenerans*, and H = *A. hibisci*)

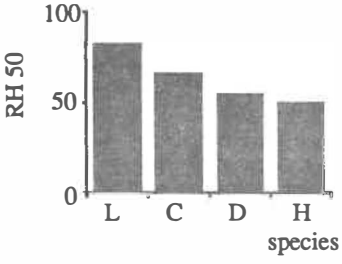


Figure 4: Sensitivity of the eggs of four phytoseiid species to low humidity at 25°C. RH 50 = relative humidity at which 50% of the eggs no longer hatch. (L = *A. limonicus*, C = *A. cucumeris*, D = *A. degenerans*, and H = *A. hibisci*)

Table 1: Ability to reproduce on a diet of sweet pepper pollen of four phytoseiid species. (±: 0-1 egg/day, +: 2-3 eggs/day)

	A. limonicus	*A. cucumeris*	*A. degenerans*	*A. hibisci*
eggs	±	+	+	+

As *A. limonicus* clearly shows the highest predation and oviposition rates on both first- and second-instar larvae of *F. occidentalis* (Figure 1 and Figure 2), this predator may be a promising agent for thrips control. In addition, *A. limonicus* does not enter diapause under short-day conditions (Figure 3). On the other hand, eggs of *A. limonicus* are very sensitive to low humidity (Figure 4), which indicates that drops in humidity levels during frost periods might reduce the effectiveness of *A. limonicus* as control agent. Similar results were reported for a strain of *A. limonicus* from California (McMurtry and Scriven, 1965).
Compared to *A. cucumeris, A. degenerans* and *A. hibisci* show lower capacities to capture second-instar larvae of *F. occidentalis* (Figure 2). But since both species do produce on pollen (Table 1), do not enter diapause (Figure 3) and are more tolerant to drought, especially *A. hibisci* (Figure 4), they may be good candidates for thrips control in greenhouses, especially during winter.

Acknowledgements
We thank Prof. Dr. J. McMurtry & Mr. S.J. Newberger (University of California) for shipment of *A. degenerans, A. hibisci, A. scutalis* and *A. tularensis*, and Dr. N. Martin (DSIR, Auckland, New Zealand) for his help with collecting *A. limonicus*. Maurice Sabelis, Jan Bruin and Arne Janssen are thanked for their comments on an earlier version of this paper.

References
BAKKER, F., KLEIN, M., MESA, N. & BRAUN, A., 1992. Drought tolerances of phytophagous mites and their predators on cassava. Exp. Appl. Acarol., in press.
DINH, N.V., SABELIS, M.W. & JANSSEN, A., 1988. Influence of humidity and water availability on the survival of *Amblyseius idaeus* and *A. anonymus* (Acarina: Phytoseiidae). Exp. Appl. Acarol. 4: 27-40.
HOUTEN, Y.M. VAN, 1991. Diapause induction in the thrips predators *Amblyseius barkeri* and *Amblyseius cucumeris* (Acari: Phytoseiidae) in Dutch greenhouses. Proc. Exper. & Appl. Entomol., N.E.V. Amsterdam 2: 202-207.
HOUTEN, Y.M. VAN, OVERMEER, W.P.J. & VEERMAN, A., 1987. Thermoperiodically induced diapause in a mite in constant darkness is vitamin A dependent. Experientia 43: 933-935.
MCMURTRY, J.A. & SCRIVEN, G.T., 1965. Life history studies of *Amblyseius limonicus* with comparative observations on *Amblyseius hibisci* (Acarina: Phytoseiidae). Ann. Entomol. Soc. Am. 58: 106-111.
MOREWOOD, W.D. & GILKESON, L.A., 1990. Diapause induction in the thrips predator *Amblyseius cucumeris* (Acarina: Phytoseiidae) under greenhouse conditions. Entomophaga 36 (2): 253-263.
OVERMEER, W.P.J., NELIS, H.J.C.F., LEENHEER, A.P. DE, CALIS, J.N.M. & VEERMAN, A., 1989. Effect of diet on the photoperiodic induction of diapause in three species of predatory mite, *Amblyseius potentillae, A. cucumeris* and *Typhlodromus pyri*. Exp. Appl. Acarol. 7: 281-287.
RIJN, P.C.J. VAN & SABELIS, M.W., 1992. Does alternative food always enhance biological control? The effect of pollen on the interaction between Western Flower Thrips and its predators. This volume.
WINSTON, P.W. & BATES, D.H., 1960. Saturated solutions for the control of humidity in biological research. Ecology 41: 232-237.

OBSERVATIONS ON THE EFFECTIVENESS OF TRAP PLANTS FOR THE CONTROL OF WESTERN FLOWER THRIPS (Frankliniella occidentalis)

E.J. HOYLE and M. SAYNOR
ADAS Reading, Coley Park, Reading, Berks.

ABSTRACT
The potential of using flowering trap plants as part of an IPM programme to control Western Flower Thrips was investigated. The relative attractiveness of various flowering plants was tested and showed Gloxinia, Browallia, Gerbera and Impatiens to be among the best. In trials on IPM in pot plants (Cyclamen, Primula) and AYR Chrysanthemums, pot plants in flower were used as traps within the crop still in the vegetative stage. The results showed massive numbers of WFT on the trap plants compared to the surrounding crop. This suggests the thrips are attracted off the crop to the trap plant. However, the presence of a trap plant in the plot did not greatly reduce the level of thrips on the surrounding crop.

Introduction

Western flower thrips (WFT) is a serious pest in the horticultural industry. It causes silvery flecking on leaves and flowers, and distortion of the flower buds and fruits. WFT is also an important vector of Tomato Spotted Wilt Virus in ornamentals. Although there are effective biological control agents of WFT, it is still often a problem on nurseries. Several different control methods used in a combined IPM programme will give the most effective control against this pest. Trapping is a well used method of both controlling and monitoring insect pests. Using flowering plants as traps for WFT in a vegetative crop has previously been trialled by ADAS. A "push-pull" mechanism was used applying antifeedant to the crop and using trap plants to attract the thrips. This trial was set up by Dr. M. Saynor, at ADAS Reading, to investigate further the possibilities of trap plants in an IPM situation. The trap plants were used in conjunction with an IPM trial of 4 treatments. This report will not analyse the effect of the base treatments, but will concentrate on the overall results of using trap plants. The full trial results will be published at a later date.

Materials and Methods

1. Host Preference:
15 different species of flowering plant were assessed for their relative attractiveness to WFT. A single plant of each species (in flower) was used in every test. The 15 plants were arranged in a semi-circle around a central point where WFT was released. The test was repeated 5 times, releasing 150 or 160 WFT each time. Approximately 24 hours later the number of WFT in the flowers of each plant was assessed.
Species used in the test were:- Aster, Browallia, Cuphea, Cyclamen, Gerbera, Ivy-leafed geranium, Zonal geranium, Gloxinia, Impatiens, New Guinea Impatiens, Marigold, Petunia, Streptocarpus, Verbena, Vinca.

2. Trap Plant Effect:
Trap plants were included in 2 separate trials, one on AYR Chrysanthemums and the other on pot plants, cyclamen and primula. The trap plants in the pot plant trial were Gloxinia and New Guinea Impatiens, in the chrysanthemum trial pot chrysanthemums were used. Trap plants were placed in two of the four replicates of the basic trial, (4 treatments) Hence trap plants versus no trap plant was replicated 8 times. The plot size was $4m^2$ for the chrysanthemums, $1.6m^2$ for the cyclamen (40 plants), $2.0m^2$ for the primula (80 plants), each separated by polythene barriers, 1.5m high between plots and 4m high between blocks. The crops were artificially infested with WFT, introducing adult thrips on a number of occasions.
The levels of WFT were assessed on the trap plants once a week and on the crops once every two weeks. Assessments were carried out by tapping the plants 5 times over a white tray. Adult and nymph WFT were counted and then removed from the glasshouse. The flowers were taken off the trap plants at each assessment and trap plants were replaced every 3 weeks. Assessments of the trap plants stopped when the crop itself came into flower.

Results
1. Host Preference:
On average 68% of the WFT released were retrieved from the flowers. Gloxinia was the host most favoured by the WFT, from which 19.1% of the total caught were recovered, Browallia and Gerbera also attracted a high percentage.

2. Trap Plant Effect:
The number of WFT collected from the trap plants was much higher than those from the crop. In the chrysanthemum trial an average of 191 WFT were collected from each trap plant (5 stem pot chrysanthemum) over 3 assessments, this compared to an average of only 11 WFT being collected from 5 stems of the crop over 3 assessments.
The presence of a trap plant in the plot did not consistently reduce the level of WFT on the crop. In the pot plant trial some of the assessments showed numbers of WFT greater on the crop with trap plants than the crop without. In the chrysanthemum trial numbers on the crop with trap plants did keep below those in plots without trap plants but the difference was very slight.

Discussion
Trap plants work on the same principal as yellow or blue sticky traps: they attract the thrips away from the crop. One of the main characteristics of WFT is that they are attracted to flowers. The initial trial on host preference showed that WFT are more attracted to certain species of flower when given a free choice. From the results of this trial Gloxinia and New Guinea Impatiens were chosen as trap plants for the next trial. Gloxinia for its attractiveness to thrips and the Impatiens because it also flowers profusely and continuously.
The results of the main trial suggest that trap plants strongly attract thrips. This is demonstrated by the much higher numbers of WFT on the trap plants than on the surrounding crop. However, in this trial the levels of thrips on plants in the plots with trap plants were not significantly lower than they were in plots where there were no trap plants. This may have been due to the experimental set up in the glasshouse. Although polythene barriers were erected to divide up the

plots these did not prevent the movement of thrips. Indeed sticky traps at the top of the screens caught higher numbers of WFT than those close to the crop. It is also possible that thrips were attracted to the trap plants from other plots without trap plants. This would confuse the results and show the trap plants to be less effective than they actually were.

The trials show that flowering plants will attract WFT and can therefore be used as traps. Their effectiveness at subsequently reducing the level of thrips on the surrounding crop needs to be further investigated using more efficient screening between plots.

If using trap plants, the regular removal of the flowers, and WFT along with them, is vital to prevent the plants becoming a breeding ground. Careful management and good husbandry is therefore necessary to maintain a supply of pest-free and healthy trap plants.

In the future trap plants could be treated with a persistent insecticide, so any thrips feeding on the plant would be controlled. This would avoid having to treat the entire crop with chemical. No work has yet been done on this principal, and it is possible that the chemical may act as a deterrent so counteracting the trapping factor.

From discussions at the IOBC conference it may also be possible to use trap plants to help establish beneficial insects. Predators introduced onto the trap plants would control the WFT attracted there. The pollen on the flowering trap plant would act as an alternative food source if WFT were not present.

INTEGRATED PEST MANAGEMENT IN SPRING BEDDING PLANTS: A SUCCESSFUL PACKAGE FOR COMMERCIAL CROPS

R J Jacobson

Bunting Biological Control Limited
Great Horkesley, Colchester CO6 4AY, England

Summary

A total IPM package for the control of thrips, whiteflies and aphids in spring bedding plants was tested over two years at a nursery in the North of England. The package included strategic planning, pre-crop preparation and monitoring techniques, as well as the selection of appropriate formulations and rates of use of beneficial species. The results compared favourably to chemical based control regimes previously used at the same nursery and the package has now been adopted more widely.

1. Introduction

There are many difficulties associated with IPM in spring bedding plant crops which are not encountered in mono-crops of longer duration, for example:

i) Planning - There is usually a large diversity of plants grown on a bedding plant nursery and often many different cultivars within a single glasshouse. Each has its own spectrum of pests and the overall IPM programme can be very complex.

ii) Stability - Plants are moved around the nursery as they progress from propagation to growing-on areas and then re-spaced or replanted in pots, tubs or baskets. Pests can be moved with them and the IPM programme for each glasshouse block has to be constantly revised.

iii) Establishment of beneficials - Some plants are only on the nursery for a few weeks. Pests can attack them but there may not be time for beneficials to become properly established.

iv) Baskets and tubs - Problems may be encountered where mixed plant species are grown within the same container. Plants such as verbena and fuschia, which are particularly vulnerable to the major pests, can provide an initial breeding site from which insects move onto less susceptible cultivars. Chemical treatments are also difficult in these situations due to the varying tolerance of the different cultivars.

v) Pesticide residues - Where plants are propagated elsewhere and brought on to the nursery to be 'grown-on' they often arrive with residues of recently applied persistent pesticides. These residues may no longer have any effect on the pests but can still be detrimental to beneficial species. Furthermore, it can be very difficult to obtain an accurate history of the plants.

vi) 'Bought-in' pests - Plants brought on to the during the season may be infested and cause a sudden increase in pest numbers.

vii) Temperature - In the earlier part of the season the plants are grown at low temperature, in some cases with little more than frost protection. This limits the reproductive rate of all insects and mites but favours the development of the pest species.

It is important that any IPM programme takes all these factors into account without becoming so complex that it can only be managed by a specialist entomologist.

With these difficulties in mind, an IPM package was designed for spring bedding plant crops at a commercial nursery in the North of England and evaluated during the spring and summer of 1991 and 1992. Approximately two hectares of assorted ornamentals (Table I) grown in 3m wide beds of modules, trays and pots, and in hanging baskets and tubs, were included in the project. The large retail outlets which this grower supplied demanded complete freedom from pests. In previous years the grower had suffered problems caused by Thrips tabaci (Lindeman), Frankiniella occidentalis (Pergande), Trialeurodes vaporariorum (Westwood) and Myzus persicae (Sulzer). These pests had threatened profitability both as a result of direct damage and the phytotoxic effects of the insecticidal treatments.

The overall objective was to minimise plant loss using an IPM programme which could be managed on a day to day basis by the nursery staff.

2. Basic Strategy

The complex of pests which affect spring bedding plants, the relatively short period they are in production and the quality standards set by the customers, demand that the primary strategy be prevention of any pest development. A chemical based control regime would achieve this by frequent routine applications of pesticides. A prophylactic approach is also required when using biological control organisms. In this programme, relatively large numbers of beneficials were introduced regularly, starting before the pests were detectable.

3. Components of the IPM Package

The success of an IPM programme depends on more than just the release of parasites and predators. Strategic planning and detailed management are equally important. The following components were built into this package:

3.1 Training - All the nursery staff were trained to recognise the pests, symptoms of their damage, and the beneficial species. More detailed training was provided to the individuals who were to be responsible for the daily management of the systems.

3.2 Pre-crop preparation - After removal of the previous crops the glasshouses were thoroughly cleaned and fogged with dichlorvos and pyrethrins/resmethrin to minimise survival of pests.

3.3 'Bought'in plants - Ideally plants brought onto the nursery should be held in a quarantine area until they have inspected for infestation. Unfortunately, space was not available for this but all plants were carefully examined as soon as possible after arrival.

3.4 Crop hygiene - Where crops are of relatively short duration and moved during their production the greatest stability is in the weed population. Weeds provide breeding sites for pests and allow a 'green bridge' between crops. High priority was therefore given to weed removal in and around the glasshouses.

3.5 Planning - Before the start of the season a list was compiled of all the major plants included in the cropping programme and a summary prepared of the susceptibility of each to the three most important groups of pests (Table I). This list formed the basis of the IPM programme and was used by the nursery staff to calculate weekly requirements of parasites/predators. Wherever possible plants which were hosts to a similar range of pests were grouped together to simplify treatment.

3.6 Beneficial organisms: choice of species, formulations and rates of use - The rates of use detailed below formed the basis of the programme but, in practice, quantities were 'rounded-up' to the unit size of the products supplied (Table 2).

i) Whitefly Control -
Encarsia formosa (Gahan) were used to prevent the establishment of T. vaporariorum from week 11. They were introduced weekly in the vicinity of susceptible plants at the rate of 1 parasitised whitefly scale per 2 M^2 throughout the production of the crop. The aim was to overpopulate the area so that young whitefly scales were killed by the wasps egg laying activity. It was considered that lower rates aimed at establishing breeding colonies of the parasite would allow a proportion of the whiteflies to complete their development and risk rejection by the customer. If

whiteflies were found on the plants the rate of introduction was doubled in that area.

ii) Thrips Control -
Amblyseius cucumeris (Oudemans) were used to suppress development of thrips. The formulation depended on the method of growing:

Where susceptible plants were grown in 3m wide beds of modules, trays or pots, the A.cucumeris were distributed with the stored product mites upon which they were reared, in a specially formulated mixture of bran and vermiculite. A Cooper-Peglar 'Carpi' dusting machine was used to facilitate efficient, safe and even distribution of the material. Fifty A cucumeris were applied per m^2 each week, starting week 11. If any thrips were found breeding on the plants the rate was doubled.

Where susceptible plants were grown in hanging baskets, tubs or other containers, protection was provided with breeding colonies of A.cucumeris in controlled release sachets. The colonies remained active for several weeks releasing large numbers on to the plants. It was intended to place one sachet in each container every 6 weeks but in practice it was rarely necessary to make more than one introduction.

iii) Aphid Control
The most common aphid pest of bedding plants in the north of England is M. persicae. Aphidius matricariae (Haliday) were introduced to susceptible crops at 2 week intervals from week 12 at the rate of 1 parasitised aphid per $2m^2$. These treatments were supplemented as necessary by spot applications of the selective aphicide, pirimicarb.

3.7 Crop Monitoring - Careful monitoring is vital to the success of any IPM programme and this was achieved both by the use of yellow sticky traps (10 x 10cm) and by direct crop observation. Traps were supported on stands just above the crop at one per 250 m^2 but at an increased frequency to obtain specific information about smaller batches of plants. The traps were examined weekly and the number of pests recorded, tabulated and presented graphically for ease of interpretation. Up to 2 specimens of each pest per trap was considered acceptable. If more were recorded the source of the problem was identified and appropriate action taken.

4. Results

The pest monitoring system was refined during 1991 and worked efficiently in 1992. Results of mean trap counts in each of the 13 glasshouse blocks are detailed in Tables 3 and 4. Applications of pirimicarb were required on two occasions.

5. Discussion and Conclusions

The following facts demonstrate the overall success of the package:

i) Both T. vaporariorum and F. occidentalis were detected on sticky traps throughout the experimental period but insecticidal treatments were not required against either species. The only insecticidal treatments applied were pirimicarb to combat sudden large invasions of aphids including Aulocorthum solani (Kaltenbach) and Macrosiphum spp, against which A. matricariae is not particularly effective.

ii) No plants were lost due to the phytotoxic effects of pesticides. In previous years routine insecticidal treatments including the use of dichlorvos, malathion, deltamethrin, heptenophos, nicotine, pyrethrins / resmethrin and pirimicarb had caused unacceptable phytotoxicity.

iii) No plants were rendered unmarketable, or downgraded in quality, due to direct pest damage.

iv) Where an increase in pest activity was detected on traps the breeding site was identified at a very early stage and effective action taken. The only detectable activity on plants at the time of sale were parasitised aphids. As a result, no plants were rejected by the nurseries' own quality control checks, or by customers, due to the presence of pests.

The overall success must be attributed to all components of the package. The increased awareness of the nursery staff and the detailed monitoring work were particularly important features.

Following the results of the first years trials the grower expanded the programme to include a second nursery of similar size and now intends further expansion on other sites in 1993.

Acknowledgements

My thanks to all at J. Coletta and B. Tyson of Woodmansey, North Humberside, for their dedication to this project and for their thorough crop monitoring. I am also grateful to the late Joe Hussey who made an important contribution in the early stages of this work.

Table I - Simplified summary of the main plants grown on the nursery and their susceptibility to the three major groups of pests.

PLANT	WFT	WHITEFLY	APHIDS
Ageratum	0	-	-
Alyssum	-	-	-
Antirrhinum	0	-	-
Arabis	0	-	-
Aster	#	-	0
Aubretia	0	0	0
Begonia	-	-	#
Carnation	-	-	#
Cinneraria	#	#	#
Dahlia	#	-	#
Fuchsia	#	#	#
Geranium	#	#	-
Impatiens	#	-	0
Lobelia	#	-	-
Marigold/Tagetes	#	0	-
Mesembryanthemum	#	-	0
Nemisia	0	0	-
Pansy	-	-	0
Petunia	#	0	0
Phlox	#	-	0
Polyanthus	0	0	#
Primroses	0	0	#
Salvia	#	-	-
Sweet Pea	-	-	-
Verbena	#	#	0

Key # = Routine action required
0 = Action only if pest is found
- = Pest rarely a problem

NB - the susceptibility of plants to the various pest species is constantly under review. More detailed lists have been prepared for individual cultivars etc.

Table 2 - Description of Biological Control Material Used

Biological Organisms	Product Name	Formulation	Unit Size
Encarsia formosa (Gahan)	Bunting Encarsia formosa (EO1)	Parasitised scales mounted on hanging cards	1500 wasps on 25 cards
Amblyseius cucumeris (Oudemans)	Bunting Amblyseius cucumeris 'Puffer System' (AC4)	Bran/Vermiculite mix	10,000 predators per litre bottle
Amblyseius cucumeris (Oudemans)	Bunting Amblyseius cucumeris 'Controlled Release System' (AC3)	Breeding colony in sachet	400 sachets (without hooks)
Aphidius matricariae (Haliday)	Bunting Aphidius matricariae (AM50)	Parasitised aphids	500 in 250 ml bottle

Table 3 - Mean number of F. occidentalis on traps in each glasshouse block.

Week No.	Glasshouse Block 2	3	4	5	6	7	8	9	10	11	12	13
13	0	0	0	0	0	0	0.2	-	0	0	-	-
14	0.2	0	0.5	0	0.3	0	0.5	0	0	0	0	-
15	0.7	0.3	2.3	0.5	0	0.6	0.3	0.3	0	1.3	2.0	-
16	0.2	0.6	3.7	0	0.2	0.2	0.5	0.6	0	0.3	0	0.2
17	1.2	0.3	2.0	0	0.2	1.5	0.8	0.7	0.6	0.2	0	0.3
18	0.5	0.2	11.0	0	1.0	0.6	0.2	1.8	0	0.2	0.6	0.2
19	1.2	0	6.0	1.2	0	0.5	0.8	0.5	0.3	1.2	0.3	0.3
20	0.8	0.2	11.0	1.2	0.2	1.0	4.7	4.8	2.0	4.5	5.2	7.5
21	3.2	1.2	7.8	0	-	0.8	1.2	6.9	1.0	2.0	2.0	2.0
22	10.3	-	6.3	-	0.3	0.6	2.0	2.2	0.3	1.5	0.5	3.0
23	2.5	1.2	0	-	0.6	1.3	-	0.6	0.5	-	-	-

Table 4 - Mean number of T. vaporarium on traps in each glasshouse block.

Week No.	Glasshouse Block 2	3	4	5	6	7	8	9	10	11	12	13
13	0	0.2	0	0	0.3	0	0	-	0	0	-	-
14	0	0	0	0	0	0	0	0	0	0	0	-
15	0.2	0	0.6	0	0	0	0	0.3	0	0	0	-
16	0	0.2	0.5	0	0	0	0	0	0	0	0	0
17	0	0.2	1.7	0	0.2	0.8	0	0.3	0.2	0	0	0.3
18	0	0.5	0.6	0.2	0	0.2	0	0	0	0	0	0.2
19	0	0.2	0.6	0.2	0	0	0.2	0.2	0	0	0	0
20	0	1.7	0.3	0.3	0.2	0.3	0	0.5	0	0	0.2	0.2
21	0	-	0	0.5	-	0.2	0.2	0.6	0	0	0.3	0
22	0	0.2	0	-	0	0	0.2	1.0	0	0	0	0
23	0	0.3	-	-	0.2	0	0	0.2	0	-	-	-

THRIPS (*FRANKLINIELLA OCCIDENTALIS* (PERGANDE)) RESISTANCE IN CHRYSANTHEMUM; THE IMPORTANCE OF POLLEN AS NUTRITION

C.M. de Jager & R.P.T. Butôt

Department of Population Biology, University of Leiden, PO Box 9516, 2300 RA Leiden, The Netherlands

Summary

In a preliminary experiment thrips resistance in five chrysanthemum cultivars with and without flowers was measured. Both cultivars with and without flowers differed significantly in thrips resistance. Twenty to sixty times as many thrips were found on plants with flowers compared to plants without flowers. In literature it is suggested that the higher number of thrips in chrysanthemum flowers is a result of pollen being present. Therefore it would be possible that the differences in thrips resistance between the cultivars were caused by the variation in pollen production.

Five additional experiments were done to determine the importance of chrysanthemum pollen as thrips nutrition. In two experiments the thrips were confined to a small area on chrysanthemum petals. A significant, positive pollen-effect on fecundity and larval growth was found. The addition of chrysanthemum pollen to petals improved the nutritive value for F. occidentalis.

However, when whole flowers were used in three different experiments no pollen-effect was found. Therefore we suggest that in whole flowers thrips feeds preferentially on another element with a high nutritive value such as young female reproductive tissue or nectar. Moreover, differences in thrips resistance between flowering chrysanthemum cultivars are not caused by the variation in pollen production.

Introduction

The use of pesticides for crop protection is a major threat to the environment. A possible reduction of pesticide use can be found in breeding of pest-resistant varieties. A project has been initiated to develop a biotechnological test to scan chrysanthemum seedlings for resistance against pests like *Frankliniella occidentalis* and *Liriomyza trifolii*. Chrysanthemum is an important ornamental crop for the dutch economy and the thrips species *F. occidentalis* is a major pest on chrysanthemum and other crops. To develop a resistance test the mechanisms of resistance need to be studied in detail.

Thrips resistance of different chrysanthemum cultivars with and without flowers is measured. The importance of pollen as thrips nutrition and the effect of pollen production on thrips resistance is studied.

Materials and methods

Plant and insect source

Six chrysanthemum cultivars (FR17, CR15, FR05, FR07, CR14, V01) which were thought to vary in resistance were selected. These cultivars are referred to as cv 1 to cv 6. Cuttings of these cultivars were grown in a growth room which was programmed for 20°C, 70% RH, and a 8L:16D photoperiod.

A thrips strain that has been reared for several months on the flowers of the chrysanthemum cultivar FR16 was used for all experiments. The thrips rearing conditions were 20°C day and night temperature, 70% RH and a 12L:12D photoperiod.The experimental conditions were similar to the thrips rearing conditions.

Thrips resistance of chrysanthemum cultivars with and without flowers

Five chrysanthemum cultivars were used to measure thrips resistance (cv 1 to cv 5). As a measure of resistance population growth was taken. Equally sized plants with and without flowers were tested. Ten plants per cultivar were put in a whole-plant cage. Twenty adult female thrips were released into each cage. After four weeks the thrips were counted. Data were analysed by ANOVA and means separated by Duncan's multiple range test.

Pollen as thrips nutrition and the role of pollen in thrips resistance

Five experiments were conducted to study the importance of pollen as thrips nutrition and the role of pollen in thrips resistance. Data were analysed with a paired t-test.

In the first and second experiment the value of pollen as thrips nutrition was investigated. Pollen of cultivar 4 were added to petals of 6 chrysanthemum cultivars (cv 1 to cv 6). From each of 18 plants (exp. 1) or 24 plants (exp. 2) per cultivar 2 petals were used, 1 with and 1 without pollen. In the first experiment one first instar larva was confined to a petal with or without pollen (fig. 1). The growth of the larvae was determined by measuring their length on the first and fourth day. In the second experiment one adult female was confined to a petal with or without pollen (fig. 1). Fecundity was measured by counting the number of eggs the females laid within 24 hours.

In the third, fourth and fifth experiment the role of pollen in thrips resistance was determined. In these experiments thrips resistance of whole, differently treated chrysanthemum flowers was measured by putting the flowers with 7 adult female thrips in pots. After 6 days the number of larvae was counted. In this case fecundity and egg outcome was taken as a measure for resistance.

In experiment 3 pollen of cultivar 4 were added to whole chrysanthemum flowers of four different cultivars (cv 1 to cv 3 and cv 6). From each of 20 plants per cultivar 2 flowers were tested for resistance, 1 with and 1 without extra pollen.

In experiment 4, thirteen plants of cultivar 2 were used. The anthers of each of 2 flowers per plant were cut. On one flower the anthers were then removed and on the other the anthers remained on the flower. Next the flowers were tested for thrips resistance.

In experiment 5 the pollen production per flower was determined of all cultivars (cv 1 to cv 6). Twenty plants per cultivar were used. The pollen production of a single flower of a plant was compared to the thrips resistance of another flower of the same plant. A Spearman's rank correlation test was used to determine the correlation between pollen production and thrips resistance.

Results

Thrips resistance of chrysanthemum cultivars with and without flowers

The five chrysanthemum cultivars both with and without flowers differed significantly in thrips resistance. In addition twenty to sixty times as many thrips were found on plants with flowers compared to plants without flowers (fig. 2).

Pollen as thrips nutrition and the role of pollen in thrips resistance

When thrips were confined to chrysanthemum petals, a significant positive effect of pollen was found on larval growth (fig. 3a) and fecundity (fig. 3b). The height of the pollen effect was differend for each chrysanthemum cultivar.

No effect of the addition or removal of pollen was found in the experiment with whole flowers (fig. 4a and 4b). In addition no correlation was found when own pollen production was compared to thrips resistance (r_S=-0.486, p=0.28) (fig. 4c).

The high number of larvae found in whole flowers of cultivar 6 (exp. 3 and exp. 5) are not explained by the number of eggs which females laid in petals (exp. 2).

Discussion

Differences in thrips resistance between chrysanthemum cultivars were found both in plants with and without flowers. Plants without flowers proved to be far more resistant than plants with flowers. Therefore it is important to know which factor determines thrips resistance in plants with flowers.

In literature it is suggested that the higher number of thrips in chrysanthemum flowers is a result of pollen being present (Oetting, 1991; Teulon, 1991; Trichilo *et al.*,1988). Therefore it would be possible that the differences in thrips resistance between the flowering cultivars were caused by the variation in pollen production. In the first and second pollen experiments pollen proved to be good thrips nutrition. However, there was no correlation found between the pollen production per flower and the thrips resistance. A possible explanation could be that the quality of the pollen also played a role. However, when pollen of good quality were added to whole chrysanthemum flowers in experiment 3, no effect was found. There was no effect of pollen removal either. Therefore we suggest that in whole chrysanthemum flowers thrips feeds preferentially on another element with a high nutritive value, such as young female reproductive tissue or nectar.

In preventing thrips damage in chrysanthemum cultivation, breeders may resort to isolating plants with flowers and using resistant cultivars. These resistant cultivars are not necessarily the ones with low pollen production.

Acknowledgements

The authors wish to thank P.G.L. Klinkhamer, T.J. de Jong, K. Vrieling and E. van der Meijden for useful comments on the experimental design and their help with the data evaluation. We also wish to thank the chrysanthemum propagation firms Chrysanthemum Breeder Association N.V., Fides Research and Breeding B.V. and Hoek Breeding B.V. for supplying plant material for experimentation and for their technical advice.

References

OETTING, R.D. (1991). The effect of host species and different plant components on thrips feeding and development. In: *Virus-thrips-plant interactions of tomato spotted wilt virus* (Eds: H. Hsu & R.H. Lawson), Beltsville: Agricultural Research Service, pp. 15-20.

TEULON, D.A.J. & PENMAN, D.R. (1991). Effects of temperature and diet on oviposition rate and development time of the New Zealand flower thrips, *Thrips obscuratus*. *Entomol. Exp. Appl.* **60**: 143-155.

TRICHILO, P.J. & LEIGH T.F. (1988). Influence of resource quality on the reproductive fitness of flower thrips (Thysanoptera: Thripidae). *Ann. Entomol. Soc. Am.* **81**(1): 64-70

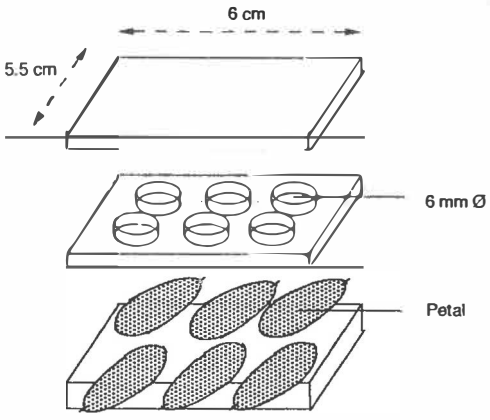


Fig. 1: Thrips are confined to chrysanthemum petals with or without pollen. The plexiglas plates are hold together with binder clips.

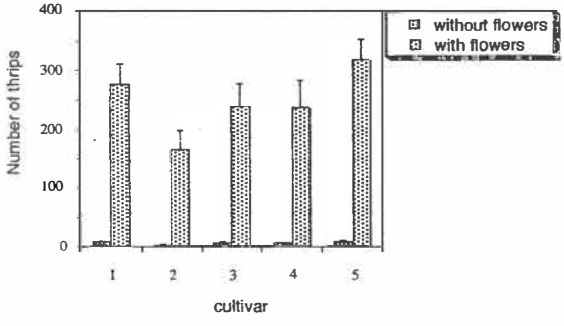


Fig. 2: Thrips resistance in chrysanthemum cultivars with and without flowers.

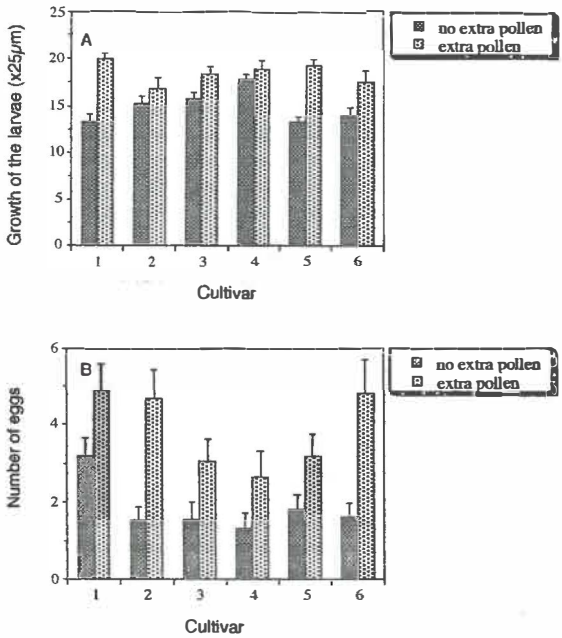


Fig. 3: The influence of pollen addition to chrysanthemum petals on larval growth (A) and fecundity (B).

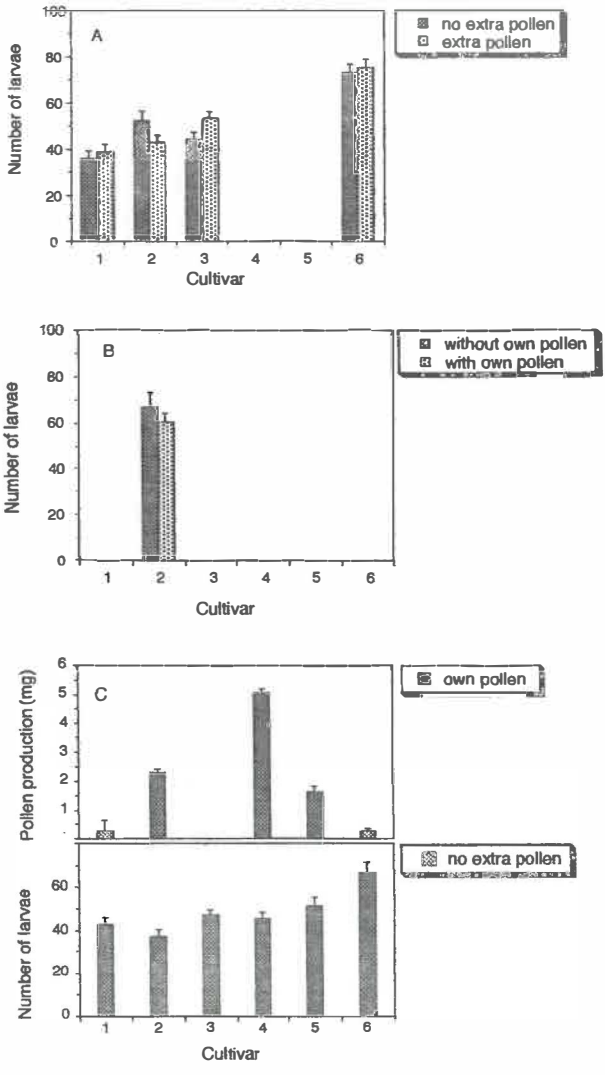


Fig. 4: Number of larvae in whole chrysanthemum flowers with and without extra pollen (A), in flowers with and without anthers (B) and compared to own pollen production per flower (C).

IPM IN GLASSHOUSE ORNAMENTALS:

THE FIRST STEPS IN PRACTICE

Ravensberg, W.J. & K. Altena

Koppert B.V.
Veilingweg 17
2651 BE Berkel en Rodenrijs
The Netherlands

1. Introduction

Until now biological control in glasshouse ornamental crops has not been applied in the Netherlands. Although technically possibilities do occur, factors such as export demands (zero-tolerance) and a wide choice of chemical pesticides with low costs were limiting the application of biological control. Incentives to change to a more complicated way of pest control were not there. This is now slowly changing because of new ideas and opinions about crop protection, zero-tolerance, avoiding resistance problems, environmental pollution and consumer's demands. Since 1991, we have been able to gather some experiences with biocontrol in commercial greenhouses, in chrysanthemum, gerbera and poinsettia.

2. Chrysanthemum

A biological control programme was started in 1990 at a grower who only sells its flowers to the domestic market through a big super market chain. Growers who produce chrysanthemums for export purposes, are very reluctant to try IPM because of the zero-tolerance demands of the trade. Still an impenetrable (psychological) barrier for biological control in the Netherlands.
After a transition period of four months with selective chemicals, biological control was initiated in the early spring of 1991 following a preventive approach. Natural enemies were released against spider mite, whitefly, leafminers, aphids, thrips and caterpillars. Against slugs metaldehyde was used, fungicides were hardly used.
Spidermite, whitefly and leafminer (*L. trifoli* and *L. huidobrensis*) control was excellent. Aphids caused some problems in spring, but later with slightly higher rates of beneficials control was good.
As expected *Frankliniella occidentalis* causes the difficulties. *Amblyseius cucumeris* was released, later in combination with *Orius insidiosus* and *Verticillium lecanii* (MYCOTAL). The effects of *A. cucumeris* and *V. lecanii* were very difficult to see, *Orius* reproduced well and nymphs were found in the growing buds where thrips larvae are also found. Thrips control was satisfactory untill August, immigration from outdoors caused to much damage and the programme was stopped. Untill then results were to the satisfaction of the grower and the super market. There had been no difference between these flowers and chemically controlled flowers whereby flowers were carefully checked on abnormities.
In spring 1992 the programme was started again, but T.S.W.V. was the reason of stopping in the early summer.
Resumively it can be said that technically biological control in an AYR chrysanthemum seems possible, but the number of beneficials and the costs are still too high. *F. occidentalis* is the main reason for this.

3. Gerbera

Gerbera seems to be an interesting crop for biological control since only the flowers are harvested and some damage on the leaves can be tolerated. In this respect gerbera corresponds with the vegetable crops in which biological is such a success.
Some pests, like whitefly and leafminer, only occur on the leaves. The same applies to aphids, spider mites and caterpillars, only when high densities occur damage is caused on the flowers. However, thrips is a real flower pest, and low numbers cause severe damage.
The biological control experiment was started on a commercial gerbera crop, grown on rockwool, in the summer of 1990. The first six months were used to change from the use of broad spectrum, persistent pesticides to selective, non-persistent pesticides. In December the programme with beneficials was started following a preventive approach (table 1). The results are discussed per pest.

Table 1. IPM programme in gerbera

pest	control	introduction rate
whitefly	*Encarsia formosa*	preventive 3 /m²/week curative 6-9 /m²/week
leafminer	*Dacnusa sibirica* *Diglyphus isaea*	after the first signs: 3 times 0.5 /m²/week (90/10= D.s./D.i.)
thrips	*Amblyseius cucumeris*	preventive 100/m² if thrips is expected repeat every 6-8 weeks (bags)
	Orius insidiosus	preventive 1/m² if thrips is expected a second introduction after 2 weeks if thrips is present 5/m²
aphids	*Aphidius* sp.	preventive 0.5/m²/week curative 3 times 1-2/m²/week
	Aphidoletes aphidimyza	2/m²/week in spots, 3 times
spider mites	*Phytoseiulus persimilis*	curative 6/m², repeat if necessary
caterpillars	*Bacillus thuringiensis*	on young larvae

Whitefly

Trialeurodes vaporariorum was present in this glasshouse, although more and more growers face problems with *Bemisia tabaci*. During the first 3 months of 1991 the control by *Encarsia formosa* failed because of the use of methiocarb against slugs. Later metaldehyde was used without problems to *Encarsia*. Sometimes buprofezin was used spotwise as a corrective measure.

Leafminers

Leafminers are a prominent pest in this crop and an intensive chemical programme is often used. In this case we faced a *Liriomyza trifolii* infestation, release of *Dacnusa sibirica* and *Diglyphus isaea* was very successful.
Both species of parasites are needed depending on the season and the density of leafminers as shown by the percentage parasitism and mortality by host-feeding (table 2).

Table 2. Introduction of leafminer parasites and their effect

		introduction	parasitization D.s.	D.i.	dead larvae	reduction
1990						
week	50	1/m² *				
	51	1/m² *	59%	22%	11%	92%
1991						
week	1	1/m² *	11%	28%	15%	54%
	2	1/m² *	22%	34%	17%	73%
	3	½/m²	11%	31%	46%	88%
	5	½/m²	52%	9%	26%	87%
	10		0%	40%	60%	100%
1992						
week	5		0%	0%	0%	0%
	6	½/m² *	–	–	–	–
	7	½/m² *	69%	0%	0%	69%
	8		33%	0%	0%	33%
	9	½/m²	–	–	–	–
	10	½/m²	92%	0%	0%	92%
	11	½/m²	69%	0%	14%	83%
	14		33%	46%	13%	92%
	16		9%	59%	32%	100%
	31		0%	43%	43%	86%

remarks:
Only *Minex* has been introduced. This product contains 90% *Dacnusa sibirica* (D.s.) and 10% *Diglyphus isaea (D.i.).*
** spotwise introductions*

Thrips
Control of thrips, particularly *Frankliniella occidentalis*, askes for an intensive programme. Selective pesticides are not available, the use of *Amblyseius cucumeris* and *Orius insidiosus* is aimed at the prevention of damage.
O. insidiosus reproduces on the pollen of gerbera, oviposition occurs in the leaves and the flowers. To have pollen available it is necessary to keep some (second class) flowers in the crop. The same is needed for *Amblyseius cucumeris*, also *Amblyseius barkeri* occurs spontaneously in the flowers.
In July 1991 a lot of thrips invaded the glasshouse and this meant the end of the IPM programme. IPM was taken up again in December 1991. During spring 1992 more predators (table 1) were introduced then in 1991. Since May thrips is present, both predators are also occuring in most of the flowers and thrips damage only occurs on a very low level (in August 1992) and is acceptable for the grower.

Other pests
Spider mites are wel controlled by *Phytoseiulus persimillis*. Caterpillars can be controlled by *Bacillus thuringiensis*. Aphids (*Aphis gossypii*) were already found in January and are well controlled by *Aphidius* and *Aphidoletes*. Diseases (powdery mildew) are easily controlled with fungicides.

The first steps in practice are promising. Much attention is still needed and a good cooperation between the grower and the adviser is essential. Even a successful application of biocontrol for 8 or 10 months is appreciated and interest is growing among growers.
The costs for biological control are a little but higher than chemical control but they were not a limiting factor to the grower.

4. Poinsettia

Biocontrol of whitefly in poinsettia lookes rather difficult because of the zero-tolerance, the occurence of *Bemisia tabaci* and intensive inspections of the Ministry of Agriculture because of both issues.
However, 1991 an IPM project started in cooperation with the Plant Protection Service of the Ministry of Agriculture. The first step was made in the production of stock plants for cuttings. Two species of whitefly were present in this case. *E. formosa* was introduced every week, 3-9/m² per week per m² depending on the numbers of whitefly.
An intensive checking (weekly) of plants and sticky traps is needed.
The use of nematodes, *Steinernema feltiae* against the larvae of Sciarids is needed, because parathion or oxamyl are harmfull for *Encarsia formosa*.
Host-feeding of *E. formosa* plays a major role in the control of whitefly. Sometimes buprofezin was needed. All participants were satisfied, the cost of the IPM programme were 40% lower than the guided chemical programme.
The project was set up again in 1992 with 4 cutting growers. The results are comparable with those of last year. The project may be continued in the plant production of poinsettia. Some growers are interested.

5. Discussion

The results of the last two years have lead to an increasing interest on biological control among growers and the suppliers of natural enemies. Next year IPM in gerbera will be expanded to about 10 growers. They will get extra attention, but it will be a regular commercial programme as in vegetables.
For chrysanthemum IPM in AYR crops is not yet feasible, the costs are to high.
Experiments will be continued in cuttings and in glasshouses where the ventilation openings are covered with mesh.
In poinsettia cuttings IPM is sucessful and it will be continued, in the plant production experiments are set up for this autumn.
In other crops experiments are going on, like in Ficus, ferns, palms, Bouvardia, Cymbidium and some potplants.

DOES ALTERNATIVE FOOD ALWAYS ENHANCE BIOLOGICAL CONTROL? THE EFFECT OF POLLEN ON THE INTERACTION BETWEEN WESTERN FLOWER THRIPS AND ITS PREDATORS.

Paul C.J. van Rijn & Maurice W. Sabelis
University of Amsterdam, Department of Pure and Applied Ecology
Kruislaan 302, 1098 SM Amsterdam, The Netherlands

Summary
The effects of pollen as an alternative food source are studied on a biological control system consisting of the Western Flower Thrips, *Frankliniella occidentalis*, and the predatory mite *Amblyseius cucumeris* on greenhouse crops.
Experiments show that pollen availability enhances development and reproduction of both prey and predator, whereas predation rate is decreased by pollen feeding of both prey and predator.
Population models predict a positive overall effect of pollen on thrips control, as long as the predator-prey system is nearing equilibrium conditions. However, when the system is not at equilibrium, e.g. just after release of predators, pollen can cause the prey to reach higher numbers.

Introduction

For a number of predator-prey systems it has been stated that biological control can be enhanced by the presence of alternative food sources for the predator. For example pollen can act as an alternative food source for predatory mites (McMurtry & Johnson, 1964, Kennett et al., 1979). However, besides the positive effects on the predator population growth, these food sources can have adverse effects on the (per capita) predation rates. In addition, it can potentially be used by some herbivores as well. So the question arises under which conditions alternative food provision is beneficial.
We studied the effects of pollen on a system consisting of the Western Flower Thrips, *Frankliniella occidentalis* (Pergande), and the predatory mite *Amblyseius cucumeris* (Oudemans), on greenhouse crops. In this system, both the thrips and its predator can utilize pollen. The effect of pollen on different properties of predator and prey were determined by experiment, whereas mathematical models are used to predict the overall effect of pollen on the prey population level.

Experimental results

(1) Adding sweet pepper pollen to a diet of cucumber leaves increases the oviposition rate of thrips with about 70% (from 2.7 to 4.7 eggs/day on average).
(2) Adding pollen increases the relative growth rate of the larval stages with about 50%. This has two consequences:
a) the total developmental time of the thrips will be shortened (since pupal development is not affected by the pollen), and
b) it will reduce the risk of predation, since capture success of the predator declines rapidly with prey size (Van der Hoeven & Van Rijn, 1990).
(3) On experimental arenas of cucumber leaves with high densities of thrips larvae, thrips consumption by this predator is reduced with about 30% (from 5.9 to 4.3 larvae per day) when ample pollen is present.

(4) The predatory mite can also utilize pollen for development and reproduction (Van Rijn & Van Houten, 1991). In fact, ovipositional rate is similar when ample pollen is offered instead of a high density of thrips larvae.
(5) Observations on isolated populations on plants in the greenhouse show that adult predatory mites are arrested in areas with pollen alone, as well as in areas with thrips alone (Van Rijn & Sabelis, 1990).

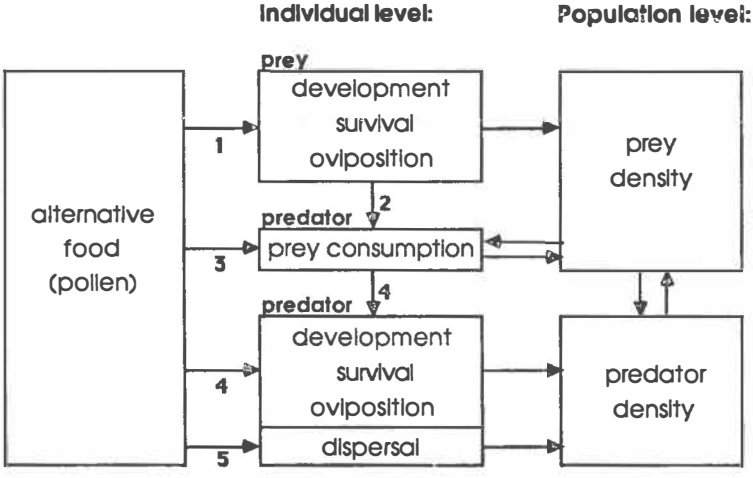


Figure 1: Diagram showing how pollen availability affects populations of predator and prey.

Predictions at population level
Figure 1 shows the five mentioned effects of pollen on this predator-prey system. The first three cause pollen to increase the growth rate of the thrips population, at a given size of the predator population. The remaining two effects cause pollen to speed up the predator population growth, especially at low prey densities.
To predict the overall effect of pollen availability on the prey population, we constructed population models that included all the different effects of pollen, assuming homogeneous distributions.

Simulations resulted in damped oscillations. This stability is due to the invulnerability of all non-larval stages.
The models predict the following effects of pollen on the prey population:
(1) The equilibrium prey density will be lower in presence of pollen, since the equilibrium density is dominated by parameters determining predator population growth. When the predator population is able to increase due to pollen alone, the thrips will be driven to extinction.
(2) The initial peaks of the prey population will be higher when pollen is available, due to the increased prey population growth. The height of these peaks depends on the initial number of predators and prey.
Although the effect of pollen on the equilibrium prey density is dominated by the effect of pollen on life history of the predator, prey densities obtained in the initial, fluctuating period depend on the relative effects of pollen on properties of predator and prey.

Discussion

When the biological control system is near equilibrium, our model predicts that, even though pollen promotes population growth of both thrips and predatory mite, the overall effect on thrips control is positive. Good prospects for testing this prediction exist in greenhouse crops, such as sweet pepper and cucumber, especially because host plant varieties are available with low and high production of pollen.

When populations are not near equilibrium, predictions on the impact of pollen on thrips control are less straightforward. Whether the impact is positive or negative now depends on the extent to which prey population growth is promoted relative to that of the predator, and on the initial numbers of predator and prey. This is because the prey may reach a larger population size through pollen feeding, before the predators become sufficiently numerous to suppress the prey population.

In the 'non-equilibrium' situation one may expect to enhance the positive effects of pollen on biological control by the following measures.

(1) Introducing the predators in high numbers, as this will reduce the initial growth of the prey population.

(2) Introducing the predators as soon as pollen is available. Now, the predator population can start growing, using pollen as a food source, before the prey population starts increasing (cf. Ramakers, 1990).

(3) Making pollen more permanently available and from an earlier date, e.g. by changing crop cultivars or planting dates.

The possible effects of pollen on the biological control of thrips are important, not only for growers and biological control companies, but also for plant breeders. By altering the properties that govern the production, edibility or nutritional value of pollen, plant breeding may affect biological control.

Literature

HOEVEN, W.A.D. VAN DER & P.C.J. VAN RIJN, 1991. Factors affecting the attack success of predatory mites on thrips larvae. Proc. Exper. & Appl. Entomol., N.E.V. Amsterdam, Vol.1: 25-30.

MCMURTRY, J.A. & H.G. JOHNSON, 1964. Some factors influencing the abundance of the predacious mite *Amblyseius hibisci* in southern California (Acarina: Phytoseiidae). Ann. Entomol. Soc. Am. 58: 49-56.

KENNETT, C.E., D.L. FLAHERTY & R.W. HOFFMANN, 1979. Effects of wind-borne pollens on the population dynamics of *Amblyseius hibisci* (Acarina: Phytoseiidae). Entomophaga 24: 83-98.

RAMAKERS, P.M.J., 1990. Manipulation of phytoseiid thrips predators in the absence of thrips. SROP/WPRS Bull. 13: 169-172.

RIJN, P.C.J. VAN & Y.M. VAN HOUTEN, 1991. Life history of *Amblyseius cucumeris* and *A. barkeri* (Acarina: Phytoseiidae) on a diet of pollen. Modern Acarology. Academia, Prague and SPB Academic Publishing bv, The Hague, Vol.2: 647-654.

RIJN, P.C.J. VAN & M.W. SABELIS, 1990. Pollen availability and its effect on the maintenance of populations of *Amblyseius cucumeris*, a predator of thrips. Med. Fac. Landbouww. Rijksuniv. Gent 55: 335-341.

IPM IN INTERIOR LANDSCAPES

P. Sopp
Applied Horticulture Division, Fargro Limited, Toddington Lane, Littlehampton, West Sussex BN17 7PP, United Kingdom

Introduction

The UK interior landscape industry underwent a rapid expansion during the property boom of the 1980s. Many large office and hotel complexes now have extensive plantings often extending over several floors of the building and including mature trees over 5 m tall. The almost universal use of air conditioning provides a constant temperature, often with supplementary lighting, which results in ideal conditions for pest infestation. The cosmetic nature of the plantings means that there is often a zero or at least a very few low acceptable level of pest. In the past, infested plants were either removed or treated with a pesticide. The former is no longer an economic option with the larger plants and the latter is no longer permitted. The current situation in the UK in relation to chemical sprays on interior landscapes is that only amateur products specifically approved for use in the home on house plants may be used (Pesticide Register 8, 1990). This limits the number of products to less than a dozen, most based on permethrin. In addition many of the client companies will not allow the use of any chemical sprays because of Health and Safety concerns and worries of staff.

Applied Horticulture have, in conjunction with a number of interior landscape companies, developed biological control programmes on a range of sites. This article reviews the success or otherwise of some of these introductions and the practical problems encountered. The philosophy which runs through almost all our programmes has been to use regular introductions of natural enemies as a biological insecticide and not to allow pest populations to reach levels at which the occupiers of the building notice them. This approach has prevented, in most situations, the development of balanced populations of pest and natural enemy.

The pests

Tetranychus urticae

Perhaps the most feared pest by landscape companies. The low humidity and warm temperatures produced by air conditioning are ideal for spider mite population growth. *Phytoseiulus* has proved to be a very effective control in areas where the relative humidity can be kept above 60% for example on Helexine used for ground cover. *Phytoseiulus persimilis* is introduced at rates of between 10 and 25 per m^2 on a weekly or fortnightly schedule, depending upon spider mite numbers. In one case a severe infestation of spider mite on several 11 m tall Bamboo was discovered shortly after the plants had been installed. The client refused permission to spray the plants so 60,000 *Phytoseiulus* were introduced over two weeks. The bamboo were in the central atria of a large open-plan office building where the humidity was set at 40%, a level apparently required by the sophisticated computer systems. An inspection seven days after the second introduction revealed very low numbers of *Phytoseiulus* and almost no evidence of egg production. A further introduction was made a week later with the same result. No pesticide residues were detected. It appears that *Phytoseiulus* were leaving the bamboo for areas of higher humidity such as the ground cover. Subsequent experience has shown that *Phytoseiulus* will only survive on large plants if the humidity is constantly above 60%. Periodic misting of plants has very little effect and the

installation of more permanent misting is not acceptable because of the risk of Legionaires disease.

Trialeurodes vaporariorum
Rarely a significant pest on interior landscapes largely due to the lack of suitable host plants. Control using *Encarsia formosa* has been very successful. *Encarsia* is introduced weekly at a rate of between 5 and 10 per m^2 depending on the level of whitefly. The whitefly is usually restricted to a small area or a single species of plant and is relatively easy to monitor. A plant species which is highly attractive to whitefly such as Fuchsia can be used as an indicator plant.

***Frankliniella occidentalis* and other thrips**
Thrips are uncommon in interior landscapes although they are often introduced on flowering plants used as temporary displays. Thrips can often survive on the types of plants used in interior landscapes but rarely increase to damaging levels. Where control is necessary *Amblyseius cucumeris* has proved to be very successful when introduced either in slow release sachets or in several introductions using shaker bottles. The best results are achieved when *Amblyseius* is released as soon as thrips are seen.

Aphids
One of the most common pests on interior landscapes especially on Hedera. Control is usually achieved using a combination of *Aphidoletes aphidimyza* and *Aphidius matricariae* introduced at weekly intervals for four weeks after the aphids are found. A rate of 10 of each per m^2 has usually been sufficient. *Aphidius* often occurs naturally and introductions are not always suitable for sites with twenty-four hour security lighting. The low humidities prevent the use of *Verticillium lecanii*, even it its use were allowed.

***Planococcus citri* and other mealybugs**
Mealybugs are one of the most common pests on interior landscapes as most of the plants are suitable hosts. They are one of the most difficult pests to control. *Cryptolaemus montrouzieri* has been successful on most release sites if released at the early stages of a mealybug infestation. *Cryptolaemus* will ultimately gain control of even heavy infestation but not before copious amounts of honeydew have been excreted and also a large number of *Cryptolaemus* larvae produced. The larvae closely resemble very large mealybugs and are often mistaken for them by landscape contractors and the building's occupiers. If the mealybug species is *Planococcus citri* the specific parasite *Leptomastic dactylopii* can be used. However, commercial supplies are not always available. Releases of 5 per m^2 repeated twice at fortnightly intervals have been successful.

***Saissetia coffeae* and other soft scales**
These have proved to be the most difficult pest to control. Scale is a very frequent pest on the large Ficus, often in excess of 5 m tall, which are a common feature of interior landscapes. Wherever possible *Metaphycus helvolus* has been used in an attempt to control scale. Releases have been made fortnightly from early April when day length and light intensity are sufficient for activity. The major problem encountered has been the sporadic supply of parasites which has prevented sufficient numbers being released. Where it has been possible to maintain releases the results have been variable. Monitoring has revealed how important it is to release parasites on bright days and when scale populations are low. Once leaves have accumulations of honeydew *Metaphycus* will not be successful and physical removal of scale and washing of leaves will be necessary.

Otiorhynchus sulcatus* and *Lycoriella auripila

These pests are rare in landscapes. *Lycoriella* can often be controlled by reducing overhead irrigation and allowing the surface of the compost to dry out. However, even small numbers of adult sciarid flies can be troublesome especially in open-planned offices where flies are attracted to computer screens. Drenches of *Heterorhabditis* nematodes have been very successful in controlling the larvae of both sciarid and vine weevil. A single application is usually sufficient to eliminate the pest.

The comments and rates outlined above are only guidelines. A feature of interior landscapes is that they are all unique and each site must be visited, a detailed assessment of pest levels made and thereafter regular monitoring visits. Control programmes have to be continually developed and rates of use adjusted as pest populations change. Monitoring should be as frequent as possible, ideally weekly at first, although in practice monthly visits are often made.

Specimen plants are frequently imported from Southern Europe or the Americas and planted directly into the landscape. This lack of any quarantine or inspection often leads to pests being present from day one, including non-endemic pests such as *Diaprepes* sp. It is recommended that all plants are quarantined for at least two weeks, during which inspections and, if necessary, treatments are made. Plants can be treated with chemicals during quarantine which would not be legal once in the interior landscape.

The pesticide history of all plants should be known in order to prevent the release of natural enemies onto toxic residues.

One of the most common problems encountered has been office staff who bring their own plants into the building. These are frequently infested with pests and are outside the control of the landscape company. In some cases the landscape company and the building's occupiers have agreed that no plants can be brought into the building unless they have been purchased from the landscape company.

The use of natural enemies has to be carefully explained to the building's occupiers otherwise staff concerns over the release of insects can arise. Some controls such as *Orius* or *Chrysopa* cannot be used in some situations because of their size and appearance.

Methods of introduction have to be adapted to be as visually unintrusive as possible. The use of controlled release sachets or cards with *Encarsia* have to be disguised or hidden among foliage. The size of the market is not yet sufficient to support the use of coloured cards or specific release systems. The release of *Phytoseiulus* and *Amblyseius* from shaker bottles gives particular problems of vermiculite or bran on the foliage. Indeed it is almost impossible to introduce such predators onto large plants, especially plants such as bamboo within significant numbers falling on the ground. A few plastic beakers hung or wedged among the foliage can be filled with vermiculite or bran from which the predators can emerge onto the plant.

The interior landscape industry is increasing its use of biological control but, at the same time, is realising that it is not a panacea and requires commitment and an understanding of the principles involved. However, the benefits in good pest control and the removal of health and safety concerns are increasingly recognised.

EFFECT OF *AMBLYSEIUS CUCUMERIS* AND *ORIUS INSIDIOSUS* ON *FRANKLINIELLA OCCIDENTALIS* IN ORNAMENTALS

A. Sörensson[1] and B. Nedstam[2]
[1]Swedish Univ. of Agricultural Sciences, P.O.B. 44, S-23053 Alnarp, Sweden
[2]Swedish Board of Agriculture, P.O.B. 44, S-23053 Alnarp, Sweden

Summary
The thrips predators *Amblyseius cucumeris* (Oud.) and *Orius insidiosus* (Say), alone and in combination, established well on infestations of *Frankliniella occidentalis (Pergande)* in saintpaulia, impatiens, brachyscome and gerbera. The combination of predators reduced thrips numbers most in all four crops. This could be an alternative to chemical control of WFT in these ornamentals.

1. Introduction

The western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), is a severe pest of greenhouse crops. Biological control with the predatory mite *Amblyseius cucumeris* (Oud.) is used on a large scale in greenhouse vegetables in the Netherlands (Ramakers *et al.*,1989). In England this method is also used in ornamentals (Wardlow *et al.*,1992).
The anthocorid bug *Orius insidiosus* (Say) has recently been introduced in Europe, and is now recommended together with *A. cucumeris* to control WFT in vegetables in the Netherlands (Hubert,1992). *O. insidiosus* has been successful as biological control agent of WFT in pot chrysanthemum in cage experiments (Brodsgaard,1992). Studies of searching behaviour in *O. insidiosus* have shown differences in arrestment between chrysanthemum and rose (Beekman *et al.*,1991). This could contribute to understanding why biological control fails on rose but not on chrysanthemum.
In this paper we report on introductions of the two predators in four different ornamentals in greenhouse chambers with WFT.

2. Materials and Methods

Saintpaulia, impatiens (New Guinea hybrid), gerbera and the bedding plant *Brachyscome multifida*, all in early flowering stage, were placed in four greenhouse chambers, in groups of 20 pots per chamber of each plant species in week 24 (14 June). WFT from a rearing on *Brassica* spp. were introduced as adults, 70 per chamber, in week 25 (17 June).
Predators were released according to the following scheme (per chamber):

- *A. cucumeris* only, four bags of "THRIPEX-PLUS" per chamber (one bag per 20 plants) in week 24 (14 June) and the same amount in week 26 (28 June). Each bag is a rearing unit with 250 predatory mites from the start and with continuos release of several hundreds of mites during a few weeks.
- *O. insidiosus* only, as adults, 5 pairs per chamber in week 25 (18 June) and the same amount in week 26 (25 June).
- *A. cucumeris* and *O. insidiosus*, the same amounts and dates as in the previous two chambers.
- no predators released (control chamber).

Samples of flowers/flower heads were taken weekly during weeks 26 - 31 in saintpaulia and brachyscome and weeks 27 - 32 in impatiens. In gerbera we sampled only four times during week 27 - 34. For each treatment 10 subsamples of 1 - 10 flowers/flower heads were taken. Thrips and predators were collec-

ted with the turpentine extraction method (Evans,1933), modified by Lewis (1960), and counted using 10-40x magnification.
Daily mean temperature in the greenhouse fluctuated between 22 and 27°C during the period with a minimum night temperature of 19°C.

3. Results and Discussion

In saintpaulia flowers (fig.1.) *A. cucumeris* was found in rather low numbers all six weeks and *O. insidiosus* in very low numbers week 28-31. WFT infestation was also low, reaching a maximum three weeks after introduction when control chamber had highest numbers, predators in combination lowest. This trend continued all through the period. Unintended spread of predators into control chamber could explain why WFT population rapidly decreased also here.
In impatiens flowers (fig.2.) predators occurred in higher numbers and differences in WFT infestation with the control was bigger, specially for predators in combination. As in saintpaulia a mixture of predators was found everywhere four weeks after first release.
Flower heads of brachyscome (fig.3.) contained fairly many predators, but any effect on WFT population compared to the control could only be seen where predators were combined.
Flower heads of gerbera (fig.4.) are good breeding sites both for WFT and predators. Only the combination of predators could keep WFT maximum under 100 per flower head (at the same time WFT in control reached 393). No samples were taken in control chamber week 31 due to lack of open flower heads. WFT feeding on foliage had probably affected plant growth too much.
Adults and immatures of WFT and *O. insidiosus* were counted separately, but total numbers are given in figures 1-4. WFT adults:larvae was close to 1:10 through weeks 26-29, then shifted towards 1:1 which could reflect increasing predation on larvae. *O. insidiosus* adults:nymphs was steady around 1:4.
The overall impression is that a combination of *A. cucumeris* and *O. insidiosus* resulted in fairly good control of *F. occidentalis* in these ornamentals. We worked with rather high thrips infestations. In a normal Swedish situation with quite slow build-up of thrips populations most of the year, preventive use of *A. cucumeris* (bag method) supported by introductions of *O. insidiosus* whenever pollen for feeding or WFT is available, could be an alternative to chemical control in many ornamentals.

References

BEEKMAN,M., FRANSEN,J.J., OEITING,R.D. & SABELIS,M.W., 1991. Differential arrestment of the Minute Pirate Bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), on two plant species. Med.Fac.Landbouww.Rijksuniv.Gent 56: 273-276.
BRODSGAARD, H., 1992. *Orius insidiosus* as a successful biological control agent of *Frankliniella occidentalis* on glasshouse pot chrysanthemum. Bulletin OEPP/EPPO Bulletin 22 (in press).
EVANS, J.V., 1933. A simple method of collecting thrips and other insects from blossom. Bull ent. Res. 24: 349-350.
HUBERT, L., 1992. Trips op laag niveau houden. Groenten+Fruit 17 Jan.: 20-21.
LEWIS, T., 1960. A method for collecting Thysanoptera from Graminae. The entomologist 93: 27-28.
RAMAKERS, P.M.J., DISSEVELT, M. & PETERS, K., 1989. Large scale introductions of phytoseiid predators to control thrips on cucumber. Med.Fac.Landbouww. Rijksuniv.Gent 54(3a): 923-929.
WARDLOW, L.R., BROUGH, W. & NEED, C., 1992. IPM in ornamentals in England. Bulletin OEPP/EPPO Bulletin 22 (in press).

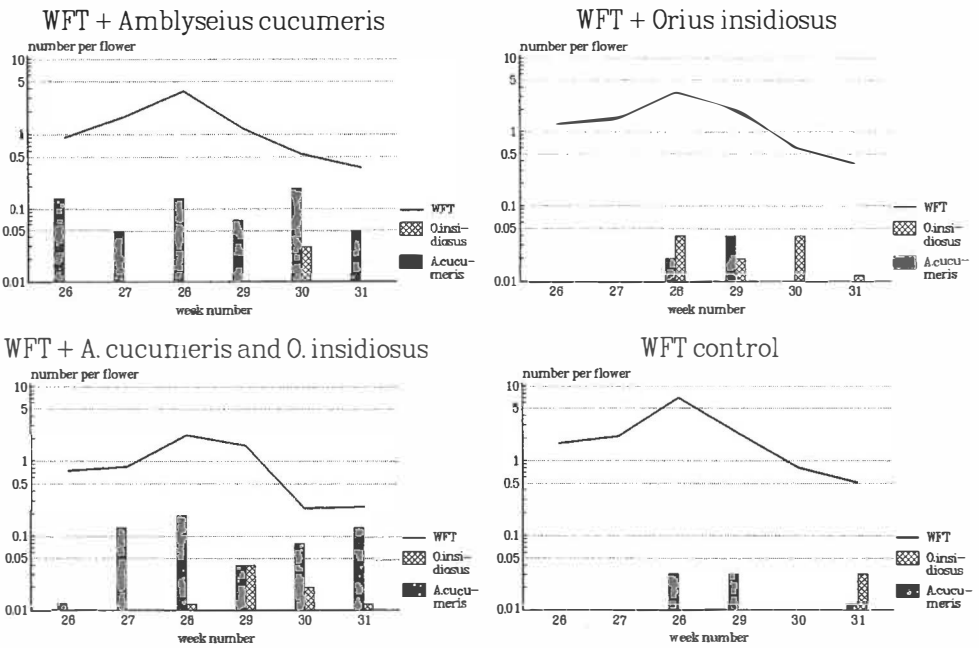


Fig.1. Mean number of Western Flower Thrips and predators in saintpaulia.

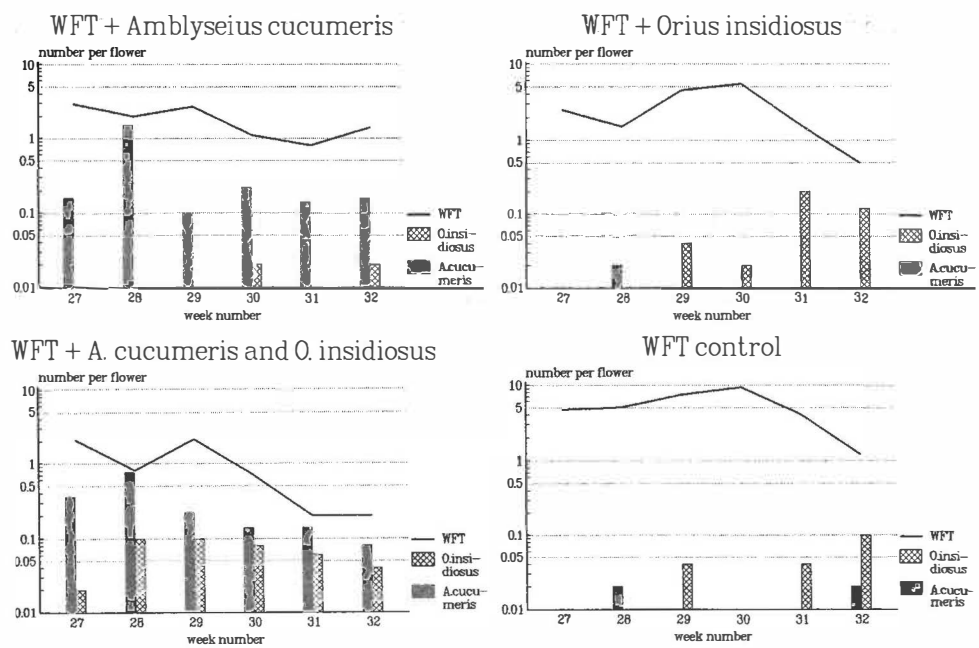


Fig.2. Mean number of Western Flower Thrips and predators in impatiens.

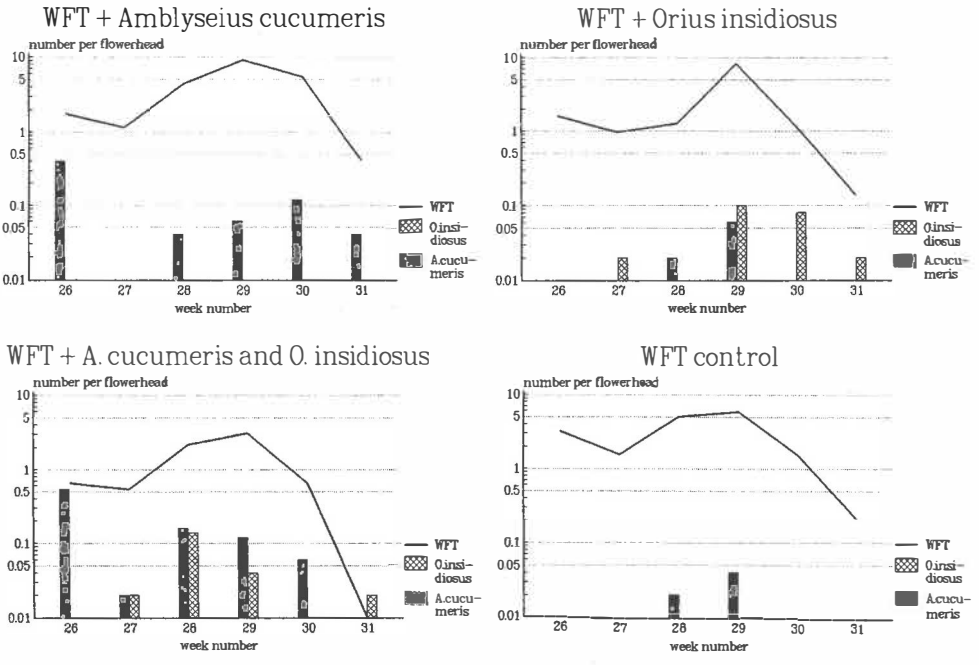


Fig.3. Mean number of Western Flower Thrips and predators in brachyscome.

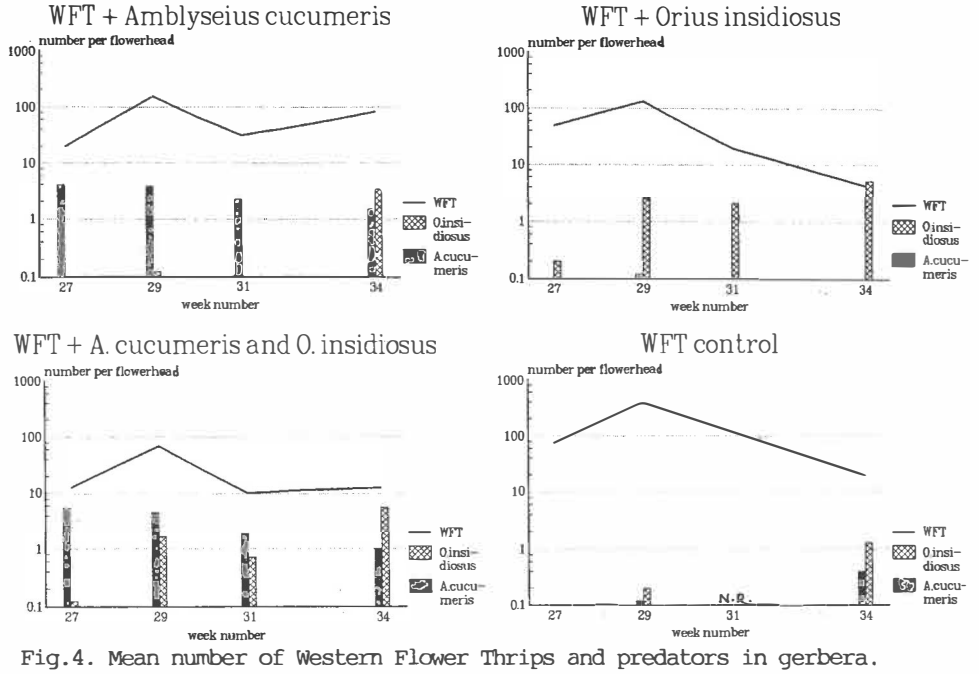


Fig.4. Mean number of Western Flower Thrips and predators in gerbera.

IPM PRACTICES IN GREENHOUSE POINSETTIA CROPS IN ALBERTA, CANADA

Marilyn Y. Steiner
Alberta Environmental Centre, Bag 4000, Vegreville, Alberta, Canada

Summary

Poinsettia crops in Alberta are host to both greenhouse and sweet potato whiteflies (*Trialeurodes vaporariorum* and *Bemisia tabaci*), with fungus gnats as a minor pest. IPM approaches for whiteflies have stressed clean-up of cuttings, sampling protocols and action thresholds using yellow sticky traps, and evaluation of *Encarsia formosa*. An action threshold of 5/trap/week is suggested for *B. tabaci*, higher for *T. vaporariorum*. *Encarsia* worked well on a mixed species population at rates of 1-2/plant/week, but was not economic at present prices.

Introduction

The major poinsettia pests in Alberta are greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) and sweet potato whitefly, *Bemisia tabaci* Genn. Fungus gnats are an occasional problem, particularly in association with fungal root pathogens. The greenhouse whitefly is generally considered "home-grown", whereas the sweet potato whitefly is imported annually on cuttings from out-of-Province producers. Attempts are being made to produce cuttings locally, but the bulk will likely remain imported. Difficulties in control arise primarily as a result of poor pest management practices, particularly immigration from adjacent crops and from weeds. Pesticide resistance is not yet a major factor but is increasing. Since aldicarb was withdrawn from the market place two years ago, the main choice of chemicals has been sulphotep, endosulfan and insecticidal soap. Horticultural oils, deltamethrin, dienochlor + kinoprene, and acephate are used less frequently.

Biological control using *Encarsia formosa* is practised by only a few small operations. It is considered too expensive and not reliable.

IPM research areas

Sampling protocols for monitoring adult whiteflies

Yellow sticky card catches have correlated well with adult sweet potato whitefly in the crop, less well where both whitefly species are present. Data for greenhouse whitefly alone is still being collected. Traps (10 cm x 15 cm) are placed in an east/west vertical orientation at a density of one/200 plants. For 15 cm pots, five sweet potato whiteflies/trap/week correlates well with about 5% of plants with adult whitefly after the crop is spaced. This level has been suggested to growers as an action threshold early in the crop, tolerance decreasing closer to bract formation.

Trap orientation

Total catches on yellow sticky cards were found to vary with orientation. Traps angled at 45° to the horizontal, upper surface facing east or south caught the most sweet potato whitefly, those held vertically north/south the least. For practical purposes, traps in commercial greenhouses are standardised at a 90° to the horizontal east/west orientation.

Cultivar preferences

Choice and no-choice experiments on cuttings showed differences between cultivars and between whitefly species with regard to feeding preferences, egg deposition, and nymphal survival. Because the majority of adult whiteflies are home-bodies rather than travellers, adult feeding preferences are less important in practice than egg deposition and nymphal survival. Favoured cultivars were Jinglebells, Pink Peppermint, Celebrate, Angelika and Supjibi.

Phytotoxicity of pesticide dips to cuttings

Dips are considered one way of reducing infestations of whitefly on imported cuttings. Cultivars varied in their sensitivity to dips. Endosulfan, insecticidal soap and 0.5% horticultural oil were generally safe, unless cuttings were treated with an incompatible material prior to shipping.

Biological control using *Encarsia formosa*

Three commercial co-operators attempted control using this method. It was successful in only one smaller operation, at a weekly *Encarsia* rate of 1-2/plant, and occasional supplementing with yellow sticky traps at one/30 plants. Trap catches remained below 10/trap most of the season and were 5/trap at harvest. No pesticides were applied; the absence of residues is viewed as one reason why the control was successful. Both whitefly species were present.

Major problems with the use of *Encarsia* are (i) cost (*Encarsia* are more expensive than in Europe); (ii) pesticide residues on cuttings and/or in the greenhouse; (iii) variable parasite quality; (iv) release system more suited to vegetables than poinsettias; (v) rates and introduction period still largely guesswork.

More acceptable to growers is the use of nematodes for fungus gnat control. Two or three applications have given good control and they can be applied fairly easily in irrigation water.

BIOLOGICAL CONTROL OF COTTON WHITEFLY *BEMISIA TABACI* (Genn.) (HOMOPTERA: ALEYRODIDAE) BY *ENCARSIA FORMOSA (EULOPHIDAE; HYMENOPTERA)* ON *EUPHORBIAE PULCHERRIMA* AND *HYPOESTES PHYLLOSTACHYA*

C. Stenseth
Norwegian Plant Protection Institute, 1432 AAS, Norway

Summary
Experiments were carried out to see the effect of *Encarsia formosa* on a pure population of *Bemisia tabaci* and on a mixed population of *B. tabaci* and *Trialeurodes vaporariorum*. Large scale experiments were carried out in commercial greenhouses with releases of *E. formosa* for control of *B. tabaci* on *Euphorbiae pulcherrima* and *Hypoestes phyllostachya*.

E. formosa parasitised *B. tabaci* both in pure population and in a mixed population of *B. tabaci* and *Trialeurodes vaporariorum*. Nymphs killed by causes other than parasitisation were most numerous with the largest dosage of *E. formosa*, and more numerous in pure populations of *B. tabaci* than in a mixed population of *B. tabaci* and *T. vaporariorum*.

On mother plants of poinsettia, 1.3 *E. formosa* per plant every fortnight during the cropping season gave satisfactory control of *B. tabaci*, but not an eradication. In production of pot plants of poinsettia, 1 *E. formosa* per two plants every fortnight gave satisfactory control. In production of *H. phyllostachya*, repeated releases every fortnight of four *E. formosa* per m² combined with dipping of the cuttings in buprofezin before planting gave good control.

Introduction
Two species of *Aleurodidae*, the greenhouse whitefly *Trialeurodes vaporariorum* (Westw.), and the cotton whitefly, *Bemisia tabaci* (Genn.), are known in Norwegian greenhouses. The former infests many greenhouse plants, while the latter has become one of the main pests on poinsettia, *Euphorbia pulcherrima* (Stenseth, 1990).

The present paper reports an investigation of the ability of *E. formosa* to parasitise or kill the cotton whitefly by causes other than parasitisation ("overkilling") as well as parts of large scale experiments with different dosages of *E. formosa* to control cotton whitefly on poinsettia and *Hypoestes phyllostachya*.

Materials and methods
Parasitisation and "overkilling"
Poinsettia plants of the cultivar "Starlight" were exposed to egg laying females of *B. tabaci* for 1-2 days. The plants were then cleaned of whiteflies and placed in 1 m² insect cages. Two different dosages of *E. formosa*, 1 parasite:200 whitefly nymphs and 1 parasite:50 nymphs, were released on a pure population of *B. tabaci* (nymphs) and a mixed (about 1:1) population of *B. tabaci* and *T. vaporariorum*. The nymph population contained 2nd-4th instars. For estimation of number of parasites the nymphs were counted before releases of the parasite. The dosages of *E. formosa* used refer to the number of parasitised *T. vaporariorum* pupae from commercial production. 85-92% of the pupae hatched to parasites. The primary effect of one release was recorded on surviving nymphs, parasitised nymphs or nymphs killed by causes other than parasitisation ("overkilling").

In another experiment the total effect of two releases of *E. formosa*, days apart, was measured. The dosages of *E. formosa* were the same as mentioned above. Poinsettia plants with a known number of whiteflies were put into the insect cage for each release of parasites.

Control experiments Five large-scale experiments were carried out.

Experiment 1 (Table 3) was carried out in a commercial greenhouse from 15 March to 27 September. In this period the greenhouse was used for production of pot plants *Hypoestes phyllostachya, Kalanchoe blossfeldiana,* poinsettia, *Dianthus chinensis, Verbena* sp and *Streptocarpus* sp. Both *B. tabaci* and *T. vaporariorum* were present on *H. phyllostachya* from the beginning of the experiment. There were releases of four *E. formosa*/m² every second week. The cuttings of *H. phyllostachya* were also immersed in 0.00125% buprofezin before planting. Infestation of *Myzus persicae* was controlled with *Aphidius matricariae* and pirimicarb. The whitefly infestation was estimated by counting the plants with or without whiteflies of altogether 100 randomly selected plants of *H. phyllostachya* and poinsettia. The temperature in the greenhouse was 20°-30°C.

Experiment 2 (Table 4) was carried out in an experimental greenhouse with "Winterstar" poinsettia. The plants were treated as mother plants. At the time of planting one *B. tabaci*/plant was released. Four weeks later one *E. formosa*/plant was released and later one *E. formosa*/3 plans was released at 14-day intervals. Before the releases of *E. formosa* started 15 plants were isolated under insect cages, four places in the greenhouse (untreated). At the end of the experiment the total number of hatched adult whitefly were counted on 60 plants. The temperature was 22°-27°C.

Experiment 3 was carried out in a greenhouse with commercial production on pot plants of poinsettia cultivars "Lilo", "Top White" and "Femina" infested with *B. tabaci*. *E. formosa* was released at 14 day intervals. The dosages and number of releases are shown in Fig. 1. The population of *B. tabaci* was measured by yellow sticky traps (10 x 20 cm), 20 traps per 1000 m². The temperature was 20°-22°C.

Experiment 4 (figure 1) was carried out in a greenhouse with commercial production of pot plants of the poinsettia cultivars "Lilo", "Angelica", "Femina" and "Top White" infested with *B. tabaci*. One *E. formosa*/2 plants was released every fortnight. The registration of the population of *B. tabaci* and the temperature were the same as in experiment 3.

Experiment 5 (table 5) was carried out in a commercial greenhouse with mother plants of the cultivars "Lilo", "Red Sails", "Starlight" ad "Winterstar" infested with *B. tabaci*. 1, 3 *E. formosa*/plant was released every fortnight. The population of *B. tabaci* was estimated with yellow sticky traps. The temperature was 20°-27°C.

The dosages of *E. formosa* used in all experiments refer to the number of parasitised *T. vaporariorum* pupae of commercial production. The emergence of adult *E. formosa* varied from 60-90%.

Results

Parasitisation and "overkilling". Table 1 shows that the highest dosage of *E. formosa* gave significantly fewer surviving whiteflies than the lowest dosage of *E. formosa*. *B. tabaci* was parasitised both in a pure population and in a population of half *B. tabaci* and half *T.*

vaporariorum. There were no significant differences in the parasitisation between the two dosages, one *E. formosa:*50 nymphs and one *E. formosa*:200 nymphs. But more nymphs were parasitised in a mixed population of the species than in a pure population of *B. tabaci*. The percent "overkilling" was highest at the largest dosage of *E. formosa* and there was significantly more "overkilling" in a pure population of *B. tabaci* than in a mixed population of both species. Table 2 shows the control of whitefly after two releases of *E. formosa* 14 days apart. Both dosages of *E. formosa* showed good control 6 weeks after the last release.

Control experiments. Four *E. formosa*/m² combined with dipping of the cuttings before planting gave effective control of the whitefly infesting *H. phyllostachya* (Table 3). This table also shows that four *E. formosa*/m² did not give a satisfactory control of whitefly on poinsettia.

In mother plants of poinsettia a dosage of 1.3 *E. formosa* per plant and repeated releases throughout the crop period gave satisfactory control of *B. tabaci* (Table 5), but at the end of the period the whitefly population tended to increase. A dosage of one *E. formosa* per 3 mother plants and repeated releases every fortnight did not satisfactorily control *B. tabaci* (Table 4). Figure 1 shows the two experiments on control of *B. tabaci* on pot plants of poinsettia. In experiment 3, a dosage of one *E. formosa*/10 + 1/5 plants, 1/4 plants and 1.3 plants was not sufficient to avoid an increase of the whitefly population, and Sulfotep was used to control the whitefly. In experiment 4, one *E. formosa*/2 plants every fortnight gave good control of *B. tabaci*. In November, azalea plants strongly infested with *T. vaporariorum* were taken into the greenhouse and all plants were sprayed with buprofezin.

Discussion

Bemisia tabaci was both parasitised and "overkilled" by *Encarsia formosa*. Overkilling" was more dominant in a pure population of *B. tabaci* than in a mixed population of *B. tabaci* and *Trialeurodes vaporariorum*. The reason might be that the nymphs of *B. tabaci* are smaller than those of *T. vaporariorum* and are more easily killed without giving a new parasite.

Boisclair *et al* (1990) assumed that the control of *B. tabaci* might be attained through repeated introductions of *E. formosa* during the cropping season. Wardlow and Albert (1990) found in their experiments with poinsettia that weekly releases of one *E. formosa*/3 plants were necessary for control of *B. tabaci*. The present large scale experiments also show that regular introductions of *E. formosa* during the cropping season are necessary to control *B. tabaci* on poinsettia. A dosage of 1.3 *E. formosa*/plant every fortnight gave sufficient control in mother plants. The tendency of the whitefly population to increase at the end of the season might be due to the plants being larger for the parasite to search for whitefly nymphs. In cutting production of poinsettia the goal is whitefly-free cuttings. This was not attained with releases of *E. formosa*. Buprofezin has a long-lasting effect on young nymphs of whitefly (Stenseth & Singh, 1990). Use of *E. formosa* on the mother plants and dipping the cuttings in buprofezin before planting can complement each other, and give cleaner plants. In pot plants, 1 *E. formosa*/2 plants every fortnight gave sufficient control.

References

Boisclair, J., Bruren, G.J., & van Lenteren J.C. (1990). Can *Bemisia tabaci* be controlled with *Encarsia formosa*? - SROP/WPRS Bull. XIII/5 (1990): 32-35

Stenseth, C & Singh, H.M. (1990). Buprofezin mot veksthusmellus og bomullsmellus. - Gartneryrket, 80 (1): 18-19.

Stenseth, C. (1990). Mellus på prydplanter i veksthus. - Gartneryrket 80 (3): 16-18.

Wardlow, L. & Albert R. (1990). Dreaming of a green Christmas. - Grower, 114 (5): 21-25.

Table 1. Primary effect of different dosages of *Encarsia formosa* (E.f.) on nymphs of *Bemisia tabaci* (B.t.) and nymphs in a mixed (1:1) population of *B. tabaci* and *Trialeurodes vaporariorum* (T.v).
Host plant: Poinsettia

	% nymphs		
	reached adult stage	parasitised	"overkilled"
Untreated	92.0	0	8.0
1 E.f:200 nymphs of B.t	28.9	28.2	42.9
1 E.f:200 nymphs of B.t + T.v	35.5	34.8	29.6
1 E.f: 50 nymphs of B.t	4.8	22.9	72.2
1 E.f: 50 nymphs of B.t + T.v	9.4	34.8	54.9
LSD (P = 0.05)	4.5	11.9	12.8

Table 2. Effect of different dosages of *Encarsia formosa* (E.f) on a pure population of *Bemisia tabaci* (B.t.) and a mixed (1:1) population of *B. tabaci* and *Trialeurodes vaporariorum* (T.v). Two releases of *E. formosa* at fortnightly intervals on poinsettia.

	Numbers of nymphs/plant		
	first release	second release	Accumulated number of adult whiteflies
	13/6	27/6	7/8
Untreated	877	312	5212
1 E.f:200 nymphs of B.t	1060	471	9
1 E.f:200 nymphs of B.t + T.v	529	591	59
1 E.f: 50 nymphs of B.t	1093	372	0
1 E.f: 50 nymphs of B.t + T.v	589	539	4

Table 3. Percent of plants of *Hypoestes phyllostachya* and poinsettia infested with whiteflies after releases of 4 *Encarsia formosa*/m² every fortnight on a mixed population of *Bemisia tabaci* and *Trialeurodes vaporariorum*. The cuttings of *H. phyllostachya* were also dipped in buprofezin before planting. Experiment 1.

	% plants infested with whiteflies	
Date	*H. phyllostachya*	Poinsettia
5/4	0	0
17/4	0	0
2/5	0	0
18/5	0	0
8/6	0	0
21/6	4	0
6/7	0	0
1/8	0	12
15/8	0	32
28/8	0	50
12/9	6	56
22/9	2	100

Table 4. Total number (accumulated) of *Bemisia tabaci* (B.t) per mother plant of poinsettia after five releases of *Encarsia formosa* (E.f) at fortnightly intervals. First release, 1 *E. formosa*/plant and later, 1 *E. formosa*/3 plants. Experiment 2.

Treatment	Accumulated number of whiteflies/plant
Untreated	27.4
E. formosa	5.1

Table 5. Number of *Bemisia tabaci* recorded on yellow sticky traps in a greenhouse with mother plants of poinsettia treated with 1.3 *Encarsia formosa* per plant every fortnight from 24 April to 14 August. Experiment 5

Date	Number of whiteflies per 10 traps
9-16 April	1
15-22 May	3
12-19 June	7
10-18 July	7
7-14 August	14

BIOLOGICAL CONTROL OF THE GREENHOUSE WHITEFLY ON THE ORNAMENTAL *GERBERA JAMESONII*: HOW DOES *ENCARSIA FORMOSA* BEHAVE IN A PATCH?

Susanne Sütterlin, Arjan van Leest & Joop van Lenteren
Department of Entomology, Wageningen Agricultural University,
P.O.Box 8031, 6700 EH Wageningen, The Netherlands.

Summary
In patch time allocation experiments with two cultivars of *Gerbera jamesonii* at two host densities the residence time, walking activity, host acceptance and giving-up time of the parasitic wasp *Encarsia formosa* were measured. If hosts were available the residence time was two and a half times longer and the overall walking activity dropped from about 60 to about 45 percent. The last fact seems to be dependent on the egg load of the wasps; the percent walking decreases when fewer mature eggs are in the ovarioles. The above mentioned parameters gave the same results for the two cultivars. Fourty percent of the first encountered hosts was accepted for egg-laying.

Introduction
Biological pest control in ornamentals is desired to reduce the abundent use and the strong dependence on pesticides in this field of horticulture. More reasons are mentioned by Van Lenteren (1990). To develop a reliable method of biological control in ornamentals, the tritrophic system *Gerbera jamesonii, Trialeurodes vaporariorum* and *Encarsia formosa* has been chosen as a model (Sütterlin et al., 1990). Among the factors that could hamper the biological control of whiteflies was the leaf structure and hairiness of the host plant (Sütterlin et al., 1992). Hair density, -shape and -length might influence the searching efficiency of *E. formosa* (van Lenteren & de Ponti, 1990). On the other hand the leafshape and -size could influence the patch time allocation of the parasitoid, in addition to the presence and the density of hosts in the patch. How long does a female search for hosts on a Gerbera leaf? How 'active' does she search? In how many host encounters does that result? How many of the encountered hosts does she accept? To answer these questions we studied the behaviour of *E. formosa* on a single Gerbera leaf in an intact plant.

Materials and methods
Host plants and whitefly hosts
The Gerbera varieties 'Fame'(low hair density, 112 trichomes per cm^2) and 'Parade'(high hair density, 338 trichomes per cm^2) were used. The plants were three to five months old. We infested half of the plants arificially by putting on leafcages with 10 whitefly females for 24h on the young leaves. In this way we achieved a 'high' infestation rate of about 20 larvae per leaf, three weeks after infestation at 21°C and 16h photophase. The whitefly larvae were now situated on the medium aged leaves of the plant.
Parasitoids
All *E. formosa* females used were not older than 24 hours and had the opportunity to feed on honey. Adults were individually kept in gelatine capsules before they were tested.
Experimental procedure
Several plants were situated in a semicircle, in the middle of which the testplant stood. A wasp was released in the center of the lower side of a medium old leaf. From that moment on the female was observed. Behavioural elements as walking, standing still, encountering a host, adopting oviposition posture and the exact location of the *E. formosa* (lower middle, lower edge, upper middle, upper edge of the leaf, or contact with host) were recorded on a microcomputer with the software programme 'The Observer' (Noldus, 1989). Half of the experiments were carried out on leaves without hosts, the other half on leaves that had a host density of approximately 20 larvae (stage three or four) and prepupae. The wasps were observed until they left the leaf or until they stood still for a period longer than 3600 s ('inactive female'). After each experiment the encountered hosts were checked for parasitoid eggs. We measured the residence time, the walking activity, the host acceptance and the giving-up-time of the females. Definitions of the mentioned expressions are as follows:
Residence time is the time a wasp stays on a patch (leaf).
Giving-up-time is the time it takes the female to leave the patch after the last host has been visited.
Host acceptance is the number of encountered hosts that resulted in egg-laying. All hosts visited, in which we did not find parasitoid eggs after checking, are considered *rejected*.
Walking activity is the percentage walking of the total time spent on the leaf (time walking plus time standing still). If hosts were offered to the parasitoid, handling time is not included.

Results

The residence time and the activity are given for individual wasps on both investigated varieties of Gerbera and on leaves without and with hosts. Wasp numbers of table 1,2 and 3 refer to the same individual.

Table 1: The residence time (seconds) of *Encarsia formosa* on Gerbera leaves with and without hosts.

Wasp number	cultivar Fame		cultivar Parade	
	without hosts	with hosts	without hosts	with hosts
1	2538.3	15228.8	3374.0	7782.8
2	3000.0	12352.0	10429.6	16499.8
3	3880.1	1513.5	994.8	5299.8
4	8248.8	9182.7	3785.5	6971.3
5	5224.0	17095.4	1810.7	8980.4
6	10222.2	9080.4	8316.3	20407.6
7	5198.7	7486.7	5414.1	12496.6
8	2356.9	10376.1	13236.1	17075.3
9	1364.8	4896.0	7108.7	16307.1
10	3102.7	5443.1	3222.9	23170.7
11	524.6	14895.3	979.2	22196.6
12	3021.2	18400.1	12726.6	13194.1
13	10644.3	5006.3	9320.4	19128.6
14	817.7	17271.9	361.2	29009.4
15	3841.9	6223.9	1642.6	5740.3
16	470.3	11593.6	4506.4	8118.3
17	6795.2	13916.3	3755.3	11521.1
18	7674.7	801.2	3622.0	16203.6
19		2864.3	5313.9	7143.9
20			11142.9	
21			5765.9	
mean	4386.8 seconds	9664.6 seconds	5563.3 seconds	14065.6 seconds
σ(n-1)	3181.1	5517.2	3931.9	6739.4
total #	18	19	21	19

The residence time was significantly different when comparing leaves with and without hosts (table 1) (Mann-Whitney-U test, $p << 0.05$). However, the residence time on the two cultivars with hosts did not differ apparently because of a very high variability. The average residence time of *E. formosa* on leaves without hosts is 4910.5 s +/- 3551.0. On leaves with hosts available the average residence time is 11865.1 s +/- 6739.4. The walking activity of the wasps was not significantly different on cultivars Fame and Parade. Data have been given as percentages for a better understanding, however when an arc sinus transformation was done the test results were the same. On leaves with and without hosts the walking activity was different ($p = 4.8 * 10\text{-}4$); it was lower on infested leaves (see table 2).

Because of 'inactivity', many wasps were removed from the leaves with hosts, and these were not used for the calculations to determine the giving-up time. Giving-up times for the two cultivars were the same (see table 3).

Table 2: The percentage activity of *Encarsia formosa* on Gerbera leaves with and without hosts.

Wasp number	cv. Fame		cv. Parade	
	without hosts	with hosts	without hosts	with hosts
1	26	55	32	45
2	91	58	40	51
3	90	67	87	49
4	26	81	73	61
5	76	41	80	81
6	43	53	88	26
7	55	32	80	24
8	85	34	49	45
9	87	97	18	17
10	94	63	88	52
11	36	29	80	20
12	42	50	25	47
13	60	15	49	60
14	74	47	26	52
15	73	6	28	79
16	78	20	66	49
17	85	82	70	27
18	79	47	90	46
19		30	41	34
20			56	
21			69	
total #	18	19	21	19
mean	66.7 %	47.7 %	58.8 %	45.5 %
$\sigma(n-1)$	23.0	23.8	24.2	17.9

Conclusions and discussion

* When hosts are available the residence time is more than twice as long as on uninfested leaves.

On infested leaves the residence time is most likely underestimated, because of 'inactivity' we had to remove several wasps. The inactivity could be due to time or egg load. On this moment a more detailed analysis of the data is carried out estimate the effects of contacts with hosts and start-time on the residence time.

* The walking activity of the wasps is only 43.5 % on leaves with hosts, compared to 62.4 % when hosts are not available.

An explanation of the decreased activity might be that due to oviposition during the foraging on infested leaves females are less motivated to search when ovarioles do contain only a few mature eggs. The egg load of the females has to be considered in further analysis.

* Residence time and activity of females was the same on the two Gerbera cultivars with the same host density.
* The acceptance was higher on the cultivar Parade (27 %) when compared to Fame (17 %).

* On Gerbera, cv. Parade, 40 percent of the first encountered hosts are accepted by *E. formosa* for egg-laying.
* It is interesting to observe that the giving-up time on leaves with hosts, is the same as the total residence time on leaves without hosts.

Although there were some, mainly non-significant differences in behaviour of *E. formosa* on the two Gerbera cultivars, we do not expect large differences in parasitization efficiency. The quantitative effects of the differences found in this research will be evaluated with the Encarsia-whitefly-host plant model of Van Roermund (in prep.).

Table 3: Giving-up times of *Encarsia formosa* on leaves with hosts of two Gerbera cultivars.

wasp number	cultivar Fame	cultivar Parade
1	2206.2	
2		4714.9
3	2916.4	3970.9
4		213.9
5	726.3	4692.1
6	116.6	2580.7
7		3931.6
8	1909.1	3571.3
9	1396.3	3129.4
10		4853.1
11		422.0
12	345.6	981.9
16	2962.6	
17	3331.1	
18 (*)	796.9	
19 (*)	2859.9	
mean	1580.3	3005.6
σn-1	1264.0	1733.4
total #	11	11

(*) These wasps have had no encounter with hosts.

References

LENTEREN, J.C. VAN, 1990. Integrated pest and disease management in protected crops: the inescapable future. SROP/WPRS Bull. XIII/5: 91-99.

LENTEREN, J.C. VAN & DE PONTI, O.M.B., 1990. Plant-leaf morphology, host-plant resistance and biological control. Symp. Biol. Hung., Budapest, 39, 365-386.

NOLDUS, L.P.J.J., 1989. Chemical Espionage by Parasitic Wasps. Chapter two: The Observer, pp. 35-60. Ponsen & Looijen B.V., Wageningen.

ROERMUND, H.J.W. (in prep.). A population dynamic model of Trialeurodes vaporariorum (Westwood) and Encarsia formosa Gahan on the host plant tomato.

SÜTTERLIN, S., RIJSOORT, J. VAN & LENTEREN, J.C. VAN, 1992. Does the leaf surface of a Gerbera plant influence the searching behaviour of the parasitic wasp Encarsia formosa? Proc.Exper. & Appl.Entomol., N.E.V. Amsterdam, 3: 19-24.

SÜTTERLIN, S., LENTEREN, J.C. VAN & FRANSEN, J.J., 1990. Dispersal of the greenhouse whitefly, Trialeurodes vaporariorum (Westwood),

Acknowledgements

We wish to acknowledge Terra Nigra Company for providing the plants, Leo Koopman for rearing the whiteflies and Koppert Company for supplying the parasitoids.

SITUATION OF IPM ON ORNAMENTALS IN FINLAND

Vänninen, Irene & Lindqvist, Isa
Agricultural Research Centre, Institute of Plant Protection
SF-31600 Jokioinen,Finland

Summary: Good results obtained from trials of controlling Sciarid flies on Poinsettias with Steinernematid nematodes have encouraged the Finnish greenhouse growers to start adopting the use of these biological control agents. Steinernematids used at the rate of 5000 - 25 000/plant reduced the number of emerging flies by 73 - 85 % as compared to chemical control (mevinphos) and untreated plants. A survey done among the growers with the help of questionnaires in 1992 revealed a great interest for biological control on ornamentals. 48 % (32 out of 67) of the growers responding to the questionnaire were in principle willing to try biological control in their greenhouses if supervised by the Agricultural Research Centre. Most growers wanted trials in controlling aphids, spider mites, greenhouse whiteflies, and thrips, which are the most important and regularly occurring pests of cut flowers and pot and group plants in Finland.

1. Introduction

Finnish growers of greenhouse vegetables have used biological control for over 20 years now. On ornamental plants, however, only Steinernematid nematodes are used so far to control Sciarid flies on Poinsettias. The attitude of growers of greenhouse ornamentals towards biological control was surveyed in 1992 with the help of questionnaires in order to find out the possible barriers for a wider introduction of biological control on ornamentals. At the same time, information was collected on occurrence of pests and their present control methods on cut flowers, pot plants and group plants. Basic results obtained from the survey and results from tests where Steinernematids were used to control Sciarid flies on Poinsettias are presented here.

2. Attitudes of growers towards biological control and the most important pests of greenhouse ornamentals in Finland

The questionnaire inquired about the frequency of occurrence of several insect and mite pests on ornamental plants, the severity of damage caused by the pests if not controlled appropriately, and their present control methods. Growers' interest towards biological control was surveyd by asking whether they would in principle be willing to try biological control in their greenhouses under the supervision of Agricultural Research Centre.

Responses to the inquiry were obtained from 67 growers of ornamental plants, the overall response percentage being 20. Three growers had tried biological control against aphids and greenhouse whiteflies, but the results were either unsatisfactory or were left unspecified. However, 32 growers (48 %) stated they were interested in trying biological control in their greenhouses if trials would

be done under the supervision of Agricultural Research Centre. The general mental climate for introducing biological control on ornamentals is very positive among the Finnish growers even if taken into consideration that it must have been mainly the most innovative and active growers that responded to the questionnaire.

Control of aphids, spider mites, and greenhouse whiteflies was considered by the growers to be the most urgent targets of research. This corresponds with the status of different insect and mite species as pests of ornamentals as revealed by the inquiry (Table 1). Aphids, spider mites and whiteflies infest greenhouse ornamentals more regularly during cultivation cycles than other pest species listed in Table 1. Thrips are a fourth important pest group that must be included as a target of research.

Table 1. Percentage of greenhouse cultivations infested regularly or occasioanlly with different insect and mite pests during the cultivation cycles of cut flowers, pot plants and group plants. Scale for severity of damage caused by the pest if not controlled appropriately: 0 - 5 (0 = no significance, 5 = severe damage). n= no. of cultivations from which information was obtained through questionnaires. The value in parentheses under the plant's name gives the total greenhouse area of the plant in Finland in m^2 x 1000 for roses, chrysanthemums and other cut flowers, or the number of plants x 1000 for Poinsettia, other pot plants, and group plants grown in Finland in 1991.

	Plant					
	Roses (425) n = 34	Chrysan-themums (177) n = 20	Other cut flowers (156) n = 13	Poinsettia (2013) n = 16	Other pot plants (9207) n = 22	Group plants (34242) n = 22
Pest	Percentage of cultivations infested with the pest (severity of damage)					
Aphids	91 (1.7)	95 (2.2)	92 (1.2)	6 (2.0)	82 (2.3)	82 (1.9)
Tetranychus urticae	88 (2.6)	65 (1.8)	77 (2.4)	-	32 (1.3)	14 (2.5)
Thrips tabaci	24 (3.7)	20 (2.8)	23 (2.7)	-	23 (2.9)	18 (3.1)
Frankliniella occidentalis	35 (3.6)	40 (1.9)	15 (0.0)	13 (3.0)	32 (2.9)	14 (3.9)
Trialeurodes vaporariorum	18 (1.4)	45 (2.1)	15 (0.1)	88 (2.5)	36 (2.0)	32 (0.6)
Bemisia tabaci	-	5 (2.0)	-	13 (1.8)	5 (1.0)	-
Sciarid flies	12 (0.0)	15 (0.0)	15 (0.0)	63 (2.9)	41 (0.8)	23 (0.5)
Caterpillars	3 (3.0)	15 (1.0)	8 (3.0)	-	-	-
Otiorhyncus spp.	27 (1.6)	15 (2.7)	8 (4.0)	-	5 (0.0)	-
Leafminers	-	10 (1.5)	15 (0.0)	-	5 (0.0)	-
Tarsonemid mites and Tyrophagus spp.	3 (2.0)	-	-	-	27 (3.0)	-

3. Control of Sciarid flies on Poinsettias with Steinernematid nematodes

The pest complex of Poinsettias is relatively simple and hence Poinsettias are a good starting point for introducing biological control for ornamentals. Tests were run in commercial greenhouses in 1989 and 1991 in order to show the growers the potential of Steinernematid nematodes for control of Sciarids on Poinsettias. In 1989, the nematodes reduced the number of emerging flies by 73 - 80 % compared to mevinphos, and by 79 - 84 % compared to untreated controls (Table 2a). In 1991, the reduction of emergence was 74 - 85 % compared to untreated controls (Table 2b).

In the near future, trials will be initiated using Encarsia formosa against the greenhouse whitefly in order to reduce the relatively heavy pesticide use against this important pest of Poinsettias in Finland. There is also a considerable interest for Verticillium lecanii among the growers. Trials using it against whiteflies and thrips on ornamentals are under way. However, at the present Finland's registration legislation treats microbial biopesticides similarly to chemical pesticides. The costly and lengthy registration procedure can threaten the chances of obtaining the fungus into the relatively small Finnish market.

Table 2a. Control of Sciarid flies on Poinsettia (Euphorbia pulcherima var. Annette Hegg Vinterstar) in a commercial greenhouse in 1989 using a Finnish isolate of Steinernema feltiae and a commercial nematode product obtained from Christian Hansen's Biosystems in Denmark. 25 000 nematodes in 25 ml of water were applied to the pots in the beginning of September. Mevinfos sprayed as 0.01 % a.i. concentration served as the chemical control. Untreated plants were treated with water only. There were four replicates of 38-40 plants in a greenhouse containing 12 500 plants altogether. The replicates harboured 9-10 plants of each treatment. Additionally, four pots/replicate were treated with each nematode in order to verify the persistence of nematodes in the soil during the test. The location of the treatments within the replicates and the location of the replicates in the greenhouse was randomized. At harvest in December the plants were cut and the pots were placed in small cages in +23°C for 3 weeks, with several pots in each cage. The emerging Sciarid flies were collected in yellow sticky traps hanging in the cages.

Treatment	No. of Poinsettias per treatment	Total no. of insects emerging from the pots (1)	No. of Sciarid flies	
			Total	Per plant
Steinernema feltiae (Finnish isolate SFS22)	39	118	118	3 (2)
Steinernema spp. (Christian Hansen's Biosystems)	38	151	148	4 (2)
Mevinphos	40	617	616	15
Untreated	40	749	744	19

(1) A few specimens of Ephydridae also emerged from the pots

(2) All four pots used for checking the persistence of nematodes in the soil contained nematodes at harvest. The soil of each pot was baited with three Tenebrio molitor larvae and the presence of nematodes in the cadavers was checked by dissecting.

Table 2b. Control of Sciarid flies on Poinsettias (var. Annette Hegg Vinterstar) in a commercial greenhouse in 1991 using a Steinernema spp. product obtained from Christian Hansen's Biosystems in Denmark. Treatment 1: 5000 jiffy pots on a table of 50 m^2 were sprayed with 25 million nematodes before sticking the cuttings into the jiffy pots. Treatment 2: 2500 of the abovementioned plants received an additional treatment with 10 000 nematodes/plant when the Poinsettias were planted into plastic pots. Controls (3) were treated with water only. At harvest 8 plants per treatment were selected at random and put individually in small cages which were kept in +22-23 °C. The emerging Sciarids were collected with yellow sticky traps during 3 weeks.

Treatment	No. of plants analyzed per treatment	No. of emerged Sciarids per plant (1)		Nol of pots with nematodes at harvest/total no. of pots checked for nematodes (2)
		Mean	Standard dev.	
1	8	5.9 B	4.2	3/6
2	8	10.3 B	9.6	2/6
3	8	38.9 A	19.2	0/2

(1) Statistical treatment was done with analysis of variance and Duncan's multiple range test. Means with a same letter are not significantly different ($p<0.05$ %).

(2) See (2) in Table 2a for the method.

INTEGRATED PEST MANAGEMENT TECHNIQUES IN PROTECTED ORNAMENTAL PLANTS

L. R. Wardlow, P. J. Davies and W. Brough,
c/o ADAS, Olantigh Road, Wye, Ashford, Kent, United Kingdom

Summary

Integrated pest management (IPM) in protected ornamentals has expanded to about 30 ha during the past few years. The technique is used on a wide range of ornamentals and has been particularly successful against western flower thrips. Monitoring the IPM is of the greatest importance and training of growers and workers to monitor properly has paid dividends. Techniques for assisting monitoring are described and include the use of sticky traps, crop inspections, plant sampling, quality control of natural enemies and methods of introducing them. Results of monitoring over a whole season on a large nursery are discussed. It was evident that a continual programme of IPM reduced the risks of pest recontamination from mature crops to new crops and allowed crops to be grown consistently with low levels of pest that did not cause damage.

Tomato spotted wilt virus (TSWV) has been almost non-existent on nurseries using IPM although many of them suffered badly from the virus before the IPM programmes were implemented. This is a surprise because IPM nurseries tend to live with the continual presence of western flower thrips.

Introduction

IPM in protected ornamental plants is now well established in Great Britain where up to 50 growers are now using the technique on about 30 ha producing a wide range of crops. Hardly any species or type of plant has not been tested for its suitability for IPM, but each requires its own programme requiring a low or high input of natural enemies depending upon its pest complex and the cultural conditions on the nursery (Wardlow et al, 1992). Of all the crops, Cinerarias are so susceptible to TSWV that few growers risk IPM on them and in hydrangeas, Phytoseiid predators do not seem to adequately control spider mites. On the other hand, IPM is surprisingly successful in ivy-leaved, geraniums, fuchsias and Impatiens, crops that gave rise to some doubt about their IPM potential originally.

Growers have realised that regular monitoring of pests and natural enemies is an essential part of ensuring successful IPM. With ADAS assistance, they have instigated routines of plant inspections, sampling of leaves, buds and flowers and sticky trap records that their staff carry out during their normal duties. ADAS has also provided special training courses for growers and staff so that they can build up the expertise needed for these monitoring routines. An important part of these courses is the identification of insects caught on sticky traps.

This paper describes various monitoring techniques that have evolved during these early years of IPM and examples of monitoring data are used to demonstrate how IPM systems work in practice.

Methods and materials

(a) Monitoring techniques

ADAS entomologists usually visit IPM nurseries on a regular (monthly) basis as a part of a plant protection service for which growers are charged a fee. Such consultancy visits are too expensive to waste on inspecting crops in great detail so the consultant is very dependent on the monitoring data obtained by the grower and his staff. Any extra monitoring by routine collection of material for analysis in ADAS laboratories is therefore a bonus. Different techniques and routines also evolved to suit the particular nursery, they not only make the job of consultancy easier but also they may act as quality controls on the components of the IPM programmes. The list of techniques described in this paper were accumulated from many nurseries over the past two or three years.

(b) IPM in practice

The nursery of H. Evans & Sons in Hadlow, Kent comprises 3 ha of glasshouses in ten greenhouses varying from 0.1 ha to 0.5 ha in size. There is year-round production of pot plants, hanging baskets and bedding plants in some house with benches and in other units with heated ebb and flow concrete floors. The cropping programme is complex and involves buying in small plants or production from seed on site. There are many plant species that are highly susceptible to western flower thrips and the cropping programme ensures that if allowed, the pest continually survives from one crop to another. The grower decided to try IPM about three years ago following a spate of intensive insecticide use that did not control the thrips and its virus and caused severe phytotoxicity to many crops. Use of insecticides is now rare and when used, usually only those that integrate well with natural enemies are used. Following an ADAS training course given on site, various staff were given specific responsibilities for the future monitoring of IPM on the nursery.

Table 1. Cropping schedule in twelve greenhouses at an ornamental nursery in Kent 1992.

House	Cropping details
A	Pot fuchsia January-mid June and pot bedding* plants early April-end of July.
B	Pack bedding early March-late June, poinsettias last week of June.

* Bedding plants include many species but thrips-prone species were plentiful, ie Ranunculus, Impatiens, Verbena, Brachychome.

C	Pack bedding plants early March-last week of June, then Poinsettias.
D	Pack bedding plants late February-late May, Poinsettias last week of June.
E	Pot Fuchsias early January-mid May, pack bedding plants early April-early July, Poinsettias from early August.
F and G	Pot Campanula early January-early April, pack Impatiens and Salvia from mid-March, pot Gerbera early May-early July, Poinsettias from early August.
H	Pot Hydrangeas early January-late February, pot Ivy-leaved Geraniums from early January-mid July, then poinsettias.
I	Pack bedding plants from early February onwards, pot Zonal Geraniums, Gerbera and Fuchsias from mid April, hanging baskets of mixed bedding plants over floor crop from early January. Poinsettias from early August.
J	Pot Hydrangeas early January-late February, pot Zonal Geraniums from early February, hanging baskets of mixed ornamentals over floor crop from January, Poinsettias from early August.
K and L	Pack bedding plants from early January, pot Cinerarias early January-late February, hanging baskets of mixed ornamentals over floor crop from early April, pot Chrysanthemums mid-May-late June, pot Cyclamen from late May through to winter.

Results and discussion

(a) Monitoring techniques

i) Sticky traps

In large mono-crops about one trapping site per 1000 m^2 usually suffices, each trapping site should consist of one yellow and one blue sticky trap which need not exceed 12 x 12 cm (larger traps take longer to examine). The most enduring trap fixing system seems to be on strong wires (60-100 cm high) inserted into a 15 cm plastic pot filled with concrete. Trap height is generally fixed at just above the crop canopy. Traps are examined weekly; on yellow traps the numbers of thrips, whiteflies, leafminers and sciarids are recorded (winged aphids are noted) and on blue traps, thrips are recorded. Thrips are divided into western flower thrips (easily recognisable females), dark thrips (outdoor species) and pale thrips (onion thrips or male WFT).

In this way, the trapping system fits well within the crop and does not hinder staff when having to handle and move plants. Counts of thrips are done more frequently (several times per week) during the height of summer in order to monitor any large immigrations from outdoors. More trapping sites are used in mixed cropping situations, especially in very pest-susceptible crops or any batches of bought-in material.

ii) Crop inspections

No grower finds sufficient time to routinely examine plants for pests but this task can be obviated in several ways. In mixed cropping, some plant species act as good indicators because they are susceptible to certain pests. Within plant species or types there are often certain cultivars that also show pest susceptibilities. Restricting intensive monitoring to areas of young crops adjacent to mature crops (especially if flowering) and to the warmer areas of the greenhouse can also save time. Various weeds are also useful indicators. Any open flowers are always worth checking for thrips by tapping into the palm of the hand. Physical signs of some pests are easy to see without handling the plants (ie leafminer tunnels) but some are less obvious, for instance, looking for a few cast skins of aphids can reveal which plants should be examined in more detail.

iii) Plant sampling

With very small pests such as thrips, low numbers may not cause damage symptoms yet it is important to know of their presence in order to assess the state of the IPM programme. Crop examination often fails to find these pests, especially if hidden in growing points or buds.

Representative samples of leaves (upper, middle and lower portions of the plant) can be better examined under a binocular microscope in the laboratory. Though laborious, this type of check is invaluable for assessing the success or otherwise of predatory mites, it is also useful for revealing signs of low levels of thrips feeding. As IPM in ornamentals develops in future, more refined sampling methods will emerge.

Sampling of buds is particularly useful for warning of any breakdown in the IPM of thrips. If the buds sampled are restricted to those first to break open (however slight) and these are put through one of the several available thrips extraction

techniques in the laboratory then this gives time for any remedial action on the rest of crop. The techniques also recover Amblyseius spp and aphids. Buds should always be cut into four, one vertical and one horizontal cut, before placing in any extraction apparatus. In ADAS, the Tulgren funnel extraction method is preferred due to its simplicity.

iv) Quality control of natural enemies

Various conditions of storage of natural enemies both at source and on the nursery will affect the performance of IPM. Regular monitoring reveals any inconsistencies but it has also proved useful in checking differences in conditions between individual greenhouses or handling by individual members of staff.

During ADAS consultancy, growers are encouraged to record when the natural enemies are received and introduced and to save such items as cards of Encarsia, mummified aphids and cocoons of Aphidoletes for a laboratory check. It is much more difficult to check the quality and numbers of predatory mites in bottles of carrier but it is hoped that a rapid technique will be developed soon; it is much simpler checking predators in a CRS packet.

In the laboratory, sub-samples of Aphidoletes cocoons and the carrier are sprinkled thinly over double-sided sticky tape strips on which emerged and non-emerged cocoons and dead adults (sexed) can be counted under a binocular microscope. The cocoon data gives highly accurate information but data on adults is subjective, nevertheless it is important to know if there has been appreciable adult mortality.

v) Introducing natural enemies

Much can be done by the grower to help the biological controls work as efficiently as possible. For instance, it is very wasteful to introduce Phytoseiulus if plants are due to be spaced within a few days or to crops where there is no contiguous foliage canopy for them to spread. Amblyseius also work better when there is a good canopy but since these are usually distributed weekly it is not quite so important.

Many growers do not like the presence of the carrier of Amblyseius on foliage, it spoils the appearance of the crop and can create foci of Botrytis. Some growers have overcome this problem by placing long strips of lightweight screening material on the

crop, applying the carrier onto it and leaving for 24 h for predators to walk off; the material is then rolled up and the carrier removed from the greenhouse. The following week, the strips are placed over areas of crop different to the previous week to ensure as wide a distribution of predators as possible.

There are many theories about where to place Encarsia for maximum effect. Advocates of placing cards amongst the crop canopy should remember that the microclimate here may be slightly cooler and probably more humid; this could be a disadvantage if growing temperatures are borderline (16-18°C). ADAS usually take the view that there should be as many release sites as possible placed in the warmest situation so that wasps emerge quickly. It is also important to have a system so that it is known where the release sites are, subsequent releases can then be made to obtain a better distribution.

When CRS packets are used in pot plants, they may often be introduced at the pot-thick stage. Since these packets have to endure for 6-8 weeks they will be transported on the pots when they are moved to one or two further spacings. It is never convenient for staff to ensure that those pots with packets are placed in the correct position (3 per m^2) in these spacings, so their distribution may become very uneven. Some broadcast treatments of Amblyseius may be necessary in these circumstances (further introductions of CRS packets being too expensive).

In some crops, ie Begonia, Aphidoletes is the major component of the IPM programme (against Aphis gossypii) being introduced weekly at 1 cocoon/2m^2/wk; because of its importance growers like to see the adults flying off into the crop. Cocoons are therefore placed in a thin layer on the base inside a polystyrene box that is covered with fine mesh material. The cocoons are dampened regularly with a fine mist of water to encourage emergence and the adult midges are released each morning. This system has the advantage that the midges can mate inside the box before release and since they are covered at night, they are less affected by nightly sulphur vaporisation that is necessary for mildew control.

(b) IPM in practice

i) Thrips control

Table 1. Number of thrips per sticky trap every two weeks in twelve greenhouses on an ornamental nursery in Kent, 1992: solid line at date indicates change of crop to Poinsettias (non host crop for thrips)

Green-house	Fortnight ending	A	B	C	D	E	F	G	H	I	J	K	L	Per cent WFT (mean of all traps)
9	Feb 29	-	-	-	-	-	-	-	-	5	2	1	0	80.0
11	Mar 14	-	-	-	-	-	-	-	-	1	1	0	0	100.0
13	" 28	14	0	0	0	0	0	0	0	1	2	0	0	83.3
15	Apr 11	4	0	0	2	0	2	1	5	2	0	0	0	77.5
17	" 25	10	12	0	5	0	5	5	6	4	0	0	0	73.1
19	May 9	22	13	5	3	10	8	4	14	3	2	1	0	81.8
21	" 23	13	30	11	2	9	4	6	21	7	2	1	1	85.2
23	Jun 6	50	25	10	18	36	39	14	35	56	27	10	7	77.8
25	" 20	51	7	21	15	34	27	25	63	54	27	16	11	68.8
27	Jul 4	31	6	19	16	14	22	31	50	27	40	53	71	64.6
29	" 18	167	18	13	6	19	7	29	63	69	29	29	64	28.9
31	Aug 1	131	52	7	3	44	9	2	36	86	65	67	111	28.0
33	" 15	220	18	20	19	107	23	29	25	200	95	448	2257	15.0
25	" 29	25	10	9	4	29	8	17	11	69	45	78	100	32.2
37	Sept 12	12	1	11	8	13	10	10	9	17	25	50	43	46.9
39	" 26	2	-	2	5	3	6	3	6	10	10	10	21	69.1

These trap counts of thrips show that there was an inherent population of western flower thrips on the nursery from early in the season, undoubtedly carried over from the previous year. Greenhouse K and L are particularly interesting in this respect since the Cyclamen crop from the previous year was a potential source of thrips.

In all houses the IPM programmes worked so well up to late July that maximum levels of up to 20 WFT/trap/week resulted in negligible crop damage by thrips. From mid-July to mid-August counts of thrips increased dramatically, mainly due to immigrations of various species from outdoors (see decline in proportion of WFT in Table 1); these posed a particular threat to Cyclamen in houses I, J, K and L but there was negligible flower damage and thrips numbers declined.

In house A, the proportion of WFT remained generally higher than in other houses due to breeding in Fuchsia flowers that were retained on site longer than desired due to some slowness in sales.

Wherever Poinsettias were grown, thrips counts declined dramatically from early September onwards.

ii) Other pests

Glasshouse whitefly counts on sticky traps were consistently below 3/trap/week in most houses throughout the season; however counts increased to up to 15/trap/week in Gerbera (house I) during late May but then declined. Chrysanthemum leafminer attacked Gerberas during May but these were successfully parasitised by Dacnusa and Diglyphus.

Aphids were generally controlled well by Aphidius and Aphidoletes but some nicotine or heptenophos sprays were occasionally needed, especially on hanging baskets.

Fungus gnats have occasionally caused serious problems on the nursery but there were no outbreaks during 1992 and trapping records confirmed this low presence.

Conclusions

(a) Monitoring and techniques

The accumulation of experience during the past few years is helping to improve and simplify the practical use of IPM. The value of training cannot be understated since many ideas can then emanate from the people who actually apply or introduce the natural enemies. This involvement

encouraged by the pleasanter working atmosphere created by IPM should ensure many further developments in future. It is important that laboratory facilities are made available to support any new ideas.

(b) IPM in practice

On such a large nursery with such diverse year-round cropping there is little opportunity to eradicate pests from the site. Although houses are emptied and sterilised, it is impossible to prevent recontamination of new crops from mature crops; western flower thrips is a particularly difficult pest in this respect. However, though some components of the IPM programme are discontinued in winter, the weekly application of Amblyseius continues on prone crops throughout the season. The benefits of this can be seen in houses I, J, K and L where cyclamen from the 1991 season did not seriously recontaminate the 1992 crops. Similarly the 1992 cyclamen crop (in spite of intensive thrips attack in late summer) showed decreasing thrips numbers eventually. Seemingly, the continual bombardment of all crops with IPM allows the grower to suppress thrips most of the time and removes worry about whether recontamination can be kept in check or not. The IPM programme in effect becomes a site control programme, each crop being an investment for its neighbours and the subsequent crops. Even the presence of weeds in greenhouses becomes less important in these circumstances, in fact they become very useful for monitoring the IPM programme.

Acknowledgements

We are grateful to the many growers and their staff in south-east England who helped us to build up our expertise in this relatively new field of IPM. We are particularly grateful to H. Evans and Sons for allowing us to monitor IPM in practice. Thanks are also due to Mrs R. Johns and Mrs S Watson who collected sticky trap records and Mrs A Hodges who gave laboratory support.

References

WARDLOW, L. R. BROUGH, W. and NEED, C. (1992). Integrated pest management in protected ornamentals in England. Bull. OEPP/EPPO, 22, 493-498.

ENTOMOPATHOGENIC NEMATODES FOR LEAFMINER CONTROL

E. C. WILLIAMS

Central Science Laboratory, MAFF, Hatching Green, Harpenden, Herts AL5 2BD, UK

Summary

Entomopathogenic nematodes have been successfully used to control a number of soil pests of ornamentals such as black vine weevils and sciarids. Although they have not proved to be of great value against foliar pests, their foliar application and survival in cryptic environments shows great promise. In Britain in 1992, there were only three species of nematode available as commercial biocontrol agents. They belong to two families the Steinernematidae and the Heterorhabditidae. Initial investigations using *Steinernema feltiae* and *Heterorhabditis megidis* against the South American leafminer, *Liriomyza huidobrensis*, have proved encouraging. The protection afforded by the mines made by the larvae appears to provide an hospitable environment for the nematodes, enabling them to locate and successfully parasitise the larvae. Conditions of high humidity, a suitable temperature and low exposure to shortwave ultraviolet radiation could possibly be important in the parasitism of insects by these organisms.

Introduction

The entomopathogenic nematode formulations being manufactured on a commercial scale belong to two families: the Steinernematidae and the Heterorhabditidae (Poinar, 1990). Their use in Britain is currently advocated against soil borne pests such as black vine weevil larvae and glasshouse sciarids in protected crops.

Steinernematids and heterorhabditids have a similar and simple life cycle consisting of eggs, four juvenile stages and an adult. If there is a paucity of food, a non feeding third stage infective juvenile, sometimes referred to as the dauerlarva, is formed which is adapted to tolerate extended periods of adverse conditions (Wouts, 1979; Kondo and Ishibashi, 1988; Poinar, 1990). Entomopathogenic nematodes have a unique symbiotic relationship with bacteria of the genus *Xenorhabdus* and can kill an insect within 48 hours (Poinar, 1983). They locate their hosts by responding to excretory products such as carbon dioxide (Gaugler et al., 1980; Gaugler et al., 1991). Entry is thought to occur mostly through the natural openings such as the mouth, spiracles and anus (Mracek et al., 1988). Once inside the host, they invade the haemocoel and release bacteria, via their anus', which then proliferate causing septacaemia. The bacteria provide favourable conditions for nematode reproduction by supplying various nutrients and inhibiting the growth of other bacteria (Poinar and Thomas, 1966). When food reserves have been depleted, the hardy infective stage of the nematode is formed (Popiel et al., 1989) which leaves the cadaver in search of a new host.

This paper examines the factors that should be condsidered when using nematodes as biocontrol agents and discusses the potential of entomopathogenic nematodes against pests of cryptic nabitats with particular reference to the leafminer, *L. huidobrensis*.

Factors affecting nematode efficacy:

(i) moisture

Entomopathogenic nematodes occur naturally in the soil in the intersitial spaces

where their survival and movement is affected by the availability of water. Although many nematodes within the Nematoda have an ability to survive severe dehydration (Womersley, 1990), infective juveniles of the Steinernematidae and Heterorhabditidae seem to have developed little resistance to evaporative water loss (Wormersley, 1990). They thus cannot tolerate the severe, rapid dehydration that can occur after foliar and soil surface applications in biocontrol situations (Kaya et al., 1981).

(ii) temperature

Temperature affects mobility, survival, development and reproduction of the nematodes (Dunphy and Webster 1986). The temperature ranges within which nematodes survive, infect and develop vary with the species and strain (Molyneux, 1985; Molyneux, 1986; Westerman and van Zeeland, 1989; Simons and Van der Schaaf, 1986). *S. feltiae* has been observed to survive and retain infectivity over fairly wide ranges, -10 to 35°C and 9 to 33°C respectively (Samiege, 1963; Molyneux, 1986). *Heterorhabditis heliothidis* has been shown to infect in a range from 11°C to 32.3°C (Blackshaw and Newall, 1987). The region from which a nematode species or strain has been originally isolated appears to be important in determining the temperature range to which it is best adapted (Molyneux, 1986). Although adapting nematodes to selected temperatures might improve effectiveness, acclimatisation by culturing at the required temperatures has proved to be transient (Burman and Pye, 1980).

(iii) shortwave ultraviolet radiation

The effects of ultraviolet (UV) radiation and sunlight on nematodes have been examined by Gaugler and Boush (1978). They found that longwave UV radiation (366 nm) did not adversley affect juveniles of *Neoaplectana carpocapsae.* Conversly shortwave UV radiation (254 nm) caused high mortality even at exposure times as short as 3.5 minutes. Nematode reproduction and development were acutely sensitive to this wavelength. This sensivity appeared to be most extreme during cell division which occured as soon as infective juveniles entered the host. Experiments observing the effects of sunlight showed that when shielded by glass, nematodes showed no loss of pathenogenicity or reproductive capacity compared to unshielded ones which lost nearly all their ability to produce lethal infections (Gaugler and Boush, 1978). As glass screens most ultraviolet and all light with a wavelength less than 375 nm (Nelson, 1991) it is probable that nematodes will be sheltered from this adverse effect under glasshouse conditions. Since, supplemental lighting such as low and high pressure sodium lamps emit no UV light and incandescent and fluorescent ones emit variable but small amounts of shortwave UV light (Nelson, 1991) it is unlikely that nematode survival will be affected by these artificial light sources.

The cryptic habitat of the leafminer

A cryptic habitat is one which is found within the host plant of an insect pest. It is often protected, sometimes hidden and provides more favourable conditions for nematode survival than the foliar environment. By reducing exposure to low levels of moisture, extremes of temperature and shortwave ultraviolet radiation the longevity and infectivity of the nematodes can be enhanced.

The dipteran leafminer *Liriomyza huidobrensis* is a serious pest which has been recently introduced into Great Britain. Difficulties in controlling the pest in this country have been compounded by the lack of effective registered pesticides. As a

consequence biological alternatives have been sought. The hymenopterous parasitoids *Dacnusa sibirica* and *Diglyphus isaea* have provided good control under certain conditions but there is still a need for more biological control agents.

L. huidobrensis is highly polyphagous, both cosmetic and physiological damage being caused by the larvae which bore voraciously through the leaf (Parella and Bethke, 1984). Feeding punctures, which are made solely by the female with the aid of her ovipositor, provide adults of both sexes with food. In severe cases, young plants can die by the reduction in photosysnthetic tissue brought about as a result of the leaf punctures alone (Parella, 1987).

Suppression of *L. trifolii* using *S. carpocapsae* has been shown to be promising (Harris et al., 1990). Nematodes are believed to enter the mines either through tiny tears in the epidermal surface or through feeding punctures made by the adult female flies. They travel down the length of the mine, probably in response to cues emitted by the host (Gaugler et al., 1991, Gaugler et al., 1980), then parasitise the larvae. Laboratory investigations using *S. feltiae* and *Heterorhabditis megidis* against *L. huidobrensis* indicate that parasitism of this pest by these agents is possible (Williams, unpublished). Further studies on the mechanism of action of the nematodes against this pest and the precise conditions required for nematode efficacy need to be undertaken, however, before these organisms can be considered as part of any integrated programme for the control of leafminers.

Compatibility with pesticides and other biocontrol agents

Entomopathogenic nematodes used in isolation against most insect pests are unlikely to bring the desired high levels of control required on ornamentals. Together with other agents, however, such levels may well be achieved. The compatibilty of entomopathogenic nematodes with other biocontrol agents and pesticides should therefore be considered.

Work on both heterorhabditids and steinernematids has indicated the feasibility of integrating nematodes with certain chemical pesticides, for example, deltamethrin and dicofol (Rovesti et al., 1988; Rovesti and Deseo, 1990). They also found that tolerance by both genera to fungicides and herbicides, such as triforine and glyphosate, was greater than to other pesticides.

Research into the compatibility of nematodes with certain parasitoids has shown that the latter can be susceptible to attack by the nematodes at some stages of their lifecycle. Ichneumonid parasites, *Hyposter exiguae*, within the larvae of the armyworm, *Pseudaletia unipuncta*, were adversley affected by *Neoaplectana carpocapsae* (Kaya and Hotchkin, 1981). The nematodes were able to parasitise larvae as they emerged or shortly after emergence from their hosts. They could also cause the death of a host before the parasite larvae had completed their development. Pupae of certain braconids and ichneumonids which formed cocoons were resisitant to nematode infection because of the physical barrier imposed by the cocoon.

Bari and Kaya (1984) showed that the combination of *Bacillus thuringiensis* var. *kurstaki* with the nematode *Neoaplectana carpocapsae* when controlling the artichoke plume moth in its vegetative growth phase did not result in significantly greater control than the nematodes alone. Babercheck and Kaya (1990), however, have described an enhanced effect between nematodes and an entomopathogenic fungus. They confirmed that when *Beauvaria bassiana* and the nematodes *Steinernema feltiae* and *Heterorhabditis heliothidis* were applied in combination against the lepidopteran *Galleria mellonella* the period of lethal infection was shorter than when the two were applied

in isolation. They also showed, however, that in dually infected hosts the nematodes and fungus were antagonistic which could have detrimental effects on pathogen recycling.

Conclusion

There is potential for commercially expanding the use of entomopathogenic nemtodes to those organisms that live for part of their lifecycle in a cryptic environment. Much more detailed research is required to examine exactly how these organisms are reaching their hosts and the precise range of conditions under which they are most effective. Until now nematodes, as well as other biological contol agents, have not been totally predictable in their outcome. More emphasis needs to be placed on the predictive approach and as Georgis and Gaugler (1991) point out, for this to be achieved, critical variables not only need to be identified but a standardisation of experimental procedure must be adopted so that results can be closely compared.

Entomopathogenic nematodes are unlikely to be the definitive biocontrol method for most pests. As part of informed integrated pest management programmes, they will no doubt become an increasingly important component in the future.

Acknowledgements

I thank Plant health Division of MAFF for funding this work and MicroBio Division of Agricultural Genetics Company Ltd for kindly supplying the nematodes. *Liriomyza huidobrensis* was held under MAFF licence No. 336A/41/32.

References

BABERCHECK, M. E. & KAYA, H. K., 1990. Interactions between *Beauvaria bassiana* and the entomogenous nematodes *Steinernema feltiae* and *Heterorhabditis heliothidis*. J. Invertebr. Pathol. **55**: 225-234.

BARI, M. A. & KAYA, H. K., 1984. Evaluation of the entomogenous nematode *Neoaplectana carpocapsae* (=*Steinernema feltiae*) Weiser (Rhabditida: Steinernematidae) and the bacterium *Bacillus thuringiensis* Berliner var. *kurstaki* for suppression of the artichoke plume moth (Lepidoptera: Pterophoridae). J. Econ. Entomol. **77**: 225-229.

BLACKSHAW, R. P. & NEWALL, C. R., 1987. Studies of the temperature limitations to *Heterorhabditis heliothidis* activity. Nematologica **33**: 180-185.

BURMAN, M. & PYE, A. E., 1980. *Neoaplectana carpocapsae*: movements of nematode populations on a thermal gradient. Exp. Parasitol. **49**: 258-265.

DUNPHY, G. B. & WEBSTER, J. M., 1986. The temperature effects in the growth and virulence of *Steinernema feltiae* strains and *Heterorhabditis heliothidis*. J. Nematol. **18**: 270-272.

GAUGLER, R. & BOUSH, G. M., 1978. Effects of ultraviolet radiation and sunlight on the entomogenous nematodes *Neoaplectana carpocapsae*. J. Invertebr. Pathol. **32**: 291-296.

GAUGLER, R., CAMPBELL, J. F. & GUPTA, P., 1991. Characterisation and basis of enhanced host-finding in a genetically selected strain of *Steinernema carpocapsae*. J. Invertebr. Pathol. **57**: 234-241.

GAUGLER, R., LEBECK, L., NAKAGAKI, B. & BOUSH, G. M., 1980. Orientation of the entomogenous nematode *Neoaplectana carpocapsae* to carbon dioxide. Environ. Entomol. **9**: 649-652.

GEORGIS, R. & GAUGLER, R., 1991. Predictability in biological control using entomopathogenic nematodes. J. Econ. Entomol. **84**: 713-720.

HARRIS, M. A., BEGLEY, J. W. & WARKENTIN, D. L., 1990. *Liriomyza trifolii* (Diptera: Agromyzidae) supression with foliar applications of *Steinernema carpocapsae* (Rhabditida: Steinernematidae) and abamectin. J. Econ. Entomol. **83**: 2380-2384.

AYA, H. K. & HOTCHKIN, P. G., 1981. The nematode *Neoaplectana carpocapsae* Weiser and its effect on selected ichneumonid and braconid parasites. Environ. Entomol. **10**: 474-478.

KAYA, H. K., HARA, A. H. &. REARDON, R. C., 1981. Laboratory and field evaluation of *Neoaplectana carpocapsae* (Rhabditida: Steinernematidae) against the elm leaf beetle (Coleoptera: Chrysomelidae)

and the western spruce budworm (Lepidoptera: Tortricidae). Can. Ent. **113**: 787-793.

KONDO, E. & ISHIBASHI, N., 1988. Histological and SEM observations on the invasion and succeeding growth of entomogenous nematodes, *Steinernema feltiae* (strDD-136), in *Spodoptera litura* (Lepidoptera: Noctuidae) larvae. App. Ent. Zoo. **23**: 88-96.

MOLYNEUX, A. S., 1985. Survival of infective juveniles of *Heterorhabditis* spp. and *Steinernema* spp. (Nematoda: Rhabditida) at various temperatures and their subsequent infectivity for insects. Rev. Nematol. 8: 165-170.

MOLYNEUX, A. S., 1986. *Heterorhabditis* spp. and *Steinernema* (=Neoaplectana) spp. temperature and aspects of behaviour and infectivity. Exp. Parisitol. **62**: 169-180.

MRACEK, Z., HANZAL, R. & KODRICK, D., 1988. Site of penetration of juvenile steinernematids and heterorhabditids (Nematoda) into the larvae of *Galleria mellonella*. J. Invertebr. Pathol. **52**: 477-478.

NELSON, P. V., 1991. Greenhouse Operation and Management. Fourth Edition. Prentice Hall. pp.361-374.

PARRELLA, M. P., 1987. Biology of *Liriomyza*. Ann. Rev. Entomol. **32**: 201-224.

PARRELLA, M. P. & BETHKE, J. A., 1984. Biological studies of *Liriomyza huidobrensis* (Diptera: Agromyzidae) on chrysanthemum, aster and pea. J. Econ. Entomol. **77**: 342-345.

POINAR, G. O., Jr., 1983. The natural history of nematodes. Prentice-Hall, Englewood Cliffs, NJ. pp.323.

POINAR, G. O., Jr., 1990. Taxonomy and Biology of Steinernematidae and Heterorhabditidae. In Entomopathogenic nematodes in biological control. R. Gaugler and H.K. Kaya (eds). CRC Press, Inc. Florida. pp.23-61.

POINAR, G. O., Jr. & THOMAS, G. M., 1966. Significance of *Achromobacter nematophilus* Poinar and Thomas, (Achromobacteriaceae: Eubacteriales) in the development of the nematode, DD136 (*Neoaplectana* sp. Steinernematidae). Parasitology **56**: 385-390.

POPIEL, P., GROVE, D. L. & FRIEDMAN, M. J. 1989. Infective juvenile formation in the insect parasitic nematode *Steinernema feltiae*. Parasitology **99**: 77-81.

ROVESTI, L., HEINZPETER, E. W., TAGIENTE, F. & DESEO, K. V., 1988. Compatibility of pesticides with the entomopathogenic nematode *Heterorhabditis bacteriophora* Poinar (Nematoda: Heterorhabditidae). Nematologica **34**: 462-476.

ROVESTI, L. & DESEO, K., 1990. Compatibility of chemical pesticides with the entomopathogenic nematodes *Steinernema carpocapsae* Weiser and *S. feltiae* Filipjev (Nematoda: steinernematidae). Nematologica **36**: 237-245.

SCHMIEGE, D. C., 1963. The feasibility of using a neoaplectanid nematode for control of some forest insect pests. J. Econ. Entomol. **56**: 427-431.

SHAPIRO, M., MCLANE, W. & BELL, R., 1985. Laboratory evaluation of selected chemicals as antidessiccants for the protection of the entomogenous nematode *Steinernema feltiae* (Rhabditidae: Steinenermatidae) against *Lymantria dispar* (Iepidoptera: Lymantriidae). J. Econ. Entomol. 78: 1437-1441.

SIMONS, W. R. & VAN DER SCHAAF, D. A., 1986. Infectivity of three *Heterorhabditis* isolates for *Otiorhynchus sulcatus* at different temperatures. In Fundamental and applied aspects of invertebrate pathology. R. A. Samson, J. M. Vlak & D. Peters. (eds) Proceedings of the Fourth International Colloquium of Invertebrate Pathology, Veldhoven, the Netherlands. Foundation of the Fourth International Colloquium of Invertebrate Pathology, Wageningen, the Netherlands: pp.285-289.

WESTERMAN, P. R. & VAN ZEELAND, M. G., 1989. Comparison of *Heterorhabditis* isolates for the control of *Otiorhynchus sulcatus* at low temperatures. Med. Fac. Landbouww, Rijksuniv. Gent. **54/3b**: 1115-1121.

WOMERSLEY, C. Z., 1990. Dehydration survival and anhydrobiotic potential. In Entomopathogenic nematodes in biological control. R. Gaugler and H. K. Kaya (eds). CRC Press, Inc. Florida. pp.117-137.

WOUTS, W. M., 1979. The biology and lifecycle of a New Zealand population of *Heterorhabditis heliothidis* (Heterorhabditidae). J. Nematol. **12**: 62-72.

SUMMARY OF THE WORKSHOP

(Edited by L.R. Wardlow and R. Jacobson)

Introduction

Chairpersons and secretaries of each session of the workshop summarised their subject areas for a final discussion to identify gaps in knowledge. Prospects for future work, especially of a collaborative nature were then discussed.

Sessions

1. Status of IPM in ornamentals (W. Ravensberg/L. Hoyle)

The use of IPM varied from nil to more than 20 ha in some countries. Extensive programmes were being used on a wide range of species in Denmark, Germany and the United Kingdom and limited programmes (mainly nematodes, *Encarsia* and *Verticillium lecanii*) in Sweden, Finland or Italy. Most countries had little commercial use but experimental programmes were in progress. Considering that the total world area constituted of IPM only about 60 ha it would seem that there would be considerable scope for expansion. The following factors would have an influence on the speed of expansion:-

(i) Possible introduction of registration of biological agents, causing difficulties for producers.
(ii) Possible changes in regulations regarding the importation of non-indigenous species.
(iii) Lack of availability of biological agents in some countries.
(iv) 'Zero-tolerance' of pests causing difficulties for exporting countries.
(v) Statutory pest control in some countries, especially of 'new' pests.
(vi) Poor attitude of growers.
(vii) Reductions in extension services.
(viii) Availability of effective pesticides (affected by EC regulations).
(ix) The range of commercialised biological agents.
(x) Control of diseases, especially those resistant to fungicides.

It was agreed that future work should entail:-
(i) Improved flow of information to growers with IOBC taking the lead role. An impending release of videos from several countries might be better centrally co-ordinated.
(ii) Expansion of research into screening greenhouse apertures.
(iii) More information on integrating pesticides.
(iv) New biological agents, including micro-organisations.

2. Biology and other topics (B. Nedstam/N. Helyer)

This session confirmed extensive gaps in biological knowledge and provided considerable discussion on future collaborative work.

(i) **Pest monitoring**
Much work was needed on threshold levels of pests, especially in relation to the 'zero-tolerance' problem. Interpretation of sticky trap counts needed urgent investigation (project to be co-ordinated by J. Frey). There was much scope for work on trap and 'banker' plants.

(ii) **New biological agents and techniques**
The session introduced new species of *Amblyseius*. In several countries *Hypoaspis* showed promise. The use of parasitic nematodes against leafminers was a new concept.

(iii) **Biology**
New data presented at the workshop was particularly welcome because there was such a shortage of information, particularly on the recently commercialised natural enemies. It was suggested that EC funding could be sought to expand work on biology, behaviour and taxonomy. It was agreed that the biological control of diseases needed higher priority and that entomologists should be better informed of progress (Simon will co-ordinate and possibly produce an update for 'Sting').

(iii) **Manipulation of environments**
Some techniques and features that enhanced the performance of natural enemies demonstrated that there was much scope for future work in this area.

(iv) **'Zero-tolerance' of pests**
Experience of IPM in Denmark, Germany and the United Kingdom showed that clean crops can be produced under the system. It was encouraging (De Goey) that the element of 'zero-tolerance' requirement for Dutch crops applied to only a small proportion of exports. This meant that a large proportion of Dutch ornamentals could be grown by IPM.

3. IPM in pot plants, bedding plants and amenity situations (M. Berlinger/ H. Brodsgaard)

Much technical information was supplied in this session. It was significant how successful IPM has been on a wide range of crops and how expertise was improving. In the United Kingdom, no virus (TSWV) problems had been experienced since IPM began about four years ago.

There was a trend towards an expanding complex of biological control agents to be used and the "overkill" principle was strongly supported.

Training of growers and their staff to monitor IPM was of paramount importance. Carefully designed monitoring programmes were required.

The importance of propagators was discussed and it was agreed that the provision of clean plant material, free from harmful pesticides was an essential component of successful IPM.

4. *Bemisia tabaci* (A. Enkegaard/J. Buxton)

This pest merited its own section due to its world-wide importance. Most countries suffered from infested imports, especially on poinsettias, but of course, the problem both indoors and outdoors in the USA dominated the scene. It was agreed that European countries should expect to see an expansion in the host range of the pest and new physiological disorders in crops (presumably due to virus?)

Delegates were dismayed to hear that resistance to buprofezin was increasing in Italy. This insecticide integrated well with *Encarsia* and was far too useful to lose.

Encarsia generally controlled the pest on poinsettias in northern Europe but failed elsewhere. The search for new natural enemies was proceeding rapidly in USA. Ultimately the pest would probably require a package of IPM incorporating every available control.

It was agreed that the *Bemisia tabaci* 'Working Group' should continue in its present form as a part of the 'IMP in ornamentals' working group of IOBC. Enkegaard agreed to co-ordinate information and to produce regular updates for 'Sting'.

5. IPM in cut flowers (R. Albert/F. Bertaux)

Work had been restricted to chrysanthemum, Gerbera and roses; results were generally disappointing, especially in roses. However, Helyer demonstrated that *Verticillium lecanii* could be the mainstay of a chrysanthemum programme if relative humidities could be raised artificially. A winter programme of *V. lecanii* and *Amblyseius* sp had worked well in chrysanthemums in the United Kingdom, but summer programmes would also depend upon *Orius* spp and *Anthocoris* spp. Much investigative effort was required in this area. Perhaps this research could be easier if *V. lecanii* was registered for use in more countries that at present.

It was encouraging that resistance of chrysanthemums to various pests had been investigated in The Netherlands, demonstrating the future importance of these features in IPM programmes.

Resistance to insecticides and reductions in availability of insecticides meant that research on IPM in cut flowers was of high priority. Although there were biological controls for most of the pests, new problems such as capsids should also be considered.

6. Footnote (editors)

There was considerable discussion during the final session of the workshop about the threat of virus developing during IPM. The impending threat of *Thrips palmi* accentuated the problem. It was agreed that the problem could be partially alleviated if better procedures were available for testing insects for virus. Insects could be routinely tested before embarking on an IPM programme and regularly tested thereafter; the presence of virus should then be related to threshold levels of the insect. It seems that little work was being done and prospects were somewhat obscure.

Pests such as *F. occidentalis* and *B. tabaci* (and *T. palmi* eventually?), because of their resistance to insecticides, have created the expansion of IPM in ornamentals. Yet these pests are amongst the most viruliferous species of the insect world and IPM could fail if the virus threat is not monitored. It is ironic that the present economic climate in the world is likely to restrict this basic research. Effort put into the ornamental scene could have far-reaching consequences for dealing with these pests on outdoor crops. The threat of virus transmitted by these pests on outdoor crops has promulgated considerable investment by the USA for *B. tabaci*, but in Europe the threat from any of these pests is dealt with on a more perfunctory basis.

IPM in ornamentals has demonstrated that the impossible is possible after all. Now is the time for European Governments to decide that a centralised decision to prevent the impending catastrophe of widespread virus problems on agricultural/horticultural crops should be made. At present, virus problems are restricted to a few crops in the Mediterranean countries, whereas northern European insects do not carry much virus. However, the longer these pests are allowed to proliferate, the greater the risk of increasing their virus-transmitting potential. Now is the time for action and IPM is the only solution.