IOBC WPRS OILB SROP

WORKING GROUP

"INTEGRATED CONTROL IN PROTECTED CROPS UNDER MEDITERRANEAN CLIMATE"

CONTRIBUTIONS TO THE MEETING AT
ALASSIO (ITALY), 29 SEPTEMBER - 2 OCTOBER 1991

GROUPE DE TRAVAIL

"LUTTE INTÉGRÉE EN CULTURES PROTÉGÉES : GROUPE CLIMAT MEDITERRANÉEN"

CONTRIBUTIONS A LA REUNION A
ALASSIO (ITALY), 29 SEPTEMBRE - 2 OCTOBRE 1991

WPRS BULLETIN
BULLETIN SROP
1991 / XIV / 5

PREFACE

La production maraîchère et ornementale protégée du Bassin Méditerranéen s'est accrue spectaculairement dans les derniers lustres. La croissance de la demande de produits maraichers hors-saison et un climat exceptionellement doux en hiver ont permis de surpasser les 60.000 ha de surface permanente tout au long du litoral méditerranéen.

L'élargissement du milieu "serre" nous a ammené de nouveaux problèmes de maladies et ravageurs tout en conservant, et souvent en augmentant, les plus traditionels. La technologie classique de protection phytosanitaire, basée en bonne mésure en l'utilisation de produits chimiques, s'avère de plus en plus inefficace et dangereuse pour les produits de consommation en frais. Des solutions dans le cadre de la lutte integrée, et spécialement de la lutte biologique, sont demandés, parfois même exigées, par les consommateurs, et aussi par les agriculteurs!

En ce qui concerne le R+D sur la lutte biologique et integrée, en voilà la réponse: le présent volume avec une trentaine de contributions qui ont été presentées et discutées à la rencontre du Groupe de Travail de l'OILB/SROP sur les Cultures Maraichères et Ornementales Protégées, Section Méditerranéenne, à lesquelles il faudrait en ajouter bien d'autres qui, malheureusement, ne pourront pas être publiées.

Au lecteur interessé à approfondir la connaissance des solutions de lutte biologique et integrée pour les problèmes de maladies et ravageurs des cultures maraichères et ornementales de la Méditerranée, je lui prie de ne pas hésiter à se mettre en contact avec les auteurs de ce volume. Aux collègues du Groupe, et spécialement au Professeur Garibaldi et au Dr. Gullino, mes plus vifs remerciements pour leur effort afin de disposer des contributions écrites avant la rencontre et pour l'organisation de la rencontre. Sans l'habituelle efficacité du Dr. Minks, responsable de la commission de publications de l'OILB/SROP, il n'aurait pas été possible non plus de publier à temps ce volume.

Ramon Albajes
Animateur du Groupe de l'OILB/SROP
"Cultures Maraichères et Ornementales, Section Méditerranéenne"

TABLE OF CONTENTS

****

FROM ROUTINE TO RATIONAL METHODS IN PHYTIATRY.

C. Van Assche and Marleen Vangheel,
University Leuven,
Belgium.

Since the origin of plant cultivation, and apart from the development of the considered identity and culture, unwanted flora and fauna identities induced lower quantitative and qualitative yields. The very first attempts to prevent pests and diseases manually, evoluated throughout the centuries towards an integration of resistance breeding and gen technology, including a justified minimal input of chemicals into a total integrated constellation.

This pest control is a rationally based integration and combination of all plant protection methods, such as the physical, chemical, biological and agricultural technical ones (Figure 2). At this moment, there is a strong evolution in the appreciation of current production methods. The more classical way of thinking as to disease and pest control is evolving towards a more integrated mastering of the plant, completely focussing on a preventative approach, framing in the overall farming hygiene.

BIOLOGICAL AND INTEGRATED PEST CONTROL IN PROTECTED CROPS OF NORTHERN ITALY'S PO VALLEY: OVERVIEW AND OUTLOOK.

G. Celli(*), M. Benuzzi(**), S. Maini(*), G.Manzaroli(**), L. Antoniacci(**), G. Nicoli(*) (1).

(*) Istituto di Entomologia "G. Grandi" - Università di Bologna - Via Filippo Re, 6 - 40126 BOLOGNA (Italy).

(**) BIOLAB - Centrale Ortofrutticola - Via Dismano, 3845 - 47023 CESENA (Italy).

- SUMMARY -

The status of Integrated Pest Management (IPM) and biocontrol of pests in protected strawberry, tomato, cucumber, sweet pepper and poinsettia is reported.
Key arthropod pests, release techniques of beneficial arthropods and integrated control with fungicides are discussed. Biocontrol applications in eggplant and lettuce are in advanced testing stages.

- INTRODUCTION -

Protected crops in the Po river valley, are generally cultivated in unheated plastic tunnels, a method that in effect divides the growing season into spring and summer cycles. They start in March and end in autumn at the first frost. Leaf crops such as lettuce, chicory and valerian are the only ones grown during the winter. Table 1 reports acreages of the main protected crops in the Po valley.

In light of the successful application of biocontrol techniques in greenhouses of northern Europe during the 1960s and 1970s, BIOLAB began in 1983 the initial testing of these strategies in northern Italy. These trials were first carried out on strawberry, an important cash crop in the area, and from 1985 on cucumber, sweet pepper, tomato and eggplant. The resulting data led to the development of a package of low-impact (soft) control techniques that integrate biological and selective fungicide treatments, together with crop management practices, designed to limit the spread of pathogens. This comprehensive approach had to overcome one major complication. For, unlike the situation in northern Europe, the greenhouses in the Po valley are usually not heated, and our tests thus had to contend with abrupt daily temperature jumps which at certain time of the year register differences of 20 to 25° C between minimum and maximum values. The use of any single beneficial arthropod had therefore to be evaluated on a crop by crop basis at different period over the year.

(1) Research funded by ENEA - Area Energia e Innovazione and Emilia Romagna Regional Government

The present survey is on the one hand a status report of the advances recorded by IPM in our area's main protected crops, and on the other it provides a short-term outlook of soft control strategies currently under development.

TAB. 1 - ACREAGES OF THE MAIN PROTECTED CROPS IN PO VALLEY

CROP	ACREAGES (HA)	% OF ITALY'S AREA
STRAWBERRRY	1.315,13	**41,36**
MELON	1.243,51	80,18
TOMATO	761,47	13,97
SWEET PEPPER	389,36	18,82
LETTUCE	205,43	22,88
EGGPLANT	77,09	6,17
CUCUMBER	65,22	15,66

- STRAWBERRY -

The initial 1983 trials (Celli et al. 1988) progressively led to an IPM strategy over an increasingly greater area and eventually to the passage from experimental to practical application. The major strawberry arthropod pests are aphids (Macrosiphum euphorbiae (Thom.), Chaetosiphon fragaefolii (Cock.)) and the two-spotted spider mite (Tetranychus urticae Koch). M. euphorbiae, a poliphagous species, also attacks potato, tomato, pepper and eggplant; C. fragaefolii is confined to strawberry. It is to be noted that aphids are more dangerous in northern than in southern Italy, and for this reason are frequently treated by insecticide sprays. The chemicals used in these sprays are usually of long persistence when applied in spring or pyrethroids when applied just before the harvest.

Chrysoperla carnea (Steph.), has proved to be effective against aphids in strawberry. In the first trials in 1983 were released 80 C. carnea eggs/m^2; the eggs were ready to hatch. Subsequent trials showed that second instar larvae were easier to use. While eggs were easier to store and handle, larvae releases were more immediately effective.

This is explained by the predatory activity of C. carnea during its three instars: 2-5% the first, 8-10% the second and the rest in the third. The problem regarding larval cannibalism and the need for quick releases were solved by a special container. Cardboard cylinders (7 cm. diameter, 16 cm. height) containing a given number of eggs of both predator and Ephestia kuehniella Zell. - as a factitious prey for C. carnea larvae up to second instar - were fitted with cardboard strips to prevent cannibalism. The containers were stored at 26°C to allow embryonic development, hatching and growth to second instar (age of release). Each container had more than 500

larvae which were released directly onto the crop. Aphids outbreaks occurred almost exclusively in spring. Sampling should be conducted by checking at least 100 leaflets per 500 m^2 tunnel for aphids. When more than 30% of the leaves are infested, C. carnea should be released at a rate of 18-20 second instar larvae/m^2. It takes about 8-10 days from release date for the predator to be fully effective. The second instar C. carnea larvae can withstand some hours of temperatures as low as -2°C. Note that the predator returns to activity at 10°C but is more effective at temperatures above 20°C (see the article of Nicoli et al., in this volume). Thus C. carnea is suitable for tunnel release in spring when temperature can vary markedly from day to night.

T. urticae can be found on the crop from transplant (late July-August) but is usually not harmful untill next spring, as harvest approaches. Unlike aphid outbreaks T. urticae infestations are less intense in Po valley than in center and southern Italy, where environmental conditions are more favourable to the mite. Phytoseiulus persimilis Athias-Henriot has shown to be satisfactory in controlling T. urticae with releases of 4-6 predatory mites/m^2. Release effectiveness was enhanced by developing a reliable system of adult female T. urticae sampling based on the percent of infested leaves (Benuzzi and Nicoli, in press).

The application of low impact pest control strategies has made it possible to detect, as in other regions of Italy, a wild P. persimilis strain around Cesena near the Adriatic coast. It is the most northerly wild population to be found so far in Italy. It may prove to be suitable for mass rearing because it is already well adapted to withstand temperatures below 0°C.

Other insect pests of strawberry include leaf-rollers (Tortricidae) and noctuid moths, which attack either at post-transplant or close to bloom. The application of Bacillus thuringiensis Berl. subs. kurstaki preparations (not yet registered for this crop) and of insect-associated nematodes has shown promising results. Nematodes can also be applied against ground larvae of Othiorrhinchus rugosostriatus Goeze.

Fungi control is usually handled by selective fungicides and/or by crop management practices designed to limit pathogens spread. For example wetting sulphur or other synthetic active ingredients are usually employed against powdery mildew (Oidium fragariae Harz.). An effective approach against grey mould (Botrytis cinerea Pers.) is ventilation in tunnel so as to eliminate any stagnant humidity that might induce infection. Also effective whether in tunnel or in open field are such fungicide as Vinclozolin, Procymidone or Iprodione which are compatible with the use of beneficial arthropods.

Table 2 summarize these control strategies.
IPM is already used on a large scale in the Emilia-Romagna protected strawberry crops. The region wide IPM program currently covers 80-100 ha of tunnel-grown strawberry, i.e. one - third of this crop's total acreage in the region.

IPM-grown strawberry has already proven to be a domestic marketing success and its prospects appear promising also for export markets.

TAB. 2 - STRAWBERRY IPM STRATEGY

MAJOR PESTS	CONTROL STRATEGIES	NOTES
APHIDS M. euphorbiae C. fragaefolii	C. carnea 18-20 2nd instar larvae/m²	Use of natural pyrethrum for very early outbreaks
TWO SPOTTED SPIDER MITE T. urticae	P. persimilis 4-6/m²	Release rate related to presence of wild P. persimilis population
Different species of Lepidopteran pests	B. thuringiensis	In progress of registration for this crop.
POWDERY MILDEW Oidium fragariae	Wetting sulphur, Penconazole	Do not use Pyrazophos
GREY MOULD Botrytis cinerea	Ventilation	Vinclozolin, Procymidone, Iprodione are harmless to beneficial arthropods.

- TOMATO -

Fresh tomato is another tunnel-grown crop that is highly compatible with IPM techniques. The key pest in the Po valley is the whitefly Trialeurodes vaporariorum (Westw.) although aphids can also be harmful. Protected tomato is usually grown in spring and summer seasons. Outbreaks of whitefly may be negligible in spring expecially in unheated tunnels, whereas its attack is always harmful in summer, from June transplant till October. Seasonal inoculative releases of Encarsia formosa Gahan can keep whitefly infestation under injury levels (Nicoli and Benuzzi, 1989). Unlike the winter and spring outbreaks of whitefly in southern Italy, the attacks in the Po valley occur in periods when temperature is not a conditioning factor of the parasitoid activity. E. formosa is usually released twice monthly in spring and weekly in summer, when higher infestations occurs, as 4-6 parasitized pupae/m². The Mirid bug predators Macrolophus caliginosus Wagner and Dicyphus errans L. provide in many cases a natural control of whitefly in the summer. This because the releases of E.

formosa instead of treatments with broad-spectrum insecticides leaves the Miridae undisturbed and active against whitefly. To control the aphids M. euphorbiae and Myzus persicae (Sulz.) active ingredients that are compatible with E. formosa, i.e. Pirimicarb or partially selective i.e. Heptenophos can be employed in spring, only when early outbreaks occur. It should be noted however that, especially in summer, despite their being found on tomato, the aphids can, in many cases, be controlled by a number of parasitoid and predator species that keep damage below the economic threshold. Such other arthropod pests as Liriomyza trifolii (Burg.) and L. bryoniae (Kalt.) or T. urticae are sporadically found as harmful. Anyway, if necessary can be effectively controlled by releases of their respective natural enemies Diglyphus isaea (Walk.) and P. persimilis. Selective fungicides should be used as indicated in table 3.

TAB. 3 - TOMATO IPM STRATEGY

MAJOR PESTS	CONTROL STRATEGIES	NOTES
WHITEFLY T. vaporariorum	E. formosa 4-6 parasitized per release	Number of releases in relation to crop cycle and previous infestations.
APHIDS (Different species)	Pirimicarb Heptenophos or natural control	Chemical sprays necessary only in early outbreak
LEAFMINERS Liriomyza spp.	D. isaea (0.1-0.2/m^2)	Only in case of attack (rare in this crop).
TWO SPOTTED SPIDER MITE T. urticae)	P. persimilis (8-10/m^2)	
LEAF MOULD Cladosporium fulvum	Chlorthalonil, Penconazole	
LATE BLIGHT Phytophtora infestans	Chlorthalonil, Copper oxichloride	
GREY MOULD Botrytis cinerea	Crop management practices or Vinclozolin, Iprodione, Procymidone	

- SWEET PEPPER -

Although IPM is not as wide in this as in the above mentioned crops, pepper potentially represent a growth area for IPM strategies. In the Po valley the key pest is the european corn borer Ostrinia nubilalis (Hb.) which even at low population level can cause severe damage as the larvae bore into many fruits bringing with them bacterial diseases as well. The other more frequent pests in this crop are the T. urticae and several species of aphids. Releasing P. persimilis and C. carnea against the respective targets entails employing a strategy that limits O. nubilalis infestations without resorting to broad-spectrum insecticides. While satisfactory results have been achieved by applying B. thuringiensis (not yet registered for pepper) and Trichogramma maidis Pint. and Voeg. alone or together (Maini and Burgio, 1990), screens covering tunnel openings can, when it is possible to use them, completely prevent crop damage by european corn borer larvae. P. persimilis is to be released once or twice - within a week - just when T. urticae is detected for a total of no more than 8-10 predatory mites/m^2. Aphids can be controlled right after transplant, i.e. before the plants are large enough to touch one another, by insecticides (Pirimicarb or Heptenophos). By contrast C. carnea should be released for aphid control only when plants touch each other (one or two releases of 10-20 2nd instar larvae/m^2). Note that if the tunnels are fitted with screens, C. carnea cannot escape and will reproduce inside the tunnel. This means that apart from its immediate impact as larvae on the aphids, C. carnea will control the insect pest throughout the pepper growing season.

The attacks of noctuid moths in northern Italy, unlike in the south are often negligible. Outbreaks can be controlled to a certain extent by B. thuringiensis. See table 4 for fungicide protocols.

- CUCUMBER -

The main pest of cucumber and such other cucurbitae as zucchini, melon and watermelon whether as protected or protected only during the first part of the growing season, is Aphis gossypii Glover. The increasing development of strains resistant to Pirimicarb is a serious drawback to the use of beneficials and acts as a check on the widespread application of IPM strategies.

The only other significant cucumber pest is T. urticae. In practice P. persimilis (8-10 predatory mites/m^2) (Nicoli and Benuzzi, 1988) can effectively control the two-spotted spider mite only if Heptenophos sprays against A. gossypii have not been employed at short intervals.

This active ingredient is still the only one that is effective against aphids, has a short waiting period and is one of the few insecticides that is partially selective to P. persimilis.

TAB. 4 - SWEET PEPPER IPM STRATEGY

MAJOR PESTS	CONTROL STRATEGIES	NOTES
EUROPEAN CORN BORER *O. nubilalis*	Screen cover	Early cover (early May)
APHIDS (Different species)	*C. carnea* 10-20 2nd instar larvae/m^2	Use of Pirimicarb for early outbreak
TWO SPOTTED SPIDER MITE *T. urticae*	*P. persimilis* 8-10/m^2	Difficult to release when plant are very small.
STEM ROT *Phytophtora capsici*	Copper oxichloride Propamocarb Metalaxyl Benalaxyl	Prevention techniques and proper management methods are important
GREY MOULD *Botrytis cinerea*	Vinclozolin Procymidone	
POWDERY MILDEW *Leivellula taurica*	Wetting sulphur Propiconazole Triadimefon	

TAB. 5 - CUCUMBER IPM STRATEGY

MAJOR PESTS	CONTROL STRATEGIES	NOTES
APHIDS *A. gossypii*	Heptenophos	Spray carefully to prevent disrupting *P. persimilis*
TWO SPOTTED SPIDERMITE *T. urticae*	*P. persimilis* 8-12/m^2	
WHITEFLY *T. vaporariorum*	*E. formosa* 4-6 parasitized pupae/m^2 per release	Outbreaks rare
POWDERY MILDEW *Erysiphe cichoracearum*	Wetting Sulphur Traidimefon Penconazole Triadimenol	
DOWNY MILDEW *Pseudoperonora cubensis*	Chlorthalonil Propamocarb	

On the other hand chemical control poses the already cited problems of resistance and of observing the legal waiting periods.

The results of A. gossypii control trials using Aphidoletes aphidimyza Rond. are still being evaluated. However it would appear that this predator is limited in scope by low overnight temperatures occuring at the onset of A. gossypii attacks and its rapid growth cycle.

Also on the study is the fungus Verticillium lecanii Viegas. It appears to be effective against aphid colonies in Po valley greenhouse conditions, although further testing is needed to confirm the preliminary results. Table 5 shows the IPM strategies for cucumber pests.

- POINSETTIA -

This is the first ornamental for which a IPM approach has been developed (Table 6) this crop has two key pest, T. vaporariorum and Bemisia tabaci (Genn.); such other pests as thrips and T. urticae may occasionally be found on poinsettia but usually cause either negligible damage or can be controlled by selective means which do not interfere with the use of beneficial arthropods.

E. formosa is released to control both species of whiteflies. Trials conducted by Boisclair et al. (1990) and by Benuzzi et al. (1990) have shown E. formosa also to be effective against B. tabaci. It is recommended that E. formosa be employed as 0.5-1.5 parasitized pupae/plant/release in one release per week for 8-12 weeks. The release rates against B. tabaci are to be increased proportionally (up to a maximum of 2 parasitized pupae/plant/release) and depending on parasitization trends. Thus E. formosa is applied on B. tabaci in poinsettia in a sort of inundative release technique rather than in seasonal inoculative releases as is the case against T. vaporariorum. In 1990 E. formosa passed from the experimental stage to practical application: it was released on over 500,000 potted plants in the Po valley and other regions of the country. The findings of such a large scale operation show that E. formosa is at least as effective, if or even more, as chemical control.

- RESEARCH IN PROGRESS -

IPM strategies are currently in various stages of development in the following target areas.

1) Eggplant
   The major pests affecting this crop, T. urticae, T. vaporariorum, aphids and Leptinotarsa decemlineata (Say),

TAB. 6 - POINSETTIA IPM STRATEGY

MAJOR PESTS	CONTROL STRATEGIES	NOTES
WHITEFLIES T. vaporariorum B. tabaci	E. formosa	0.5 - 2 parasitized pupae/plant/release 8-12 weekly releases
APHIDS THRIPS SPIDER MITES	Do not use pesticides	Generally not economically harmful
FUNGUS DISEASES	Propamocarb Furalaxyl Benomyl	

constitute a complicated situation. The biocontrol of this beetle (CPB) would open up new prospects in extending the use of beneficial arthropods to this crop given that E. formosa and P. persimilis can control the respective target pests (Benuzzi and Nicoli, 1989)
Microbial control of CPB by nematodes has been tested but they demand certain environmental conditions that are not always possible to achieve with eggplant. B. thuringiensis subs. tenebrionis has also been tested: preliminary results are very promising (Maini et al. 1991) but it will take a long time to get the B. thuringiensis subs. tenebrionis products registered in Italy. Edovum puttleri Grissell a CPB egg parasitoid, has also shown encouraging results. Field and greenhouse tests have demonstrated its host searching capability and satisfactory control effectiveness (Maini et al. 1991). Current studies are also aimed at economical mass rearing of E. puttleri.

2) Lettuce

Tests have been under way since 1990 to assess the effectiveness of C. carnea, released as second instar larvae, against aphids. These pests are particularly harmful to lettuce in spring, when chemical treatments are generally employed. The preliminary findings are encouraging: practical application involving a single inundative release of the predator (20 2nd instar larvae/m^2) is being tested.

3) Western flower thrip Frankliniella occidentalis (Pergande)

This insect of American origin was reported in Italy in 1989 (Arzone et al., 1989). In the Po valley, unlike southern Italy, it is almost exclusively harmful to flower and ornamental crops. Because of F. occidentalis (WFT)

resistance to chemical insecticides, and because growers continue to spray this thrip to no effect save that of their disruptive action on the beneficials employed in the control of other arthropod pests, it is necessary to develop a biological control strategies to limit WFT damages. The studies undertaken thus far have focused on finding the most suitable natural enemies of WFT. Furthermore several species of the genus Orius have proved promising in this respect, and further work is in progress.

Ceranisus menes (Walker) was found wild near Bologna and experimental rearing of this parasitoid on F. occidentalis is already set up.

- CONCLUSIONS -

Practical applications of biological control and IPM strategies in the Po valley have made consistent advances in recent years. Thanks to the results attained by research and the subsequent promotional marketing of crops grown under IPM. In the wake of advances in IPM and the practical results they had achieved, a feasibility study undertaken in 1987 gave rise to the establishement of the first biofactory in Italy for the mass rearing of beneficial arthropods. This project was a joint effort involving ENEA - Area Energia e Innovazione, Emilia-Romagna Regional Government, and the biological control research unit of the "G. Grandi Institute of Entomology, University of Bologna". BIOLAB is an important step forward in demonstrating that radical changes in the protection strategies of crops in Italy are possible and that these methods are indispensable in bringing together ecology and economics. It should be noted in closing that further progress on nation-wide scale in biological control and IPM would depend on efficient extension services throughout the country and a more accurate monitoring of chemical residues on horticultural crops.

References

ARZONE, A., ALMA, A. & RAPETTI S., 1989. Frankliniella occidentalis (Perg.) (Thysanoptera Thripidae) nuovo fitomizo delle serre in Italia. Inf. Fitopat. 39(10):43-48.

BENUZZI, M., PIZZIGATTI, L. & NICOLI, G., 1989. Influenza di alcuni antioidici sul ragnetto rosso (Tetranychus urticae Koch) e il suo predatore (Phytoseiulus persimilis Athias-Henriot) su fragola. Inf. Agr. Verona, 45(13):101-105.

BENUZZI, M. & NICOLI, G. 1989. Phytoseiulus persimilis Athias-Henriot release rate compared to the infestation level of Tetranychus urticae Koch on protected strawberry. Pratical Application of Integrated Control in Protected Crops, Proc. of Joint Expert's Meeting, Antibes, 1989 (in press).

BENUZZI, M. & NICOLI, G. 1989. Integrated pest control on aubergine in unheated greenhouses in northern Italy (Po valley): initial results. Proc. of the CEC/IOBC Group Meeting,

Cabrils 1987. Edited by Cavalloro R. & Pelerents C. Balkema/Rotterdam/Brookfield 1989: 323-337.
BENUZZI, M., NICOLI, G. & MANZAROLI, G. 1990. Biological control of Bemisia tabaci (Genn.) and Trialeurodes vaporariorum (Westw.) by Encarsia formosa Gahan on poinsettia. Bull. SROP/WPRS XIII/5:27-31.
BOISCLAIR, J., BRUEREN, G.J. & VAN LENTEREN J.C. 1990. Can Bemisia tabaci be controlled with Encarsia formosa? Bull. SROP/WPRS XIII/5:32-35.
CELLI, G., NICOLI, G. & BENUZZI, M. 1987. Biological control in protected crops in northern Italy's Po valley. Bull. SROP/WPRS X/2:37-40.
CELLI, G., BENUZZI, M. & NICOLI, G. 1988. Sviluppo di una strategia di lotta integrata sulla fragola in coltura protetta in Emilia-Romagna nel quinquennio 1983-1987. Atti Giorn. Fitopat. 1988, 2:213-222.
MAINI, S. & BURGIO, G. 1990. Lotta biologica contro Ostrinia nubilalis (Hb.) (Lepidoptera, Pyralidae) su peperone in coltura protetta. Boll. Ist. Ent. "G. Grandi" Univ. Bologna. 44:23-36.
MAINI, S., NICOLI, G. & MANZAROLI G. 1990. Evaluation of the egg parasitoid Edovum puttleri Grissell (Hym. Eulophidae) for biological control of Leptinotarsa decemlineata (Say) (Col. Chrysomelidae) on eggplant. Boll. Ist. Ent. "G. Grandi" Univ. Bologna, 44:161-168.
MAINI, S., NICOLI, G., BENUZZI, M. & MOSTI, M. 1991. A comparative study of Colorado potato beetle (Leptinotarsa decemlineata (Say) sensitivity to preparations of Bacillus thuringiensis Berl. spp. tenebrionis. Bull. SROP/WPRS XIV/1:69-70.
NICOLI, G. & BENUZZI, M. 1988. Prove di lotta biologica contro Tetranychus urticae Koch con Phytoseiulus persimilis Athias-Henriot su cetriolo in coltura protetta. Inf. Fitopat. 38(3):53-59.
NICOLI, G. & BENUZZI, M. 1989. Lotta biologica con Encarsia formosa Gahan (Hym. Aphelinidae) contro Trialeurodes vaporariorum (Westw.) (Rhyn. Aleyrodidae) su pomodoro in coltura protetta. Boll. Ist. Ent. "G. Grandi" Univ. Bologna, 43:139-156.

BIOLOGICAL PEST CONTROL IN GLASSHOUSE ORNAMENTAL CROPS IN TUSCANY. *

G. DEL BENE, S. LANDI
Istituto Sperimentale per la Zoologia Agraria - Firenze

Summary

This paper gives the results obtained when using natural enemies in the control of several insects which are harmful to flowering and ornamental plant cultivations. *Trialeurodes vaporariorum* and *Bemisia tabaci*, whose native entomophagous insects are indicated, may be controlled by 4 releases of *Encarsia formosa* (6 individuals/m^2) starting in February, as long as the minimum temperature in the glasshouse is 20° C. The hyperparasitic activity of the *Encarsia tricolor* males is important as it prevents the establishment of a stable *E. formosa* population.

When considering the Agromyzids *Lyriomyza trifolii* and *Chromatomyia* spp., whose entomophagous complex is indicated, *Diglyphus isaea*, which appears suitable for control on gerbera at a dosage of 3 individuals/m^2 , does not give satisfactory protection to the chrysanthemum, where the most harmful leafminer is *C. syngenesiae*. *Neoseiulus barkeri* used at the rate of 140 individuals/m^2 on gerbera, rose and chrysanthemum to control mixed populations of *Frankliniella occidentalis* (predominant), *F. intonsa* and *Thrips tabaci* has given negative results. Finally, entomoparasitic nematodes were able to control *Otiorrhynchus* spp. on ornamental plants in the nursery, both in the glasshouse and in the open air.

1. Introduction

Some of the more harmful pests to glasshouse ornamental crops in Italy include several polyphagous species such as the thrips *Frankliniella occidentalis* (Pergande), which has been introduced recently (DEL BENE, GARGANI, 1989), the Aleyrodids *Trialeurodes vaporariorum* (Westw.) and *Bemisia tabaci* (Gem.), the Agromyzids *Liriomyza trifolii* (Burgess), *Chromatomyia horticola*

* Work carried out with a grant from the Ministry of Agriculture and Forests (Project: Integrated and biological control; Subproject: Integrated control in glasshouses).

(Goureau) and *Chromatomyia syngenesiae* Hardy, as well as the Curculionids of the *Otiorrhynchus* genus.

Biological methods of control with natural enemies of these species, particularly when they attack vegetables, are becoming more and more widespread. However, little research has yet been done into their possible application with flowering and ornamental plants due to: 1) a low tolerance for damage, imposed by export regulations and by the particular aesthetic characteristics of the top quality; and 2) the high cost of the product which makes the cost of chemical treatment irrelevant. All the same in the flower-producing sector interest is growing, particularly to avoid a rise in pest resistance, and on account of 'green' policies in public life.

Our research into biological control methods has been concerned with the principle phytophagous pests of glasshouse cultivations of chrysanthemum, gerbera, rose and plants originally from the tropics, and potted ornamental plants in the nursery (glasshouse and open air). Previous to intervention, studies were made of the entomophagous complex of the key pests.

2. Whiteflies and their natural enemies.

The most common aleyrodid is *T. vaporariorum*, even if *B. tabaci* appears more and more frequently. In Tuscany the following Aphelinids have been isolated (DEL BENE, 1990a) from *T. vaporariorum*: *Encarsia formosa* Gahan, of Nearctic origin, in use in biological control methods, *Encarsia tricolor* Foerst. and *Encarsia partenopea* Masi. In Italy also *Encarsia lutea* Masi and *Encarsia pergandiella* Howard have been reported, the latter being introduced in Campania in 1979 by VIGGIANI and MAZZONE. Furthermore, in Tuscany, *E.formosa*, *E. tricolor*, *E. lutea* and *Eretmocerus mundus* Mercet were isolated from *B. tabaci* (DEL BENE, 1990a).

2.1. Releases of *E. formosa*. Materials and Methods.

Research was carried out on a) tropical plants (*Cyphomandra betacea*, *Gossipium arboreum*, *Patagonula americana*, *Psidium guajava*), and b) gerbera. The plants were cultivated in glasshouses with minimum temperatures of 20°C and 15°C respectively.

E. formosa was used in inundative releases as it is easily obtainable, being produced industrially (En-Strip, Koppert): the percentages of the Aphelinid emerging from the parasitized pupal cases always exceeded 90%.

The development of the infestation was followed by monitoring the adults with chromotropic traps, and estimating the presence of pre-imaginal stages with samplings of 100 - 200 leaves every two weeks. The percentage of active parasitization-(parasitized Aleyrodids/unparasitized + parasitized Aleyrodids) x 100 - for the different Aphelinid species was calculated by isolating the visibly parasitized pupal cases in gelatine capsules until emergence of the parasitoid.

The same sampling method was used in adjacent glasshouses, where chemical control methods had been used or no treatment at all.

In both experimental situations, the first signs of infestation were recorded in February and *Encarsia* was introduced at the end of the month at the rate of 6 individuals/m^2. Between February and May, in the glasshouses with tropical plants 4 releases of *E. formosa* were made every 25 days; on gerbera 6 releases at fortnightly intervals.

2.2. **Results**

a) In the glasshouses with tropical plants infestation reached a maximum in May when considering the presence both of adults and of preimaginal stages of *T. vaporariorum* (Table 1.). Parasitization also increased following releases of *E. formosa*, so that the level of infestation decreased rapidly from June. Up till May almost all individuals from the parasitized pupal cases isolated in the laboratory were *E. formosa* females, while from June, *E. tricolor* males, the hyperparasites, predominated.

Table 1. Tropical plants: 4 releases *E. formosa* (6/m^2). Average number, per dm^2 of leaf surface of *T. vaporariorum* larvae. The data for October refer to 1) *T. vaporariorum*, 2)*Bemisia tabaci*, in untreaded adjacent glasshouses.

Date	Unparasitized larvae	Larvae parasitized by *E. formosa* F	*E. formosa* M	*E. tricolor* F	*E. tricolor* M	% active parasitization
Feb.	10					
Mar.	504.5	85.5				14.5
Apr.	641.2	72.8				10.2
May	765.7	181.4	2,9			19.4
Jun.	483.1	205.3	3.9		245.7	48.5
Jul.	107.6	3.8			126.6	54.8
Aug.	0				1.2	100.0
Oct.1	2158.3	2295.9	39		1021.2	60.8
Oct.2	46.5	14.5			17.7	40.3

It should be noted that *E. formosa* also spread to nearby glasshouses where releases had not been made.

By October *T. vaporariorum* and *B. tabaci* had been attacked 60.8% and 40.3% respectively. When comparing the two white flies, on *T. vaporariorum*,*E.formosa* predominated over *tricolor*, but on *B. tabaci* the data was almost identical for both Aphelinids.

b) on gerbera (Table 2) the first pupal case parasitized by *E.formosa* was recorded in March. In June, after 6 releases of the Aphelinid, the highest figure was recorded for both parasitized forms (2.73/leaf) and unparasitized forms (366/leaf), so that the parasitization percentage was only 0.8%. Consequently chemical treatments were necessary: an insect growth regulator (flufenoxuron) was used and reduced the *T. vaporariorum* population to levels which would not be harmful. As

a result in July the highest percentage for parasitization was recorded, 20%, due for almost half to *E. tricolor* (female:male = 1:3).

Table 2. Gerbera: 6 releases *E. formosa* (6/m^2). Number of *T. vaporariorum* larvae on 100 leaves.

Date	Unparasitized larvae	Larvae parasitized by *E. formosa* F	*E. formosa* M	*E. tricolor* F	*E. tricolor* M	% active parasitization
Mar.	941	1				0.10
Apr.	1570	92	11			6.15
May	16150	6				0.03
Jun.	33660	205		18	50	0.80
Jul.	220	27		7	22	20.28
Aug.	2					

It should be noted that in adjacent glasshouses treated with insecticide there was no onset of infestation on the part of *T. vaporariorum*.

2.3. Discussion

By introducing *E. formosa* at the first signs of *T. vaporariorum* infestation through 4 releases of 6 individuals/m^2 from February, satisfactory results were obtained only when the minimum temperature in the glasshouse did not go below 20° C. The Aphelinid was also able to contain *B. tabaci*.

Where *E. formosa* is successful, the action of *E. tricolor* males must not be underestimated, as their preimaginal development is as hyperparasites and they represent a limiting factor of the primary parasite. Consequently the effectiveness of *E. formosa* may be short-lived on account of the difficulty in establishing a stable population. This is due to the limiting action of the males of the native species.

Many researchers, following releases of *E. formosa*, evaluate parasitization of this species by counting the black pupal cases, while omitting to isolate them and to determine which Aphelinids emerge. In this way the action of *E. tricolor* goes unnoticed.

3. Leaf-miners and their native parasitoids.

The most harmful Agromyzid species for glasshouse cultivations in Tuscany is *Liriomyza trifolii*, reported for the first time in Italy about 10 years ago (ARZONE, 1979). *Chromatomyia horticola* and *C. syngenesiae* can also cause noticeable damage, this latter species particularly on the chrysanthemum.

Numerous entomophagous insects attack the three species (DEL BENE, 1984 and 1989). In Tuscany the Eulophids *Chrysonotomyia formosa* (Westwood), *Cirrospilus vittatus* Wlk., *Diglyphus isaea* (Wlk.), *Hemiptarsenus dropion* (Wlk.) and *Pnigalio sp.* have been

obtained from *Liriomyza trifolii*; the Braconids, *Dacnusa aerolaris* (Nees), *Dacnusa veronicae* Griffiths, and the Eulophids, *Chrysocharis* spp., *Chrysonotomyia formosa* (Westwood), *Cirrospilus vittatus* Wlk., *Diglyphus isaea* (Wlk.), *Hemiptarsenus dropion* (Wlk.) and *Pediobius acantha* (Wlk.) from *Chromatomyia* spp..

The most widespread, in decreasing order, were *D. isaea*, ectoparasite, *C. formosa*, endoparasite, and *H. dropion*, ectoparasite.

3.1. **Releases of *D.isaea*. Materials and Methods.**

In Tuscany *D. isaea* is the most naturally found parasitoid; it develops on *Liriomyza* and *Chromatomyia* spp., and is reared on an industrial scale. Consequently it is easily obtainable in large quantities. On flower cultivations, it has been used (DEL BENE, 1990b) in releases of 0.2 - 3 adults/m^2 to increase its action of control of the Agromyzids. Satisfactory results have been obtained on gerbera, as long as intervention was on recently established plantations.

More recent experiments have concerned a glasshouse of chrysanthemums of 400 m^2, planted in February, where a release of 3 adults/m^2 was made at the beginning of March. The insects used had been reared by Biolab of Cesena.

At two-weekly intervals, samplings were made of 100 leaves, where the number of mines by parasitized and unparasitized Agromyzid larvae was recorded. To determine the different entomophagous species, their larvae and pupae, and parasitized Agromyzid larvae taken from the mines were reared in gelatine capsules.

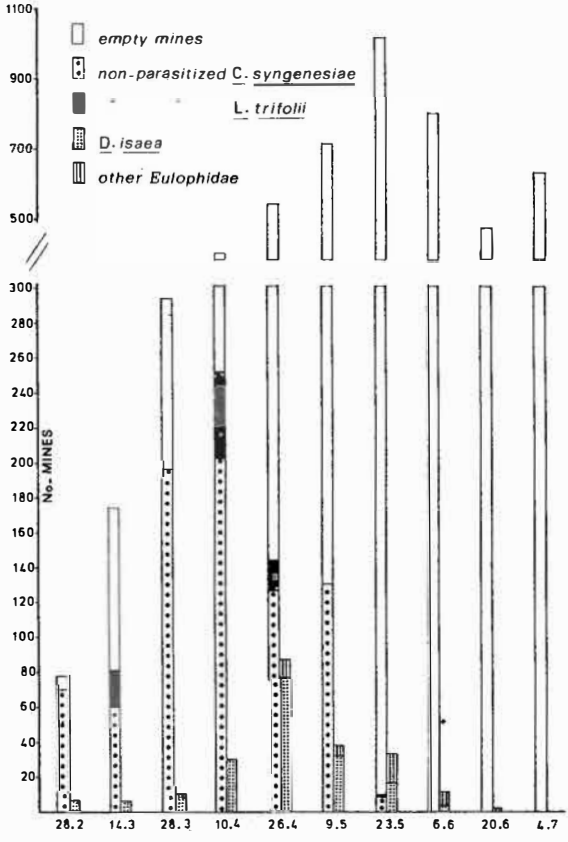
3.2. **Results**

At the end of February the plants (Figure 1) had been attacked by *C. syngenesiae* larvae (0.7/leaf), a small percentage of which were parasitized by *D. isaea*. Following the release of the Eulophid at the beginning of March, the number of mining larvae attacked by *D. isaea* was constant for the whole month and increased noticeably in April, without, however, the parasitization percentage exceeding 37.7%. In April, in fact, also the Agromyzid infestation (*C. syngenesiae* predominant) reached its maximum level. Moreover the aesthetic damage caused by the mines, even if they were empty, increased constantly so that at the moment of harvesting, in May, there were nearly 7 mines/ leaf.

The plants were left after flowering to verify the dynamics of the phytophagous insect populations. The leafminers were controlled only 2.5 months after the release of *D. isaea*: in fact by the end of May 76.8% of parasitization has been reached, a satisfactory result even if it is not the value (90%) that WARDLOW (1985) considered necessary. Furthermore, the upper foliage of the plants sustained leafminer damage of many more than 1 mine, which DE LARA (1981) considers a good result on the chrysanthemum, and HEINZ and PARRELLA (1990) on marigolds.

As well as *D. isaea*, *C.vittatus*, an ectoparasite found between May and June, *Chrysocharis* sp. and *C. formosa* also exerted a certain role in control.

Figure 1. Number of mines with parasitized and unparasitized Agromyzids on 100 chrysanthemum leaves.



3.3. **Discussion**

In the past satisfactory results have been obtained on gerbera, whose flowers do not suffer direct damage, using *D. isaea* to control *L. trifolii* (DEL BENE, 1990b). However, the chrysanthemum, whose flowers are marketed with the leaves and has only a three-month cycle, does not appear to be a suitable cultivation to protect with *D. isaea*, that takes more than two months to demonstrate its efficiency. It would be possible to let the parasitoid act only in the first vegetative phase, as the possible presence of mines on the lower part of the plant, that is below the point where the stem is cut, would not affect the value of the flower. Following this, chemical treatment is the only way of keeping within the accepted low tolerance levels, and the use of *D. isaea* does not appear economically worthwhile as the cost is 400 Italian lire/individual, and this only for partial control.

4. Thrips

F. occidentalis, which was first reported in 1987 in glasshouses in the Pescia area (DEL BENE, GARGANI, 1989), has rapidly become the most harmful pest to protected cultivations and is the most widespread when compared with the native *Thrips tabaci* Lind. and *Frankliniella intonsa* (Trybom), this latter being frequently found on the rose. As well as causing direct damage due to feeding habits and ovideposition, it is the principle carrier of the TSW Virus, which has recently been isolated in Italy (LISA et al., 1990).

4.1. Control using predatory mites.

As many researchers (RAMAKERS, 1978, 1980; HANSEN, 1989; LINDQUIST, TIITTANEN, 1989) have successfully used *Amblyseius cucumeris* (Oud.) and *Neoseiulus barkeri* (Hughes) with *T. tabaci*, we examined the possibility of controlling *F. occidentalis* with these predators.

In our laboratory trials, *A. cucumeris* has shown that it is able to reproduce for successive generations by preying on larvae of both *T. tabaci* and *F. occidentalis* (CASTAGNOLI et al., 1990). In the glasshouse where other AA. have obtained positive results exclusively on horticultural plants, we have carried out experiments on flowering cultivations (chrysanthemum, gerbera and rose) which had been attacked by mixed populations of different thrips species, but prevalently *F. occidentalis*. *N. barkeri*, supplied by Siapa, was used and was distributed in June at the onset of infestation at the rate of 140 individuals/m^2 and then again 15 days later.

No results were obtained: in fact, in the successive samplings no differences were observed either in the number of *F. occidentalis*, *F. intonsa* and *T. tabaci*, or in the damage found in differently treated plots.

5. Weevils

The Curculionids of the *Otiorrhynchus* genus represent the greatest problem for many ornamental plants grown in the nursery, either in the glasshouse or in the open air. Damage from *O. sulcatus* F., *O. armadillo* Rossi, *O. salicicola* Heyd., *O. rugosostriatus* Goeze and *O. aurifer* Boh. on more than 100 botanical species has been reported (DEL BENE, PARRINI, 1986).

Damage caused by adults attacking the leaves of the plant is essentially aesthetic. On the other hand damage caused by larvae on the roots and on the hypogean part of the trunk may have fatal results.

5.1. Microbial Control.

Research was carried out with Nematodes Rhabditida, the bacterium *Bacillus thuringiensis* var. *tenebrionis* (SAN4181WG) and the fungus *Verticillium lecanii* (Vertalec). By using doses of 250 mg/l and 2.5 g/l of the commercial product respectively for the latter two agents, the larval mortality obtained was totally insufficient to consider practical applications.

However, positive results were obtained with *Heterorhabditis* spp. (Terbiot, Scam) and *Steinernema* spp. (Pianbot, Scam) not

only at ideal temperatures of the soil in the glasshouse, but also at a daily average of 10.7°C (1 - 11°C min.; 10 - 20°C max) in the open air in November.

Potted yew plants with the soil infested with a fixed number of *O. sulcatus* and *O. salcicola* larvae were treated with applications of about 30,000 nematodes/dm^3 of soil. In the glasshouse mortality always exceeded 90%, but it was also 69.5% and 90% respectively for *Heterorhabditis* and *Steinernema* spp. in the open air. Consequently the low temperature of the soil in the open air, which is lower than the 12°C threshold established by KLINGLER (1989), is not a factor that limits nematode activity when daytime temperature is sufficiently high, as usually occurs in Tuscany, even in winter.

The research, as well as confirming the effectiveness of the insect-parasite nematodes in the glasshouse, suggests good prospects for control even in the open air, which is a very important practical consideration as a large part of nursery cultivations in Tuscany are in the open air.

6. Conclusions

The result of the experiments reported in this paper are satisfactory only in part. They show that there is still a lot of work to be done on the protection of flowering plants, particularly if the plant has a short vegetative cycle as is the case of the chrysanthemum.

Other problems arise due to the high cost of *D. isaea*, and to the low tolerance level of leafminer damage to the upper leaves on the chrysanthemum; and to the thermal requirements of *E. formosa* and the interference of this species with native parasitoids.

7. References

ARZONE A., 1979 - L'Agromizide neartico *Liriomyza trifolii* (Burgess) nuovo nemico di gerbera in Italia. - Inf. Fitopatol. 3: 3-6.

CASTAGNOLI M., DEL BENE G., GARGANI E., SIMONI S., 1990 - Possibilita' di controllo biologico di *Thrips tabaci* Lind. e *Frankliniella occidentalis* (Pergande)(Thys. Thripidae) con *Amblyseius cucumeris* (Oud.)(Acarina Phytoseiidae) - Redia, 73:53-61.

DE LARA M., 1981 - Development of biological methods of pest control in the United Kingdom glasshouse industry. - Proc. Br. Crop Prot. Conf., Pest Diseases: 599-607.

DEL BENE G., 1984 - Osservazioni sul ciclo biologico di *Liriomyza trifolii* (Burgess) (Diptera Agromyzidae) su gerbera e sui suoi nemici naturali in Toscana. - Redia, 67: 435-448.

DEL BENE G., 1989 - Nemici naturali di *Liriomyza trifolii* (Burgess), *Chromatomyia horticola* (Goureau) e *Chromatomyia syngenesiae* Hardy (Dipt. Agromyzidae) in serre di crisantemo e gerbera. - Redia 72 (2): 529-544.

DEL BENE G., 1990a - Controllo biologico di *Trialeurodes vaporariorum* e *Bemisia tabaci* con *Encarsia formosa* e parassitoidi indigeni. - Riv. Agric. Subtropic. e Tropic. 84 (2): 237-248.

DEL BENE G., 1990b - Impiego di *Diglyphus isaea* (Wlk.) (Hym. Eulophidaea) per il controllo di *Liriomyza trifolii* (Burgess), *Chromatomyia horticola* (Goureau) e *Chromatomyia syngenesiae* Hardy (Dipt. Agromyzidae) in serre di crisantemo e gerbera. - Redia 73 (1): 63-78.

DEL BENE G., GARGANI E., 1989 - Contributo alla conoscenza di *Frankliniella occidentalis* (Pergande) (Thysanoptera Thripidae). - Redia 72 (2): 403-420.

DEL BENE G., PARRINI C., 1986 - Note sulla biologia di specie di *Otiorrhynchus* (Coleoptera Curculionidae) dannose a piante ornamentali in vivai della Toscana. - Redia 69: 341-359.

HANSEN L.S., 1988 - Control of *Thrips tabaci* (Thys. Thripidae) on glasshouse cucumber using large introduction of predatory mites *Amblyseius barkeri* (Acarina Phytoseiidae. - Entomophaga 33, 1: 33-42.

HEINZ K.M., PARRELLA M.P., 1990 - Biological control of insect pests on greenhouse marigolds. - Envirom. Entomol. 19 (4): 825-835.

KLINGLER J., 1989 - Use of *Heterorhabditis* sp. against *Otiorrhynchus sulcatus* in Switzerland. - IOBC-WPRS Bull. XII/4: 7-8.

LINDQUIST I., TIITTANEN R., 1989 - Biological control of *Thrips tabaci* (Thys. Thripidae) on greenhouse cucumber. - Acta Entomol. Fennica, 53: 37-42.

LISA V., VAIRA A.M., MILNE R.G., LUISONI E., RAPETTI S., 1990 - Tomato spotted wilt virus in cinque specie coltivate in Liguria. - Inform. Fitopat. 12: 34-91.

RAMAKERS P.M.J., 1978 - Possibilities for biological control of *Thrips tabaci* Lind. (Thys. Thripidae) in glasshouses. - Med. fac. Landbouww. Rijksuniv. Gent 43, 2: 463-469.

RAMAKERS P.M.J., 1980 - Biological control of *Thrips tabaci* (Thys. Thripidae) with *Amblyseius* spp. (Acari Phytoseiidae). - IOBC-WPRS Bull., III/3: 203-208.

VIGGIANI G., MAZZONE P., 1980 - Sull'introduzione in Italia di *Encarsia pergandiella* Howard (Hym. Aphelinidae), parassita di *Trialeurodes vaporariorum* (Westw.) (Hom. Aleyrodidae). - Boll. Lab. ent. Agr. Portici 37: 39-43.

PROGRESS IN IPM IN GLASSHOUSE VEGETABLES IN BELGIUM.

M. VAN DE VEIRE.

Laboratory of Agrozoology
Faculty of Agricultural Sciences
State University of Ghent
Coupure 653, 9000, Ghent, Belgium

Summary

In Belgium, in glasshouse vegetables, IPM is being increasingly used, due to the commercial availability of correcting chemicals (buprofezin, cyromazine) for biological whitefly and leafminer control, and the widespread use of bumble bees and honey bees, resp. in tomatoes and sweet peppers.

Nowadays it is possible to control the glasshouse whitefly, the leafminers **Liriomyza bryoniae**, **L. trifolii** and **L. huidobrensis** efficiently. The twospotted spider mite, **Tetranychus urticae**, aphids spp. and some caterpillar spp. can be controlled with either biocontrol agents, selective chemicals or **Bacillus thuringiensis**.

Western flower thrips, **Frankliniella occidentalis**, and some resistant aphids (**Aphis gossypii**) are more difficult to control, as biological control has only recently been introduced and still needs to be improved. Resistant caterpillars, and some bug species in sweet peppers, cannot be controlled with chitin inhibitors and oxamyl as the use of these products is illegal in Belgium.

In lettuce, the most widely cultivated glasshouse vegetable, aphids and leafminers can be controlled with selective chemicals (pirimicarb, cyromazine), but true IPM, including biological control, is not applied.

1. Introduction.

Pest control in glasshouse vegetables has been done for many years since World War II with broadspectrum pesticides. They have been very efficient and provided cheap and reliable control. Probably they prevented the outbreak of some noxious organisms to become pests, but at the same time they probably eliminated numerous beneficial organisms as well.

However, due to the development of resistance, mainly as a consequence of the wrong, useless or frequent application at high doses of the pesticides, insect species like whiteflies, leafminers, western flower thrips, noctuid moths became real problems for glasshouse growers.

In the early seventies, biological control methods became popular in The Netherlands, as they appeared to be very efficient for whitefly control, and had great advantages (van Lenteren, 1989). Furthermore, the methods fitted quite well in the general public's concept of improving the environmental quality. Soon these methods were also widely applied by tomato growers in Belgium.

However, it became evident that pure biological control could not always be used to solve the problems. In The Netherlands corrections of poor biological control were done (cyanide gas to improve biological control of whiteflies; local dichlorvos treatments to guarantee a clean start of the culture; oxamyl treatments, either sprays or drenches, to correct poor biocontrol of whiteflies and leafminers). In Belgium, cyanide gas treatments and oxamyl sprays and drenches after transplant are not legally allowed, which seriously hampered the use of biological control methods. Belgian growers have been reticent to use biological control in the seventies because of the poor reliability of the method. The latter was very often caused by insufficient guidance and advice to the growers, and the poor quality of the natural enemies, due to greater distances between producer and user.

During the development and improvement of biological control methods in the seventies, agrochemical industries developed some very efficient broadspectrum insecticides like pirimiphos-methyl and the synthetic pyrethroids, which initially could compete succesfully with biological control. However, after some years, resistance against these new chemicals was established, so that pure chemical control could not be considered as to offer the solution.

The long term solution is given by the use of different methods and techniques (chemical, biological, physical, mechanical), which is called integrated pest management (IPM). (Fougeroux, 1986).

We believe that the use of selective pesticides is a powerful means for the improvement of biological control and the further use of the method, as growers want in the first place reliable control. The recent introduction of bumble bees for

pollinating purposes has stimulated the use of IPM greatly, as most growers, cultivating heated tomatoes, consider the bumble bee as a highly reliable and cheap cultural technique.

2. IPM in glasshouse vegetables.

Through paying more attention to cultural practices and hygiene, biological control can be made much more efficient, so as to be easier accepted by the growers.

The development of detection and monitoring methods for pest organisms and the determination of economic threshold levels considerably help towards a more rational pest control. Colour attraction based on yellow and blue sticky traps is being used by many growers in Belgium and The Netherlands for detection of whiteflies, leafminer flies and thrips.

As IPM is a strategy of pest management using all ecological acceptable methods, chemical insecticides can be used, either as selective compounds, or as selectively used broadspectrum compounds (organochlorines, organophosphates, carbamates, pyrethroids). The latter may be useful at the start or the end of the crop growing, to eradicate the pest organisms. Some conventional broadspectrum pesticides can be used in IPM through application in the drip irrigation (oxamyl) system without serious interference with the natural enemies **E. formosa, D. sibirica, P. persimilis.** The best known example of a chemical compatible with biocontrol systems is pirimicarb, a selective carbamate aphicide, although most beneficials exposed to spray deposits of pirimicarb will die soon after exposure.

Many years ago, the possibilities of selective chemicals in pest control were stated by some researchers but agrochemical industries were not very interested so that only a few products (insect growth regulators) were developed (Metcalf, 1980), amongst which diflubenzuron, methoprene and phenoxycarb, interfering with the growth and moult of insect larvae.

3. Significance of selective chemicals in IPM in glasshouses.

Fortunately, the industries attitude has changed a lot, and a number of selective chemical insecticides, based on specific action sites, are being developed. Some of them are already registered in Belgian glasshouse vegetables to control whiteflies and leafminers (buprofezin, cyromazine).

Some products are close to or have in the mean time been registered in many countries: the chitin inhibitors flucycloxuron, diafenthiuron, flufenoxuron (insecticide/acaricide) (Anderson et al. 1986; Streibert et al. 1988); pyridaben (insecticide/acaricide) (Hirata et al. 1988); the JH analog pyriproxifen (insecticide)(Yamomoto,

et al. 1990).

Teflubenzuron is not yet legally allowed in Belgium, although it is an interesting compound to control several Noctuids and exerts some side-effects on the greenhouse whitefly. Chlorfluazuron and triflumuron also are highly toxic to caterpillars; they are not registered in Belgium.

Finally, a few preparations which might be classified either as biocontrol agents or as pesticides are already on the market or in the experimental stage. A first group of products are the BT preparations (Bacillus thuringiensis). These are stomach poisons in worldwide use (Burges et al. 1976) on more than 4,000 ha of greenhouses in 1985 (van Lenteren, 1989). They fit in IPM schemes quite well. However, the susceptibility of caterpillar species differs, so that dose rates have to be adapted to the pest insect.

Another group are the baculoviruses. These substances are only found in invertebrates and are very specific, as one virus is only active on one or on a very few species. Viruses for control of **Mamestra brassicae, Spodoptera exigua, S. littoralis, Heliothis armigera** (Lepidoptera, Noctuidae) have been found (Mamestrin, Spodopterin). Today, these substances are not yet registered in Belgium, in contrast with the U.S. and Germany, but whenever they become available commercially, they will be of great value in IPM programs (Smits, 1987; Biache, 1987).

4. Current situation of IPM in protected crops in Belgium.

The glasshouse vegetable area (lettuce, tomatoes, cucumbers, sweet peppers, in order of importance) in Belgium is almost completely situated in Flanders, spread over the provinces Antwerp, East-Flanders, West-Flanders, and to a lesser extent Brabant and Limburg. Biological pest control is being carried out on large scale in Antwerp, as in this province, most vegetable growing is monoculture, done on rockwool, in heated houses by growers who have had a professional education and have a horticultural background; the same can be said more or less for the East-Flanders growers. However, in West-Flanders, less specialized growers produce vegetables in unheated houses, with crop rotations, so that fewer pest problems occur; as many of these growers have no horticultural background, and are now confronted with specific glasshouse pest problems, they prefer broadspectrum pesticides over biocontrol agents. Efforts have been made to promote biological control, however, with poor results.

Biological control of the greenhouse whitefly is done by 80% of the Antwerp and East-Flanders growers, while only 50% of the West-Flanders growers use the parasitic wasp. However, the registration of buprofezin (in 1988), used as correction agent for poor biological control of the greenhouse whitefly, or as control agent, has provoked almost a general use of this product for IPM of whiteflies. The

treatment dose is 75 g active ingredient per ha, with a treatment frequency of 2, or maximum 3. Buprofezin does not negatively affect natural enemies used in biological control (**E. formosa, D. sibirica, D. isaea, P. persimilis**), neither does it affect the bumble bee **B. terrestris**. (Van de Veire et al.,1989).

Cyromazine was registered recently (February 1991) for leafminer control in tomatoes, lettuce and ornamentals in Belgium. (Van de Veire, 1989; Van de Veire & Bleyaert, 1990). The 2 species of leafminers (Liriomyza bryoniae, L. trifolii, **L. huidobrensis**) may severely damage the aforementioned crops, particularly **L. huidobrensis** in lettuce, a powerful chemical control or correction agent is now available for the growers. Cyromazine can be used to correct poor biological control (by **Dacnusa sibirica**) of leafminers , f.i. in spring tomatoes.

Buprofezin and cyromazine are IGRs, interfering with chitin synthesis. Although their chemical structure and spectrum of activity is different, they exert some similar properties: both products are highly efficient to control whitefly and leafminer larvae, resp. at low dosages and they have a couple of weeks residual activity. Buprofezin can control the whiteflies with 150 g AI/ha in 2 treatments with an interval of 14 days. Cyromazine can even control leafminer larvae with one single treatment, early in the season, a rato of 100 g AI/ha. However, normally, 2 treatments are required if no **D. sibirica** wasps spontaneously occur in the greenhouse.

Both products are harmless to the bumble bee, **Bombus terrestris**, which is now generally employed in heated tomatoes, for pollinating of the flowers. This is of utmost importance as the bumble bee has replaced almost completely mechanical pollination, due to its efficiency and lower cost (Dewael & Van de Veire, not published). Moreover, they are compatible with **D. sibirica, E. formosa, Diglyphus isaea**, and aphid parasites.

Buprofezin and cyromazine have a low toxicity to mammals (LD_{50}, oral rat > 2200, resp 3800) and the safety period is short (3 days for buprofezin; 14 days for cyromazine). Finally, the products are cheap, taking into consideration their compatibility with beneficial organisms.

In recent years, we have established a number of beneficial organisms that spontaneously occured during the summer months in commercial glasshouse vegetables in which IPM was being carried out. These organisms are summarized in table 1.

Table 1.

Beneficial organisms, spontaneously occuring in commercial greenhouse vegetable crops, applying IPM.

Organism	Crop	Predator Parasite	Prey/Host
Orius spp.	Sweet pepper	Predator	Aphids/Thrips Spider mites
Anthocoris spp.	Sweet pepper	Predator	Idem
Eulophidae spp.	Sweet pepper	Parasitic wasp	Caterpillars
Chrysopa spp.	Sweet pepper	Predator	Numerous preys (aphid; whitefly)
Aphidius spp.	Sweet pepper	Parasitic wasp	Aphids
Aphidoletes aphidimyza	Sweet pepper Cucumber	Predator	Aphids
Spider spp.	Tomato	Predator	Numerous preys
Diglyphus isaea	Tomato	Parasitic wasp	Leafminer larvae
Praon volucre	Tomato Sweet pepper	Parasitic wasp	Aphids
Therodiplosis persicae	Cucumber	Predator	Spider mite (nymph/adult)

It is clear that the aforementioned organisms alone, with some exeptions (**D. isaea, Aphidius, Praon**), cannot fully control the pest insects or mites, but they may be of great help to decrease pest population levels.

5. Practical IPM schedules in glasshouse vegetables in Belgium.

A. TOMATOES.

Pest		Control method
Greenhouse whitefly (T. vaporariorum)	*	Parasite (E. formosa)
	*	Buprofezin
Leafminers (L. bryoniae) (L. trifolii) (L. huidobrensis)	*	Parasites (D. sibirica; D. isaea)
	*	Cyromazine
Post-harvest	*	Removal of leafminer pupae from the foil the foil
Aphids (M. persicae)	*	Pirimicarb
	*	Parasitic wasps (A. matricariae)
	*	Gall midges (A. aphidimyza)
Twospotted spider mite (T. urticae)	*	Specific acaricides, compatible with biocontrol agents (bromopropylate, fenbutatinoxid hexythiazox)
Caterpillars (several species)	*	B. thuringiensis (bacterial preparations)
Thrips (Thrips tabaci) (F. occidentalis)	*	Predatory mite (A. cucumeris)

Disease		Control method
Fungal diseases (Botrytis) (Erisyphe) (Phytophtora) (Cladosporium) (Fusarium)	*	Numerous fungicides, compatible with biological control vinclozolin, bitertanol, iprodione, fenarimol, carbendazim
Soil fungi; nematods	*	Oxamyl; steaming

Detection whiteflies, leafminers, thrips: yellow sticky plates 10-15/ha, hung in transplanted young plants.

2. CUCUMBERS.

Pest	Control method
Whitefly (T.vaporariorum)	* Parasitic wasp (E. formosa) * Buprofezin
Western flower thrips (F. occidentalis)	* Predatory mite (A. cucumeris) * Physical control: thripstick
Twospotted spider mite (T. urticae)	* Predatory mite (P. persimilis) * Specific acaricides: hexythiazox, fenbutationoxyd, bromopropylate, clofentezine.
Aphids (M. persicae) (A. gossypii)	* Parasite wasp (A. matricariae) * Gall midge (A. aphidimyza) * Pirimicarb
Caterpillars (Numerous species)	* B. thuringiensis (bacterial preparations)

Disease	Control method
Fungal diseases (Powdery mildew) (Botrytis)	* Fungicides (compatible with biological control) imazalil, bitertanol, fenarimol, vinclozolin, iprodione
Soil fungi; nematods	* Oxamyl; steaming.

Detection whiteflies: yellow sticky plates (10-12/ha)

3. SWEET PEPPER.

Pest	Control method
Twospotted spider mite (T. urticae)	* Predatory mite (P. persimilis) * Specific acaricides: hexythiazox, fenbutatioxyd, bromopropylate, dicofol, clofentezine.
Western flower thrips (F. occidentalis)	* Predatory mite (A. cucumeris) Dichlorvos (smoke; up to a couple of days before introduction of the predatory mite) * Orius predatory bugs (spontaneous occurence in the greenhouse) * Thripstick
Aphids (M. persicae)	* Pirimicarb * Parasitic wasps (A. matricariae)
(A.gossypii)	* Gall midge (A.aphidimyza) * Heptenophos (local treatments)
Liocoris tripustulatus (bug)	* Dichlorvos (spray/smoke)
Caterpillars (several species)	* B. thuringiensis (bacterial preparations)
Greenhouse whitefly (T. vaporariorum)	* Parasitic wasp (E. formosa) * Buprofezin

Disease	Control method
Fungi (Rhizoctonia, Sclerotinia, Botrytis, Powdery mildew)	* Specific fungicides vinclozolin, iprodione, fenarimol.

Detection thrips: blue sticky plates (10-20/ha).

Some potential chemicals, which fit into IPM schemes are not legally allowed. Oxamyl is only registered as a soil drench before planting, although it may help a lot to correct

poor biological whitefly, thrips, aphid and bugs control. Chitin synthesis inhibitors, well known for their toxicity to caterpillar species, may not be used in glasshouse vegetables; they would be very interesting to control the BT-resistant species, **Chrysodeixis chalcites** and **Spodoptera exigua**.

6. Conclusions.

The Belgian glasshouse growers can now efficiently control whiteflies and 3 species of leafminers with biological and /or selective chemical control (buprofezin, cyromazine), without affecting honeybees and bumble bees.

Spider mites, aphids, caterpillars, can be efficiently controlled with biocontrol agents and/or selective chemicals. (**P. persimilis**, **B. thuringiensis**, pirimicarb).

Western flower thrips, resistant aphids (**A. gossypii**), are much more difficult to control, as the predatory mite **A. cucumeris** the wasp, **A. matricariae** and the midge **A. aphidimyza** have only been introduced recently (from 1990 onwards) in the glasshouses.

Resistant caterpillars (**S. exigua**, **C. chalcites**) are problems, as no chitin synthesis inhibitors are registered up till now.

7. Acknowledgement.

Research supported by the IWONL (Instituut tot Aanmoediging van het Wetenschappelijk Onderzoek in Nijverheid en Landbouw). Centre for Integrated Control, section: Ghent. Director: Prof. Dr. C. Pelerents.

8. References.

ANDERSON, M., FISHER, J.P., ROBINSON, J. and DEBRAY, P. 1986. Flufenoxuron -an acylurea acaricide/insecticide with novel properties. Proceedings of the 1986 British Crop Protection Conference -Pests and Diseases Vol. 1: 89-96.

BIACHE, G. 1987. Potentialités insecticides en lutte intégrée de préparations à base de **Bacillus thuringiensis** ou de **Baculovirus** contre les noctuelles de la tomate et du concombre en cultures protégées. CEC. Integrated Pest Management in Protected Vegetable Crops. Joint Expert's Meeting, Cabrils, Spain, 27-29 May 1987.

BURGES, H.D. and JARRETT, P. 1976. Adult behaviour and oviposition of five noctuid and torticid moth pests and their control in glasshouses. Bull. Ent. Res. 66: 507-510.

FOUGEROUX, M. 1986. Principles of integrated pest management.

Acta, Septembre, 1986.

HIRATA, K., KUDO, M., MIYAKE, T., KAWAMURA, Y. and OGURA, T. 1983. NC-129. A new acaricide. Brighton Crop Protection Conference, -Pests and Diseases-1983.

METCALF, R.L. 1980. The ecology of insecticides and the chemical control of insects. In: Ecological theory and Integrated Pest Management Practice. M. Kogan (Ed.). John Wiley & Sons New York pp. 251-297.

SMITS, P.H. 1987. Nuclear polyhedrosis virus as biological control agent of **Spodoptera exigua**. Doctoral Thesis.

STREIBERT , H.P., DRABEK, J. and RINDLISBACHER, A. 1988. CGA-106630- A new type of acaricide/insecticide for the control of the sucking pest complex in cotton and other crops. Brighton Crop Protection Conference - Pests and Diseases. 2-2 25-32.

VAN DE VEIRE, M. and BLEYAERT, P. 1990. Control of the leafminer **Liriomyza huidobrensis** (Blanchard) on glasshouse lettuce with the IGR cyromazine.
Med. Fac. Landbouww. RUG, **55**(2b), 1990, 661-666.

VAN DE VEIRE, M. 1989. Control of the leafminer **Liriomyza trifolii** in glasshouse tomatoes with the insect growth regulator cyromazine and side effect on the wasps **Dacnusa sibirica** and **Encarsia formosa**.
To be published in the "Proceedings" of the Joint Expert's Group IPM. Meeting held at Antibes, France, 16-19 October, 1989.

VAN DE VEIRE, M. and VACANTE, V. 1989. Buprofezin: a powerful help to integrated control in greenhouse vegetables and ornamentals.
Boletin de Sanidad Vegetal. Fuera de Serie - No. 17, 1989. Proceedings of a Scientific Congress, Barcelona, Spain, 25-28 October 1988. Eds. R. Cavallero and V. Delucchi.

van LENTEREN, 1989. World situation of integrated pest management in greenhouses. Proceedings of a symposium on "Insect Control Strategies and the Environment" held in Amsterdam. February 17th, 1989.
ICI Agrochemicals, 32-50.

YAMOMOTO, H. and KASAMATSU, K. 1990. Effects of fa juvenile hormone mimic, S-71639, on the greenhouse whitefly, **Trialeurodes vaporariorum** , and the green peach aphid, **Myzus persicae**, in a greenhouse. Advances in Invertebrate Reproduction 5. Eds. Hoshi, M. and Yamashita,O., Elsevier Science Publishers B.V. 1990.

CONSERVATION OF NATIVE MIRID BUGS FOR BIOLOGICAL CONTROL IN PROTECTED AND OUTDOOR TOMATO CROPS.

O. ALOMAR[1], C. CASTAÑE[1], R. GABARRA[1],
J. ARNÓ[2], J. ARIÑO[2] and R. ALBAJES.[3]

[1] IRTA, Centre de Cabrils, 08348 Cabrils (Barcelona).
[2] ADV, Mercat de Flor, N-II, 08340 Vilassar de Mar.
[3] Centre UPC-IRTA, Area de Protecció de Conreus; Rovira Roure 177, 25006 LLeida, Spain.

Summary
The coexistence of both field and protected crops with similar crops may interfere with implementation of IPM due to their interrelation. An IPM program for outdoor tomato crops based on conservation of native predators has been developed. Implementation in commercial fields has reduced pesticide use by 75%. The same predators are also present in greenhouses under IPM. Conservation of these predators to enhance natural control in the area deserves consideration.

1. Introduction. Pest control in vegetable mediterranean crops.

Protected crops in the Mediterranean occupy about 50.000 ha, which represent the most important area in the world with this growing system (ca. 30% of the total).

During the past 15 years, notable progress has been made to implement IPM programs in several countries of this area (e.g. Nucifora and Michelakis, 1988; Zipori *et al.*, 1988; Carnero *et al.*, 1989; Michelakis, 1990; Onillon, 1990). Despite these efforts, IPM is only applied in ca. 10% of the surface, which is rather low compared with glasshouse crops in cold climates (Van Lenteren and Woets, 1988; Onillon, 1990).

Most efforts of implementation of IPM in Mediterranean greenhouses have adapted inoculative Biological Control programs based on repeated releases of natural enemies until they are established in the crop (e.g. *Encarsia formosa* Gahan). This method has some limitations: (1) movement of pests between greenhouse and surrounding field crops and/or non-crop areas. This brings sudden increases in pest populations which are difficult to predict or control by the normal natural-enemy and pest dynamics; (2) temperatures and humidities within the greenhouse vary more than in heated glasshouses; (3) often, a shorter growing period which raises the cost of introductions; (4) a high number of fungicide sprays, and (5) a concentration of large areas of vegetable production (e.g. Almeria and Sicily with ca. 15000 ha each) with a great variety of crops which hinders a slow introduction of the new technology.

Under these circumstances, in order to increase IPM implementation in protected vegetable crops in the Mediterranean it therefore seems necessary to: (a) assess the elements which in the context of field and protected crops and non-crop vegetation may impose limits on the amplitude of pest population fluctuations; (b) select other species or biotypes of natural enemies which may be more adapted to climatic conditions of the greenhouse; (c) contribute to the training of growers and advisors; and (d) improve preventive measures in order to reduce the need for fungicide sprays (e.g. adoption of correct cultural practices, solarization and use of resistent cultivars).

Interrelation between field and protected crops is especially important in our area (Alomar *et al.*, 1989). In this paper we show how an IPM program for outdoor tomato crops based on conservation of native predators can succesfully be applied. As the same control agents are also found in the greenhouses, we can incorporate them into the movement of insects between crops (protected and field) and non-crop environments mentioned earlier.

2. An IPM program for outdoor tomato crops.

2.1 Background. Origin of the decision chart.

By studying non- or slightly-sprayed vegetable crops, several natural enemies have been found in the surroundings of Barcelona (Bordas *et al.*, 1985). Among them are Mirids and Anthocorids. On tomatoes, Anthocorids are rare, but of the mirids two were abundant: *Dicyphus tamaninii* Wagner and *Macrolophus caliginosus* Wagner.

D. tamaninii was evaluated as a potential biological control agent (Gabarra *et al.*, 1988, Salamero *et al.*, 1987). Laboratory and cage experiments showed it to be a polyphagous predator. However, *Dicyphus* may also be phytophagous and feeding on fruit causes yellow spots. At extreme infestations, individual fruit may be malformed. These diminish its commercial value for cosmetic reasons.

Studies on feeding preferences revealed that nymphs preferred insect prey to tomato fruit, and only when whitefly (*Trialeurodes vaporariorum* Westwood) density was excessively low did they switch to fruit feeding. Plant feeding is also known from other predaceous mirids (Wheeler, 1976; Niemczyk, 1978); in some cases damage to fruit has been related to shortage of alternative insect prey (Sanford, 1964; MacPhee, 1976; Coutin *et al.*, 1984) but the role of these facultative predators in IPM is not well documented.

With this hypothesis in mind an IPM program was developed for outdoor tomato crops, which allows the conservation of native mirid bugs up to a level where they may excessively control whitefly and start damaging the fruit. In 1987 and 1988 a preliminary program was applied. We used nominal action levels based on previous results. These action levels were established for 1989 and 1990 as shown in Figure 1.

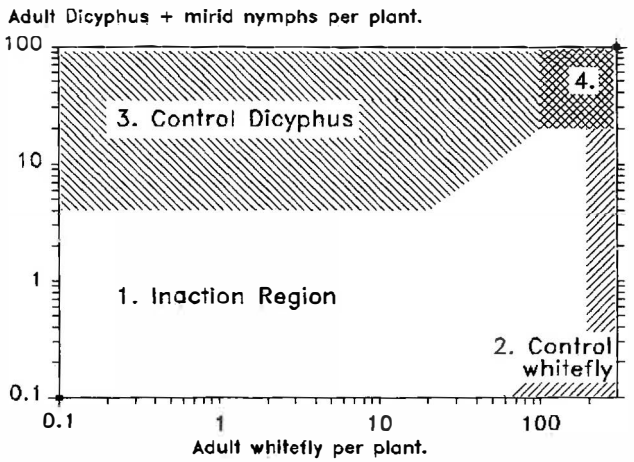


Figure 1. Decision chart for IPM in outdoor tomato crops (see text for explanations).

2.2 Application.

Fields are monitored weekly by visual methods. Mirid bugs are recorded from plant terminals (top seven leaves) from 20 plants per field. Whitefly adults are assessed on the top three leaves of the same plants. Separate records are made for adults of both mirids and for mirid nymphs. For the decisions, adult *Dicyphus* and mirid nymphs are pooled for each plant.

Counts of both predators and prey are plotted on the axes of the graph (Fig. 1). Decisions are made according to the Region. In Region 1, the population of both is small, or mirids are sufficient to control whitefly without damaging the fruit; no intervention is needed. In Region 2, the number of mirids may be too low and a selective insecticide is recommended against whitefly (buprofezin or quinomethionate) to aid subsequent regulation by predators. In Region 3, whitefly is not a problem but the number of mirids may lead to feeding damage on the fruit; a short-persistance spray (e.g. pyretroid) is therefore recommended to reduce the predator population.

With this model, it was to be expected that high predator and whitefly populations would not be desirable due to great risk of both damages appearing. As no field data were available, Region 4 was not clearly delimited.

2.3. Results.

Of the 10 fields where it was applied in 1989, only in one were results insatisfactory due to an erroneous application of quinomethionate made while still in Region 1. As a result the whitefly dropped and the bugs switched to tomato fruits, causing localized damage. A corrective spray against the bugs balanced the situation again.

In 1990 a sequential decision plan was used in most of the 35 fields under IPM. Decisions were based on the proportion of plants in Region 3. Results in relation to habitual pests considered by the program are shown in Figure 2. Pest control of habitual pests (whitefly, aphids, leaf-eating moths and leafminers) was very satisfactory in 29 (83%) of the fields; nor was there damage by bugs. Of those, only corrective sprays against mirids had to be applied in 23 (an average of 1.3 per field). In 6 fields an additional spray had to be applied for whitefly. On average, 1.9 sprays were applied per field for *Dicyphus*-whitefly management.

In the other 6 fields damage was recorded, caused either by whitefly, *Dicyphus* or both. All could have been avoided with a correct application of proper cultural practices. In four cases, the proximity of abandoned tomato fields or greenhouses with high and constant sources of either whitefly or *Dicyphus* made control difficult. The other two fields started with very high populations of both insects. In spite of a quick increase in the mirid, the development of sooty-mold on leaves could not be avoided. Whitefly control was quick but damaged fruit was also recorded. These results confirmed our suspicions and a spray was therefore recomended for both (i.e. pyretroid + buprofezin) to return the system back to the inaction region (Fig. 1, Region 4).

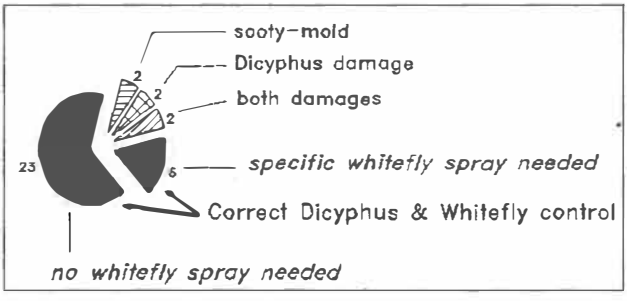


Figure 2. Application of the IPM program in tomato (1990). Black sectors show succesful *Dicyphus*-whitefly management. Dashed and crossed sectors indicate 'failures' (see text). Figures indicate the number of fields in each case.

2.4 Other pests not considered in the Decision chart.

Restricted use of pesticides contributes to natural control of other pests. The program has shown its effectiveness in maintaining the populations of most pests (whitefly, aphids, leafminers and leaf-eating noctuids (*Chrysodexis chalcites* (Esper), *Autographa gamma* (L.) at tolerable levels. A different consideration is deserved by *Heliothis armigera* (Hübner). In laboratory experiments, *D. tamaninii* preys on eggs. During 1987-89 no fruitworm damage was recorded, but in 1990 very high populations (ca. 600 males per pheromone trap during 4 weeks) were registered. Under these circumstances the mirids are not able to exert sufficient control.

D. tamaninii also feeds on the western flower thrips *Frankliniella occidentalis* (Pergande), but its action under field conditions has not been evaluated. Nevertheless, very low WFT populations have been observed on tomatoes in our area since its introduction two years ago. This is not the same in other crops or regions of Spain.

3. Presence of the mirids in protected crops.

The use of *E. formosa* and *Diglyphus isaea* (Walker) in greenhouses in our area has given very good control of pests (Gabarra *et al.*, 1989). Nevertheless, these mirids have also been observed in the greenhouses where IPM is applied. Results from the last three years show how between 60 and 100% of IPM-greenhouses have mirid nymphs at the end of the growing season. Two samples taken during the cropping period also indicate that *D. tamaninii* and *M. caliginosus* establish themselves in the greenhouses (Figure 3). It is therefore plausible that they contribute to the effectiveness of *E. formosa* in controlling whitefly.

Although both mirids have been observed feeding on parasitized black pupae, in no case was there a failure of whitefly control because of mirid presence. Clearly the presence of these native predators within the greenhouse has to be evaluated.

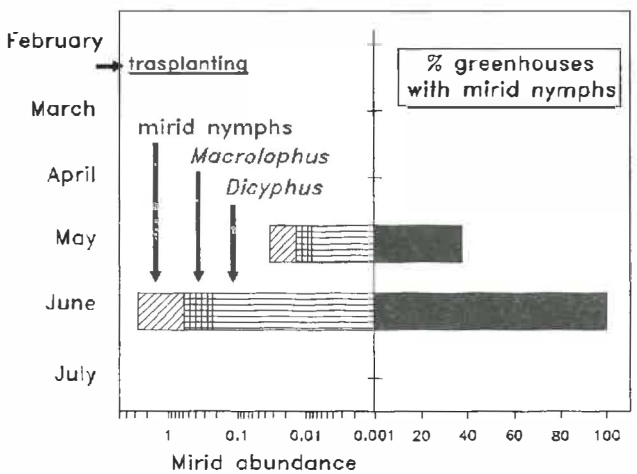


Figure 3. Establishment of mirids in greenhouses under IPM (1990). Mirid abundance, the average number of insects (*D.t*, *M.c* or nymphs) per greenhouse (means of counts on 50 plants per greenhouse; n= 16 greenhouses).

4. Benefits of the IPM program on outdoor tomato.

In view of the results achieved so far, we can make the following assessment of the program:

4.1 Reduction in spraying intensity.

Before the implementation of the current IPM program, intensive and routine pesticide applications were common in this region, regardless of pest numbers. A survey made in 1983 showed how farmers sprayed on a calendar basis, half of them weekly and half every fortnight. One or more insecticides may have been used in each spray. Sometimes the spraying interval was reduced to 3 days even during the harvest. Half of them also considered necessary to add another insecticide for *Heliothis* control. All farmers also incorporated a fungicide, 65% on a weekly base, the rest every fortnight. Many combined broad spectrum pesticides. Similar practices are still used by some growers.

Figure 4 shows estimated average insecticides and fungicides applied by growers during 1983 and mean number of sprays made in IPM fields during 1989 and 1990. An average of 3 (1989) and 5 (1990) insecticide applications were made in IPM fields. Compared with the 1983 use of insecticides, the IPM program would represent a reduction between 75 and 60% in insecticide application.

Fungicide use has also been reduced by 80%. Fungicides are recommended on a preventive basis by technicians, and clearly shows how technical advice is profitable for growers.

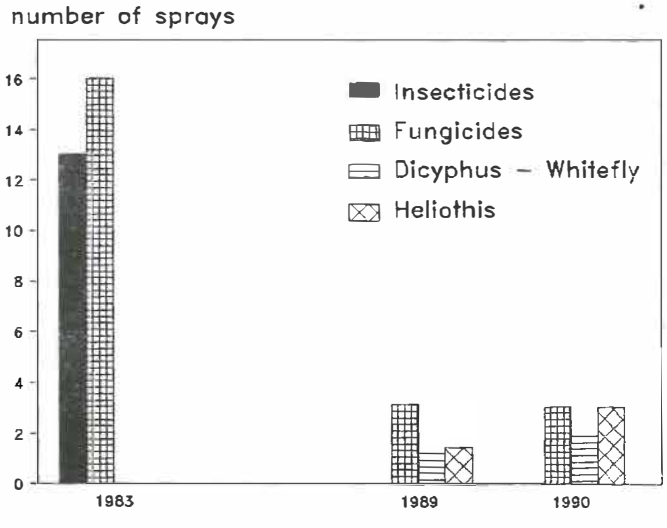


Figure 4. Estimated average broad-spectrum insecticide and fungicide sprays applied in 1983; and mean number of sprays made in IPM fields for disease control and selective *Heliothis* and *Dicyphus*-whitefly management (1989 and 1990).

4.3 Control of other pests.

The present natural enemies do not seem to control *Heliothis* in years of high populations. The repetitive use of *Bacillus thuringiensis* Berliner is difficult because of high costs and little efficacy at advanced larval stages. The use of viral preparations (Biache, 1989) or of resistant varieties which incorporate the *B.t*-protein are some of the alternatives for the future which have to be evaluated. More specific natural enemies should also be studied.

4.4 Conservation of mirids in tomato crops: an appraisal of the future.

The spontaneous presence of these mirids in IPM greenhouses, and the fact that they reproduce, allows us to consider the possibility of taking advantage of these polyphagous predators, at least during the last phase of the cropping period. In fact Malausa *et al.* (1987) consider the possibility of inoculative releases of *M. caliginosus* in greenhouses.

This is especially encouraging if we consider that both mirids prey upon aphids (unpubl. results; Foglar *et al.*, 1990). We must not forget, that at present there are no efficient mass-reared control agents for aphids present in our crops (*Myzus persicae* (Sulzer) and *Macrosiphum euphorbiae* (Thomas), and the increasing difficulty of selectively controlling them with pirimicarb. However, we must find out their compatibility with other natural enemies.

Moreover, conservation of these facultative predators in the greenhouse allows them to move to field crops and non-crop vegetation at the end of the growing season thus contributing to Biological Control in the area.

5. Aknowledgements.

The cooperation of growers of the two ADV is appreciated. This work was partially funded by CICYT project number 85-237.

6. References.

ALOMAR, O., CASTAÑE, C., GABARRA, R., BORDAS, E., ADILLON, J. & ALBAJES, R. 1989. Cultural practices for IPM in protected crops in Catalonia, in R. Cavalloro and C. Pelerents (eds.), *Integrated Pest Management in Protected Vegetable Crops - Proceedings of the CEC/IOBC Expert's Group Meeting, Cabrils, 1987*. A.A. Balkema, Rotterdam. ISBN: 90 6191 874 X, pp. 347-354.

BIACHE, G. 1989. Potentialités insecticides en lutte integrée de préparations à base de *Bacillus thuringiensis* ou de baculovirus contre les noctuelles de la tomate et du concombre en cultures protegées, in R. Cavalloro and C. Pelerents (eds.), *Integrated Pest Management in Protected Vegetable Crops*. A.A. Balkema, Rotterdam. ISBN: 90 6191 874 X, pp. 99-105.

BORDAS, E., GABARRA, R., ALOMAR, O., CASTAÑE, C., & ALBAJES, R. 1985. La lutte integrée dans les cultures maraichères en Catalogne: présent et futur. IOBC/WPRS Bull. 1985/VIII/I: 1-9.

4.2 Implementation of IPM in the area.

Since 1988 two advisors for IPM are employed, who are financed partly by grower's organizations (Associació de Defensa Vegetal del Maresme, ADV) and by the government. The program has been succesfully applied by growers, thus increasing their interest and understanding of IPM. At present 87% of the members of the ADV apply IPM in at least one of their outdoor tomato fields.

The use of a sequential decision plan has also lowered the sampling time by 60% and allowed advisors to monitor more fields (Figure 5).

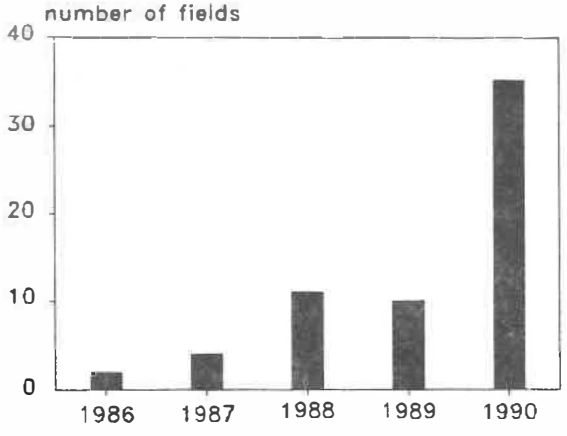


Figure 5. Increase in the number of outdoor tomato fields under IPM.

4.3 The Decision-chart.

This simple decision-chart based on relative abundances of facultative predator and prey has shown its usefulness. Nevertheless, further developments should also account for stage of plant growth and the complex of mirid bugs present. Mirid counts are based on adult *Dicyphus* spp. and mirid nymphs. *Macrolophus* does not seem to damage the plants (personal observations; Malausa and Drescher, 1989) and adults are therefore not considered, but nymphs are included due to the difficulty of recognizing them in the field. *Macrolophus* is more abundant during the end of the cropping period; in some fields it is clearly dominant. Fine-tuning of the counts should be considered to avoid over-rating of 'damaging mirids' and under-rating of predatory activity.

Nesidiocoris tenuis (Reuter) is a pest in other countries (El-Dessouki *et al.*, 1976; Raman and Sanjayan, 1984). It is also present in field tomato crops in our area (Goula, 1985) but no damage has been recorded so far. Modifications of the decision chart will have to be made in case this is so.

CARNERO, A., PEREZ PADRON, F., BARROSO ESPINOSA, J., ESPINO DE PAZ, A. & RUMEY UCELAY, L. 1989. IPM of tomatoes in the Canary Islands, in *Practical Application of Integrated Control in Protected Crops - Proceedings of a Joint Expert's Meeting, Antibes, 1989*. (in press).

COUTIN, R., MILAIRE, H.G., MONNET, Y. & ROBIN, J. 1984. Cultures fruitères. Punaises et poire pierreuses. Phytoma 355:31-34.

EL-DESSOUKI, S.A., EL-KIFL, A.H. & HELAL, H.A. 1976. Life cycle, host plants and symptoms of damage of the tomato bug, *Nesidiocoris tenuis* Reut. (Hem: Miridae) in Egypt. Zeit. Pflanzenkr. u. Pflanzenschutz 83(4): 204-220.

FOGLAR, H., MALAUSA, J.C. & WAJNBERG, E. 1990. The functional response and preference of *Macrolophus caliginosus* (Heteroptera: Miridae) for two of its prey: *Myzus persicae* and *Tetranychus urticae*. Entomophaga 35(3): 465-474.

GABARRA, R., CASTAÑE, C., BORDAS. E. & ALBAJES, R. 1988. *Dicyphus tamaninii* Wagner as a beneficial insect and pest of tomato crops in Catalonia. Entomophaga 33(2): 219-228.

GABARRA, R., ALOMAR, O., CASTAÑE, C., BORDAS. E. & ALBAJES, R. 1989. Current situation of IPM in protected crops in Catalonia (Spain), in *Practical Application of Integrated Control in Protected Crops - Proceedings of a Joint Expert's Meeting, Antibes, 1989*. (in press).

GOULA, M. 1985. *Cyrtopeltis (Nesidiocoris) tenuis* Reuter 1895 (Heteroptera, Miridae), nueva cita para la Península Ibérica. Actas II Congresso Ibérico de Entomologia, in Bolm. Soc. port. Ent., Suppl. 1: 93-102.

MACPHEE, A.W. 1976. Predictions of destructive levels of *Atractotomus mali* and *Campylomma verbasci* (Hemiptera: Miridae). Can. Ent. 108:423-426.

MALAUSA, J.C., DRESCHER, J. & FRANCO,E. 1987. Perspectives for the use of a predaceous bug *Macrolophus caliginosus* Wagner (Hemiptera, Miridae) on glasshouse crops. IOBC/WPRS Bull. 1987/X/2: 106-107.

MALAUSA, J.C. & DRESCHER,J. 1989. La phytophagie chez les Mirides prédateurs (Heteroptera): Evaluation des risques d'apparition des dégâts sur la tomate (abstract), in *Practical Application of Integrated Control in Protected Crops - Proceedings of a Joint Expert's Meeting, Antibes, 1989*. (in press).

MICHELAKIS, S.E. 1990. A new approach to whitefly control in Crete, in J.E. Casida (ed.), *Pesticides and alternatives*, Elsevier. pp. 229-234.

NIEMCZYK, E. 1978. *Campylomma verbasci* Mey-Dur (Heteroptera, Miridae) as a predator of aphids and mites in apple orchards. Polskie Pismo Entomol. 48: 221-235.

NUCIFORA, A. & MICHELAKIS, S. 1988. Progress in the development of integrated control of vegetable crops in the mediterranean area, in R. Cavalloro and M.J. Way (eds.), *Integrated Crop Protection: from principles to practical implementation. Proceedings of the CEC/IOBC/EPPO international joint conference*. Luxemburg, Office for Official Publications of the European Communities. pp. 138-146.

ONILLON, J.C. 1990. The use of Natural Enemies for the Biological Control of Whiteflies, in D. Gerling (ed), *Whiteflies: their Bionomics, Pest status and Management*. Intercept Ltd, Andover, UK. pp. 287-313.

RAMAN, K. & SANJAYAN, K. 1984. Host plant relationships and population dynamics of the mirid, *Cyrtopeltis tenuis* Reut. (Hemipetra: Miridae). Proc. Indian natn. Sci. Acad. B%=(4): 355-361.

SALAMERO, A., GABARRA, R. & ALBAJES, R. 1987. Observations on the predatory and phytophagous habits of *Dicyphus tamaninii* Wagner (Heteroptera, Miridae). IOBC/WPRS Bull. 1987/X/2: 165-169.

SANFORD, K.H. 1964. Life history and control of *Atractotomus mali* a new pest of apple in Nova Scotia (Miridae: Hemiptera). J. Econ. Entomol. 57(6): 921-925.

VAN LENTEREN, J.C. & WOETS, J. 1988. Biological and Integrated Pest Control in Greenhouses. Ann. Rew. Entomol. 33: 239-269.

WHEELER, A.G. Jr. 1976. Lygus bugs as facultative predators, in D.R. Scott and L.E. O'Keefe (eds.), *Lygus Bug: Host Plant Interaction*. Proceedings of a Workshop, XV International Congress of Entomology, Washington D.C. University Press of Idaho, Moskow, Idaho. pp. 28-35.

ZIPORI, I., BERLINGER, M.J., DAYAN, E., DAHAN, R., SHMUEL, D. MORDECHAI, S. & AHARON, Y. 1988. Integrated control of *Bemisia tabaci* in greenhouse tomatoes planted early in the season. Hassadeh 68(9): 1711-13.

EMBRYONIC AND LARVAL DEVELOPMENT OF CHRYSOPERLA CARNEA (STEPH.) (NEUR., CHRYSOPIDAE) AT DIFFERENT TEMPERATURE REGIMES

G. NICOLI*, D. GALAZZI*, M. MOSTI**, G. BURGIO*
* Istituto di Entomologia "G.Grandi" - Università di Bologna
via Filippo Re,6 - 40126 BOLOGNA (ITALY)
** Biolab - Centrale Ortofrutticola, via Dismano,3845
47020 Cesena (FO) (ITALY)

Summary
The common green lacewing Chrysoperla carnea (Steph.) (Neur., Chrysopidae) is mass-reared as a predator in Italy for release as second instar larvae against aphids on protected crops (mainly strawberry). Eggs and larvae were reared at 10, 14, 18, 22, 27°C constant temperatures and two thermoperiods from 6 to 22°C and from -2 to 26°C; UV-sterilized eggs of Ephestia kuehniella (Zell.) (Lep., Pyralidae) were used to feed larvae. Survival, egg consumption and development times were recorded. At the lowest temperature, C.carnea had a high mortality of embryo and first instar larva, and was unable to pupate. However, in the two thermoperiods the survival was very high. The C.carnea larva consumed about 3% of the E.kuehniella eggs during first instar, 9% during second instar and 88% during the third. At the same temperature regime, females consumed more eggs than males and their cocoon weight was significantly higher. A prediction model was drawn up to show the rate of development in relation to temperature.

1. Introduction

Chrysoperla carnea (Steph.) is a very voracious and polyphagous predator during the larval period. This chrysopid is widely used in biological control also because of its aptitude for rearing (Principi, 1983). The Centrale Ortofrutticola of Cesena's Biolab has been mass-rearing C.carnea since 1985 for release as second instar larvae against aphids mainly in plastic tunnel-grown (unheated) strawberry. The larvae (about 18/m²) are released at onset of infestation against the two more common species, Macrosiphum euphorbiae (Thom.) and Chaetosiphon fragaefolii (Cock), usually during March and April (Celli et al., 1988; Benuzzi and Nicoli, 1988). Inside unheated greenhouses the temperature range is broad on sunny days, whereas the maximum temperature is lower and the range is narrower on cloudy days.

C.carnea development using aphids, Lepidoptera eggs and mites, both at constant and fluctuating temperatures were studied by many authors. Two reviews deal with preimaginal development in laboratory (Canard and Principi, 1984) and prey consumption

(Principi and Canard, 1984) in some chrysopids. Tauber and Tauber (1983) also studied the influence of relative humidity and concluded that development time is not affected by RH between 35 and 75%.

The experiment was carried out to investigate the temperature influence (both constant and fluctuating) on embryonic and larval development, particularly on survival, predation and development rates.

2. Materials and methods

Tests were conducted inside climatized incubators, each measuring 0.48 m^3, with computer-controlled temperature and RH (75 ±15% in all tests); temperature and RH were continuously registered by thermohygrographs. Photoperiod was LD 16:8, with a constant light intensity of 500 lx. The temperature regimes tested were 10, 14, 18, 22 and 27°C constant and two daily thermoperiods TA (from 6 to 22°C) and TB (from -2 to 26°C) (fig.1). These latter are analogous to real ones registered in tunnel on a cloudy (TA) or a sunny day (TB).

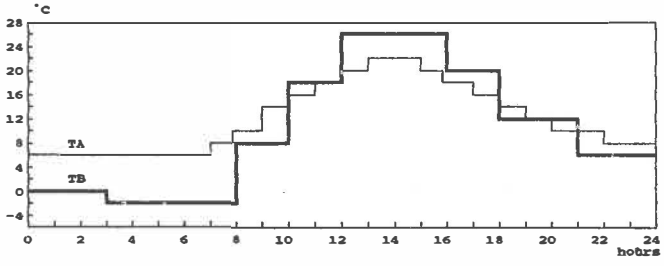


Fig.1: The two thermoperiods tested.

The C.carnea individuals used in these trials were mass-reared and supplied by Biolab where the larvae are fed on Ephestia kuehniella (Zell.) frozen eggs and the adults reared on artificial diet composed of honey and "Bacto-yeast extract" at 26°C, 75% RH and LD 16:8 photoperiod. E.kuehniella eggs are an optimal prey for C.carnea (Pasqualini, 1975; Principi and Canard, 1984) and are widely used by biofactories.

At the beginning of tests, about 500 C.carnea adults were put in a cage for oviposition at 27°C for two hours. The eggs were isolated in petri-like dishes (3.5 cm diameter and 1.0 cm high) and immediately put in climatized incubators. Larvae were fed ad libitum on E.kuehniella eggs which were UV-sterilized within 24 hours of laying. Depending on instar and on temperature regime, 60-600 eggs were glued by gum arabic on 4 cm^2 cardboard squares, which were changed every 1-5 days and always immediately after moult. The preyed-upon eggs were counted under a binocular microscope. Hatching, moulting and cocoon spinning were monitored three times a day.

The experiment was divided in two parts: i) from egg to first

moult and ii) from first moult to cocoon spinning. Cocoons were kept at 27°C, weighed 24 h after spinning and the sex of emerged adults was recorded.

Statistical analysis

Means and standard deviations were calculated by considering each individual as a replication. In order to compare prey consumption and the weight of the cocoon in females vs. males, the Mann-Whitney U test was applied using the large sample formula, wherein No.>20 (Siegel, 1956). The predation data at the different temperature regimes were analyzed using the Kruskall-Wallis test, followed by distribution-free multiple comparison (Hollander and Wolfe, 1973).

3. Results and discussion

Survival

Table 1 shows C.carnea survival rates at different temperature regimes. The individuals kept at 10°C showed low survival and were unable to spin cocoons and to pupate. Both thermoperiods appear favourable to embryo and first instars.

Tab.1: Percent survival of Chrysoperla carnea at different temperature regimes.

t	Eggs	Hatching	First moult	2nd instar larvae	Second moult	Cocoon	Adult
°C	No.	%	%	No.	%	%	%
10	50	42	14	20	85	0	0
14	50	44	38	20	100	100	100
18	50	60	54	20	100	95	95
22	50	62	54	20	100	100	95
27	50	68	68	25	100	100	96
TA(6/22)	50	92	86	25	100	96	92
TB(-2/26)	50	86	80	25	96	92	84

Prey consumption

Table 2 shows egg predation during larval development. C.carnea consumed about 3% of E.kuehniella eggs during first instar, 9% during the second and 88% during the third. At the same temperature regime, the female cocoons were always significantly heavier than the male's ($p<0.01$; Mann-Whitney U test), confirming Canard and Principi (1984). Table 3 shows the total number of preyed-upon eggs during second and third instars, separately for males and females. At the same temperature regime females showed significantly higher predation than males. Figure 2 shows egg predation per day. The number of preyed-upon eggs/day at the TA and TB thermoperiods is not significantly different than at the 14°C constant regime.

Tab.2: Ephestia kuehniella eggs preyed-upon by Chrysoperla carnea and cocoon weight.

t (°C)	No	Larva 1 $\bar{X}$±SD	No.	Larva 2 $\bar{X}$±SD	Larva 3 $\bar{X}$±SD	Cocoon (mg)	P
10	7	39.4±11.0	13	53.2±30.5	890.8±179.8	-	
14	19	33.6±10.1	5♀♀ 15♂♂	162.4±19.5 105.1±30.2	1325.0±181.0 956.8±140.4	12.0±1.0 9.3±0.5	**
18	27	29.3±7.2	14♀♀ 5♂♂	112.1±14.5 91.0±12.4	1019.6±106.8 840.2±80.7	11.2±0.8 9.2±0.2	**
22	27	27.7±9.7	9♀♀ 10♂♂	80.2±10.0 65.9±17.5	946.4±78.1 799.0±123.6	10.3±0.5 8.9±0.8	**
27	33	24.3±4.8	11♀♀ 13♂♂	94.1±28.3 89.3±35.8	980.4±137.4 771.9±78.8	10.9±1.1 8.5±0.7	**
TA (6/22)	43	31.8±8.1	10♀♀ 13♂♂	111.7±20.4 91.5±18.6	1184.9±116.4 1007.2±199.6	10.7±0.6 9.2±0.6	**
TB(-2/26)	40	25.3±7.3	5♀♀ 16♂♂	99.2±26.6 83.4±12.7	907.4±43.4 759.2±127.9	10.0±0.4 8.6±0.6	**

** = Female cocoons were significantly heavier than the male's ($P<0.01$; Mann-Whitney U test).

Tab.3: Total preyed-upon eggs during 2nd and 3rd instar larvae of Chrysoperla carnea, separately for females and males.

t (°C)	♀♀ No.	♀♀ $\bar{X}$ ± SD	♂♂ No.	♂♂ $\bar{X}$ ± SD	P
14	5	1487.7 ± 188.5 b	15	1061.9 ± 136.1 c	**
18	14	1131.7 ± 108.9 ab	5	931.2 ± 76.3 bc	**
22	9	1026.7 ± 81.6 a	10	864.9 ± 127.4 ab	**
27	11	1074.5 ± 149.6 a	13	861.2 ± 92.2 ab	**
TA(6/22)	10	1296.6 ± 120.5 b	13	1098.8 ± 205.0 c	**
TB(-2/26)	5	1006.6 ± 68.5 a	16	842.6 ± 127.9 a	**

- Different letters in the same column indicate significant differences; Kruskal-Wallis test, followed by distribution-free multiple comparison ($\alpha = 0.05$) (Hollander and Wolfe, 1973).
- ** = $P<0.01$ (Mann-Whitney U test) for ♀♀ vs. ♂♂ data comparison at the same temperature regime.

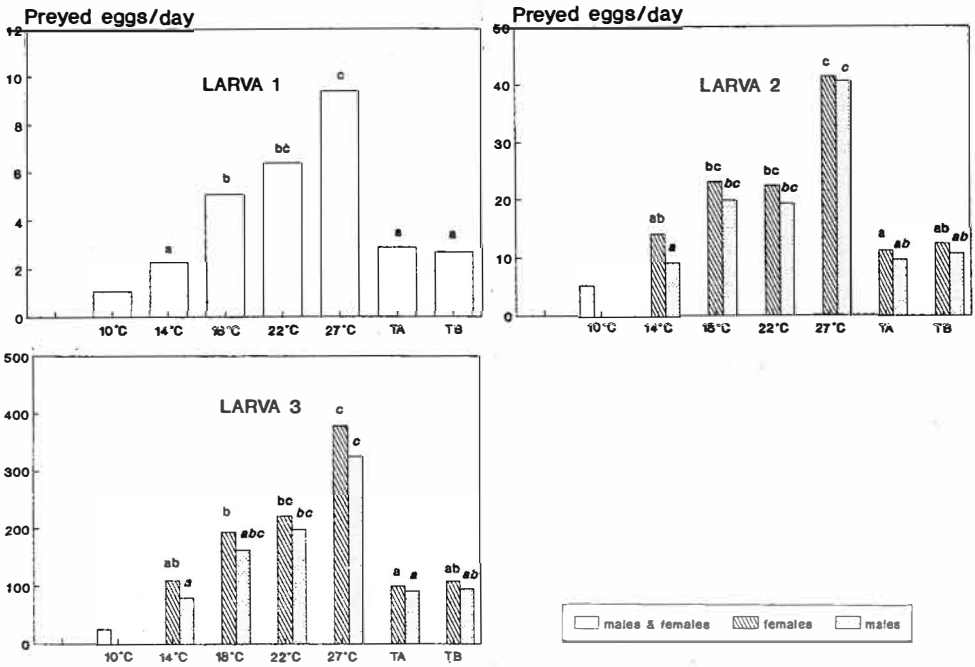


Fig.2: Ephestia kuehniella eggs predation per day by Chrysoperla carnea. Females and males data were analyzed separately. Same bars indicated by different letters are statistically different; Kruskal-Wallis test, followed by distribution-free multiple comparison (α =0.05) (Hollander and Wolfe, 1973). The data at 10°C were not analyzed because C.carnea can not complete development.

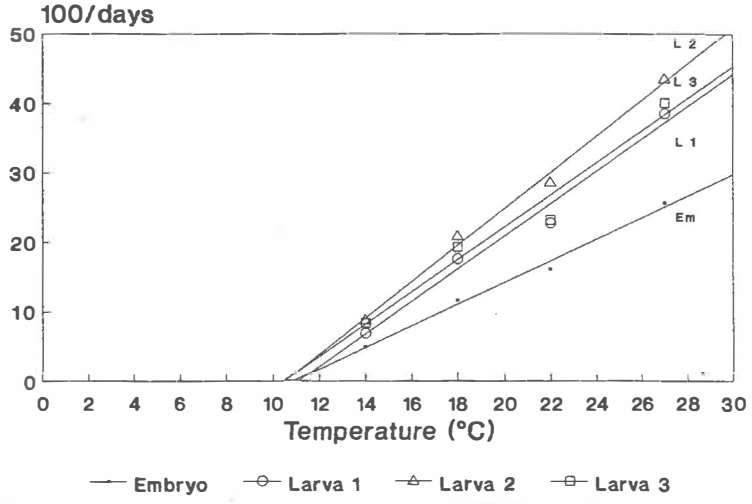
Development

Table 4 shows the development time of the pre-imaginal instars tested. Male and female data were not separated because no significant difference between sexes was found at the same temperature regime. Pasqualini (1975) reported similar findings at constant 20°C.

Tab.4: Development time (days) of Chrysoperla carnea at different temperature regimes ($\bar{X}$ ± SD).

t (°C)	No.	Egg	Larva 1	No.	Larva 2	Larva 3
10	7	33.9±1.2	35.2±3.0	13	28.8±2.4	36.1±6.8
14	19	20.2±0,6	14.4±1.3	20	11.4±0.7	11.9±0.6
18	27	8.6±0.4	5.7±0.7	19	4.8±0.3	5.2±0.4
22	27	6.2±0.2	4.4±0.3	19	3.5±0.3	4.2±0.6
27	33	3.9±0.0	2.6±0.3	24	2.3±0.4	2.5±0.4
TA(6/22)	43	14.9±0.8	10.9±0.9	22	9.8±0.5	11.3±1.1
TB(-2/26)	40	12.3±0.6	9.3±0.7	21	7.9±0.4	8.1±0.6

Figure 3 shows the regression equations for the rate of development at constant temperature from 14 to 27°C and the estimated threshold temperatures.



Embryo	Y= -16.8939 + 1.55464X (r^2=99.12, P<0.01)	To=10.9
Larva 1	Y= -25.8600 + 2.33469X (r^2=97.82, P<0.05)	To=11.1
Larva 2	Y= -27.3811 + 2.60709X (r^2=99.38, P<0.01)	To=10.5
Larva 3	Y= -24.2772 + 2.32776X (r^2=97.22, P<0.05)	To=10.4

Fig.3: Regression equations for the rate of development (100/days) of Chrysoperla carnea in the 14-27°C temperature range.

These latter were used to calculate effective temperatures for all the instars, thus making it possible to calculate the regression equations for all six temperature regimes (tab.5).

Tab.5: Regression equations for the rate of development (100/days) vs. effective temperature above threshold temperature. The equations are for 6 thermal regimes (4 costant temperatures and 2 thermoperiods).

Embryo	Y = -14.2427 + 1.44467X	(r^2=98.21, P<0.01)
Larva 1	Y = -23.1513 + 2.22263X	(r^2=97.85, P<0.01)
Larva 2	Y = -24.9157 + 2.50466X	(r^2=99.25, P<0.01)
Larva 3	Y = -21.5311 + 2.21453X	(r^2=97.39, P<0.01)

Effective temperature = $\frac{\sum(T - To)}{24}$ + To (for T-To>0)

T = mean hourly temperature; To = threshold temperature.

The parallelism test was employed to compare the slopes of the equations calculated on all regimes and those on the four constant temperatures; no significant differences were found. Therefore the regression equations calculated on the four constant temperatures represent a prediction model for calculating development rates even at fluctuating temperatures (for an effective temperature range between 14 and 27°C).

4. Conclusions

At a constant temperature close to its thershold C.carnea shows a high mortality of both embryo and first instar and is unable to pupate. However, the favourable range for development is expanded in the lower temperature range when thermoperiods are employed. This indicates that the predator can be released in greenhouse even when the temperature drops close to 0°C for a few hours. As temperature increases, C.carnea's predatory activity (expressed as the number of preyed-upon eggs/day) and its development rate increase. The data about predation can be used to optimize the number of E.kuehniella eggs distributed to the larvae in mass-rearing, whereas the prediction model can be valuable in production scheduling. The sunny-day thermoperiod resulted in a significantly more rapid larval development than the cloudy-day's ($p<0.001$).

The model can indicate when the C.carnea larvae moult to the third instar, reaching the meximum of activity. However this fact can only be linked to field effectiveness by also studying temperature influence on the predator search activity.

References

BENUZZI, M. & NICOLI, G., 1988. Lotta biologica e integrata nelle colture protette. Ed. Centrale Ortofrutticola, Cesena: 167 pp.

CANARD, M. & PRINCIPI, M.M., 1984. Development of Chrysopidae. In: Canard, M., Séméria, Y. & New, T.R., (eds.). Biology of Chrysopidae. Dr W.Junk Publ., The Hague: 294 pp.

CELLI, G., BENUZZI, M. & NICOLI, G., 1988. Sviluppo di una strategia di lotta integrata sulla fragola in coltura protetta in Emilia-Romagna nel quinquennio 1983-87. Atti Giorn. Fitopat., 2: 213-222.

HOLLANDER, M. & WOLFE, D.A., 1973. Nonparametric statistical methods. Wiley & Sons, New York: 503 pp.

PASQUALINI, E., 1975. Prove di allevamento in ambiente condizionato di Chrysopa carnea Steph. (Neuroptera, Chrysopidae). Boll. Ist. Ent. Univ. Bologna, 32: 291-304.

PRINCIPI, M.M., 1983. I Neurotteri Crisopidi e le possibilità della loro utilizzazione in lotta biologica e in lotta integrata. Boll. Ist. Ent. Univ. Bologna, 38: 231-262.

PRINCIPI, M.M. & CANARD, M., 1984. Feeding habits. In: Canard, M., Séméria, Y. & New, T.R., (eds.). Biology of Chrysopidae. Dr W.Junk Publ., The Hague: 294 pp.

SIEGEL, S., 1956. Statistica non parametrica per le scienze del comportamento. Organizzazioni speciali, Firenze: 269 pp.

TAUBER, M.J. & TAUBER, C.A., 1983. Life history traits of Chrysopa carnea and Chrysopa rufilabris (Neuroptera: Chrysopidae): influence of humidity. Ann. Entomol. Soc. Am., 76 (2): 282-285.

LUTTE BIOLOGIQUE CONTRE FRANKLINIELLA OCCIDENTALIS AVEC ORIUS MAJUSCULUS SUR CONCOMBRE

Y. TROTTIN-CAUDAL, D. GRASSELLY, M. TRAPATEAU, H. DOBELIN (1)
P. MILLOT (2)

(1) Ctifl Centre de Balandran BP 32 30127 BELLEGARDE - FRANCE
(2) INRA Station de Zoologie et de Lutte Biologique
37, Bd du Cap 06606 ANTIBES Cedex - FRANCE

SUMMARY

The thrips *Frankliniella occidentalis* identified in France in 1986 is now present in every crop region on different vegetable, horticultural and perennial species.
As chemical control is difficult, the biological solution seems the only possible one with the respect of severe preventive measures.
Predatory mites *Amblyseius sp* are sold and successfully used only on pepper.
Different species of anthocorid bugs *Orius sp* are studied. The efficiency of *Orius majusculus* on *F. occidentalis* in experimental insect-proof cucumber glasshouses is described in this paper.
The strategy of releases with one Orius per 100 thrips on a population of 10 individuals per leaf was the most interesting. This result has to be confirmed in other greenhouse conditions.
Observations on the behaviour of *F. occidentalis* and its predator on cucumber are given.

INTRODUCTION

Le thrips *Frankliniella occidentalis*, identifié en France depuis 1986 (Bournier et Bournier, 1987), est actuellement présent dans toutes les régions de production. Très polyphage et vecteur du Tomato Spotted Wilt Virus (TSWV), il provoque des dégâts considérables sur de nombreuses espèces maraîchères, horticoles et pérennes, en cultures sous abri et en plein champ dans la zone méditerranéenne (Gebre Selassié et al., 1988).

La lutte chimique est difficile et non satisfaisante. Les nombreux traitements nécessaires pour contrôler le ravageur présentent une phytotoxicité non négligeable et perturbent la lutte intégrée utilisée sur le concombre en particulier.

L'emploi de mesures prophylactiques sévères est impérative et la solution biologique apparaît la seule envisageable à terme.

Des acariens prédateurs sont commercialisés, mais ne sont utilisés avec succès que dans les pays du Nord de l'Europe (Ramakers, 1990 ; Altena et al., 1990) et au Canada (Gilkerson et al., 1990 ; Steiner et Tellier, 1990), sur poivron seulement.

Actuellement, la recherche s'oriente vers un autre prédateur, une punaise du genre *Orius*.

Les programmes ont débuté au Canada en 1988, aux Pays Bas et en France à l'INRA d'Antibes (1) en 1989. Les premières études montrent qu'*Orius sp* est un prédateur de thrips intéressant.

(1) INRA Institut National de la Recherche Agronomique

Grâce à l'expérience du Ctifl (2) acquise sur *Thrips tabaci* et *F. occidentalis* (Grasselly et al., 1989 ; Trottin-Caudal et Grasselly, 1989 ; Trottin-Caudal et al., 1990) et suite aux travaux de l'INRA sur *Orius majusculus* (Millot, 1991), un essai à été mis en place sur la Station Ctifl de Balandran (Gard) pour étudier l'efficacité du prédateur sur une population de *F. occidentalis* en culture de concombre sous serre verre dans différentes conditions définies par le niveau initial de population de thrips et le rapport proie-prédateur.

MATERIEL ET METHODES

1 - Dispositif - Méthodologie

- L'essai s'est déroulé au Printemps-été 1990 dans 5 compartiments de serre contigues de 61 m2, étanches aux insectes (toile de maille 0,2 mm aux ouvrants). La culture de concombre est conduite sur pains de laine de roche à raison de 6 lignes de 11 plants par compartiment (variété Carmen tolérante à l'oïdium). La plantation a été effectuée le 22 mars au stade 3-4 feuilles des plants.

- 5 traitements ont été comparés, dont 1 témoin (cf. tableau n°1) :

1 : apport de 1 orius pour 20 thrips sur une population de thrips "faible",
2 : apport de 1 orius pour 100 thrips sur une population de thrips "faible",
3 : apport de 1 orius pour 20 thrips sur une population de thrips "forte",
4 : témoin. Pas d'apport d'orius sur une population de thrips "faible",
5 : apport de 1 orius pour 100 thrips sur une population de thrips "forte".

L'infestation artificielle de thrips *F. occidentalis* sous forme d'adultes et de larves de 2ème stade (origine Hyères et Centre de Balandran) a eu lieu du 2 au 23 avril sous forme de lâchers répétés, à partir du stade 8 feuilles des plants de concombre.

Elle a été homogène sur tous les plants des compartiments : le nombre moyen d'individus par plante est de 2,2 pour les traitements n°1, 2, 4 et de 11 individus par plante pour les traitements n°3 et 5.

Les adultes d'*Orius majusculus* ont été introduits en un seul lâcher le 7 mai (origine INRA d'Antibes) à raison de 16 points d'apport par compartiment. Les populations de thrips atteignent alors environ 250 individus par plant dans les traitements 2 et 4 et 1000 individus par plant dans les traitements 3 et 5. Seul le traitement 1 ayant subi le 27/4 un traitement généralisé Heptenophos (Hostaquick) contre les pucerons a une population de thrips plus faible.

(2) Ctifl Centre Technique Interprofessionnel des Fruits et Légumes

Tableau n°1 : Nombre d'orius introduits

Traitement	Population de thrips estimée /plante	Population de thrips estimée /feuille (25 feuilles /plant)	Niveau d'apport orius /F.o.	Nombre d'orius par m2	Nombre d'orius /point d'apport
1	100	4	1/20	5,5	20
2	250	10	1/100	2,7	10
3	1000	40	1/20	55	200
4	250	10	Témoin 0	0	0
5	1000	40	1/100	11	40

- Les conditions climatiques ont été homogènes dans les 5 compartiments. Les températures moyennes journalières sont de 21 à 24° d'avril à juillet et l'hygrométrie varie de 60 à 85 %.

2 - Observations

Les observations portent sur les 32 plants des 4 parcelles définies sur les 4 lignes centrales.

L'évolution des populations de thrips *F. occidentalis* et d'*O. majusculus* est suivie par des comptages hebdomadaires du nombre de proies et de prédateurs observés sur les feuilles (faces supérieure et inférieure).

Aucun comptage visuel sur fleur n'a été effectué.

Après contrôle rapide de l'homogénéité des populations de thrips dans les compartiments, d'un plant et d'une feuille à l'autre, l'échantillon a porté sur un plant par parcelle et 1 feuille sur 2 par plant.

Les 4 plants observés sont tirés au sort et sont identiques dans les 5 compartiments. Les larves, nymphes et adultes de *F. occidentalis*, de même que les larves et les adultes d'*O. majusculus* sont comptés in situ sur chaque feuille observée : les résultats sont exprimés en nombre d'individus calculé par plante.

RESULTATS

- Evolution des populations de thrips et d'orius en fonction du temps (cf. fig. n°1).

. Pour les traitements ayant la même quantité de thrips introduite, les populations évoluent de la même façon jusqu'au lâcher des orius.

. Les prédateurs se sont bien installés dans tous les compartiments. Les résultats du traitement 1 ne sont pas mentionnés suite à de nouvelles attaques de pucerons.

Deux types d'efficacité ont été observés :

- une efficacité immédiate due au prédatisme des nombreux adultes lâchés (55 par m2) observée dans le traitement 3 (population initiale de thrips forte, apport d'orius 1/10) : les populations de thrips (surtout les larves) chutent rapidement après l'introduction du prédateur. Parallèlement, les populations des orius (surtout les jeunes larves) augmentent jusqu'à 150 par plante, puis chutent la semaine suivante : cette chute est liée à la réduction des populations de thrips et au cannibalisme des larves.
- une efficacité des larves lorsqu'elles sont en nombre suffisant, soit environ 3 à 4 semaines après le lâcher, dans le traitement 5 (population initiale de thrips forte, apport d'orius 1/100 thrips) ou dans le traitement 2 (population initiale de thrips "faible", apport d'orius 1/100 thrips). Toutefois, dans le premier cas, les quantités de thrips étant plus fortes, la population continue d'augmenter et atteint les 1600 individus par plante ; le seuil de nuisibilité est dépassé et des dégâts importants sont observés sur les fruits. Dans le traitement 2, l'augmentation des thrips est plus lente (maximum de 700 thrips par plante) et les dégâts sont sans importance économique. Dans le même temps, la population du témoin, en l'absence du prédateur, dépasse les 4000 thrips par plante. L'introduction accidentelle d'orius a entraîné par la suite une réduction des populations de thrips.

En conclusion, la stratégie du traitement 2 apparaît la plus intéressante : les dégâts de thrips ont été faibles et les quantités d'orius apportées, raisonnables (2,7 par m2). Cependant, on peut penser qu'en serre de production, si les attaques de thrips interviennent sur des plantes jeunes, les apports d'orius devront être réalisés plus tôt avec un rapport proies/prédateurs plus faible.

- Comportement de *F. occidentalis* et *O. majusculus*

Suite aux comptages effectués et aux nombreuses observations réalisées en serre, plusieurs éléments peuvent être apportés sur le comportement du prédateur et de sa proie.

. Localisation sur la plante :

Les orius, larves et adultes, sont rencontrés sur l'ensemble de la végétation, sur les feuilles (limbe et pétiole), la tige, les fleurs, les fruits, voire même au sol, sur le plastique, à la recherche de proies en cas de fortes populations.

Les orius s'installent souvent entre les nervures, près du pétiole, ou dans les plis des feuilles pour muer. La plupart des oeufs sont insérés dans ou juste à côté des nervures (sur les deux faces de la feuille), principalement dans la zone proche du pétiole où la nervure est plus épaisse. Toutefois, des oeufs peuvent être observés dans le limbe, le pétiole et les fruits.

Les thrips sont surtout rencontrés sur les deux faces des feuilles et dans les fleurs.

La répartition des thrips et des orius donnée dans le tableau n°2 montre que les adultes se trouvent autant à la face supérieure qu'à la face inférieure, alors que les larves sont principalement à la face inférieure.

Tableau n°2 : Répartition des thrips et des orius sur les feuilles de concombre

	Face supérieure	Face inférieure
Thrips adulte	47,4 %	52,6 %
Thrips larve	21,7 %	78,3 %
Orius adulte	44,4 %	55,6 %
Orius larve	8 %	92,0 %

. Cycle de développement de l'orius :

Dans les conditions de l'essai (température moyenne d'environ 22°), les jeunes larves d'orius sont repérées moins de 7 jours après le lâcher des adultes.

La première génération d'adultes est observée 23 jours après le lâcher. Ceci confirme les données d'ALAUZET (1990) et de MILLOT (1991).

. Comportement de l'orius vis à vis des proies :

O. majusculus attaque la plupart des proies rencontrées dans la culture, ainsi que les adultes de *F. occidentalis*. Face à plusieurs ravageurs, il semble ne pas choisir sa proie et capture tout ce qu'il rencontre.

On peut cependant penser que la grosseur et la rapidité de la proie ont une incidence sur le nombre d'individus consommés ou tués.

On a pu noter aussi que, face à un nombre croissant de proies, *(Aphis gossypii, Tetranychus urticae)*, *O. majusculus* perd un peu de son efficacité sur le thrips *F. occidentalis* : les toiles tissées par les acariens et peut-être le miellat peuvent gêner son déplacement sur les feuilles.

CONCLUSION

Dans cet essai de lutte biologique, *Orius majusculus* s'est montré un prédateur intéressant pour contrôler les thrips *F. occidentalis* sur concombre.

En conditions de serres étanches aux insectes, avec une population de thrips et d'orius introduite de façon homogène sur la culture, le prédateur s'est bien installé et a contrôlé les populations de thrips mêmes importantes (en moyenne 40 thrips par feuille).

La stratégie d'apport de 1 orius pour 100 thrips sur une population assez faible (d'environ 10 thrips par feuille) est apparue la plus satisfaisante, mais ceci reste à confirmer dans d'autres conditions.

Plusieurs points sont encore à préciser et sont abordés en 1991 : l'étude du comportement en serre de production sur concombre, mais aussi sur poivron et fraisier, l'étude du comportement en conditions de jours courts, l'étude de la toxicité des pesticides sur *Orius sp* et la mise au point de la stratégie d'apport.

BIBLIOGRAPHIE

ALTENA, K., RAVENSBERG, W.J., 1990. Integrated pest management in the Netherlands in sweet peppers from 1985 to 1989. Bulletin SROP XIII/5 1990 : 10-13.

BOURNIER, A., BOURNIER, J.P., 1987. L'introduction en France d'un nouveau ravageur *Frankliniella occidentalis*. Phytoma, Défense des Cultures n°388 : 14-17.

GRASSELLY, D., TROTTIN-CAUDAL, Y., TRAPATEAU, M., CASTANY, CH., 1989. Comportement des larves de *Thrips tabaci* et *Frankliniella occidentalis* sur différents mélanges thripstick + insecticide en conditions de laboratoire. Compte rendu d'essai Ctifl 1988.

GEBRE SELASSIE, K., CHABRIERE, C., MARCHOUX, G., 1988. Un virus qui se réveille : le Tomato Spotted Wilt sur cultures légumières et florales. Phytoma, Défense des Cultures, n°410 : 29-35.

GILKESON, L.A., MOREWOOD, W.D., ELLIOT, D.E., 1990. Current status of biological control of thrips in canadian greenhouses with *Amblyseius cucumeris* and *Orius tristicolor*. Bulletin SROP XIII/5 1990 : 71-75.

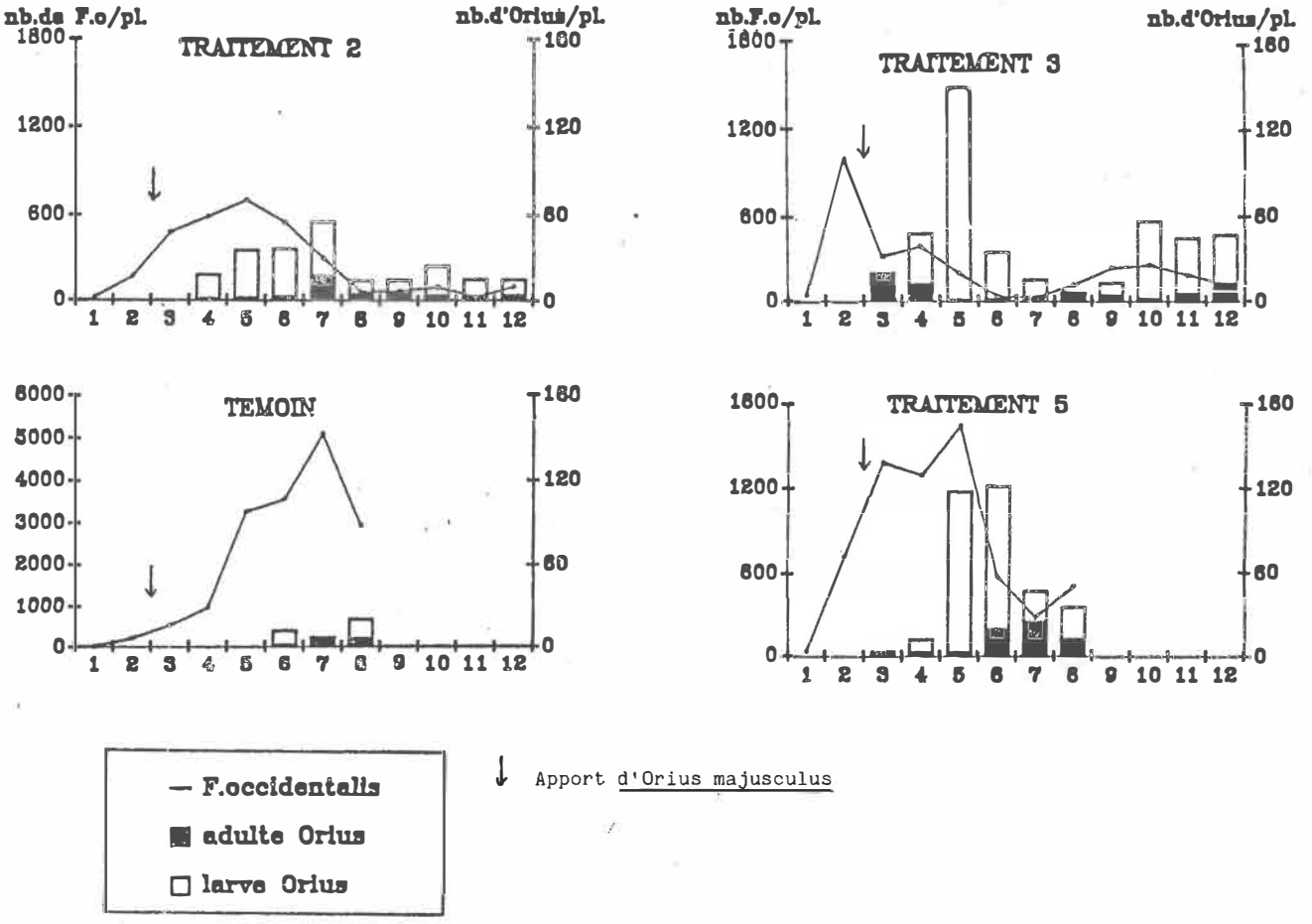
RAMAKERS, P.M.J., 1990. Manipulation of phytoseiid thrips predators in the absence of thrips. Bulletin SROP XIII/5 1990 : 168-172.

STEINER, M.Y., TELLIER, A.J., 1990. Western flower thrips *Frankliniella occidentalis* (Pergande) in greenhouse cucumbers in Alberta Canada. Bulletin SROP XIII/5 1990 : 202-204.

TROTTIN-CAUDAL, Y., GRASSELLY, D., 1989. Le problème *Frankliniella occidentalis* en culture sous abri. Situation et perspectives. PHM n°293 : 30-33.

TROTTIN-CAUDAL, Y., GRASSELLY, D., VILLEVIEILLE, M., 1990. *Frankliniella occidentalis* en France. Situation du ravageur et perspectives de lutte intégrée. Annales de l'ANPP n°3, vol III, 1990 : 1053-1063.

FIGURE n°1 : Evolution des populations de thrips et d'orius dans les 4 traitements



LUTTE BIOLOGIQUE CONTRE *Frankliniella occidentalis* AVEC *ORIUS laevigatus* sur fraisier.

Marc Villevieille (1) , Pierre Millot (2)

(1) GRISP,Domaine St Maurice, BP94, 84143 Montfavet, France
(2) INRA, Station de zoologie et de lutte biologique
37, Bd du cap 06006 Antibes, France

SUMMARY

Frankliniella occidentalis causes important losses of strawberry in southern France. The efficacity of *Orius laevigatus*as a biological control agent of *Franklinie*alla *occidentalis* was tested under experimental conditions. Results indicated that populations of *Orius laevigatus* establish readily on strawberry and that this beneficial insect offers an important possibility for the control of thrips.

1. INTRODUCTION

Depuis l'introduction de *Frankliniella occidentalis* en France d'importants dégâts ont été enregistrés sur culture de fraisier. Au début les variétés remontantes étaient plus particulièrement attaquées durant l'été et l'automne. Depuis 1988 on note des ravages de plus en plus précoces sur les variétés de saison.

C'est en Provence, sur la Cote d'Azur et dans le Sud-ouest de la France que les dégâts les plus importants sont enregistrés.

Avant floraison les thrips peuvent se développer sur les feuilles, les plantes attaquées ont alors une végétation plus réduite. A partir de la floraison l'essentiel de la population se retrouve sur les fleurs. Ces insectes provoquent une mauvaise pollinisation des ovules engendrant des fruits déformés car sans akènes ,la coulure des fleurs, l'aspect grisé et crevassé des fruits à maturité.
La lutte chimique est difficile à mettre en oeuvre :

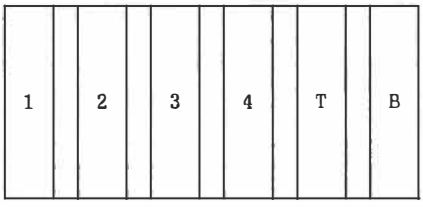
- peu de spécialités sont efficaces.
- la fréquence des récoltes empêche l'emploi de la plupart des insecticides du fait des délais de carence.

Il est de plus souhaitable que sur une culture comme la fraise on utilise le moins possible d'insecticides.
Des populations indigènes d'*Orius* sont régulièrement observées à partir de mai en culture de fraisier contaminées par les thrips. Il est donc apparu intéressant de tester l'activité de ce prédateur pour lutter contre *Frankliniella occidentalis* .

2.MATERIEL ET METHODE.

21.Dispositif et méthodologie.

L'étude a eu lieu dans une exploitation agricole de la région de Carpentras (84). La culture de fraisier variété Pajaro a été effectuée dans des tunnels plastiques de 8 m (d'une superficie voisine de 750 m_{ℓ}).



Implantation de l'essai.
T : tunnel mené chimiquement
B : tunnel mené en lutte intégrée

La culture de fraisier a succédé à une courgette cultivée en été 89. Après plantation au mois d'août elle a voisiné alors avec un poivron . Ces 3 cultures ont été très contaminées par *Frankliniella occidentalis* .

2 traitements ont été comparés:
- un tunnel mené en lutte intégrée avec *Orius laevigatus* (B).
- un tunnel mené en lutte chimique (T).

Aucune mesure prophylactique n'a été prise avant la plantation de fraises à l'automne.
Durant l'hiver un traitement insecticide (Tamaron) et herbicide (Round-up) des abords des tunnels a été effectué (les 17/2 et 22/2) . Ce traitement a été renouvelé le 4/5.

22.Observations réalisées.

Le 28/2 une étude d'échantillonnage a été menée de manière à préciser l'ordre de grandeur de l'échantillon à prélever pour une précision acceptable.

Nous avons choisi 150 fleurs correspondant à une précision voisine de 15% avec un niveau de probabilité de 90%, chiffres qui nous ont paru acceptables. (Etude effectuée avec le logiciel STAT-ITCF).

Un suivi hebdomadaire a été réalisé. A chaque fois une observation visuelle de la culture a été faite sur les tunnels B puis T suivie d'un prélèvement de 2 fois 25 feuilles et de 3 fois 50 fleurs . Ces prélèvements ont été faits sur les 2 rangs centraux de façon uniforme sur toute la longueur du tunnel mais par groupe de 5 échantillons à chaque arrêt.
Les observations ont débutées au 12/2 pour ce terminer au 5/6 avec la fin de la culture.

Chaque prélèvement a été placé dans un appareil de Berlése modifié par Bournier (extraction à l'essence de térébenthine) de manière a effectuer un inventaire exhaustif de la faune présente.

23.Réalisations des traitements.

231.Lâchers d'auxiliaires.

Le 16/02 : apport de 2000 *Phytoseïulus persimilis* soit 2,6 prédateurs au m^2.

Le 28/02 : apport de 29 tubes de 40 *Orius laevigatus* . Ces auxiliaires issus des élevages de l'INRA d'Antibes avaient 7 à 8 jours d'âge au stade adulte . Le lâcher a été effectué en début floraison.Les tubes sont déposés le matin dans la végétation.

Le rapport théorique R calculée a priori a été de 186.
Le rapport calculé a posteriori le 9/03 est de 110.

232.Traitements chimiques effectués.

2321.Tunnel T.

le 17/1 : Orthéne 50 contre pucerons et noctuelles.
le 18/1 : Appolo + Torque contre les tétranyques.
le 14/2 : Rovral contre le botrytis.
les 17/2 et 22/2 : Tamaron contre les thrips.
le 17/3 : Ronilan + Nimrod contre botrytis et oïdium.
le 29/3 : Sumisclex + Baytan MO contre botrytis et oïdium.
le 6/4 : Ronilan + Sabithane contre botrytis et oïdium.
les 4/5 et 9/5 : Dedevap contre les thrips.

2322.Tunnel B.

le 5/2 : Pirimor contre les pucerons.
le 14/2: Rovral contre le botrytis.
le 17/4: Nimrod contre l'oïdium.
le 27/4: Rubigan contre l'oïdium.
le 5/5 : Sabithane contre l'oïdium.

3.RESULTATS

31.Evolution des thrips dans le tunnel T.
Les thrips sont présents sur les feuilles dès le début de la culture (cf graphique n°2). Les traitements et les mesures prophylactiques ont permis de préserver la parcelle jusqu'au environs du 4/5 (cf graphique n°4) . A partir de cette date l'évolution est très rapide voire exponentielle . Les 2 traitements au Dedevap ne permettent pas d'enrayer la pullulation mais seulement de la stabiliser pour une semaine. Par la suite les dégâts sur la culture s'accentuent rapidement. La fin de culture voit les populations de thrips baisser du fait de la présence d'auxiliaires provenant du tunnel mené en lutte intégrée et de l'environnement: *Orius sp, Aeolothrips intermedius.* (cf graphique n°6)

32.Evolution des ennemis dans le tunnel B.

321.Le couple *Frankliniella occidentalis et Orius laevigatus*.

Frankliniella occidentalis est présent sur les feuilles dès le début de la culture (cf graphique n°1). A partir de la première fleur ceux-ci vont se déplacer jusque dans les pièces florales pour s'y développer plus intensément (cf graphique n°3). La population va stagner d'abord puis diminuer alors que le nombre d'adultes et larves d'*Orius* va croissant. (cf graphique n°5)
Le 11/05 à la suite de traitements chimiques insecticides dans les tunnels voisins une migration de thrips repoussé par les traitements a provoqué une remontée de la population qui recommence à, chuter vers le 5/06 grâce au contrôle du à *Orius* ,mais aussi peut être à *Aeolothrips intermedius, Amblyseïus californicus.* Ce dernier auxiliaire participe également au contrôle des populations d'acariens.

322.Autres ennemis.

Les premiers Tétranyques ont été identifiés le 28/05 .Ils n'ont commis aucun dégât. L'action conjuguée de *Phytoseïulus persimilis* d' *Amblyseïus sp* et des *Aeolothrips* prédateurs sont certainement la raison essentielle de ce résultat.

Le nombre de puceron dans le tunnel mené en lutte intégrée a toujours été inférieur à celui du tunnel chimique. Parmi les auxiliaires ayant participé au contrôle des pucerons il y a eu : des syrphes, des coccinelles ,des *Aphidius* ,des *Aphelinus* et aussi peut être des *Orius* .
La lutte intégrée pratiquée a permis de bien contrôler la plupart des ennemis : noctuelle défoliatrice, botrytis. Cependant la culture a subi d'importants dégâts dus à l'oïdium sur les fruits du fait de la volonté délibérée de ne pas traiter afin de ne pas gêner l'installation des auxiliaires.

4.Discussion.

41.Evolution des auxiliaires apportés.

Les *Orius laevigatus* se sont parfaitement bien implantés dans le tunnel mené en lutte intégrée. La durée de développement de la première génération a été voisine de 2 mois pour une température moyenne de 13°C. Il semble que cette première génération n'est pas immédiatement pondu sur les plantes dont elle était issue . En effet nous avons observé dans un premier temps une migration des femelles (pour la plupart) dans les tunnels voisins (avec très rapidement ponte et apparition de jeunes larves). Ce n'est que un mois après que nous avons pu observer d'assez nombreuses nouvelles jeunes larves pour pouvoir penser que les pontes des adultes de première génération avaient eu lieu.
Aucun des pesticide utilisé dans le tunnel B ne semble avoir profondément perturbé le développement de ces punaises.

42.Evolution des populations de thrips.

Dans les deux tunnels les fluctuations de population suivent assez bien soit l'évolution des auxiliaires soit les différents traitements insecticides.

5.Conclusion.

L'expérimentation menée en 1990 a mis en évidence l'intérêt de l'*Orius laevigatus* sur le contrôle de *Frankliniella occidentalis*. Il reste cependant à répondre à un certain nombre de questions (sur la biologie du couple ravageur*auxiliaire - sur les pesticides compatibles etc...) avant de développer cette technique.
De toute façon il va de soit que les mesures prophylactiques demeurent la base de la lutte contre les ravageurs en lutte intégrée .Ainsi le fort inoculum de départ en thrips a été intéressant pour le suivi des auxiliaires dans cet essai mais ne doit en aucun cas être donné en exemple comme une bonne base de départ pour la lutte intégrée.
Il est regrettable que l'essai n'est pas pu être poursuivi jusqu'à la fin juin pour voir d'une part s'il y avait éradication de la population de thrips dans la culture par les *Orius* et si ces derniers étaient capables de se maintenir en place .

BIBLIOGRAPHIE

ALTHENA K. , RAVENSBERG W.J., 1990. Integrated pest management in the Netherlands in swett peppers from 1985 to 1989 . Bulletin SROP XIII /5 1990 :10-13.

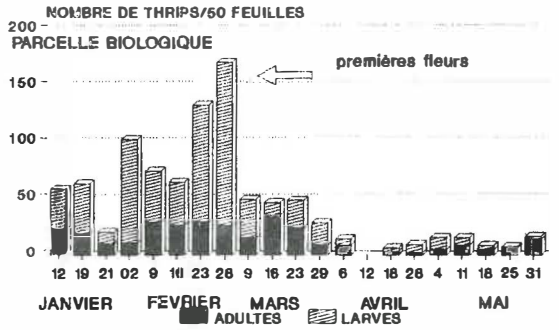
BOURNIER A., BOURNIER J.P., 1987 .L'introduction en France d'un nouveau ravageur *Frankliniella occidentalis*. Phytoma, Défense des cultures n°388 :14-17.

GILKESON L.A. , MOREWOOD W.D., ELLIOT D.E. , 1990. Current status of biological control of thrips in Canadian greenhouses with *Amblyseïus cucumeris and Orius tristicolor.* Bulletin SROP XIII /5 1990 :71-75.

TROTTIN-CAUDAL Y., GRASSELY D., 1989 .Le problème *Frankliniella occidentalis* en culture sous abri. Situation et perspectives . PHM n° 293 : 30-33.

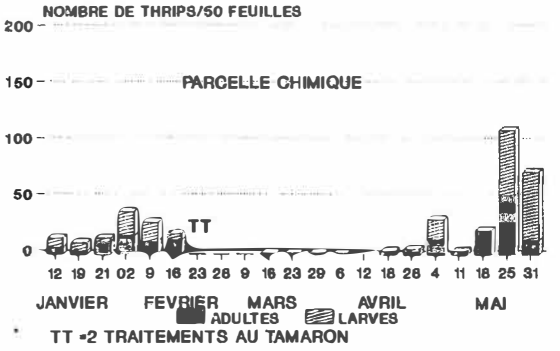
TROTTIN-CAUDAL Y., GRASSELY D., VILLEVIEILLE M., 1990. *Frankliniella occidentalis* en France :situation du ravageur et perspectives de lutte intégrée. Annales de l'ANPPP n°3, vol III, 1990: 1053-1063.

ESSAI FO/FRAISES
CARPENTRAS - 1990



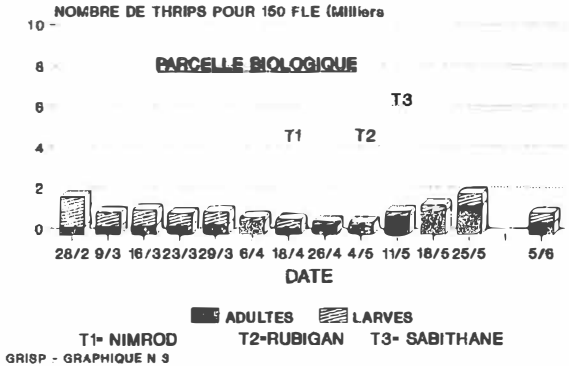
GRISP - GRAPHIQUE N 1

ESSAI FO/FRAISES
CARPENTRAS - 1990



GRISP - GRAPHIQUE N 2

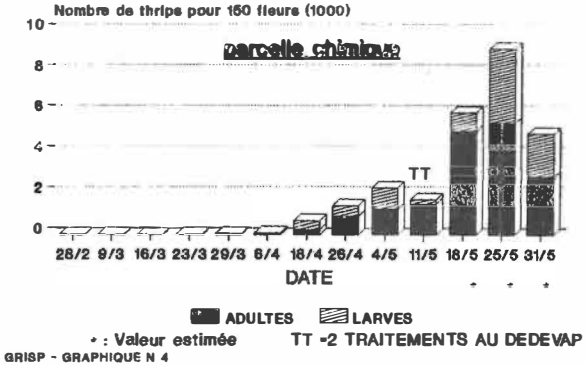
ESSAI FO/FRAISES
CARPENTRAS-1990



T1= NIMROD T2=RUBIGAN T3= SABITHANE

GRISP - GRAPHIQUE N 3

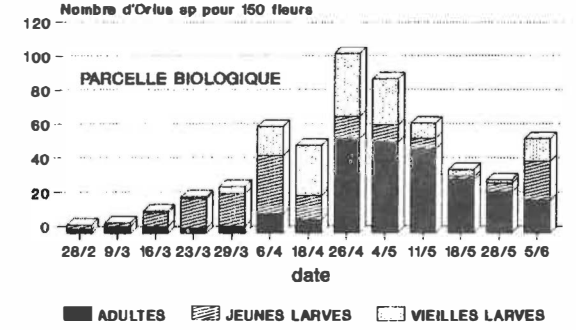
ESSAI FO/FRAISES
CARPENTRAS-1990



* : Valeur estimée TT =2 TRAITEMENTS AU DEDEVAP

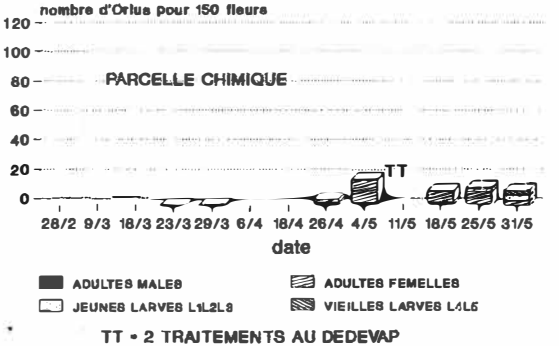
GRISP - GRAPHIQUE N 4

ESSAI FO/FRAISES
CARPENTRAS-1990



GRISP - GRAPHIQUE N 5

ESSAI ORIUS SUR FO/FRAISES
CARPENTRAS-1990



TT = 2 TRAITEMENTS AU DEDEVAP

GRISP - GRAPHIQUE N 6

RESEARCHES ON ORIUS LAEVIGATUS (FIEB.), A PREDATOR OF FRANKLINIELLA OCCIDENTALIS (PERG.) IN GREENHOUSES. A PRELIMINARY NOTE. (1)

L. TAVELLA, A. ARZONE and A. ALMA
Istituto di Entomologia agraria e Apicoltura
via Giuria 15 - 10126 Torino - ITALY

Summary
In the Albenga plain (Savona province, Liguria), in the last year Frankliniella occidentalis became a harmful pest of protected pepper cultivations. On this plant it caused necrosis on leaves and depigmentations on fruits. The pesticides were not sufficient to control its populations that appeared uncontainable compromising the crop. The autochthonous anthocorid Orius laevigatus resulted to be very efficient in controlling the western flower thrips. This predator arrived inside pepper greenhouses a short time after F. occidentalis and it prevented the multiplication of the thrips in the greenhouses with integrated pest management (IPM). In these pepper cultivations the plants did not show any foliar and fruit alterations. Researches are in progress to ascertain life history, usual victims, and host plants of the above mentioned anthocorid with the aim to use it in the biological control of the western flower thrips.

1. Introduction

In Italy, the thrips Frankliniella occidentalis (Perg.) was reported at first on saintpaulia (Rampinini, 1987) and chrysanthemum (Arzone et al., 1989), and it soon became one of the most worrying pest on vegetable and flower cultivations. This widely polyphagous insect is able to infest several plants, both in greenhouse and outdoor, on which it causes dechlorophyllations, writhings, desiccations, and malformations (Ciampolini et al., 1990). It is also one of the most efficient vectors of the tomato spotted wilt virus (TSWV), that was found in Liguria on cultivations of anemone, lisianthus, pepper, ranunculus, and tomato (Lisa et al., 1990).

Investigations on the possibility to refrain this thrips, above all by means of biological control, are carried out all around the world. Among the most studied enemies that can be used on the attacked plants, the following species have to be remembered: the mites Amblyseius barkeri (Hughes) and Neoseiulus cucumeris (Oud.), and the anthocorid Orius tristicolor (White) (Castagnoli et al., 1990; Hessein & Parrella, 1990; Tellier & Steiner, 1990).

(1) Studies of the C.N.R. coordinate research unit for Integrated Control of Plant pests: 294.

During the surveys that were made within a project of integrated pest management (IPM) on protected pepper cultivations, an anthocorid in trophic activity on F. occidentalis was constantly found. Since the finding seemed very interesting, this predator was immediately investigated in order to ascertain its identity, diffusion and role in the control of the western flower thrips.

2. Materials and methods

These researches were carried out by means of field surveys and laboratory investigations in the period from April to December 1990.

Surveys took place in the Albenga plain, province of Savona, on protected pepper cultivations. Among the 14 investigated farms, 9 used integrated pest management, the remaining 5 employed chemical control. The following treatments were suggested to the farms using integrated pest management: 1 treatment with endosulfan before planting, then possible localized treatments with dicofol against tarsonemids, pirimicarb against aphids, Bacillus thuringiensis Berl. against moths, 1 or 2 treatments with triadimefon against mildew, releases of Phytoseiulus persimilis Athias-Henriot against tetranychids. In the farms where chemical control was used, interventions were made employing acephate, dicofol, endosulfan, flucythrinate, heptenophos, methiocarb, methomyl, permethrin, pirimicarb, propargite, tau-fluvalinate, tetradifon, triadimefon.

During the surveys, the infestation dynamics of F. occidentalis together with the presence and the trophic behaviour of the natural enemies were observed. In the same time, postembryonic stages of the predator and pepper flowers and leaves were collected.

The infestation rate of the western flower thrips and the presence of the anthocorid were ascertained at the end of summer by means of a sampling in 10 pepper greenhouses, of which 5 using integrated pest management, 5 employing chemical control. In every greenhouse this sampling was made collecting 90 flowers and 30 leaves in 3 points along a diagonal in the initial (A), central (B), and final (C) positions, i.e. 30 flowers and 10 leaves per each point.

In the laboratory, the field collected material was examined so to count the thrips and the Heteroptera and to take note of the alterations on the plants. Foliar symptoms were classified as slight, moderate, remarkable, and heavy when the depigmentations involved the blade respectively up to 20%, 50%, 75%, 100%.

Anthocorid adults, that were collected during the surveys, had so variable size and colour that the specific determination on the basis of morphological features was not possible. This determination was accomplished by means of the examination of male genital paramere and female copulatory tube in comparison with the drawings by Péricart (1972).

3. Results

All the anthocorids that were collected in the different farms

resulted to belong to the species Orius laevigatus (Fieb.) (Fig.1).

The adult had a length from vertex to hemelytral tip ranging from 1.8 mm to 2.2 mm in ♂ and from 1.8 mm to 2.6 mm in ♀. Oval-elongated body, fundamentally brown blackish in colour, with thin hairs. Head and pronotum bright black in colour. Yellowish antennae with 4 segments that were covered with thin whitish hairs; in ♂ the segments III and IV more or less darkened. Hemelytrae variable in colour from light brownish yellow to dark brown, with brown blackish cuneus and transparent membrane. Hyaline hindwings. Legs entirely yellowish or light yellow-brown, the metathoracic ones in ♂ and meso- and metathoracic ones in ♀ sometimes darker.

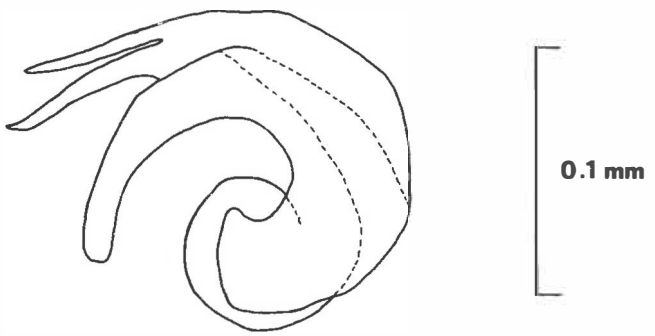


Fig.1 - Orius laevigatus (Fieb.). Male genital paramere.

In the Albenga plain, on protected cultivated pepper, the first attack of F. occidentalis was checked starting from mid-May. Adult thrips appeared when the plants were in the 1^{st}-2^{nd} floral stage and placed themselves above all in floral buds. About 10-15 days after the appearance of the western flower thrips, adults of O. laevigatus arrived in all greenhouses, but only in those with integrated pest management they became more and more abundant inside the infested pepper flowers and showed a strong predatory activity on the plant-sucking insect.

Since then, in the 9 investigated greenhouses with integrated pest management, the presence of the anthocorid resulted to be remarkable and almost constant with at least 1 specimen per floral bud during the whole productive cycle. Adults and nymphs of the predator were very abundant in the just opened flowers and fed on larvae and adults of F. occidentalis. The minute pirate bug laid its eggs in flower peduncles, stalks, and leaves. In these greenhouses the thrips were very scarce and remained localized in the flowers in such a poor quantity not to arouse any worry and not to provoke symptoms on the crops. At the end of the season, even if F. occidentalis was very rare, O. laevigatus was still well represented in pepper flowers.

In the greenhouses where chemical control was made, the thrips was continuing to multiply apparently undisturbed and colonized not only the flowers but the whole plant. The trophic activity of F. occidentalis caused the appearance both of necrotic small spots, that could involve the whole foliar blade, and of depigmentations on the fruits that were very evident on the red pepper cultivar. In

Table 1 - Presence of Orius laevigatus (Fieb.) and Frankliniella occidentalis (Perg.) in pepper flowers both in greenhouses with IPM and chemical control at the end of summer.

greenhouses	control methods	samplings	Orius laevigatus					Frankliniella occidentalis
			total	♂♂	♀♀	neanids	nymphs	
1	IPM	A	22	1	2	1	18	1
		B	23	1	6	3	13	-
		C	15	1	3	2	9	-
2	IPM	A	27	2	3	2	20	-
		B	12	5	3	1	3	1
		C	8	-	1	2	5	-
3	IPM	A	17	6	4	-	7	-
		B	37	10	8	-	19	-
		C	27	8	8	-	11	1
4	IPM	A	44	6	4	5	29	4
		B	64	2	3	3	56	-
		C	44	4	2	8	30	2
5*	IPM	A	3	-	3	-	-	102
		B	5	1	1	1	2	231
		C	-	-	-	-	-	41
6**	chemical	A	9	2	4	2	1	106
		B	4	1	-	1	2	146
		C	1	1	-	-	-	61
7	chemical	A	14	1	-	-	13	214
		B	8	3	-	-	5	325
		C	9	-	-	1	8	284
8	chemical	A	4	-	-	1	3	318
		B	1	-	-	-	1	486
		C	11	-	2	-	9	206
9	chemical	A	2	-	2	-	-	370
		B	5	-	3	-	2	358
		C	9	3	6	-	-	634
10***	chemical	A	2	-	2	-	-	757
		B	-	-	-	-	-	2323
		C	1	-	1	-	-	1108

* Greenhouse in which 1 treatment with pyrazophos was made
** Greenhouse in which treatments were stopped 2 months before
*** Greenhouse in which treatments were continuous

Table 2 - Presence of Orius laevigatus (Fieb.), Frankliniella occidentalis (Perg.), and symptoms on pepper leaves both in greenhouses with IPM and chemical control at the end of summer.

greenhouses	control methods	samplings	Orius laevigatus	Frankliniella occidentalis	
				no. specimens	symptoms
1	IPM	A	4 eggs, 1 nymph	-	no
		B	2 eggs	-	no
		C	-	-	no
2	IPM	A	3 eggs	-	no
		B	-	-	no
		C	1 egg	-	no
3	IPM	A	4 eggs	-	no
		B	-	-	no
		C	-	-	no
4	IPM	A	2 eggs	-	no
		B	1 egg	-	no
		C	-	-	no
5*	IPM	A	1 egg	5	slight
		B	-	-	no
		C	-	46	slight
6**	chemical	A	-	15	slight
		B	-	-	moderate
		C	-	-	moderate
7	chemical	A	-	58	remarkable
		B	-	31	moderate
		C	-	69	moderate
8	chemical	A	-	3	remarkable
		B	-	-	moderate
		C	-	3	moderate
9	chemical	A	-	36	remarkable
		B	-	6	remarkable
		C	-	8	moderate
10***	chemical	A	-	12	heavy
		B	-	10	moderate
		C	-	25	moderate

* Greenhouse in which 1 treatment with pyrazophos was made
** Greenhouse in which treatments were stopped 2 months before
*** Greenhouse in which treatments were continuous

spite of the many chemical treatments, at the end of the season the infestation was uncontainable.

Population density of both F. occidentalis and O. laevigatus and the phytopathological situation inside the greenhouses with integrated pest management and in those with chemical control, as they were checked at the end of summer, are reported in tables 1 and 2. For the right interpretation of these 2 tables it is necessary to keep in mind that in the greenhouse no.5 a treatment with the prohibited fungicide pyrazophos was made, in the greenhouse no.6 the treatments were stopped about 2 months before sampling, the greenhouse no.10 was continuously submitted to heavy chemical treatments.

4. Discussion

O. laevigatus is a mediterranean-atlantic species diffused in nearly all Italian regions (Servadei, 1967); it does not seem particularly linked to any host plant nor specific preys. In France it was collected above all on herbaceous and bushy plants, on which it feeds on mites, thrips, aleyrodids, aphids, and moths (Péricart, 1972). In Egypt it is commonly found also on crops, such as cotton, maize, and clover; on these plants, together with the other anthocorid O. albidipennis (Reut.), it contributes to control the offspring of mites, thrips, aphids, and moths (Tawfik & Ata, 1973; Afifi et al., 1976).

In the investigated pepper greenhouses, O. laevigatus arrived a short time after F. occidentalis, indipendently from control methods. On the other hand, the presence of this predator on the crops and its efficiency in containing the thrips resulted to be strongly affected by phytoiatric interventions. Actually in the greenhouses with integrated pest management the density of the thrips population remained very low, whereas in the greenhouses with chemical control the attacks were so high to compromise the final production. Such a population dynamics was observed also in trials carried out to test the efficiency of an unidentified Orius against Thrips palmi Karny on eggplant in greenhouses: on plants sprayed with pesticides, the thrips population quickly increased, while on the unsprayed ones, it remained at a low level owing to the controlling activity of the anthocorid (Nagai et al., 1988).

It is worthy to underline that O. laevigatus colonized naturally the infested pepper cultivations, without any artificial aid, and multiplied successfully when pesticide sprayings were lacking. In the greenhouse with integrated pest management where pyrazophos was incorrectly used, the increase of the western flower thrips shows how vulnerable is the minute pirate bug. In fact, pyrazophos was proved to be highly toxic towards the honeybee (Arzone & Patetta, 1981) and other useful arthropods (Ponti & Laffi, 1988).

The results of these first researches evidenced that O. laevigatus is very efficient in controlling F. occidentalis, it adapts very well to a protected environment, and it can survive even without preys. In the last trait, it seems to behave like O. tristicolor, that can feed on nectar (Yokoyama, 1978), but it lives longer and is more prolific in the presence of its victims (Stoltz

& Stern, 1978).

In Italy O. laevigatus is an autochthonous species but it is actually unknown from the biologic, ethologic and ecologic viewpoints. Investigations were started to ascertain the number of its generations, overwintering pattern, usual victims and host plants, preferred environment, and rearing suitability, so to test the possibility to use this species in biologic and integrated pest management programmes.

Acknowledgements - The authors are indebted with miss Malina Siccardi of the Cooperativa L'Ortofrutticola of Albenga for the assistance in field surveys.

5. References

AFIFI A.M., FARGHALI H.TH., REZK G.N. & RAGAB Z.A., 1976. Seasonal abundance of certain pests and predators in clover fields in Egypt. Bull.Soc.ent.Egypte 60: 273-278.

ARZONE A. & PATETTA A., 1981. Esame dell'azione sull'ape di alghe marine, paraquat, pyrazophos e trichlorphon in laboratorio. L'apicoltore moderno 72 (3): 87-95.

ARZONE A., ALMA A. & RAPETTI S., 1989. Frankliniella occidentalis (Perg.) (Thysanoptera Thripidae) nuovo fitomizo delle serre in Italia. Inftore fitopatol. 39 (10): 43-48.

CASTAGNOLI M., DEL BENE G., GARGANI E. & SIMONI S., 1990. Possibilità di controllo biologico di Thrips tabaci Lind. e Frankliniella occidentalis (Pergande) (Thys. Thripidae) con Amblyseius cucumeris (Oud.) (Acarina Phytoseiidae). Redia LXXIII (1): 53-61.

CIAMPOLINI M., TREMATERRA P. & TUMINO S., 1990. Dilagano le infestazioni di tripidi nelle colture floreali ed ortive. Inftore agr. 46 (1): 71-76.

HESSEIN N.A. & PARRELLA M.P., 1990. Predatory mites help control thrips on floriculture crops. California agriculture 44 (6): 19-21.

LISA V., VAIRA A.M., MILNE R.G., LUISONI E. & RAPETTI S., 1990. Tomato spotted wilt virus in cinque specie coltivate in Liguria. Inftore fitopatol. 40 (12): 34-41.

NAGAI K., HIRAMATSU T. & HENMI T., 1988. Predatory effect of Orius sp. (Hemiptera: Anthocoridae) on the density of Thrips palmi Karny (Thysanoptera: Thripidae) on eggplant. Jpn.J.Appl.Ent.Zool. 32: 300-304.

PÉRICART J., 1972. Hémiptères - Anthocoridae, Cimicidae et Microphysidae de l'ouest-paléarctique. Faune de l'Europe et du Bassin Méditerranéen 7, Masson et C^{ie} Ed., Paris: 1-402.

PONTI I. & LAFFI F., 1988. Schede fitopatologiche. Malattie crittogamiche delle piante da frutto. Ed.Inftore agr., Verona: 1-206.

RAMPININI G., 1987. Un nuovo parassita della Saintpaulia: Frankliniella occidentalis. Clamer informa 12 (1-2): 20-23.

SERVADEI A., 1967. Rhynchota Heteroptera Homoptera Auchenorrhyncha. Catalogo topografico e sinonimico. Fauna Ital. 9, Ed.Calderini, Bologna: 1-851.

STOLTZ R.L. & STERN V.M., 1978. The longevity and fecundity of Orius tristicolor when introduced to increasing numbers of the prey Frankliniella occidentalis. Environ.Entomol. 7 (2): 197-198.
TAWFIK M.F.S. & ATA A.M., 1973. The life-history of Orius laevigatus (Fieber) (Hemiptera: Anthocoridae). Bull.Soc.ent.Egypte 57: 145-151.
TELLIER A.J. & STEINER M.Y., 1990. Control of the western flower thrips, Frankliniella occidentalis (Pergande), with a native predator Orius tristicolor (White) in greenhouse cucumbers and peppers in Alberta, Canada. SROP/WPRS Bull. XIII (5): 209-211.
YOKOYAMA V.Y., 1978. Relation of seasonal changes in extrafloral nectar and foliar protein and arthopod populations in cotton. Environ.Entomol. 7: 799-802.

COLLECTION AND FIRST EVALUATION OF HYMENOPTEROUS PARASITES OF THRIPS AS BIOLOGICAL CONTROL AGENTS OF *FRANKLINIELLA OCCIDENTALIS*

A.J.M. LOOMANS
Laboratory of Entomology, Wageningen Agricultural University
P.O.Box 8031, 6700 EH Wageningen, The Netherlands.

Summary

As part of a research program on the ability of hymenopterous parasites to control western flower thrips (*Frankliniella occidentalis* (Pergande)), a number of candidates has been collected through correspondence and active search. A collection trip was made to the South of Europe during September 1990. *Ceranisus menes* (Walker) (Hymenoptera: Eulophidae), a larval parasite of thrips, was collected as female adults and parasitized hosts from protected cultures and wild vegetation sites inhabited by *F. occidentalis* and closely related species at several locations (The Netherlands, France, Italy). Adults and pupae of *C. menes* were also recieved from Japan. Preliminary experimental tests indicated that *C. menes* was able to attack and develop on *F. occidentalis* and *Frankliniella schultzei* (Trybom). Rearing methods for thrips and parasites are discussed. Development of *C. menes* took 23-30 days at 25 oC and 28-34 days at 20 oC. In rearing units upto 35 -105 hosts were parasitized per female, numbers depending on its origin. *C. menes* reproduced parthenogenitically: only females were produced. Other parasites of thrips were not able to develop themselves on *F. occidentalis* in the laboratory. Future topics of research are outlined.

1. Introduction

Since its introduction in 1983, the western flower thrips, *Frankliniella occidentalis*, rapidly has spread throughout Europe and presently is the number one key pest in many greenhouse crops. As IPM programs already developed are often seriously endangered, major efforts are put into improvement and development of biological control methods using agents capable of controlling thrips. Research on predators and pathogens has not yet resulted in a satisfactory solution or are still in an experimental phase. As no attempts have been made using hymenopterous parasites as biological control agents of *F. occidentalis*, we recently have started research on this matter (Loomans & Van Lenteren 1990). In order to investigate their potential and starting a new biocontrol program, the procedure is followed developed earlier at our laboratory (Van Lenteren 1986). Literature information on thrip parasites (Loomans & Van Lenteren 1990) pointed out a number of potential candidates. From the 36 species of thrip parasites known in literature (*ibid*, supplemented by Boucek 1988 and Polaszek pers. comm.), only one was found in association with *F. occidentalis* attacking alfalfa in Alberta-Canada in 1922 (Seamans 1923). It was found earlier in 1912 in Utah-USA and descibed as *Ceranisus americensis* Girault (Girault 1917). No proof was found however of its ability to attack and develop on western flower thrips and it has never been reported since. 12 other parasite species have been recorded as parasitizing closely related species (*Frankliniella, Thrips* etc.) within the same subfamily (Thripidae: Thripinae). This paper deals with the collection, rearing and first evaluation of some of these parasites.

2. Collection of thrip parasites

2.1. Working programme

As outlined above, research on this topic had to be started almost from scratch. Therefore our search for suitable candidates was very general at first, directing our attention to:

1. the collection of parasites of *F. occidentalis* itself, in its original area of distribution (southwestern USA, northwest Mexico) as well as in newly invaded areas (e.g. Europe);
2. the collection of parasites of closely related species, distributed worldwide.

As only few parasite species of the latter group have been reared in the laboratory, sampling *Frankliniella* populations in the field would be an important means to collect candidates. It was our strategy to start collection partly by having material sent from different parts of the

Table 1: Parasite species (Hymenoptera: Chalcidoidea: Eulophidae) attacking thrips (Thysanoptera), their geographical distribution in Europe and host range (situation 1990).

Parasite species	Distribution	Hosts	Reference
Ceranisus lepidotus	Great Britain	?	Graham 1963
Ceranisus menes	Great Britain	?	Walker 1839*
	Germany	*Kakothrips robustus*	Buhl 1937
		Thrips flavus	Buhl 1937
	France	*Kakothrips robustus*	Vuillet 1914
		Thrips tabaci	Dessart & Bournier 1971
		Thrips tabaci	Carl (CAB 1971)
	Italy	*Thrips tabaci*	Domenichini pc
	Spain	?	Gijswijt pc
	Greece	?	Gijswijt pc
	The Netherlands	?	Gijswijt pc
	USSR: Moldavia	?	Boucek 1961*
	Mordovin	?	Antsiferova et al. 1974
	Czechoslovakia	?	Boucek 1957*
	Poland	?	Miczulski 1968*
	Hungary	?	Erdös 1971
	Bulgaria	?	Pelov pc
Ceranisus pacuvius	Great Britain	?	Walker 1838*
	Denmark	?	Bakkendorf 1957*
	Czechoslovakia	?	Boucek 1957*
	Austria	?	Kirchner 1867*
	Switzerland	*Kakothrips robustus*	Kutter 1936
	USSR: Moldavia	?	Boucek 1961*
	The Netherlands	*Kakothrips robustus*	Franssen 1960
Ceranisus planitianus	Hungary	?	Erdös 1966*
Ceranisus russelli	Great Britain	*Thrips paluster, T. tabaci, Taeniothrips picipes, T. atratus, T. ericae, Frankliniella intonsa* (?)	Bagnall 1914
Ceranisus sp.	Central Europe	?	Graham 1963
Thripastichus gentilei	Italy	*Liothrips oleae*	Del Guercio 1911*
	Yougo-Slavia	*Liothrips oleae*	Tominic 1950*
	Spain	*Gynaikothrips ficorum*	Lacasa pc
	France	*Gynaikothrips ficorum*	Bournier 1967
	Germany	*Hoplothrips pedicularius*	Domenichini 1966
Entodonastichus albicoxis	Hungary	?	Szelényi 1982
Entedonastichus carbonarius	Czechoslovakia	?	Boucek 1957*
	Hungary	?	Erdös 1954*
	Bulgaria	?	Pelov pc
Entedonastichus gaussi	Germany	*Liothrips setinodes*	Ferrière 1958
	USSR: Ukrain	*Phlaeothrips coriaceus* a.o.	Dyadechko 1964 (1977)
Goetheana sp.	Bulgaria	?	Pelov pc
Megaphragma sp.	Bulgaria	?	Kostadinov (Pelov pc)
unknown	Finland	*Chirothrips hamatus*	Hukkinen 1936
unknown	Switzerland	*Taeniothrips inconsequens*	Carl et al. 1989
unknown	The Netherlands	*Kakothrips robustus*	Franssen 1960
unknown	Czechoslovakia	*Taeniothrips laricivorous*	Kratochvíl et al. 1942
(*Aphanogmus fumipennis*)	France	*Thrips tabaci*	Dessart & Bournier 1971

underligned: Thripinae, not underligned: Panchaetothripinae (Thripidae); ? : host (species) unknown; (..): occasional record on thrips host; pc = personal communication; * : in Boucek & Askew (1968)

world through correspondence and partly through active searching by ourselves in Europe.

Specialists working on thrips, parasites or both, taxonomists as well as researchers of biocontrol were requested for information on the occurrence and collection of parasites and thrips. At the IOBC meeting in Copenhagen a "search letter" was spread, explaining our topic.

Except regular sampling of *Frankliniella* populations in The Netherlands, we thought that in Europe the Mediterranean Area would be the most appropriate region to search for thrip parasites:

* this region probably fits best the ecological conditions of glasshouses in northwest Europe and the original area of distribution of the western flower thrips, California. In this region *F. occidentalis* rapidly has become a major pest, in protected as well as outdoor crops (Spain 1986 - Lacasa 1989; Portugal 1989 - Guimaraes & Lopes 1990; France 1986 - Bournier & Bournier 1987; Italy, especially Sardinia and Sicily 1988 - DeWit pers.comm.).
* twelve parasite species have been described in European literature (table 1) attacking thrip hosts. Most of them were incidental taxonomic records, collected by sweeping vegetation. Most recent records on field observations of parasites attacking Thripidae originated from the Mediterranean Area (Carl (CAB 1971), 1989, Dessart & Bournier 1971, Domenichini pers. comm., Gijswijt pers. comm.). It was thought that the chance of finding parasites would be greatest at the end of the season, when *F. occidentalis* and crops were still present and there would have been a parasite population build-up during the summer. We therefore planned the trip for September 1990.

2.2. Methodology

Collection material & methods

For the collection of live thrips and parasites we used general devices and advise described in literature (Lewis 1973, Bournier 1983, Noyes 1982) and those described by Sakimura (1937). No special sampling plan was followed. The presence of thrips and parasites on the sampling spot was verified by tapping flowers, beating vegetation above a white surface. Samples of plant material were taken into the laboratory and/or hotel room and sorted out. Adult parasites found were aspirated and put into vials supplied with honey and stored in a cooling box (about 12 C) and brought into contact with young thrip larvae later, using the rearing methods descibed below. Rearing conditions: partly trunk of the car (20-35 C), partly laboratories and hotel rooms on the way. Samples of larvae collected were transferred into rearing tubes described below. No dissections of larvae were made. At every sampled spot, adult thrips were collected and put on alcohol 70 % for identification.

Area and vegetation searched

In the Netherlands thrip infested field crops (pea, onion. leek, cabbage) and wild vegetation were sampled regularly. Occasionally protected crops were sampled as well. During our collection trip in the South of Europe, we concentrated our search to the major vegetable growing areas: Provence (France), Emilia Romagna and Po Valley (Italy), Maresme, Valencia and Murcia region (Spain). There several crops, vegetables as well as ornamentals, field crops as well as protected crops, were searched and sampled for thrip parasites. Special attention was paid to abandoned crop-sites, crops controlled biologically or grown biodynamically, field and glasshouse edges. Crops searched were cucumber, sweet pepper, egg-plant, piment, strawberry and french bean (vegetables), gladiolus, carnation, chrysanthemum and rose (ornamentals), alfalfa, onion and leek. Colleagues working on biocontrol and familiar with the local occurrence of thrip infestations and language were our guides. During travelling in between these areas we concentrated our search on wild vegetation, especially flowers.

2.3. Collection results

Collection results are presented in table 2 and table 3. Only those sites are mentioned were parasites, as adults or larvae, were collected. Individuals collected during fieldsampling were all females and all belonged to the same species, *Ceranisus menes* (Walker) (Hymenoptera: Eulophidae). Females of different origins differed however in colouring of the abdomen, varying from yellow and buff to brown with a pale base.

In field crops in The Netherlands on one occasion only a female of *C. menes* was found : July 4th in a private pea plot at Venzelderheide. In the laboratory it readily attacked first stage larvae of both *F. occidentalis* and *F. intonsa*, but rearing was not successful. In November 11 females of *C. menes* were found inside a glasshouse amongst a mixed population of *F. occidentalis* and *Frankliniella schultzei* (Trybom) inhabiting cactusflowers. In an additional sample of larvae 107 (15 %) parasite pupae were found.

Table 2: Collections of the parasite *Ceranisus menes* (Walker) (Hymenoptera: Eulophidae) at different localities, host plants sampled and thrip species (Thysanoptera) present (single occurences omitted). Adult parasites producing offspring are given between brackets. + = rearing of larvae failed, - = no larvae sampled/found.

Locality	hostplant	thrip species	date 1990	parasite adults	pupae	abdomen colour	
THE NETHERLANDS							
Venzelderheide	Pisum sativum	*Thrips fuscipennis* *Thrips major* *Thrips tabaci*	04.07	1 (0)	0	brown	
Reeuwijk	Cactaceae	***F. occidentalis*** *Frankliniella schultzei*	19.11	11 (9)	110	buff	g
		ibid.	02.11	3 (0)	-	-	ga
ITALY							
Bologna (San Luca)	Trifolium repens	*Frankliniella pallida* *Frankliniella intonsa*	13.09	1 (0)	0	brown	
	Hieracium sp.	*Frankliniella pallida* *Frankliniella intonsa* *Thrips hispanicus* *Thrips hukkineni* ***F. occidentalis***	13.09	0 (0)	14	brown	
Pietra Ligure	Centranthus ruber	*Thrips brevicornis*	16.09	16 (0)	+	brown	
FRANCE							
Beausoleil	Centranthus ruber	*Thrips tabaci* *Thrips brevicornis* ***F. occidentalis*** *Thrips (fuscipennis?)*	11.09	7 (0)	+	brown	
Pernes les Font.	Hieracium sp.	*Thrips hukkineni* *Taeniothrips hispanicus* ***F. occidentalis***	18.09	4 (0)	-	brown	
Salon de Prov.	Centranthus ruber	***F. occidentalis*** *Thrips tabaci*	29.09	1 (0)	0	brown	
St. Maximin (A)	Centranthus ruber	*Thrips tabaci* *Thrips brevicornis*	29.09	6 (1)	1	brown	
St. Maximin (B)	Centranthus ruber	*Thrips brevicornis* *Thrips tabaci*	29.09	4 (3)	0	brown	
Brignoles	Medicago sativa	*Thrips tabaci*	29.09	2 (0)	-	brown	
Hyères	Rosa sp.	***F. occidentalis***	17.09	6 (0)	0	brown	g
			28.09	66(29)	113	brown	g
	Lantana sp.	--	28.09	1 (0)	-	brown	
Jonquières-Saint-Vincent	Hieracium sp.	*Thrips tabaci* *Taeniothrips pallidivestis* *Thrips hukkineni* *Taeniothrips hispanicus*	18.09	2 (0)	-	brown	
Perpignan	Polygonum auberti	*Thrips major gracilicornis* *Thrips tabaci*	18.09	20 (2)	+	brown yellow	
		ibid. *(Taeniothrips sp.)*	27.09	152(74)	10	brown yellow	

g: collected inside glasshouses a: leg. K. Maasbach/G. Vierbergen (Plant Protection Service)

In the Mediterranean Area collection was most successful in the south of France. At several locations adults of *C. menes* could be collected from flowers of wild vegetation, inhabited by various thrip species belonging to the genera *Frankliniella, Thrips* and *Taeniothrips* (Thripidae: Thripinae) (Table 2). In samples from 2 locations parasitized larvae were found (table 3). Collection of parasites of thrips was less successful in cultivated crops in France as well as Italy and Spain. On one occasion adults of *C. menes* were collected from rose flowers inside a glasshouse at Hyères (France), infested with *F. occidentalis*: in 93 flowers of different varieties 66 adults were present and from an additional 800 larvae sampled 113 pupae were collected.

In Northern Italy, it was difficult to locate thrip infested crops. No recoveries of thrip parasites were made there. Only at one location, a natural reserve field near Collina San Luca (Bologna), recoveries of *C. menes* could be made (table 2 and 3) as adult and parasitized larvae. In the same locality this parasite was collected earlier in August (Gavazzi pers. comm.).

In Spain half of September population densities of *F. occidentalis* already were at its decline after severe attacks earlier that year. In the south (Murcia and Valencia region), most of the greenhouse crops already had been harvested. *F. occidentalis* still was present but in low numbers, on crops (piment, sweet pepper) as well as wild vegetation. In spite of sampling several crops and wild vegetation no thrip parasites were found. *F. occidentalis* was more abundant in the north, but here also no parasites were found.

Adult parasites collected, readily attacked first stage larvae of *F. occidentalis*, when brought into contact with them, but while travelling rearing was successful on one occasion only. Therefore adults collected at the end of the trip were stored at 12 oC until they arrived at our laboratory. Artificial rearing of sampled larvae on pollen and honeysolution was more successful (table 3). However the system used (after Murai 1990, see below) was quite vulnerable under travelling conditions and a number of rearings failed. Parasites and thrips both reared from a single batch of sampled larvae (table 3) can give an indication of the possible relationship between *C. menes* and the thrip species found.

Other natural enemies were not actively searched for, but *Orius* spp. were seen on a number of occasions in crops and vegetation inhabited by thrips in Italy, France as well as Spain. *Amblyseius californicus* was found regularly in association with thrips in several crops (cucumber, strawberry) at the Spanish east coast, but its relation to thrips still has to be investigated.

Table 3. Number of parasites (*Ceranisus menes*) present in batches of thrip larvae collected from host plant flowers at different localities, autumn 1990. Thrip larvae were reared to maturity using an artificial method on pine pollen and honeysolution 10 %. Only batches containing parasites are listed.

Locality	hostplant species	thrips number	species	parasitized larvae number	%	adults emerged	
Reeuwijk (Nl)	Cactaceae site 1	425	***F. occidentalis*** *F. schultzei*	107	15 %	83	g
	site 2	46	*ibid.*	3	7 %	0	g
Hyères (Fr)	Rosa sp.	800	***F. occidentalis***	113	14 %	66	g
Perpignan (Fr)	Polygonum auberti	40	*T. major grac.* *T. tabaci*	10	25 %	1	
St. Maximin (Fr)	Centranthus ruber	12	*T. tabaci* *T. brevicornis*	1	8 %	0	
Bologna (I)	Hieracium sp.	90	*F. pallida* *F. intonsa*	14	15 %	6	

g: collected inside glasshouses

3. Laboratory experiments

3.1. Development of a rearing method for thrips and their larval parasites

In literature several methods of rearing thrips have been desrcibed (see Lewis 1973, Boumier 1983). Efforts of rearing thrip parasites during many generations in the laboratory are recorded much less: Sakimura (1937) reared *C. menes* using *Thrips tabaci* on onion leaves and whole plants, Narayanan (CAB 1971) reared the same host-parasite system using bean pods and recently Murai (1990) developed an artificial method. For experimental rearing of thrip hosts and *C. menes* following methods proved to be useful:

1. Artificial rearing.

This method developed by Murai (1990), generally applied for flower inhabiting thrip species, also proved to be successful for rearing *F. occidentalis* and *C. menes*.

For oviposition and rearing of thrips and parasites, in general the procedure was followed as outlined by Murai (1990). Glass and perspex tubes (8 cm diameter and 5 cm depth) were used for oviposition and development respectively. Parafilm M was used as covering. Thin streaks of honey were placed on the side of the tube for parasite feeding. When parasite prepupae and pupae occurred they were transferred onto a piece of moist filterpaper and put into a small glass jar on an agar layer to prevent them from drying out. Adult parasites were stored after emergence at 15 oC and supplied with honey until usage.

2. Rearing on bean pods.

This method for rearing *F. occidentalis* was first adopted by Bailey & Smith (1956) and has been used many times since. It also proved to be useful for rearing *F. schultzei* (Trybom). The method described below (after Wijkamp & Peters, pers. comm.) was used for rearing parasites. Glass jars (0.5 liter) covered with fine mesh gauze (80 micron), served as rearing units for both thrips and parasites. To give thrips and parasites opportunity to pupate, 10-15 layers of coarse paper (3x4 cm) were placed on the bottom of the jar. Fresh french bean pods were put on top, pollen was supplied as an additional food source and adults of *F. occidentalis* were introduced. Units were checked at regular intervals.

For parasite rearing, bean pods which stayed in the thrip rearing unit for 1-3 days were used. Bean pods were cleaned and transferred into a new unit, similar to that described above. At 25 oC, 3-4 days after adults of *F. occidentalis* had started ovipositing, first larvae emerged. When larvae were 2-4 days old, 10 female parasites (varying in numbers from 5-15) were released in a single pot. Pots were checked every 2-3 days. 10-14 days after parasite introduction parasitized larvae had pupated in the paperlayer. Thrip adults that had emerged by then were removed. The paperlayers containing the parasite pupae were transferred into a glass jar and put at 20 or 25 oC. Emerging adults were put at 15 oC, supplied with honey, until usage.

3. Rearing on host plants.

Plants of french bean, *Phaseolus vulgaris*, reared in cages (40 x 30 x 30 cm), with fine gauze netting (80 micron) introduced with adults of *F. occidentalis* only served as a back up rearing of thrips and were not used for rearing parasites.

All experimental rearings were performed in climate rooms or incubators at 20 or 25 oC, at 45-55 % relative humidity and a 16 hour lightperiod.

3.2. Rearing results

Some overall results of the laboratory rearing experiments are presented in table 4. Using *Frankliniella* species as hosts, numbers increased during successive generations. In the rearing units adults reproduced for 4-5 days at 25 oC. Reproduction of *C. menes* differed, depending on the origin - yellow lines were more difficult to rear - and host species. Reproduction numbers were highest, using larvae of *F. schultzei* as hosts. Using *F. occidentalis* larvae as hosts reproduction numbers were less: upto 24.5 pupal offspring maximum were produced. Development and reproduction of *C. menes* were estimated from the rearing experiments as well. Females from all origins started parasitizing from the day of emergence onwards and developed from egg to adult within 23-30 days at 25 oC and within 28-34 days at 20 oC. Development of a female producing line of *C. menes* obtained from a laboratory culture from Japan (Murai, June 1990) was somewhat longer: 27-35 days and produced less offspring. Rearing however was not successful: within 5 generations this origin became extinct. Application of the bean pod method was more successful and less time consuming than the artificial method.

Table 4. Rearing results of different origins of *C. menes*, using both artificial and bean pod method and *Frankliniella* species (*occidentalis, intonsa and schultzei*) as hosts at 25 oC, 45-55 %RH and 16L:8D, maximum number of offspring per female observed when parasites were reared in groups of 10 (5-15) females per unit and rearing success (+++ : >1000; ++ : >100 offspring).

Origin	Maximin A M	Perpignan P	Hyeres H	Maximin B B	Reeuwijk E	Japan J
characteristic						
colour abdomen	brown	brown & yellow	brown	yellow (bright)	buff	yellow (barred)
adult starters	1	76	95	2	90	127
max. offspring (per female)	105.0	102.5	89.6	36.8	60.7	9.2
numbers (rearing success)	+++	+++b ++y	+++	++	+++	0

3.3. Behaviour studies

Behavioral observations were done in small glass tubes and petri-dishes. First and second instars of *Frankliniella* (*occidentalis, intonsa* or *schultzei*) were used as hosts.

C. menes searched for its hosts very actively: running on smooth parts of the surface, closely antennating an uneveness of the surface encountered and entering narrow crevices actively. It attacked both larval stages, pupal stages were attacked as well but no parasitization was observed. When standing still, it attacked larvae walking by within reach of approximately its own bodylength. After the host was contacted with the antennae, a short attack followed, the female inserted her ovipositor standing on her hind legs and turned around quickly facing away from the host larva. Most of the time the vigorously moving host was lifted up in the air, the parasite meanwhile preening its forelegs and/or antennae, sometimes the host larva and parasite stayed tail to tail. After 10-20 seconds a first instar larva became paralysed. A single oviposition took 30-50 seconds on average but could last upto 150 seconds. After that the host larva was put down, the parasite withdrew its ovipositor and walked away. Hostfeeding occured regularly: after the first cycle of attack, the parasite turned around, inserted its ovipositor standing on its hind legs, stinging the larva repeatedly, tapping its legs on the motionless larva. After 30-60 seconds it started feeding on the stinged spot upto 120 seconds. After that stinging and feeding was repeated frequently, until the host larva finally shriveled and died. The total sequence can take upto 12 minutes per single host.

The parasite attacked both stages, but parasitization was most successful in old first or young second stage larvae. Newly hatched larvae are killed more often and second stage larvae move vigorously, wagging their tail when attacked or dragging the parasite away, thus often preventing or escaping from attack. Second stage larvae of *F. occidentalis*, who are larger and move more vigourously than those of *schultzei* and *intonsa*, were rarely lifted. When standing tail to tail occasionally a second female simultaneously attacked the same larva. Females of all origins studied, Japanese as well as European, showed the same kind of behaviour. Similar oviposition behaviour has been described for *C. menes* originating from India (Carl 1971) and Japan (Sakimura 1937) attacking *T. tabaci*. There are some differences though: lifting was not described by Sakimura, whereas this was a constant characteristic in the Indian parasite and the average oviposition time was somewhat longer in Sakimura's description.

3.4. Other parasite species tested

Parasites from three other origins were introduced into our laboratory and a preliminary study on their effectiveness against *F. occidentalis* was carried out:

Thripobius semiluteus (Boucek), known as a parasite of leaf inhabiting thrip species belonging to the Panchaetothripinae (Thripidae) (Boucek 1976), was received in June 1990 from a laboratory culture in Holland, originating from the USA. It readily attacked and developed on first stage larvae of *Heliothrips haemorrhoidalis* (Bouché), but showed no reaction to first and second stage larvae of *F. occidentalis*

during behavioral observations. Rearing on *F. occidentalis* using both methods described, failed.

From Taiwan 58 pupae were received from a parasite attacking *Rhipiphorothrips cruentatus* Hood (Thripidae: Panchaetothripinae) in wax apple fields (Chiu 1984). However, only two adults emerged and died before testing. Described as *Ceranisus* sp., identification of both adults showed that they were similar to *T. semiluteus*, mentioned above.

Several hundreds of adults (males as well as females) of an eggparasite (*Megaphragma* spp. (Polaszek pers. comm.)) attacking *Megalurothrips sjöstedti* (Trybom) (Thripinae: Thripidae) in cowpea, were received as parasitized eggs from Benin. Preliminary tests on *F. occidentalis* failed, but a good rearing method needs to be developed before final conclusions can be drawn.

4. General discussion

C. menes is distributed almost worldwide (see Loomans & Van Lenteren 1990). Most records originate from eastern Asian countries, where it is abundant (Japan, Korea (a.o. Sakimura 1937), The Philippines (Ishii 1933), Taiwan (Chiu 1990), Thailand (Hirose 1990), India (Narayanan (CAB 1971)) and Indonesia (Van Heurn 1923)). Occasionally individuals have been reported from Dominican Republic (Russo 1928), Brasil and Argentina (as *Ceranisus rosilloi*, DeSantis pers. comm.), Australia and New Zealand (after revision, Boucek 1988). It has been successfully introduced into Hawaii (Sakimura 1937) and recovered later (Yoshimoto 1965). In Europe this species has been recorded on several occasions before (see table 1). Earlier samplings resulted in fairly low numbers collected (Carl surveying *Thrips tabaci*, CAB 1971), in others (Vuillet 1914 and Buhl 1937, working on *Kakothrips robustus*) high numbers were found. Collection results presented here indicate that *C. menes* was quite common in wild vegetation in the Mediterranean Area of France and Italy in autumn of 1990. Occasionally it was able to invade thrip infested cultures in glasshouses as well. Except possible preferences yet unknown of this parasite for certain host habitats, intensive chemical spraying practices certainly will have played a role in the low frequency of its presence in protected crops. Results published by Hirose (1989) also showed a very low % of parasitization by *C. menes* in sprayed crops in Thailand.

Sampling populations of *F. occidentalis* in The Netherlands as well as in the south of Europe during 1990, revealed that it was attacked by *C. menes*. By sampling wild vegetation inhabited by populations of *Frankliniella (intonsa, occidentalis, pallida, schultzei), Thrips (tabaci, major, brevicornis etc.)* and *Taeniothrips*, *C. menes* was also collected. Our rearing results show that it *C. menes* is able to attack and develop on *F. occidentalis* and *F. schultzei* in the laboratory as well as in the glasshouse. *C. menes* was found earlier in association with *F. occidentalis* collected from rose in September 1988 in Cabrils (Spain) (Bordas, pers. comm.), but at that time its relation was unknown. Autumn 1990 it has been collected by sampling roses infested with *F. occidentalis* in Israel on several occasions (Kuslitzky, pers. comm.). *C. menes* is known to parasitize larvae of many thrip species. Murai (1990) showed that it can be reared from *F. intonsa* in high numbers. It also has been recorded to attack and develop on *Thrips tabaci* (Sakimura 1937, Van Heurn 1923, Desart & Bournier 1971, Carl (CAB 1971), Murai 1988, 1990), *T. subnudula* (Narayanan (CAB 1971)), *T. palmi* (Hirose 1989) *T. hawaiiensis, T. coloratus, T. setosus* (Murai 1988, 1990), *T. flavus, Kakothrips robustus* (Buhl 1937), *Taeniothrips alliorum* (Kurosawa 1931), *Megalurothrips usitatus* (Chiu 1990), *Microcephalothrips abdominalis* (Sakimura 1937) and (probably) *Isoneurothrips fullawayi* (Yoshimoto 1965). All species mentioned are closely related and all belong to the same subfamily Thripinae (Thripidae). Daniel (1986) reported *Zaniothrips vicini* and *Retithrips syriacus* (Thripidae: Panchaetothripinae) as hosts.

Only females were collected during sampling and in the laboratory they reproduced parthenogenetically. During collections of *C. menes* in Europe only females have been found thusfar (e.g. Vuillet 1914, Buhl 1937). It is of interest to notice that in field collections of *C. menes* made in several Asian countries males are present as well, females mostly predominating (sexratio 0.60: Sakimura 1937 (Japan), Daniel 1986 (India); 0.47: Carl 1971 (India); 0.48: Hirose 1989 (Thailand); Van Heurn 1923). Murai (1990) recorded a gradual change in sex ratio in the laboratory: after several generations females reproduced parthenogenitically. This difference in unisexuals and bisexuals between these populations remains unclear.

Differences in colour of the abdomen of females collected at several origins in the field stayed consistent during laboratory rearing. Originally described from a yellow holotype (Vuillet 1914), later records of this species in literature refer to different types of colouring of the abdomen (e.g. Van Heurn 1923, Sakimura 1937). In many records however colouring has not been mentioned.

Other records (Sakimura 1937, Hirose 1989, CAB 1971, Daniel 1986, Murai 1990) on the biology of *C. menes* on other thrip hosts show similarities as well as differences, compared to our results, which might be explained by differences in origin of the parasite and in host species studied.

Differences mentioned above could indicate that possibly different biotypes of *C. menes* exist. Host preference and performance remain yet unclear. Results of our experiments are yet to premature to draw conclusions on the potential of *C. menes* to control *F. occidentalis*. Its ability to to parasitize 25 or more larvae per day and its very active searching behaviour seem promising. Its developmental time however is long in comparison to that of *F. occidentalis*. As developmental time of *C. menes* takes 10 days more on average, host and parasite generations will gradually become asynchrone. Its real effectiveness still has to be determined.

5. Future research

As *C. menes* is able to attack and develop on *F. occidentalis* in the field and in the laboratory, detailed studies are planned to evaluate its effectiveness, according to the procedure and selection criteria developed earlier at our laboratory (Van Lenteren 1986). Detailed experiments are planned on its biological characteristics at different temperatures and its searching efficiency will be studied. Collection of additional origins of this species and other potential candidates will continue.

6. Acknowledgements

Collecting natural enemies i.c. hymenopterous parasites of course cannot be done without the help of many willing cooperative hands. We like to thank Koppert Biological Systems for providing financial and logistic support. Donatella Gavazzi, Paolo Petrelli, Giorgio Nicoli (University of Bologna), Massimo Benuzzi (Biolab, Cesena), Renato Lama, Janny de Wit (Koppert Italia), Michel Allene, Alex Jauffret (Koppert France), Pierre Millot (I.N.R.A., Antibes), Rosa Gabarra, Oscar Alomar (I.R.T.A., Cabrils), Alex Ribes (Generalitat Valenciana, Silla) and last but not least Alfredo Lacasa Placensia (C.R.I.A., La Alberca-Murcia), they were all without exception perfect guides in a new world. We also like to thank Bert Vierbergen (Dutch Plant Protection Service) for his identification of thrips species and John LaSalle (C.I.E., London) for confirmation on the identity of Ceranisus menes. We especially appreciate Tamotsu Murai (Shimane Agricultural Station, Japan), Bas Nijhof (Nijhof Gewasbescherming, The Netherlands) and Manuele Tamò (Biological Control Program-I.I.T.A., Benin) for providing us thrips parasites for evaluation and all correspondants for their information and useful advice. Last but not least the author is very much obliged to Jeannette Hofkamp for her support and assistance during his searching trip in the South of Europe.

7. References

ANTSIFEROVA T.A., & Z.A. TIMRALEEV 1974. Vrogi gorokhovogo tripsa (Enemies of the pea thrips). Zash. Rast.10: 26.

BAGNALL, R.S., 1914. A chalcid parasite on thrips. Rept. Brit. Assn. Adv. Sci. 1913, London: 531.

BAILEY, D.E., & R.F.SMITH, 1956. The *Frankliniella occidentalis* (Pergande) complex in California (Thysanopter: Thripidae). Univ. Calif. Publ. Entomol., 10(6): 359-410.

BOUCEK, Z., 1976. Taxonomic studies on some Eulophidae (Hym.) of economic interest, mainly from Africa. Entomophaga, 21(4): 401-414.

BOUCEK, Z., 1988. Australasian Chalcidoidea (Hymenoptera): a biosystematic revision of genera of fourteen families, with reclassification of species. CAB Int., Wallingford UK, 832 pp.

BOUCEK, Z., & R.R. ASKEW, 1968. Palearctic Eulophidae (excl. Tetrastichinae) (Hym. Chalcidoidea). Index of entomophagous insects 3. Le François, Paris: 260pp.

BOURNIER, A., 1967. Un intéressant parasite de Thysanoptères: *Tetrastichus gentilei* (Hym. Chalcididae). Ann. Soc. Ent. Fr. (N.S.), 3(1): 173-179.

BOURNIER, A., 1983. Les Thrips. Biologie, Importance agronomique. I.N.R.A., Paris, 128 pp.

BOURNIER, A., & J.P. BOURNIER, 1987. L'introduction en France d'un ravageur: *Frankliniella occidentalis*. Phytoma, Déf. Cult. 388: 14-16.

BUHL, C., 1937. Beitrage zur Kenntnis der Biologie, wirtschaftliche Bedeutung und Bekämpfung von *Kakothrips robustus* Uz. Z. angew. Ent., 23: 65 - 113.

CAB REPORT, 1971. Investigations on the natural enemies of thrips for use as biological control agents against glasshouse thrips in the United Kingdom. CIBC European Station, Delémont-Switzerland: 35pp.

CARL, K.P., J. YUILL, M. PARESCH & C. PRIOR, 1989. *Taeniothrips inconsequens* in Central Europe and its natural enemies. C.A.B. report, 14 pp.

CHANG, N.T., 1990. *Ceranisus menes* (Walker)(Eulophidae: Hymenoptera), a new parasite of bean flower thrips, *Megalurothrips usitatus* (Bagnall) (Thripidae: Thysanoptera). Pl. Prot. Bull., 32: 237-238.

CHIU, H.T., 1984. The ecology and chemical control of grapevine trip (*Rhipiphorothrips cruentatus*) on wax apple. Pl. Prot. Bull., 26 (4): 365-378.

DANIEL, A.M., 1986. Thrips-parasite interactions in some Panchaetothripine Thysanoptera (Insecta: Arthropoda). Proc. Indian natn. Sci. Acad., B Biol. Sci., 52(4): 437-444.
DESSART, P., & A. BOURNIER 1971. *Thrips tabaci* Lindman (Thysanoptera), hôte inattendu d'*Aphanogmus fumipennis* (Thomson) (Hym. Ceraphronidae). Bull. Ann. Soc. R. Ent. Belg., 107: 116-18
DOMENICHINI, G., 1966. Palearctic Tetrastichinae (Hym. Eulophidae). Index of entomophagous insects 1. Le François, Paris: 101 pp.
DYADECHKO, N.P., 1964 (1977). Thrips or fringe-winged insects (Thysanoptera) of the European part of the USSR. Amerind Publ. Co., New Delhi, 344 pp.
ERDŐS, J., 1971. Chalcidoidea VIII. Fauna Hung., 104: 252 pp.
FERRIÈRE, C., 1958. Un nouveau parasite de thrips en Europe centrale (Hym. Euloph.). Mitt. Schweiz. Ent. Ges., 31(3-4): 320-324.
FRANSSEN, C.J.H., 1960. Levenswijze en bestrijdingsmogelijkheden van de erwtetrips (*Kakothrips robustus* Uzel). Versl. Landbouwk. Onderz., 664, Pudoc Wag.: 51pp.
GIRAULT, A.A., 1917. Notes and descriptions of miscellaneous Chalcidflies (Hymenoptera). Proc. US Natl. Mus., 53 (2213): 445-450.
GRAHAM, M.W.R. de V., 1963. Additions and corrections to the British List of Eulophidae (Hym., Chalcidoidea), with descriptions of some new species. Trans. Soc. Br. Ent., 15: 167-275.
GUIMAREAS, J.M., & A.M. LOPES, 1990. Novas e importantes pragas nas culturas protegidas em Portugal. In press, 5pp.
HIROSE, Y., 1989 (ed.). Exploration for natural enemies of *Thrips palmi* in Southeast Asia. Inst. Biol. Control, Fac. Agric., Kyushu Univ., Fukuoka: 58 pp.
HUKKINEN, Y., 1936. Tutkimuksia nurmipuntarpään (Alopecurus pratensis L.) siementuholaisista. 1. *Chirothips hamatus* Tryb., putarpääripsiainen. Valt. Maatalouskoet. Julk., 81: 1-132.
ISHII., T. 1933. Notes on two hymenopterous parasites of *Thrips* in Japan. Kontyû, 7: 13-16.
KRATOCHVíL, J. & O. FARSKY, 1942. Das Absterben der diesjährigen terminalen Lärchentriebe. Z. Ang. Ent., 29(2): 177-218.
KUROSAWA, M., 1931. A hymenopterous parasite on thrips of onion in Japan. Kontyû, 5: 188.
KUTTER, H., 1936. Ueber einen neuen endoparasiten (*Thripoctenus*, Chalcididae) des Erbsenblasenfusses (*Kakothrips robustus* Uzel), seine Lebensweise und Entwicklung. Mitt. Schweiz. Ent. Ges., 16: 640-652.
LACASA PLASENCIA, A., 1990. Un trieno de *Frankliniella occidentalis* en España evolucion temporal de una plaga importada. Phytoma España, 6: 3-8.
LEWIS, T., 1973. Thrips: their biology, ecology and economic importance. Acad. Press, London: 349 pp.
LOOMANS, A.J.M., & J.C. VAN LENTEREN, 1990. Hymenopterous parasites as biological control agents of *Frankliniella occidentalis* (Perg.)?. IOBC/WPRS Bull., 13(5): 109-114.
MURAI, T., 1988. Development and reproduction of the parasitoid, *Ceranisus brui* (Vuillet) (Hymenoptera: Eulophidae). Proc. XVIII th Int. Congr. Entomol., Vancouver 1988: 397.
MURAI, T., 1990. Rearing method and biology of thrips parasitoid, *Ceranisus menes*. IOBC/WPRS, 13(5): 142-146.
NOYES, J.S., 1982. Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea). J. Nat. Hist., 16: 315-334.
RUSSO, G., 1928. Las enfermadadas perjudiciales al cultivo de cebolla. Circ. Lab. Ent. Est. nac. agron., S. Domingo, 2: 1-25 (R.A.E., A17: 26).
SAKIMURA, K., 1937. On the bionomics of *Thripoctenus brui* Vuillet, a parasite of *Thrips tabaci* Lind. in Japan. I. Kontyû 11 (5): 370 -390. II. Kontyû 11 (6): 410-424.
SEAMANS, H.L., 1923. The alfalfa thrips and its effect on alfalfa seed production. Can. Ent., 55 (5): 101 - 105.
SZELÉNYI, G., 1982. Further data to the Torymid, Pteromalid and Eulophid fauna of the Hortobagy National Park (Hymenoptera: Chalcidoidea). Acta Zool. Acad. Scient. Hung., 27 (3-4): 379-388.
VAN HEURN, W.C., 1923. Over een waarschijnlijke parasiet (*Thripoctenus brui* Vuillet) en een vermoedlijke hyperparasiet (Genus? species?) van *Thrips tabaci* Lind. Tijdschr.Ent., 66: 119-128.
VAN LENTEREN, J.C., 1986. Parasitoids in the greenhouse: successes with seasonal inoculative release systems. In: Insect Parasitoids: J.K. Waage and D.J. Greathead, eds., Academic Press, London: 341-374.
VUILLET, A., 1914. Note sur un Chalcidien parasite de thrips des pois. C.r. Séanc. Soc. biol. Paris, 75: 552-554.
YOSHIMOTO, C.M., 1965. Synopsis of Hawaiian Elophidae including Aphelininae (Hym.: Chalcidoidea). Pacif. Insects, 7: 665-699.

Host-plant related behavior of *Bemisia tabaci*

Dan Gerling and Menachem Lindenbaum
Department of Zoology, The George S. Wise Faculty of Life Sciences
Tel Aviv University, Ramat Aviv 69978
Israel

Summary
Examinations were conducted of the following parameters: Long-distance attraction of *Bemisia tabaci* to melon vs. cotton plants, and to infested vs. uninfested leaves. Residence time of the whiteflies and number of eggs laid on infested and uninfested leaves were also monitored. Additionally, movement of emerging whiteflies within the plant was followed for the first 6 post emergence days and their egg allocation between the leaf of emergence and top plant leaf were compared. The results showed that no long distance attraction existed in both experiments, and that previous ovipositions did not effect the degree of egg laying by *B. tabaci* on the same leaf. Whiteflies remained about 3 days on the leaf of emergence and, in each case laid some eggs before moving to a higher leaf, and ending up on the top leaf of the plant.

1. Introduction

The whitefly*Bemisia tabaci* (Homoptera: Aleyrodidae) is a severe pest of field and vegetable crops both in the greenhouse and out of doors (Gerling et al 1986; Cock 1986, Osborne et al 1990). In recent years, *B. tabaci* has invaded the European greenhouse culture, where it presently causes extensive damage. For lack of better means of control, insecticides are often used to reduce its populations. Recently, also greenhouse screening has been employed with considerable success (Berlinger pers. comm.).

As stated by van Lenteren and Noldus (1990) "The development or improvement of non-chemical control methods for whiteflies requires a thorough understanding of the interactions of the insects and their host plants..." At present, the basic behavioral and ecological information for such an understanding is only partially available. In order to improve this situation, we ran experiments to elucidate some factors responsible for whitefly attraction to plants, whitefly oviposition preferences, and post emergence distribution upon the plants.

The specific questions that we asked were: 1. Is the observed preference of whtieflies in the field for melon plants over cotton (Or, 1986), based on prelanding whitefly attraction? 2. Do *B. tabaci* females prefer to oviposit on cotton leaves that have already been infested with eggs? 3. What is the post emergence behavior of *B. tabaci* adults in relation to feeding and oviposition- site selection?

2.Materials and Methods

General: *Bemisia tabaci* was cultured on Acala SJ2 cotton plants in greenhouses or at 27+1°C in temperature cabinets. All whiteflies used were about 24 hrs old. The experiments were conducted in a windowless room at 25-27°C with artificial overhead illumination (4x40 Watt, fluorescent lamps) except when otherwise stated. The cages used were glass-top sleeve cages 35x35 x34 cm. Statistical significance was tested for, using a Chi Square test (at a 0.05 level of significance) unless specified otherwise.

Details of the experiments: 1. Host plant selection. Three procedures were used for testing possible preference between long-distance recognition of melon vs. cotton. a. One cotton and one melon leaf, each with its petiole in a tube with water, were partially covered by paper so that the exposed leaf surface of both was equal (5.2 $cm.^2$). Both were placed in a sleeve cage with 100 whitefly females, and direct ovehead illumiation of 25 Watts. They were continually observed for 3 hrs and the landing whiteflies counted. Every 10 min. all of the whiteflies on the leaves were removed with an aspirator. b. The same experiment was repeated with whole, uncovered, plants; each of which had 3 true leaves. c. Experiment b. was repeated but whiteflies were counted after 24, 48, 72, 96, 120, and 144 hours. Whiteflies were not removed following counts.

2. Relation of egg presence to landing, time spent on leaf (retention), and oviposition. a. Landing. Two cotton plants, each having only one leaf (No. 1) were used within a cage. One plant was first subject to oviposition (about 1000 eggs), and the other was clean. Each leaf was partially covered with paper exposing an equal leaf area of about 5.2 cm^2 on each leaf. The procedure followed was like in 1a, with 100 whiteflies being released, counted and removed every 10 minutes for 3 hours. Thereafter, the plants and remaining whiteflies were left for 72 hours with counts conducted after, 24, 48 and 72 hours. b. Retention and oviposition. One pair of whiteflies was released on a clean cotton leaf and oviposition was counted after four days, to serve as a control. In the test, half a leaf was covered and the second half exposed to oviposition by whiteflies (about 500 eggs) for 24 hours. The leaf was then placed in a cage and a pair of whiteflies was released on the leaf. The whereabouts of the whiteflies was continually recorded for 3 hours and their oviposition on the clean half was recorded after four days.

3. Adult dispersal. We used clean cotton plants, with leaf No. 9 from the top infested with 5 whitefly pupae (all other developing whiteflies were removed at an earlier stage). Observations started upon first whitefly emergence and the following parameters were registered: Hour of emergence, No. of adults on emergence leaf, and on other leaves; and the number of eggs and their whereabouts.

Examination of female presence was conducted for 6 days, every four hours of the photophase (12 hrs). Oviposition was examined on the leaf of emergence and on the top leaf of the plant. Since the number of eggs laid is contingent upon the number of females present, we first calculted the number of "female-days" (No. of females X the number of days in which they were observed) for each leaf on each plant. The "famale-days" for the leaf of emergence were adjusted for the preovipsotion period of the emerging females, by substracting one day for each female that had emerged on this leaf. The total number of eggs that was found on each leaf was then divided by this number to obtain the average oviposition per "female-day".

3.Results and discussion

1. Host plant selection. No difference in landing frequency and numbers of adult whiteflies were observed between melon and cotton leaves (6 replicates) or whole plants (4 replicates) up to 3 hours from release. The counts conducted on 5 replicates of whole cotton vs. melon plants between 24 and 144 hours after release showed significantly more insects on the melon plants $p<0.05$ (Fig 1).

Van Lenteren and Noldus (1990) concluded that except in *Aleyrodes proletella* , "Whiteflies do not appear to use olfactory clues in host-plant selection". Rather, they exhibit preference and show attraction to yellow; and for *Trialeurodes vaporariorum* "the more yellow the more landings occurred". Both melon and cotton are adversely affected by *B. tabaci* but the former is already heavily covered with the pest under field conditions early in the season, when the latter hardly has any whiteflies on it (Or, 1986). Our present experiment ruled out the possibility that this difference is due to long distance attraction which may be related to color or shade differences between the more yellowish melon and the darker-green cotton leaves. The observed differences are, therefore, probably due to post-landing discrimination.

2. Response to previous whitefly oviposition. No significant differences were found in the landing preference tests (3 replicates) on leaf portions that were infested with eggs vs. ones that were not. Likewise, two replicates in which the whiteflies were counted on each leaf portion 24, 48, and 72 hours following release did not show significant differences between the numbers of whiteflies in the test and control.

The presence of eggs on the leaf did not change the amount of time spent on infested or clean half-leaf (except for 1 replicate where, after 24 hours more were on the infested half, 37 vs. 21 $p<0.05$). Oviposition on the clean leaf-half amounted to an average of 6.5 eggs/female during 4 days. By comparison, the number of eggs on the control leaf amounted to 14.9 per female for the same period of time. Considering that the experimental females spent about half their time on the infested side of the leaf, where they might have laid about half of their

egg complement, no difference in oviposition seemed to have been induced by the presence of eggs on the leaf (T test for independent measurements following a square-root transfomation, t=.935).

The clumped distribution of many whitefly species may be significant in the whitefly's capacity to overcome plant resistance or in its probability to survive predation. The mode by which this distribution is created is both interesting and of practical importance, since its consequences have a bearing on the sampling methods and determination of infestation levels and control strategies. The present findings, that oviposition is not affected by previous presence of eggs upon the leaf, indicates that other factors, like particular leaf selection and preference are responsible for whitefly clumping.

3. Post emergence movement. Adult whiteflies emerged mainly between 0600-1200 with about 70% emerging between 0600-0900 (Fig 2). On the average, they left the ninth leaf, on which they emerged, and started moving upwards, on the 3rd post-emergence day. Nearly all concentrated on the top two leaves within 6 days (Fig 3).

Out of the 9 replicates, females deposited eggs on the emergence leaf (No. 9) in 8 cases, and arrived and laid eggs on the top leaf of the plant, in 6 cases. No significant differences were observed in the nember of eggd laid per "female-day" between the top leaf and the leaf of emergence.

The pattern of upward movement by *B. tabaci* resembles that found for *T. vaporariorum* by Noldus et al (1985) who used somewhat different methods (a greenhouse with 24 tomato plants observed al at once). The main difference was the speed of whitefly movement which was considerably faster in their experiment (departure from the leaf of emergence started at 8.9 light hours and arrival at the top stabilized at the age of 40 LH). Since the two experiments were conducted with different plants and under different consdtions, it is impossible to conclude if the differences in movement are due to specific characteristics.

Our results, that showed consistant oviposition on the leaf of emergence support the common observation that whiteflies may have more than one generation on the same leaf. This occurs in spite of the fact that the quality of the leaf on which emergence took place is often inferior to that of younger leaves.

4.References

Cock, M.J.W. (editor) 1986. *Bemisia tabaci*. A literature survey on the cotton whitefly with an annotated biliography. C.A.B. International Institute of Biological Control, Great Britain.

Gerling, D.; Horowitz, A.R.; Baumgrtner, J. 1986. Autecology of *Bemisia tabaci*. Agric. Ecosytems Environ. 17: 5-19

Lenteren, J.C. van. and Noldus, L.P.J.J. 1990. Whitefly-plant relationships: Behavioural and ecological aspects in: Whiteflies: their bionomics, pest status and management, Intercept, Andover, UK pp 47-89.

Noldus, L.P.J.J.; Xu, R.M.; Lenteren, J.C. van 1985. The parasite-host relationship between *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) and Trialeurodes vaporariorum (Westwood) (Homoptera: Aleyrodidae). XVII. Within-plant movement of adult greenhouse whiteflies Z. ang. Ent. 100: 494-503

Or, R. 1986. Examination of Factors that Limit or Encourage Contamination of the Whitefly *Bemisia tabaci* (Gennadius) (Aleyrodidae)on Cotton Plants in the Bet Shean valley. Thesis submitted towards the M.Sc. degree of Tel Aviv University (in Hebrew with English summary) 51pp.

Osborne, L. Hoelmer, K. and Gerling D. 1990. Prospects for biological control of *Bemisia tabaci* WPRS Bulletin 13(5): 153-160

Fig 1. Host-plant selection by *Bemisia tabaci*

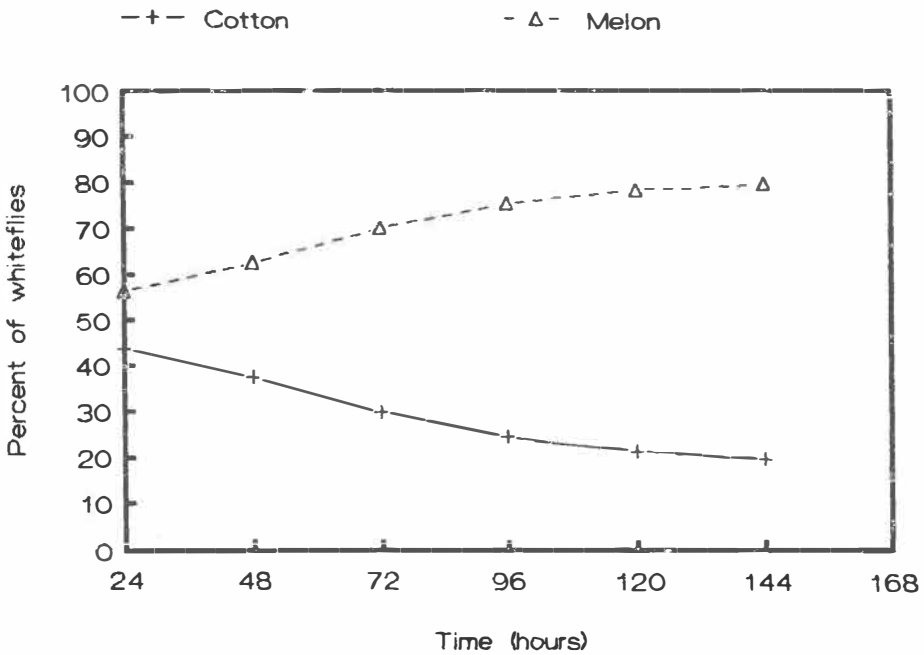


Fig 2. Hour of emergence of *Bemisia tabaci*

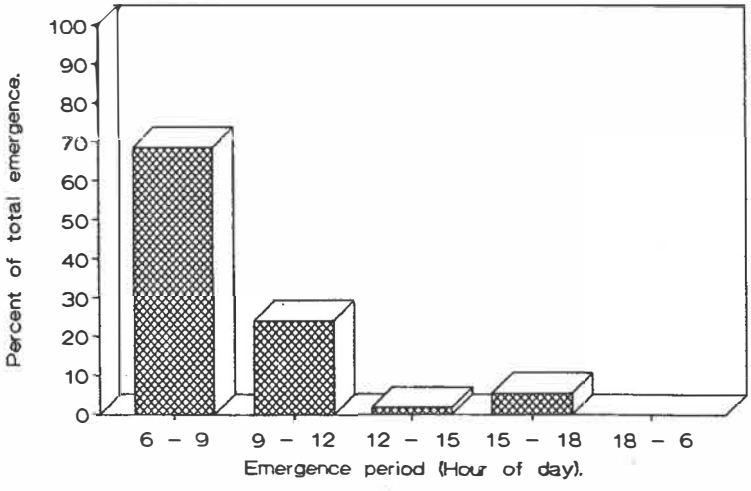
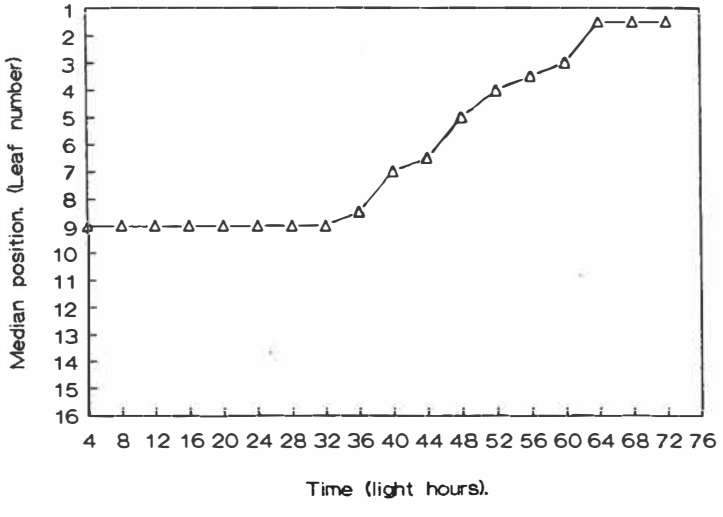


Fig 3. Within-plant movement of *Bemisia tabaci*



OBSERVATIONS PRELIMINAIRES SUR LA DYNAMIQUE DES POPULATIONS DE BEMISIA TABACI (GENN.) (HOMOPTERA, ALEYRODIDAE) SUR UNE CULTURE PROTEGEE D'AUBERGINE.

CHERMITI Brahim
Laboratoire de Zoologie, Ecole Supérieure d'Horticulture de Chott Mariem, 4042 Sousse Tunisie.

RESUME

L'étude de la dynamique des populations de Bemisia tabaci (GENN.) effectuée sur une culture protégée d'aubergine du mois de décembre jusqu'à la fin mai, révèle le développement de quatre générations successives et chevauchantes du ravageur. La durée du développement post-embryonnaire est longue pendant l'hiver et relativement courte au printemps. En outre, la répartition horizontale des populations imaginales de l'aleurode est négative alors que leur distribution verticale est étroitement liée à la phénologie de la plante-hôte.

INTRODUCTION

L'aleurode Bemisia tabaci (GENN) est un ravageur d'importance mondiale vue sa grande polyphagie et son potentiel biotique élevé (SHARAF et ALLAWI , 1980; DELATTRE, 1982; MUSUNA, 1983; VON ARX et al., 1983). En Tunisie, et surtout au sud du pays, ce ravageur occasionne de grands dommages sur les cultures protégées d'aubergine, de tomate, de piment et d'haricot ainsi que sur les cultures de plein champs (cucurbitacées).

La femelle de B.tabaci dépose ses oeufs sur la face inférieure des jeunes feuilles terminales de la plante hôte (KHALIFA et EL KHIDIR, 1964; EL HELALY, 1971). Tous les stades de l'insecte vivent fixés au végétal à part la larve néonate (durant les premières heures de sa vie) et l'adulte qui constituent les seuls stades de dissémination de l'espèce. La première au niveau de la feuille et le second au niveau de la plante-hôte ou de la parcelle.

Etant piqueur suceur de sève, B.tabaci aux stades larvaires et adulte entraine le flétrissement temporaire ou permanent de la plante (GAMEEL, 1972) voire même l'abscission foliaire (POLLARD, 1955). En outre, le miellat rejeté par les larves sur la face supérieure des feuilles se trouvant au dessous du support des aleurodes ainsi que sur les fruits favorise l'installation de la fumagine qui peut nuire à la photosynthèse et par conséquent au métabolisme interne de la plante. B.tabaci est également reconnu comme espèce vectrice de viroses (Mc LEAN, 1940; WOLF et al., 1949).

Dans une optique de recherche des éléments nécessaires à la prévision des pullulations de B.tabaci, l'étude de la dynamique des populations du ravageur ainsi que la distribution spatio-temporelle des populations imaginales du phytophage s'avèrent indispensables

MATERIEL ET METHODES

L'étude a été menée sous un tunnel plastique de 480m² situé au domaine de l'exploitation agricole de l'Ecole Supérieure d'Horticulture de Chott Mariem sur des plants d'aubergine de la variété Fabina. La plantation a été effectuée le 22 octobre 1989 sur six lignes avec un espacement de 0,5 m entre les plants et 1 m entre les lignes. La culture a été conduite normalement mais sans aucun traitement pesticide.

Le principe de la taille a consisté à laisser la tige principale monter et à éliminer complètement les rameaux secondaires partant à l'aisselle des feuilles. Cette opération a été renouvelée chaque fois que nécessaire.

L'évolution de la température et de l'humidité a été suivie à l'aide d'un thermohygrographe installé sous le tunnel.

L'étude de la dynamique des populations de B.tabaci a nécessité des comptages in situ et des prélèvements d'échantillons hebdomadaires. Selon ONILLON (1978), la manipulation d'un plant toutes les semaines lui permet d'être graduellement abandonné de ses "occupants", perdant ainsi toute signification. De ce fait, on a dû procéder à un tirage au sort de trente plants qui sont renouvelés chaque semaine pour le comptage in situ des adultes. Le denombrement des oeufs a été réalisé par des prélèvements de deux feuilles apicales sur chaque plant d'un deuxième échantillon de trente pieds tirés au sort de la même manière que précédemment

RESULTATS ET DISCUSSION

1-Distribution spatio-temporelle des adultes de l'aleurode

a- Evolution temporelle de la population imaginale de B.tabaci (figure 1)

Durant tout le mois de décembre et la première quinzaine du mois de janvier, l'échantillonnage n'a révelé que des adultes. Cette période est certainement nécessaire à la contamination et à l'installation des aleurodes sur la culture. En outre les températures n'étaient pas favorables à la ponte, celle ci n'a d'ailleurs débuté que vers le 18 janvier. Ce retard accusé dans l'apparition des formes fixes (oeufs) a été également observé par BOUBOU (1986) au Mali, GERLING et al. (1980) et par OREN et GERLING (1983) en Israël.

La population des adultes s'est maintenue faible du 7 décembre jusqu'au 18 février et ce n'est qu'à partir du 25 janvier que les effectifs des adultes de B.tabaci ont commencé réellement à augmenter pour atteindre un premier pic de 25,2 adultes par plant le 25 février.Cette augmentation de la population résulte d'une part de la sortie de nouveaux adultes en provenance des larves du quatrième stade (L.4) de la dernière semaine de janvier et d'éventuelles arrivées d'adultes de l'extérieur.

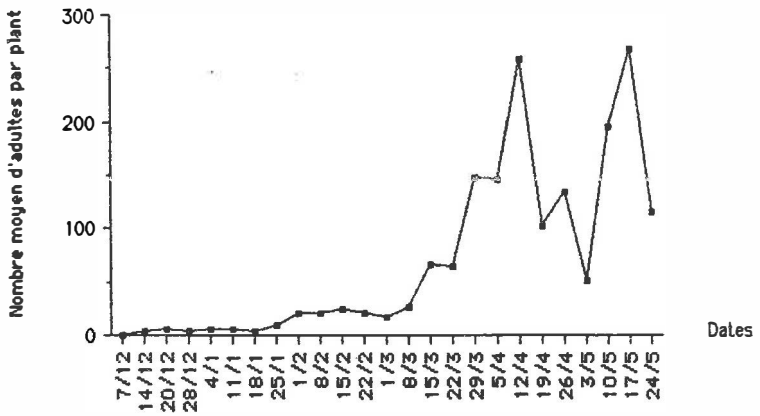


Fig.1: Evolution temporelle des adultes

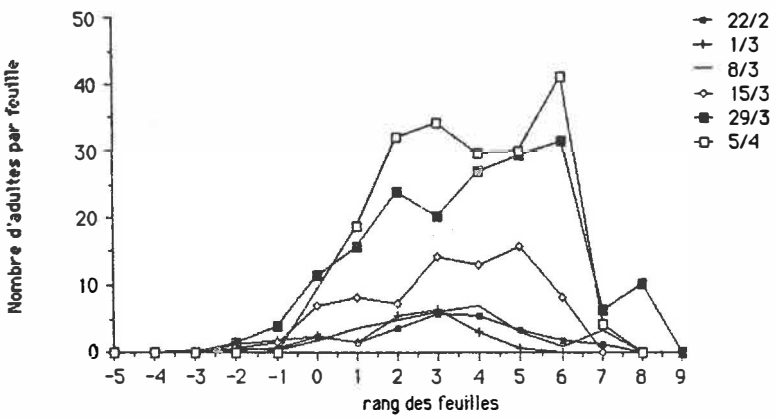


Fig.2:Distribution des adultes

Un second pic d'adultes est noté le 12 avril avec 258,23 adultes par plant suivi d'un troisième sommet le 17 mai avec 266 adultes par plant, les deux maxima d'adultes correspondent en fait aux deux sommets des (L.4) enregistrés respectivement du 22 au 29 mars et du 3 au 10 mai.

Au cours de cette phase printanière, on peut constater que le développement du ravageur est devenu plus rapide. En effet, 35 jours seulement séparent les pics printaniers d'adultes, alors que 57 jours séparent le pic hivernal du premier pic printanier. En outre, le niveau des populations a augmenté d'une façon considérable et s'est multiplié par dix.

Cette évolution favorable à la population imaginale de B.tabaci est certainement le résultat des conditions climatiques favorables et notamment la température qui ont permis une bonne croissance de l'aubergine et par conséquent une forte multiplication du ravageur dont le développement est étroitement liée à la croissance de sa plant-hôte

b- Répartition horizontale des adultes de B.tabaci

L'examen des dénombrements, plant par plant, a permis d'observer l'existance de foyers et de vérifier le comportement agrégatif des adultes de l'aleurode. Le rapport "variance/moyenne d'adultes par plant" est nettement supérieur à l'unité. L'augmentation du coefficient d'agrégation en fonction du temps traduit au travers d'une mortalité naturelle réduite mais qui affecte toute l'étendue du tunnel, la localisation préférentielle des adultes sur certains plants d'aubergine. Ces plants d'aubergine davantage contaminés par les adultes de l'aleurode se trouvent préférentiellement dans le premier tiers de l'abri serre, proche de l'entrée sud. Un gradient d'infestation de l'entrée vers le fond du tunnel ayant été mis en évidence dans l'abri serre.

c- Répartition verticale des aleurodes adultes sur un plant

Le suivi régulier de la population imaginale par les comptages d'adultes feuille par feuille a permis de vérifier que les adultes de B.tabaci suivaient étroitement la phénologie du végétal en se portant sur les feuilles jeunes au fur et à mesure de leur croissance et de leur étalement. De façon à relier la présence des adultes de l'aleurode à un stade phénologique précis ou à une feuille de rang détérminé, le niveau zéro a été attribué à la feuille située immédiatement sous le premier bouquet floral, des indices négatifs allant jusqu'à -6 étant affectés aux feuilles inférieures , les feuilles supérieures ayant des indices positifs jusqu'à la feuille de randg 10 ou 11.

La figure 2 donne une bonne représentation de la distribution des adultes sur les feuilles de rang détérminé. Le 22 février 1990 le maximum d'adulte est observé sur la feuille de rang 4 avec 5,8 adultes en moyenne et les feuilles contaminées vont de la feuille -4 à la feuille 8. La semaine

suivante (1er mars) la population imaginale s'est rassemblée et recouvre 10 feuilles seulement (-5 à 6) avec un maximum d'adultes au niveau 4 de 6,5 adultes de B.tabaci par plant. Le 8 et le 15 mars les maximum d'adultes sont observés sur les feuilles de rang 5 (7 adultes) et 6 (15,5 adultes). Enfin le 29 mars et le 5 avril, la population imaginale a augmenté et s'est distribuée sur les nouvelles feuilles apparues avec respectivement 31,5 adultes sur la feuille du rang 7 et 41 adultes au niveau de la feuille du rang 8.

Cette occupation préférencielle d'un ensemble de feuilles par les adultes nous a permis ainsi de caractériser des "niveaux foliaires d'infestation" correspendant, pour une date donnée, à l'ensemble des feuilles d'un plant présentant à cette même date un ensemble de caractérisations physiologiques qui déterminent préférentiellement la présence d'un stade du ravageur. Les niveaux d'infestation, definis pour les adultes, se retrouveront avec quelques semaines de retard, identiquement définis pour les larves du dernier stade sur lesquelles pourront être appréciées parasitisme et prédatisme. Ces niveaux foliaires d'infestation représentent à l'intérieur du plant d'aubergine les sites privilégiés d'observation de la population imaginale et de la quantification de l'action parasitaire et prédatrice des entomophages.

AVIDOV et HARPAZ (1969) et GAMEEL (1977) ont indiqué que les femelles de B.tabaci préferent pondre sur les feuilles jeunes situées au sommet de la tige. D'après THOMPSON et al. (1976) cette préférence peut être expliquée par la qualité alimentaire des feuilles. En effet, le taux de substance azotée diminue avec la sénescence des feuilles, et il est décroissant de l'extrémité vers la base des organes végétatifs. En outre, nos résultats concordent avec ceux trouvés par ONILLON et al.(1987) qui a travaillé sur Trialeurodes vaporariorum.

2-Evolution temporelle des larves du quatrième stade (L.4)

La courbe d'évolution des effectifs des (L.4) (figure 3) révèlent également l'existence de trois sommets bien individualisés; le premier est apparu durant la dernière semaine de janvier avec des effectifs de 22,36 et 31,9 (L.4) par plant. Le second est apparu pendant la dernière semaine de mars avec 121,13 et 108,96 (L.4) par plant. Quant au troisème et dernier sommet, son apparition a été relevé le 3 mai avec 813,33 (L.4) par plant.

Le premier pic des (L.4) correspond trois semaines plus tard à la première sortie massive des adultes. Cependant, les deuxième et troisième sommets des larves du quatrième stade correspondent respectivement à deux semaines et à une semaine plus tard à la deuxième et troisième sortie massive des adultes de B.tabaci.

3-Evolution temporelle des oeufs de l'aleurode .

Le premier échantillonnage a été effectué le 11 janvier

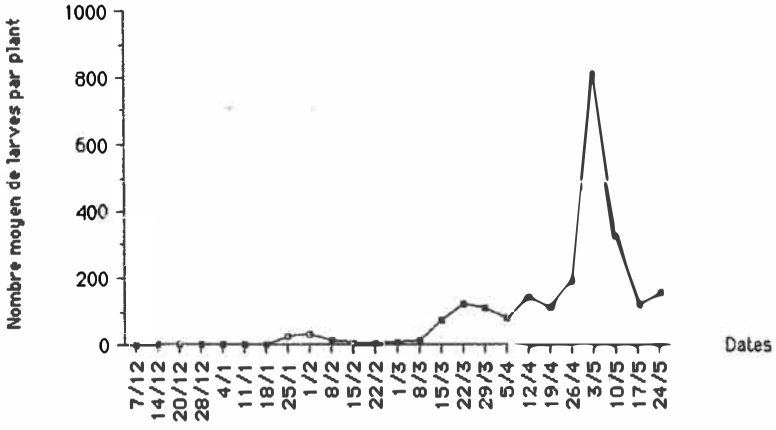


Fig.3: Evolution temporelle des larves (L4)

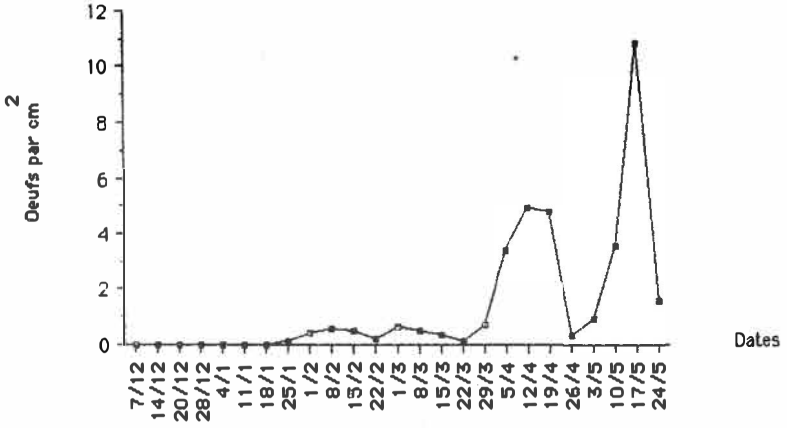


Fig.4: Evolution temporelle des oeufs

et a révélé une ponte nulle (figure 4). Ce n'est qu'à partir du prélèvement suivant que les femelles de B.tabaci ont commencé à pondre. Cependant, cette ponte est restée à un niveau relativement bas jusqu'au 22 mars. Les densités des oeufs sont maitenues faibles et n'ont dépassé guère 0,6 oeuf par cm².

OHNESORGE et al.(1981) rapporte que la ponte de B.tabaci peut être altérée par les basses températures. De même AVIDOV et HARPAZ (1969) précisent que la ponte s'arrête complètement au dessous d'une température moyenne de 14°C. Au cours de cette période qui va du 11 janvier au 22 mars la température minimale varie de 6 à 11,5°C et la température moyenne oscille entre 14 et 20°C sans toutefois présenter une évolution régulière. Cette ponte faible correspond probablement à l'installation de B.tabaci dans l'abri serre.

A cette période de ponte faible succède une deuxième phase où l'oviposition est relativement importante. Cette phase commence le 29 mars pour atteindre son maximum le 12 avril avec 4,85 oeufs par cm².

Une autre phase de ponte plus importante a été signalée au cours des prélèvements du 10 et du 17 mai avec un maximum à cette dernière date de 10,8 oeufs par cm².

4- Evolution globale des populations de l'aleurode

L'étude de la dynamique des populations de B.tabaci menée parallèlement dans l'abri serre à l'aide des comptages in situ sur des plants entiers d'aubergine et par le dénombrement des oeufs au laboratoire depuis le 7 décembre jusqu'au 24 mai 1990 révèle le développement de 4 générations.

En effet, la première génération est représentée par la faible population des (L.4) de la dernière semaine du mois de janvier. Ces larves proviennent probablement d'une ponte antérieure qui s'est apparemment produite au niveau de la pépinière ou bien juste après la plantation.

La deuxième génération de l'aleurode est matérialisée par les pontes du mois de février, la forte population des (L.4) qui s'est produite durant la dernière semaine du mois de mars et par la sortie massive des adultes du 12 avril.

Quant à la troisième génération qui est de loin la plus importante, elle est signalée par les fortes pontes de la troisième semaine du mois d'avril qui ont engendré une importante population des (L.4) durant la première semaine du mois de mai, suivie d'une nouvelle sortie des adultes du 10 au 17 mai.

La quatrième génération est représentée par les densités importantes d'oeufs du 17 mai, qui résultent certainement de la ponte des femelles apparues à cette même date. Cette génération va continuer son développement durant la première quinzaine de juin.

CONCLUSION

L'évolution des populations de B.tabaci est caractérisée par une période d'installation et de contamination de la

culture suivie d'une phase de multiplication importante dont l'intensité est fonction de l'élèvation de la température.

L'aleurode a pu se reproduire et se multiplier d'une façon continue du mois de décembre jusqu'au dernier prélèvement que nous avons effectué le 24 mai 1990. Pendant cette période tous les stades du ravageur étaient présents.

Les générations de B.tabaci sont chevauchantes. En effet, on a pu mettre en évidence quatre générations dont le développement partiel ou total s'est déroulé pendant la durée de l'étude. La première génération est faible et provenant probablement d'une infestation au niveau de la pépinière, les deuxième et troisième générations ont fait leur apparition pendant le printemps et sont plus importantes que la première. Quant à la quatrième génération qui a débuté vers le 17 mai, elle va continuer son développement durant la première quinzaine du mois de juin.

La durée du développement larvaire est longue pendant l'hiver (40 jours) et est relativement courte au cours du printemps (4 semaines).

Si la répartition horizontale des adultes est négative, leur distribution verticale est étroitement liée à la phénologie de la plante-hôte. En effet, les adultes et les oeufs sont toujours localisés au niveau des feuilles apicales des plants d'aubergine. Cependant, les larves du quatrième stade (L.4) sont souvent fixées sur les feuilles agées ou relativement moins jeunes.

Si d'ore et déjà on connait le cycle de développement de B.tabaci, plusieurs éléments de sa biologie restent à élucider et notamment la caractérisation de l'action de ses ennemis naturels. Il sera également intéressant de pouvoir définir une densité-seuil qui justifie les interventions chimiques.

REFERENCES BIBLIOGRAPHIQUES

AVIDOV Z., 1956 - Bionomics of tobacco whitefly (Bemisia tabaci GENNAD.) in Israël. Ktavim 7 (1), 25-41.

AVIDOV Z., HARPAZ I., 1969 - Plant pests of Israël. Israël Universities Press. Jerusalem.

BAGAYOKO B., 1986 - Contribution à la connaissance des aleurodes: Etude bio-écologique de Bemisia tabaci (GENN.) (Homoptera, Aleyrodidae) dans la zone sud du Mali. Thèse de Docteur Ingénieur en Sciences Agronomiques, Montpellier, 195p.

DELATTRE R., 1982 - Notes sur l'étude des cotons collants. I.R.C.T Montpellier. Division phytosanitaire, 4p.

EL HELALY M.S., EL SHAZLI A.Y., EL GAYAR F.H., 1971 - Morphological studius on immature stages of Bemisia tabaci GENNADIUS (Homoptera, Aleyrodidae). Z. Ang. Ent 68, 403-408.

GAMEEL O.I.,1972 - A new description, distribution and hosts of the cotton whitefly Bemisia tabaci (GENN.). Rev. Zool. Bot. Afric., 86, 1-2, 50-54.

GAMEEL O.I.,1978 - The cotton whitefly Bemisia tabaci (GENN.) in the Sudan Gezira. Third Ciba- Geigy seminar on the strategy for cotton pest control in the Sudan. May 8-10, Basel, Switzerland: 111-131.

GERLING O., MOTRO U., HOROWITZ R., 1980 - Dynamics of Bimisia tabaci (GENNADIUS) (Homoptera: Aleyrodidae) attacking cotton in the coastal plain of Israël. Bull.Ent. Res. 70 (2), 213-219.

KHALIFA H., EL KHIOIR E., 1964 - Biological study on Trialeurodes lubia and Bemisia tabaci (Aleyrodidae). Bull. Soc. Ent. Egypte, 43, 115-129.

Mc LEAN A.P.D., 1940 - Some leaf-curl diseases in South Africa. I leaf-curl disease of tobacco. Sci. Bull. Dep. Agr. For. Un. S. Afr. n°225, 7-46.

MUSUNA A.C.Z., 1983 - A potentially serious pest whitefly. Zimbabwe Agricultural Journal 80 (4), 143-146.

OHNSORGE B., SHARAF N., ALLAWI T., 1981 - Population studies on the tobacco whitefly Bemisia tabaci (GENN.) (Homoptera, Aleyrodidae) during the winter season. II. Some mortality factors of the immature stages. Zeit. Ang. Ent. 92, 127-136.

ONILLON J.C., 1978 - L'aleurode des serres, ravageur important du Gerbera. "Travaux sur Gerbera", Frejus 1978. Ed. ITIH, 69-76.

ONILLON J.C., GERIA A.M et VALLIER A., 1987 - Observations préliminaires sur l'efficacité comparée de Encarsia formosa et Encarsia tricolor (Hymenoptera, Aphelinidae) dans le contrôle biologique de l'aleurode des serres Trialeurodes vaporariorum (Homoptera, Aleyrodidae). Proceeding of the CEC / IOBC Group Meeting / Cabrils 27-29 May 1987, 39-54.

OREN H., GERLING O., 1983 - Fluctuation in populations of Trialeurodes vaporariorum and Bemisia tabaci in habiting the same Lantana camara plants. Abstract of parers presented of the 2end meeting on whiteflies in field crops and vegetables. Phytoparasitica 11 (1), 64-65.

POLLARD D.S., 1955 - Feeding habits of the whitefly, Bemisia tabaci (GENN.) (Homoptera, Aleyrodidae). Ann. Applic. Biol. 42, 664-671.

SHARAF N.S., ALLAWI T.F., 1980 - Studies on whiteflies on tomato in the Jordan Valley. III Laboratory and field experiments on the control of whitefly (Bemisia tabaci GENN., Homoptera: Aleyrodidae) populations with organophosphorus insecticides and the incidens of the tomato yellow leafcurl virus. Zeitschrift für Pflanzenkrankheiten und Pflanzensschutz 87 (3), 176-184.

THOMPSON A.C., LANE H.C., JONES J.W., HESKETH J.D., 1976 - Nitrogen concentrations of cotton leaves, buds and bolls in relation to age and nitrogen fertilisation. Agrnomy journal, 68, 617-621.

VON ARX R., BAUMGARTNER J., DELUCCHI V., 1983 - Oeveloppemental biology of Bemisia tabaci (GENN.) (Sternorrhyncha, Aleyrodidae) on cotton at constant temperatures. Mitt. Schweiz. Ent. Ges., 56, 389-399.

WOLF F.A., WHICOMB W.H., MOONEY W.G., 1949 - Leafcurl of tobacco in Venezuela. J. Elisha MITCHELL Sci. Soc., 65, 38-47.

ETUDE PRELIMINAIRE DE LA BIOECOLOGIE DE BEMISIA TABACI GEN. (HOMOPTERA - ALEYRODIDAE) EN MITIDJA (ALGERIE)

H. BENMESSAOUD - BOUKHALFA
DEPARTEMENT DE ZOOLOGIE AGRICOLE ET FORESTIERE
INSTITUT NATIONAL AGRONOMIQUE
EL-HARRACH - ALGER
(ALGERIE)

Summary

Bemisia tabaci Gen. is a new depredator of Aleyrodidae in Algeria. A preliminary studie of bioecology on tomato and eggplant has been effectuated.
We have infested 70 plants of eggplant and 70 plants of tomato, every one with 600 adults.
We have found four generations of Bemisia tabaci on eggplant and two generations on tomato.

1 - Introduction

L'Algerie de part sa situation geographique et son cilmat est un pays où de nombreux insectes déprédateurs sévissent notamment sur les cultures maraîchères sous abri et en plein champ. La surface occupée par les cultures maraîchères est passée de 86.000 ha en 1964 à 300.000 ha vers les années 1990 dont prés de 6 000 ha sous abri plastique.

L'augmentation des surfaces a permi une evolution de la production maraichère sans toutefois l'ameliorer. Les faibles rendements sont dûs principalement à des problèmes techniques économiques et sociaux.

A ces derniers s'ajoutent les problèmes phytosanitaires.

En effet, il apparait que les cultures maraichères sont pour de nombreux ravageurs un milieu ideal de proliferation. Parmi ces ravageurs, nous citons principalement les acariens (Tetranychus urticae), les pucerons (Aphis fabae, Myzus persicae .....) et les aleurodes (Trialeurodes vaporariorum et Bemisia tabaci).

A la suite des recommandations faites par ONILLON J.C en Octobre 1989 lors de la réunion CCE - OILB/SROP à Antibes, nous avons procedé à des prospections de cette espèce en Algérie. En effet durant cette même année des échantillons

de tomates et de poivrons récoltés dans le sud du pays montraient la présence d'aleurodes et un jaunissement du feuillage au niveau des nervures.

En 1990, B. tabaci (identifié par GERIA A. et ONILLON J.C de L'I.N.R.A d'Antibes) s'est implanté dans tout l'Algerois.

Vu le problème important que cause actuellement et de façon croissante B. tabaci dans notre pays, nous avons jugé utile d'apporter notre contribution à l'établissement des caracteristiques biologiques et écologiques de cet insecte pour pouvoir déterminer le cycle et la dynamique des populations sur deux plantes hôtes, en l'occurence la tomate et l'aubergine sous abri plastique.

2 - Generalités

Bemisia tabaci GEN. est un Insecte, Homoptère de la famille des Aleyrodidae. Cette espèce se rencontre presque partout dans le monde (MOUND et al, 1978). A la faveur d'échanges internationaux et particulièrement depuis une dizaine d'années B. tabaci a été introduit dans de nombreux pays de la communauté Européènne (GIUSTINA et al, 1989) à l'exception du Danemark qui a pris des mesures particulières pour s'en protéger.

Comme chez tous les aleurodes, le cycle évolutif passe par un stade embryonnaire, quatre stades larvaires et un stade imaginal.

Les plantes hôtes favorables au developpement de B. tabaci sont nombreuses et variées. MOUND et al (1978) ; APPERT et al (1982) ; HULDEN (1986), BOUDIER (1989) et MUSARD et al (1990) donnent une liste exhaustive de plantes hôtes de B. tabaci parmi lesquelles un grand nombre de cultures maraichères, de plantes ornementales et adventices sauvages ou florales.

En plus des dégâts specifiques aux homoptères et particulièrement aux aleurodes, (absorption de sève, rejet de miellat, installation d'un champignon saprophyte qui recouvre la plante et les fruits d'une moisissure noire de suie), B. tabaci est de loin l'espèce la plus redoutable. En effet sur 70 viroses recencés par NUNIYAPA (1980) et transmises par les aleurodes aux plantes cultivées ainsi qu'aux mauvaises herbes, une soixantaine d'entre elles peuvent être transmises par B. tabaci.

3 - Matériel et méthodes

A travers les prospections réalisées dans l'algerois, l'aubergine et la tomate semblaient être plus sensibles aux attaques de B. tabaci que d'autres cultures maraichères. En outre ces deux légumes sont largement répandus dans notre pays et trés appréciés. Parmi les variétés adaptées et repandues, en Algérie nous avons retenu pour l'aubergine : Solanum melongena L. variété "Black beauty" et pour la tomate : Lycopersicum esculentum variété "Saint pierre".

L'étude a porté sur 70 plants d'aubergine et 70 plants de tomate cultivés sous abri plastique. Les plants sont repartis en 7 lignes à raison de 10 plants par ligne.

L'infestation a été réalisée par des lâchers d'adultes de B. tabaci élevés sur tabac en serre contrôlée (600 adultes par parcelle ont été lâchés, soit environ 8 adultes par plant d'aubergine ou de tomate).

Les notations ont été effectuées sur toutes les feuilles de 10 plants pris au hasard au niveau de chaque parcelle. Les comptages ont portés sur les seuls stades visibles à l'oeil nu, soit les larves de 4 ème stade (L4) et le stade imaginal (mâles et femelles confondus).

4 - Résultats :

4.1 - Evolution dans le temps des populations de Bemisiatabaci Gen sur la tomate (Fig. N° 1)

Une semaine aprés l'infestation, nous avons procédé à un premier comptage, vers la fin mai qui a été évalué à 3, adultes par plant concernant la generation infestante cette densité se maintient pendant quatre semaines environ et vers la fin juin, nous ne trouvons plus d'adultes sur les feuilles de tomates.

A partir du debut juillet nous assistons à un accroissement de la courbe qui atteint son maximum le 11 Juillet avec une densité de 123 adultes par plant. Au delà de cette date la courbe representant les densités d'adultes par plant de tomate diminue progressivement pour atteindre 3 adultes par plant le 8 août.

Les premières larves de 4ème stade ont été decelées le 27 juin. Ces larves issues de la generation infestante apparaissent avec un nombre de 5L4 par plant et atteignent un maximum de 319 L4 par plant la semaine suivante. A partir du 5 juillet, il ya une diminution des larves de la generation infestante qui ne compte que 0,7 L4 par plant le 8 août, date au delà de laquelle les larves de 4ème stade ne

sont plus présentes sur les feuilles.

Pour cette speculation nous avons assisté à deux générations d'adultes :

- a1 = génération infestante du 29 mai au 2 juin.

- a2 Deuxième génération du 11 juillet au 8 août avec un pic de 123 adultes par plant le 11 juillet et une génération de larves de 4ème stade.

- L1 = génération infestante du 27 juin au 8 août avec un maximum de 319 L4 par plant le 5 Juillet.

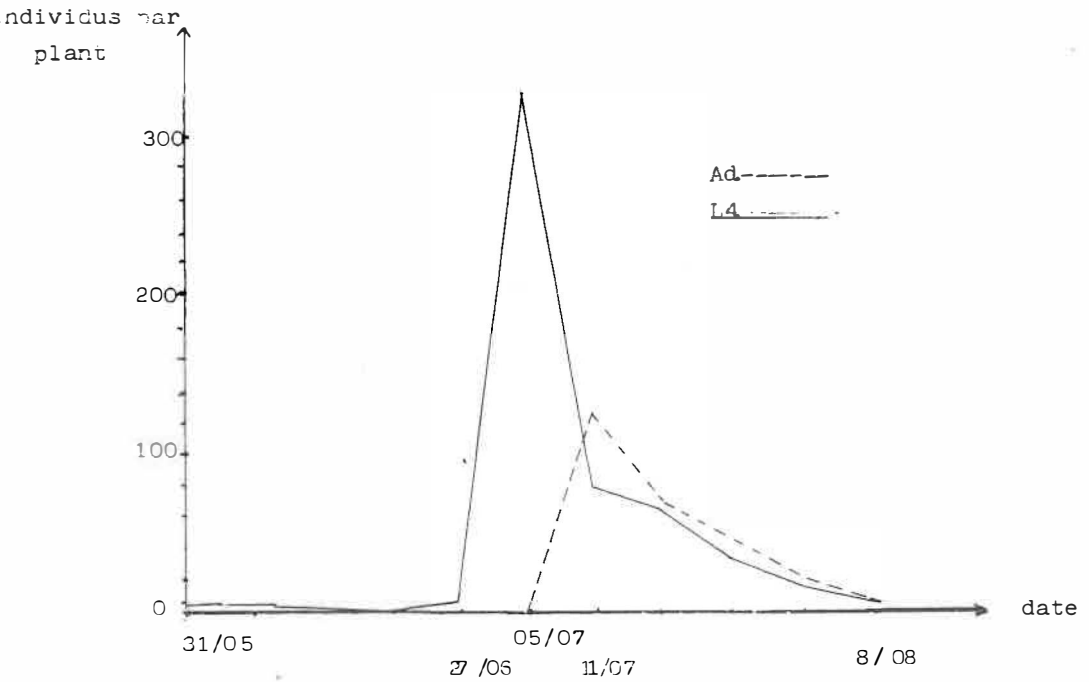


Fig N° 1 : Evolution dans le temps des populations de Bemisia tabaci Gen. sur la tomate.

4.2 - Evolution dans le temps des populations de Bemisia tabaci Gen. sur aubergines (Fig. N° 2)

Aprés un lâcher de 600 adultes effectué le 3 juin, nous remarquons que la densité reste relativement constante soit environ une cinquantaine d'adultes par plant sur les dix plants echantillonnés jusqu'à la fin juin.

Aprés cette date, la courbe montre une partie ascendante et atteint un maximum de 1400 adultes par plant le 11 juillet pour diminuerune semaine aprés à 700 adultes par plant.

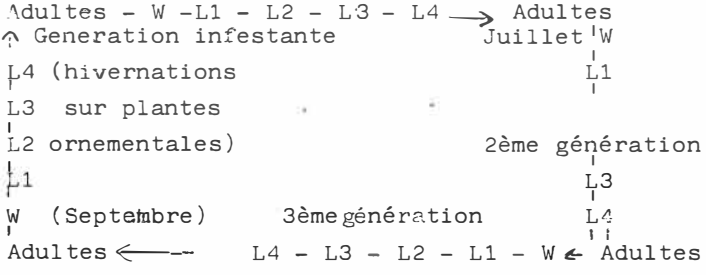
A partir de la fin juilet, le nombre d'adultes par plant augmente progressivement et nous notons un maximum de 2300 adultes par plant le 8 août . La courbe representant les densités d'adultes décroit jusqu'à la fin août puis augmente à nouveau pour atteindre à la fin de nos échantillonnages une densité de 1300 adultes par plant.

En parallèle les larves de 4ème stade apparaissent sur les feuilles d'aubergine deux semaines environ aprés l'infestation par les adultes de Bemisia tabaci.

La densité la plus importante est relevée à la première décade de juillet avec un pic atteignant approximativement les 3300 L4 par plant.

La courbe va continuer à s'accroitre progressivement pour atteindre un deuxième sommet le 1er août avec 6500 L4 par plant et diminuer quinze jours aprés.Le troisième sommet est noté à la fin du mois d'août avec un maximum de 2000 L4 par plant.

Au niveau de cette specultation nous pouvons résumer la dynamique des populations de B. tabaci comme suit :



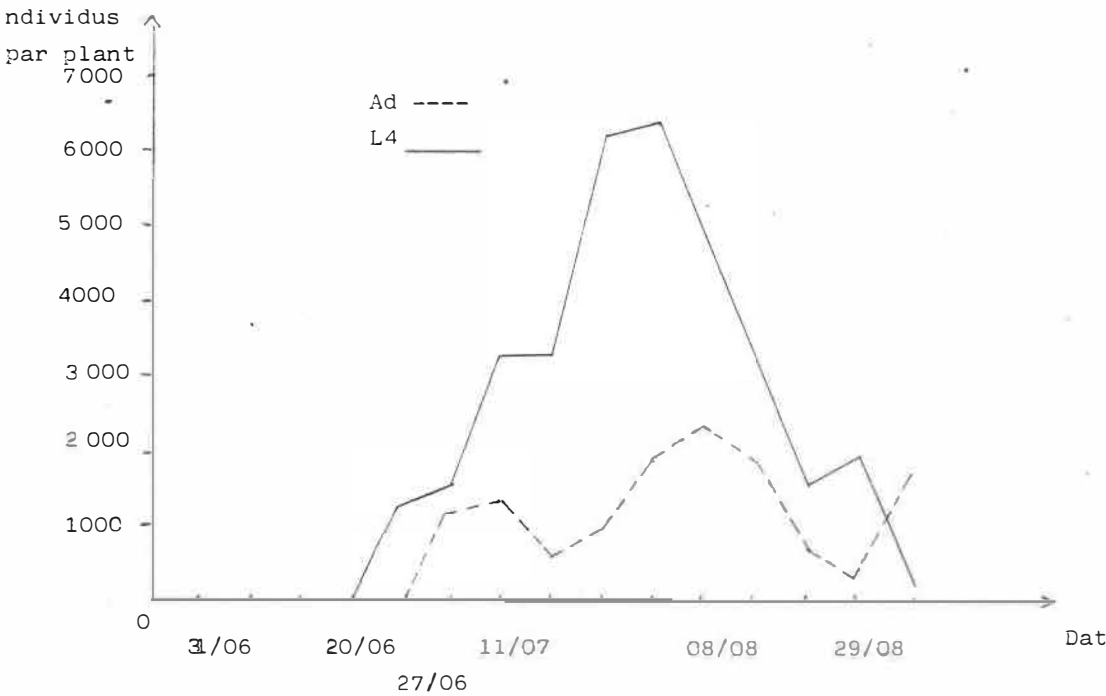


Fig N° 2 : Evolution dans le temps des populations de Bemisia tabaci Gen. sur l'aubergine.

5 - Conclusion :

Avec l'extension des surfaces maraichèress cultivées - sous abri plastique pour l'augmentation de la production, Bemisia tabaci Gen. se retrouve actuellement en pleine expansion en Algérie.

Avec ses quatre generations sur aubergine et deux générations sur tomate, l'existance de plantes ornementales autour des surfaces cultivées en maraichage, l'on conçoit la diminution de production pour les années à venir.

6 - Bibliographie

- APPERT, J. et DEUSE J., 1982. Les ravageurs des cultures vivrières et maraichères sous les tropiques. Ed. Maisonneuve et larose, Paris, 420 p.

- BOUDIER, B. ; 1989. les cultures ornementales : moins de chenilles, plus de maladies en 1988. Rev. Phytoma, N° 406; pp. 45 - 47.

-GIUSTINA, W., MARTINEZ, M. et F. BERTAUX, 1989. Bemisia tabaci : le nouvel ennemi des cultures sous serres en Europe. Rev. Phytoma, N° 406, pp. 48 - 52.

-HULDEN, L., 1986, The whiteflies (Homoptera - Aleyrodidae) and their parasites in Finland. Noctudae Entomological; 66, pp. 1 - 40 Finlanda.

-MOUND, L.A., et HALSEY, S.H. 1978. Whitefly of the world A systematic catalogue of the Aleyrodidae (Homoptera) with host plant and natural ennemy data - British. Museum (Natural History). London, 340 p.

- MUSARD, P. et CHAUVEL, G., 1990. Les cultures ornementales : la situation phytosanitaire de 1989. Rev. Phytoma, N° 416, pp. 61 - 63.

- NUNIYAPA, V., 1980. Whiteflies. In vectors of plant pathogens. Ed. Haris, Maramorosch, Academic Press. New-York, pp. 39 - 85.

Remerciements :

Je remercie Monsieur ONILLION J.C.de la station de Zoologie et de lutte biologique d'Antibes (FRANCE) pour les orientations et les critiques constructives.

APPLICATION OF SCREENS TO PREVENT WHITEFLY PENETRATION INTO GREENHOUSES IN THE MEDITERRANEAN BASIN

Berlinger M.J., Sarah Mordechi, A Leeper
Entomology Laboratory
Gilat Regional Experiment Station
Mobile Post Negev 85-280, Israel

Summary
Different screens were tested in three series of experiments: in the laboratory, in the field under low tunnels, and in commercial greenhouses. In the laboratory experiments - a good correlation was found between the density of the screen mesh, and the percent penetration of the whiteflies. In the experiments conducted under the tunnels and in commercial greenhouses, the number of trapped whiteflies was significantly lower than of those trapped outdoors, and it was below the acceptable economic damage threshold. In both field tests, in the tunnels and in the greenhouses, the number trapped was much less than what would be expected, based on the laboratory results.

1. Introduction

In Israel, as well as in many countries of the Mediterranean Basin, tomatoes and other vegetables are grown year round; outdoors in summer and in greenhouses in winter. At the end of the summer when the outdoor crops are harvested the pests which have developed on them take off in search of new host plants. These pest populations penetrate into the greenhouses and attack the newly planted crops (Berlinger et al. 1988).

The tobacco whitefly, *Bemisia tabaci,* and the tomato yellow leaf curl virus (TYLCV) which it transmits, are the most notorious pest problem of tomatoes in Israel and many Middle East countries (Berlinger et al. 1989). This insect-virus complex has become a limiting factor in tomato growing. The damage intensity depends on the whitefly population density and on the efficiency of the applied control methods. Any reduction in the number of whiteflies that reach the plants will reduce the damage significantly (Berlinger et al. 1988). Growers invest a great deal of effort, time and money, in controlling the whiteflies, and their success is usually very poor. The spread of the virus has not been prevented, not even by daily spraying, especially in recent years (Berlinger et al. 1987). Covering the plants with "Agryl", an unwoven polypropylene sheet, was found to be very effective in

preventing whiteflies from penetrating greenhouses and made it practical to grow tomatoes organically (Berlinger et al. 1988).

The use of screens is a mechanical control method, based on a physical barrier to prevent pest penetration of greenhouses. "Agryl" is suitable for tomatoes planted in late September or early October. But for earlier planting "Agryl" caused damage due to the high temperatures that built up under it (Rilski et al., 1984). It was therefore necessary to test alternative coverings. With the collaboration of our laboratory, the industry, the Agricultural Extension Service advisors, and the growers, a concerted effort has been undertaken to develop screens that will prevent whitefly penetration to a reasonable extent and also permit enough ventilation for the plants (Zipori et al., 1988). As a result of this effort, there are today three companies each manufacturing or supplying screens differing from each other in aspects of mesh density and thread gauge. These variations provide differing rates of ventilation but also different rates of whitefly penetration.

The purpose of this study was to compare the effects of the different screen mesh parameters on the rate of whitefly penetration.

2. Materials and methods

2.1. Materials

Samples of screens of various mesh were received from the suppliers (Table 1). A 17% shade screen (14/16 Mesh) was used as a control. The screens supplied by Klayman-Meteor Ltd., by Ben Tsur-Drouianoff Ltd. and by Tama Ltd., are their own products. The screens supplied by Gil-Gad 1982 Ltd. are produced by Artes Ltd., Cshio, Italy. "Agryl" is an unwoven porous polypropylene sheet, produced by Sodoca, France, and supplied by A. Steinberg Ltd.

2.2. Laboratory experiments

Each screen was tested in the laboratory as a barrier between two chambers: cell (i), a clear 220 ml plastic cup; and cell (ii), a 90 mm diameter plastic petri-dish, with an opening 5 cm in diameter cut from its base. The inner surface of the petri-dish cover was made sticky with tanglefoot, to prevent the whiteflies from returning to cell (i). For each replicate, about 120 adult whiteflies were introduced into cell (i). The whiteflies were attracted to pass through the screen into cell (ii) by a yellow light, while cell (i) was darkened. All laboratory tests were performed at fixed temperature (28°C), humidity (RH 50-60%), and illumination, and a duration of 24 hr.

2.3. Field experiments

Screened greenhouses (0.5 ha) and low tunnels (45 cm high, 3 m long) were investigated for whitefly penetration. The whitefly population density indoors was compared with that prevailing outdoors, using yellow sticky traps (Berlinger, 1980). 10 traps per replicate were used in the greenhouse experiments and 4 per replicate in the tunnel experiment. At the Ranen site- 10 commercial greenhouses covered with different screens were chosen at random and investigated weekly during 8 weeks (26/9-20/11). At the Sede Nitzan site- 4 greenhouses covered with "Agryl" were investigated weekly during 8 weeks (15/10-11/12). Low tunnels, covered with 5 different coverings and arranged in a randomized block system, with 6 replicates for each treatment, were investigated twice weekly, from 11/9 to 30/9. At each site uncovered, outdoor traps were used as controls.

Table 1. The qualifications of the tested screens

Screen No.	Producer or Supplier in Israel	Mesh*)	Thread gauge (mm)	Thread color	Notes
1.	Klayman-Meteor Ltd.	14/16	0.22	Transparent	control screen
2.	Klayman-Meteor Ltd.	22/50	0.22	Transparent	
3. **)	Klayman-Meteor Ltd.	25/50	0.22	Transparent	
4. **)	Klayman-Meteor Ltd.	25/50	0.24	Transparent	
5. **)	Ben Tsur-Drouianoff Ltd.	25/54	0.22	Transparent	
6.	Gil-Gad 1982 Ltd.	27/58	0.20	Cristal-White	
7. **)	Gil-Gad 1982 Ltd.	28/58	0.20	Cristal-White	
8.	Gil-Gad 1982 Ltd.	29/58	0.20	Cristal-White	
9.	Tama Ltd.	26/53	0.28	---	
10.**)	A. Steinberg Ltd.	--/--	-.--	White	"Agryl" unwoven sheet

*) = Number of holes per Inch, in each direction,
**) = commercial coverings

2.5. Evaluation of the results

The whitefly penetration was evaluated in two ways: (1) Number of whiteflies/trap/day; (2) Percent penetration, which was calculated by dividing the number of whiteflies which passed through the screen, by the total number of potentially available whiteflies.

3. Results and Discussion

In the laboratory experiments significant differences were found in the ability of whiteflies to penetrate through the various screens. The differences ranged from 99.3% (Table 2, screen No. 1) in the control, to 0.1% in the most dense mesh screen (screen No. 8). Investigation of the screens which are in commercial use (Table 1) shows that the whitefly penetration rate ranged between 8.8% and 0.5% (8.8%, 6.8%, 6.2%, and 0.5% for screens 5, 4, 3, 10, and 7 respectively).

Table 2. Whiteflies/trap/day and percent (%) penetration through the tested screens

No. of Screen	Laboratory tests Whitefly penetration n*)	%	± S.D.	Greenhouse tests Whiteflies n*)	/trap/ day	% penetr.	Low-tunnel tests Whiteflies n*)	/trap/ day	% penetr.
1	30	99 3	0 9	-	--	--	6	30 4	24 2
2	40	23 2	15.6	-	--	--	6	0 6	0 5
3	12	6 2	6 1	4	0.8	1 9	-	--	--
4	28	6 8	5 8	-	--	--	-	--	--
5	44	8 8	7 9	2	0.8	1 9	5	0 3	0 3
6	6	1 2	1 9	-	--	--	-	--	--
7	36	0 5	0.7	4	0.4	1 0	6	0.7	0 8
8	6	0.1	0 3	-	--	--	--	--	--
9	12	2 1	2 1	-	--	--	-	--	--
10	11	5 8	5 5	-	--	--	6	0.4	0.5
**)	--	--	--	4	40.2	(100.0)	6	88 5	(100.0)

n *) = number of experiments

**) = outdoor control.

In the tunnel experiments the catches were extremely low, and it did not exceed 0.7 whiteflies/trap/day. Their whitefly penetrate rates, compared with the uncovered control traps, were also very low (0.3-0.8%). For screen No. 2, through which 23.2% of the whiteflies passed in the laboratory tests, only 0.6 whiteflies/trap/day and a 0.5% penetration rate were found under the tunnels. Even more surprising was the result obtained in the tunnels covered with screen No. 1, through which 99.3% of the whiteflies passed in the laboratory test, but only 24.2% in the field. It seems that in the field there are additional factors influencing whitefly penetration behavior. Under the tunnels and in the commercial greenhouses, the number of trapped

whiteflies was significantly lower compared with those trapped outdoors, and bellow the accepted economic threshold (Berlinger, unpublished data).

The commercial greenhouses were sprayed twice a week to prevent the development of indoor populations, whereas the organically grown tomatoes under "Agryl" were not sprayed. Accordingly, in the sprayed greenhouses no increase in whitefly population density was noticed with time, in contrast with the organic - unsprayed - greenhouses covered with "Agryl". Therefore, the "Agryl" covered greenhouses can not be compared with the conventionally screened greenhouses.

In the tests performed in greenhouses and under low-tunnels, the penetration of whiteflies was usually lower than expected, based on the laboratory tests where the same screens were used.

In addition to whiteflies other insects were trapped by the same yellow sticky traps. All the screens used in the commercial greenhouses prevented penetration of insects which are larger in size than whiteflies, *e.g.* aphids, leafhoppers, leaf miner flies, and psyllids. The penetration of *Thrips,* mainly *Thrips tabaci,* which is smaller than the whitefly, was reduced.

In conclusion: screening the greenhouses with a suitable screen is a very efficient way to prevent primary pest penetration. Still, some pest individuals succeed in penetrating, despite all efforts, and it is necessary to apply complimentary control measures, which would be useless without the screens.

Acknowledgements

The authors express their thanks to the growers at Ranen and Sede Nitzan who kindly allowed us to perform the observations in their greenhouses; to Mr. E. Siti (Plant Protection, Extension Service, Ministry of Agriculture) for his valuable help; to Dr. A. Genizi (Dept. of Statistics, ARO, The Volcani Center, Bet Dagan) for his important help in the evaluation of the results; to the suppliers for the screens which they provided for the experiments; and to Mr. J. Hoenig, of our laboratory, for his useful technical assistance.

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., R. Dahan, 1989. *Bemisia tabaci,* the vector of tomato yellow

leaf curl virus: A challenge to southern European entomologists. pp. 67-71. 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.

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

Berlinger, M.J., R. Dahan, Sara Mordechi, 1987. Has the tobacco whitefly, *Bemisia tabaci*, developed resistance to synthetic pyrethroides? Phytoparasitica 15: 264 (abstract).

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

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

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

LES PUCERONS DES CULTURES MARAICHERES SOUS ABRIS UN SERIEUX PROBLEME EN ALGERIE.

Vers une lutte intégrée en serres.

GUENAOUI Y.* et AIT CHAABANE A.**
Institut de Technologie Agricole
BP. 120 - MOSTAGANEM (ALGERIE).

* Enseignante I.T.A.
** Stagiaire 5è A.

RESUME

En Algérie, les cultures maraîchères sous abris représentent près d'un demi-millier d'hectares qui sont, en majorité, répartis sur les zones côtières. Les cultures les plus importantes sont : la tomate, le poivron, le piment et le concombre qui occupent 90 % des superficies globales.

Ces cultures sont régulièrement attaquées par les pucerons dont les principales espèces sont *Myzus persicae* SULZ.et *Aphis gossypii* GLOV. Les traitements chimiques classiques n'empêchent pas les populations aphidiennes d'atteindre des niveaux spectaculaires.

Des investigations menées dans la région de MOSTAGANEM laissent penser à la possibilité d'utiliser des ennemis naturels, en l'occurence les Hymenoptères parasitoïdes Deux espèces du genre Aphidius semblent, en raison de leur abondance dans les prélèvements, présenter des avantages. Il s'agit d'*Aphidius matricariae* HALIDAY et d'*Aphidius colemani* VIERECK, deux souches dont il faut étudier les potentialités surtout à des températures élevées.

Des expérimentations sont en cours. Elles auront pour intérêt de poursuivre dans cette voie ou alors de s'orienter vers d'autres moyens biologiques ; car il existe dans la région, un cortège très riche en auxiliaires dont l'action est très certainement limitée par l'abus des traitements phytosanitaires polyvalents et mal ciblés. La protection phytosanitaire des cultures sous abris ne peut être efficace que si l'on met en place une stratégie de lutte intégrée comme dans les pays riverains.

1. IMPORTANCE ET REPARTITION DES CULTURES PROTEGEES EN ALGERIE

Les cultures maraîchères protégées n'ont réellement commencé à se développer qu'à partir de 1980 où les superficies occupaient 164,5 ha (BENHAMOU, 1984). La superficie des abris a connu un accroissement rapide et important jusqu'en 1985 atteignant 3602 ha. En cinq ans les surfaces n'ont augmenté que de 1200 ha totalisant en 1990, 4850 ha (BENHAMOU,1990).

Actuellement, la majorité des abris sont en forme de tunnels hemicylindriques dont la charpente est constituée de tubes en métal galvanisé. Ils sont recouverts d'un film en plastique dont la résistance varie de 1 à 3 ans selon l'épaisseur. Près de 77 % des installations sont implantées près du littoral qui offre des conditions agroclimatiques appréciables 20 % sont situés dans les plaines intérieures le reste concerne le Sud.

Les principales cultures maraîchères sont pour les solanacées : la tomate, le poivron et le piment qui occupent respectivement 30, 30 et 15 % (source : IDCM* - ALGER).Pour les cucurbitacées : le concombre (15 %) et le melon (5 %).

2. LES PROBLEMES DE RAVAGEURS DES CULTURES MARAICHERES SOUS ABRIS

Le climat du littoral algérien présente, certes, des avantages parce qu'il permet une installation précoce des cultures à des coûts relativement intéressants par rapport aux productions sous abris chauffés, mais sur le plan phytosanitaire, les problèmes se compliquent à cause des températures qui évoluent toujours en faveur des ravageurs majeurs comme les tétranyques, l'aleurode et surtout les pucerons. Grâce à la douceur du climat, ces arthropodes sont maintenus en activité toute l'année, soit sur les cultures de plein champ, soit sur les plantes hôtes spontanées. Cette situation favorise les échanges entre l'extérieur et le milieu serre, à partir d'infestations précoces.

Dans la région de MOSTAGANEM, située sur la côte Ouest, les superficies réservées aux cultures protégées sont de l'ordre de 160 ha. La tomate et le poivron occupent chacune 58 ha, tandis que le concombre et le melon totalisent 33 ha (Source : INPV* - ALGER). Ces productions sont régulièrement attaquées par les pucerons au point de provoquer la réduction des superficies.

C'est sur poivron et concombre que les dégâts des pucerons sont les plus spectaculaires. Les espèces en cause sont M.persicae et A. gossypii. La première espèce attaque le poivron tandis que la 2ème pullule aussi bien sur concombre, sa plante hôte préférée, que sur poivron. Ceci tient du fait que le poivron est plus réceptif aux pucerons que les autres solanacées.Contre ces ravageurs, les agriculteurs réalisent des traitements insecticides à partir de directives émanant des services de la protection des végétaux de la région. Mais il semble que la lutte chimique soit devenue de moins en moins efficace contre les pucerons. Toutefois cette "inefficacité" des traitements peut avoir des explications différentes. Il n'est pas exclu qu'à la suite des traitements insecticides répétés et mal ciblés, on ait favorisé l'apparition de souches résistantes chez les pucerons, comme l'ont souligné de nombreux auteurs (DELORME, 1984 ; DELORME et al 1987 ; NEEDHAM et SAWICKI, 1971); mais en même temps l'ont peut penser qu'il peut s'agir d'une mauvaise utilisation des produits phytosanitaires, soit par méconnaissance des périodes d'intervention par rapport à la biologie des espèces considérées soit par l'emploi de produits périmés. Toujours est-il que les dégâts enregistrés incitent les producteurs à réduire les superficies des cultures concernées, au profit de productions moins contraignantes et plus rentables.

*INPV : Institut National de la Protection des Végétaux
*IDCM : Institut de Développement des Cultures Maraîchères

3. LES POSSIBILITES DE DEVELOPPEMENT DE LA LUTTE INTEGREE

Afin de réduire les contaminations précoces des cultures sous abris, dans des conditions aussi favorables aux ravageurs, il est indispensable que les agriculteurs prennent plus conscience de l'intérêt que représentent les mesures prophylactiques, comme le desherbage des abris et de leurs abords, l'utilisation de plants non contaminés etc... .

Dans le cadre de notre travail de recherches à l'Institut, nous essayons de trouver des moyens biologiques qui permettent de limiter les traitements insecticides, et réguler les populations de pucerons. Nous avons commencé par dresser un inventaire des différents ennemis naturels des Aphides (prédateurs et parasitoïdes) dans la région de MOSTAGANEM. Nos prospections ont débuté au printemps dernier dans des zones non traitées de façon régulière. Ils ont permis de réaliser un nombre important de prélèvements sur différentes plantes hôtes de M.persicae et A. gossypii. Curieusement ce sont les Hyménoptères parasites qui sont les plus représentés. Mais nous avons également remarqué dans de nombreuses colonies une présence importante de larves de cecidomyie prédatrice et de syrphes. Cependant d'autres auxiliaires ont été observés. Les pucerons parasités sont prélevés au stade "momie". Le nombre récolté jusqu'à présent 538 momies. Elles sont rapportées au laboratoire, et mises en éclosoir afin de suivre les émergences. Les parasites sont ensuite séparés en fonction de leur hôte et de leur espèce, puis déterminés avec l'aide de spécialistes. Près de 70 % des parasites ont émergé. Ils appartiennent en majorité au genre Aphidius dont A. matricariae est le plus représenté numériquement.Cette espèce a déjà fait l'objet de nombreux travaux en FRANCE (RABASSE et SHALABY, 1980 ; LAFONT, 1982). La deuxième espèce rencontrée est A. colemani. Cette espèce qui a déjà été identifiée par RABASSE en 1987 sur Hyaloptérus prunicae prélevé sur pêcher à MOSTAGANEM, présente l'avantage de parasiter à la fois M. persicae et A. gossypii. Une souche de la même espèce, d'origine brésilienne a fait l'objet de nombreux travaux (TARDIEUX, 1987 ; GUENAOUI 1988 ; TARDIEUX et RABASSE, 1988 ; RABASSE et al 1989; GUENAOUI, 1990 ; GUENAOUI, 1991) ; mais il faut espérer que la souche algérienne n'ait pas son pouvoir parasitaire altéré par les températures élevées que nous connaissons dans la région d'autant qu'Aphis gossypii conserve un potentiel biotique non négligeable dans ces conditions (GUENAOUI, 1988).

4. CONCLUSION

Il semble maintenant établi que seule la lutte intégrée au sens le plus large, peut résoudre le problème de protection phytosanitaire en serre. De nombreuses erreurs de conduite des cultures sont probablement la cause d'un mauvais état sanitaire des productions. Pour y remédier il faut que les agriculteurs soient en mesure de comprendre l'importance de tous les facteurs du milieu, qu'ils soient biotiques ou abiotiques. La vulgarisation des différentes techniques devraient donc permettre aux serristes de comprendre certains mécanismes qui pour l'instant, leur échappent totalement. Avec des séances de vulgarisation et un appui technique continu, peut être opteront-ils pour la lutte intégrée?

BIBLIOGRAPHIE

- BENHAMOU F., 1984 - Les cultures sous serres. Techniques culturales et problèmes phytosanitaires. In "Séminaire sur la lutte intégrée et l'utilisation des pesticides" 16 - 20 Septembre 1984 - Club des Pins - ALGER.

- BENHAMOU F., 1990 - Les films plastiques pour la couverture des abris serres et le paillage du sol en Algérie. In "Deuxième séminaire international de la plasticulture" - 12 - 16 Février 1990 - ALGER.

- DELORME R., 1984 - Détection mécanismes et épidémiologie des phénomènes de résistance - In "Colloque sur la réduction d'efficacité des traitements insecticides et acaricides et les problèmes de résistance" - Soc. Phytiatrie et phytopharmacie 19 - 33.

- DELORME R., AUGE D., BOUCHERY Y . , CLOQUEMIN G., 1987 - Détection et caractéristiques des souches résistantes de Myzus persicae SULZ. Conf. Int. A.N.P.P. sur les ravageurs en agriculture - PARIS 1987 - 2- 227 - 236.

- GUENAOUI Y., 1988 - Lutte intégrée en cultures protégées. Contribution à l'étude des interactions entre Aphys gossypii (HOM : Aphididae) et son endoparasite Aphidius colemani VIERECK (HYM : Aphidiidae). Essai de lutte biologique sur concombre. Thèse de docteur ingénieur en sciences agronomiques - ENSA RENNES 79pp.

- GUENAOUI Y. 1990 - Contribution à l'étude des relations hôte parasitoïde entre Aphis gossypii GLOVER et Aphidius VIERECK. Thèse de doctorat en seicnes biologiques - Université de RENNES, 99 pp.

- GUENAOUI Y., 1991 - Role of température on the host suitability of Aphis gossypii GLOVER (Hom : Aphodidae) for the parasitoid Aphidius cclemani VIERECK (Hym : Aphidiidae) - Insect. parasitoïds 6th European workshop - Perugia Italy 3-5 April 1991 (unpublished).

- LAFONT Jp, 1982 - Contribution à l'étude de la biologie d'Aphidius matricariae HALIDAY et de son efficacité contre Myzus persicae SULZ (HOM : Aphididae) Mémoire E.P.H.E. - Université des sciences et techniques du Languedoc - MONTPELLIER 116 pp.

- NEEDHAM P.H et SAWICKI R.M., 1971 - Diagnostics of resistance to organophosphorous insecticides IN Myzus persicae SULZ. Nature - LONDON 230-126-127.

- RABASSE J.M et SHALABI, F.F, 1980 - Laboratory studies on the development of Myzus persicae SULZ (HOM : Aphididae) and its primary parasite Aphidius matricariae (HYM : Aphidiidae at constante températures. ACTA. Oecol. Oecol.appl.1 - 21 - 28.

- RABASSE J.M, LAFONT J.P, GUENAOUI Y., TARDIEUX I., 1989 - Parasites that can be used against the main aphid pests of vegetables under glass.-house Coll. OILB - Lutte intégrée en serre, BUDAPEST 1987 (sous presse).

TARDIEUX I. et RABASSE J.M., 1988 - Some aspects of host community and physiological suitability in aphids attacked by Aphidius colemani VIERECK. In Ecology and Effectiveness of Aphidophaga. SPB Academic Publishing, The Hague, 311-315.

Influence de la nutrition minérale de l'aubergine cultivée hors sol sur la reproduction du puceron *Macrosiphum euphorbiae* THOMAS

A. LATIGUI, J.M. RABASSE, A. CHAMPEROUX *

I.N.R.A. Laboratoire de biologie des invertébrés. F- 06600 ANTIBES

* I.N.R.A. Station d'Agronomie et de Physiologie végétale F- 06600 ANTIBES

Summary

The reproduction rate of ***Macrosiphum euphorbiae*** on eggplant growing on nutrient solutions with different anions and cations ratios was studied. No difference was found between solutions containing 5, 8, and 10 meq. NO_3^- / l., but fecundity was significantly higher with 16 meq.. No difference was found when 10 NO_3^- meq. / l. was replaced by 8 NO_3^- meq. + 2 NH_4^+ meq. Finally, when the ratio K^+/Mg^{++} was 1.5, the fecundity of the aphid was not different than with a ratio of 5.5, the concentration of NO_3^- being 12 meq. / l..

Introduction

Le potentiel biotique des insectes phytophages dépend de l'état physiologique de la plante hôte et par conséquent de son alimentation. On peut donc penser qu'une modification de la fertilisation minérale peut aussi bien être utilisée pour limiter la croissance des populations d'insectes nuisibles en culture, que pour la stimuler dans des élevages destinés à la production d'entomophages.

L'influence de la fertilisation azotée sur le potentiel biotique des aphides a été montrée par plusieurs auteurs. JANSSON et SMILOVITZ (1986) ont montré que le taux d'accroissement potentiel de ***Myzus persicae*** SULZER élevé sur pomme de terre est positivement corrélé avec la concentration de l'azote total, des amides, et des nitrates contenus dans la plante. BONIN et al.(1986) ont montré que les variétés de ***Medicago spp.*** sensibles à ***Acyrthosiphon pisum*** HARRIS sont les plus riches en produits azotés.Le potassium fourni en excès à des plantes de radis entraine une diminution trés significative de la fécondité de ***M. persicae***, alors qu'un excès de magnésium produit un effet opposé (QUOILIN, 1967).

Tableau 1: Traitements et protocole d'essais

Mise en place des essais	Nutritions	NO_3^-	$H_2PO_4^-$	SO_4^{--}	Σ	K^+	Ca^{++}	Mg^{++}	NH_4^+	Σ	$K^+/(Ca^{++}+Mg^{++})$	K^+/Mg^{++}
Essai 1: 10/2/89	a	5	1	6.5	12.5	4	5.1	1.4	0	10.5	0.61	2.86
	b	8	1	6.5	15.5	4.9	6.6	2	0	13.5	0.57	2.45
	c	10	1	6.5	17.5	5.5	7.6	2.4	0	15.5	0.55	2.29
	d	8	1	6.5	15.5	4.3	5.6	1.6	2	13.5	0.59	2.69
Essai 2: 7/3/90	e	10	1	6.5	17.5	6	6.75	2.25	0	15	0.66	2.67
	f	16	1	6.5	23.5	8.4	9.45	3.15	0	21	0.66	2.67
Essai 3: 13/11/90	g	12	1.5	4.9	18.4	6	5	4	2	17	0.66	1.5
	h	12	1.5	4.9	18.4	5.5	7.1	1	2.9	16.5	0.67	5.5

Nous avons étudié le rôle de la fertilisation minérale apportée dans la solution d'irrigation des plantes d'aubergine cultivées hors sol en serre sur le potentiel biotique du puceron ***Macrosiphum euphorbiae*** THOMAS. A cet effet, différentes concentrations d'azote nitrique (NO^-_3), un apport ammoniacal (NH_4^+), différents rapports K^+/Mg^{++} ont été testés.

Materiel et méthodes

La plante et l'insecte

La plante hôte choisie est l'aubergine cv. "BONICA" (hybride F1), sur laquelle le potentiel biotique des pucerons est élevé (RABASSE, 1980).

Le puceron ***M. euphorbiae*** est représenté par une population parthénogénétique issue d'une seule femelle et élevée au laboratoire sur aubergine à une température de 20 à 22 C°et une photopériode de 16 h depuis le 1/10/88.

Conduite de la culture

Tous les essais sont réalisés en serre. Pendant leur élevage, les jeunes plants sont irrigués à l'aide d'une solution standard dont la composition en meq./l (*) est:

NO_3^- =11 $H_2PO_4^-$=2 SO_4^{--} =2 K^+=5 Ca^{++}=8 Mg^{++}=2

Les plants sont repiqués dans des cubes de laine de roche déposés sur une portion de pain de laine de roche d'une capacité de rétention de 1.5 l. Le passage aux solutions expérimentales a lieu au stade 3 feuilles vraies (essai 1) et au stade cotylédons (essais 2 et 3); les plants sont alors placés dans la serre d'expérimentation. A partir de ce moment là, l'irrigation se fait manuellement 3 fois par jour. La quantité apportée est conditionnée par la quantité de drainage d'une plante témoin. Le drainage doit être supérieur à 30 % du volume apporté.

Mesure de la fécondité

Des femelles adultes de pucerons sont placées individuellement dans des "clip-cages" sur chaque plante en expérience, puis prélevées après qu'elles aient déposé trois larves.

(*) 1 meq. ou milliéquivalent est le millième de la masse molaire d'un élément ou d'un radical divisé par sa valence.

Lorsque les larves sont arrivées au 4° stade, deux d'entre elles sont éliminées. L'observation de fécondité est réalisée sur la femelle restante. La descendance,dans tous les essais, a été suivie pendant trois générations, la deuxième et la troisième générations étant constituées par la dixième fille de la génération précédente. Les jeunes larves étaient comptées et supprimées chaque jour. Les essais ont débuté à la floraison du 1° bouquet.

Traitements et protocole d'essais

Les différents traitements et les dates de mise en place des essais sont représentés dans le tableau 1.

Essai 1. Effet de différentes concentrations d'azote nitrique et d'un apport ammoniacal.

Chaque traitement portait sur une plante sur laquelle trois larves du 4°stade étaient individualisées. Pour la 1° génération, elles étaient déposées sur les feuille -1, -2 et -3 (**), et pour la 2° et la 3° générations sur les feuilles +1, +2, +3. La mise en place des larves a eu lieu le 19/2/89.

4 traitements: a, b, c, d,

1 plante par traitement,

3 niveaux par plante correspondant à 3 pucerons.

Essai 2. Effet de deux concentrations élevées en azote nitrique (10 et 16 meq./l)

Chaque traitement portait sur deux plantes. Sur chaque plante, 5 larves du 4° stade étaient individualisées sur la feuille -1 le 4/4/90.

2 traitements e et f,

2 plantes par traitement,

1 niveau foliaire par plante correspondant à 5 pucerons.

(**) Feuille -1= feuille se trouvant en dessous de la première inflorescence.

Feuille +1= feuille se trouvant en dessus de la première inflorescence.

Essai 3. Effet du rapport K^+/Mg^{++}

Chaque traitement portait sur 5 plantes. Sur chaque plante, 4 larves du 4° stade individualisées ont été placées sur la feuille -1 le 16/1/91.

2 traitements g, h,

5 plantes par traitement,

1 niveau par plante,

4 pucerons par niveau.

Résultats

Effet des différentes concentrations d'azote nitrique et d'un apport ammoniacal

Les résultats sont consignés dans le tableau 2. Ils ont été soumis à un test de KRUSKALL et WALLIS , qui n'a pas montré de différence significative au seuil 0.05.

Tableau 2 : Nombre total moyen des naissances de *M. euphorbiae* vivant sur des aubergines hors sol irriguées avec les solutions a,b,c,d (7 jours de reproduction par génération)

	solution a	solution b	solution c	solution d	Période
Génération 1	43	49	46.7	53	du 22/2 au 29/2
Génération 2	33	42.3	35	45	du 6/3 au 13/3
Génération 3	64.3	63.3	66.7	63.7	du 17/3 au 24/3

Nous avons, toutefois, constaté une augmentation trés significative du nombre de larves nées de la troisième génération par rapport aux deux premières générations.

Effet de deux concentrations élevées en azote nitrique (10 et 16 meq/l)

Les résultats sont consignés dans le tableau 3 (comparaison des moyennes)

Tableau 3: Comparaison des moyennes du nombre de naissances des traitements e et f (8 jours de reproduction pour la 1° et la 2° générations et 6 jours pour la 3° génération).

	solution e	solution f		période
Génération 1	55.5	62.5	*	du 7/4 au 14/4
Génération 2	55.6	57.5	-	du 17/4 au 24/4
Génération 3	18.8	48.8	**	du 28/4 au 4/5

* différence significative au seuil 0.05

** différence significative au seuil 0.01

L'analyse de la variance montre qu'il y a un effet significatif de l'action de la concentration en azote nitrique de la solution fertilisante sur le potentiel biotique des pucerons. Le test de NEWMAN et KEULS révèle qu'une concentration de 16 meq. de NO_3^- augmente le nombre de naissances (au seuil 0.05 pour la première génération au seuil 0.01 pour la troisième génération). Cette augmentation est de 13% dans la première génération, et de 159% dans la troisième génération. Cependant aucune différence n'a été observée dans la deuxième génération

Effet de la variation du rapport K^+/Mg^{++}

Les résultats sont consignés dans le tableau 4. Ils sont soumis à une analyse de la variance qui n'a pas révélé d'effet significatif des différents rapport K^+/Mg^{++} sur le potentiel biotique des pucerons. Le test a été réalisé pour chacune des 3 trois générations consécutives.

Tableau 4: Comparaison des moyennes du nombre de naissances des traitements g et h (durant toute la période de reproduction des pucerons).

	solution g	solution h	période
Génération 1	70.7	72	du 18/1 au 4/2
Génération 2	84.3	85.4	du 30/1 au 15/2
Génération 3	84.3	85	du 9/2 au 25/2

Discussion

Il a été fréquemment montré que l'apport d'azote au sol augmente les populations d'aphides sur les plantes. Cela a été observé au champ pour ***Metopolophium dirhodum*** et ***Sitobion avenae*** sur blé (CARRILLO et MELLADO, 1975; CARRILLO et MUNDACA, 1976; HANISCH, 1980) ou pour ***Aphis gossypii*** sur coton (RASMY et HASSIB, 1974). Sur plantes en pot, la fertilisation azotée augmente le taux d'accroissement de ***Myzus persicae*** sur pomme de terre (JANSSON et SMILTOVITZ, 1986) ou la reproduction de ***Brevicoryne brassicae*** et de ***M. persicae*** sur choux de Bruxelles (VAN EMDEN et BASHFORD, 1969).

Les Aphididae se nourrissent, en général, de la sève élaborée, qui véhicule des acides aminés et il n'est pas étonnant qu'une relation apparaisse entre la nutrition azotée du végétal et le potentiel biotique de ces insectes. L'essai réalisé a montré que dans le cas de l'aubergine (***Solanum melongena*** L.) produite en hors sol, la fécondité de ***M. euphorbiae*** n'augmentait qu'entre 10 et 16 meq. de NO_3^-. Il est intéressant de rapprocher ce résultat de celui obtenu par DE LA METTRIE (1976) sur la même variété et dans les mêmes conditions de culture: lorsque l'on passe de 8 à 12 meq de NO_3^- le rendement en fruits diminue et leur teneur en nitrates augmente fortement. 10 meq. de NO_3^- constitue donc une limite à ne pas dépasser en alimentation stable.

On pouvait par ailleurs faire l'hypothèse que l'apport d'une partie de l'azote sous forme ammoniacale augmentait la protéosynthèse dans nos conditions expérimentales —comme cela a été montré dans d'autres cas (BLANC, 1963 a et b)— avec des conséquences éventuelles sur la composition de la sève élaborée et sur la nutrition des pucerons. La comparaison de 10 meq. NO_3^- à 8 meq. NO_3^- + 2 meq. NH_4^+ n'a pas révélé de différences significatives au niveau de la fécondité de ***M. euphorbiae.***

Nous avons testé l'influence du rapport K^+ / Mg^{++} en donnant des valeurs extrêmes à la concentration en Mg^{++}, sans observer de différence significative. Sur ***M.euphorbiae*** élevé sur des plants de pomme de terre en solution nutritive, HARREWIJN (1970) avait obtenu le même résultat. Il faut rappeler que les différences importantes de fécondité observées par QUOILIN (1967) sur ***M. persicae*** sur radis étaient dues à des solutions complètement carencées en K^+ ou en Mg^{++}.

Cet ensemble de résultats montre donc pour l'association ***M. euphorbiae /S. melongena,*** qui nous intéresse, que:

- une forte fertilisation nitrique permet de maximiser la production de pucerons en élevage.
- des modifications agronomiquement réalistes de la fertilisation minérale semblent pouvoir difficilement constituer un moyen efficace de limitation des populations aphidiennes.

L'étude des relations fertilisation-fécondité constitue simplement une première approche des relations culture-pucerons. Il est clair que la fertilisation n'agit pas que par son influence sur la valeur alimentaire de la plante-hôte. La phagostimulation (RAHBE et al. 1988, FEBVAY et al. 1988) joue un rôle sans doute aussi important, de même que l'attractivité du végétal, son appétence ou son incidence qualitative sur la population qui se traduit par la formation d'ailés de dissémination.

BIBLIOGRAPHIE

BLANC D., (1963 a). Etude comparative du métabolisme azoté du végétal en milieu nitrique et ammoniaco-nitrique. Bull. Soc. Fr. Physiol. Végétale, 9, 186-193.

BLANC D., (1963 b). Synthèse comparée d'azote organique par ***Dactylis glomerata*** L. cultivé en milieu nitrique et en milieu ammoniaco-nitrique. C.R. Acad. Sc., 256, 2692-2694.

BONIN, J., (1976). Relations possibles entre la sensibilité de divers clones de luzerne (***Medicago sativa*** L.) au puceron du pois (***Acyrthosiphon pisum*** L.) et la composition biochimique de leur sève phloémienne. D.E.A. Poitiers.

CARRILLO R., MELLADO M.,(1975). Effecto de los afidos ***Metopolophium dirhodum*** y ***Sitobion avenae*** y del nitrogeno y potassio sobre el rendimiento, componentes del rendimiento y algunas caracteristicas morfologicas de un cultivar de trigo (***Triticum aestivum*** L.). Agro Sur, 3 , 109-116.

CARRILLO R., MUNDACA B.,(1976). Effecto del nitrogeno en las poblaciones, progenie y velocidad de desarollo de los afidos ***Metopolophium dirhodum*** y ***Sitobion avenae*** en trigo (***Triticum aestivum*** L.). Agro Sur, 4, 15-20.

FEBVAY G., BONNIN J., RAHBE Y., BOURNOVILLE R., DELROT S., BONNEMAIN J.L., (1988). Resistance of different lucerne cultivars to the pea aphid *Acyrthosiphon pisum:* influence of phloem composition on aphid fecundity. Entomol. exp. app., 48: 127-134

HANISCH H.C.,(1980). Untersuchungen zum Einfluss unterschiedlich haber stickstoffdugung zu wiezen auf die Population. Sentwieklung von Getreideblattlausen. Z. Pflanzenkrank. Pflanzenschutz, 87, 546-556.

HARREWINJN P., (1970). Reproduction of the aphid *Myzus persicae* related to the mineral nutrition of potato plants. Ent. exp. appl., 13,307-319

JANSSON R.K., SMILOWITZ Z., (1986). Influence of nitrogen on population parameters of potato insects: abundance, population growth and within-plant distribution of the green peach aphid, *Myzus persicae* (Homoptera: Aphididae). Environ. Entomol. 15, 49-55.

METTRIE M. de la., (1976). Etude de certains facteurs d'accumulation des nitrates chez l'aubergine (*Solanum melongena* L.) Mémoire ENITA Angers, 47 pp..

QUOILIN J., (1967). Nutrition minérale de la plante-hôte et fécondité de *Myzus persicae* SULZ. (Homoptera-Aphididae). Meded. Fac. Landbouwwet. Rijksuniv. Gent, 365-386.

RABASSE J.M., (1980) . Dynamique des populations d'aphides sur aubergine en serre. Considérations générales sur la colonisation et le développement des populations de quatre espèces dans le sud de la France. Bull. OILB/SROP, III/3, 187-198.

RAHBE Y., FEBVAY G., DELOBEL B., BOURNOVILLE R., (1988). *Acyrthosiphon pisum* performance in response to the sugar and amino acid composition of artificial diets, and its relation to lucerne varietal resistance. Entomol. exp. appl., 48: 283-292.

RASMY A.H., HASSIB M., (1974). Influence of plant nitrogen supply on the population of some cotton pests. Appl. Entomol. Zool., 9, 48-49.

VAN EMDEN H.F. , BASHFORD M.A., (1969). A comparison of the reproduction of *Brevicoryne brassicae* and *Myzus persicae* in relation to soluble nitrogen concentration and leaf age (leaf position) in the brussels sprout plants. Ent. exp. appl., 12,351-364.

EPICLERUS NOMOCERUS (MASI) (HYM., TETRACAMPIDAE), NOUVEAU PARASITOIDE DE LIRIOMYZA TRIFOLII BURGESS (DIP., AGROMYZIDAE) EN CULTURE SOUS SERRE

E. FRANCO* ET A. PANIS**
* I.N.R.A., Laboratoire de Biologie des Invertébrés, B.P.2078 06606 ANTIBES Cedex ** I.N.R.A., Laboratoire de Biologie des Invertébrés, 1382 Route de Biot 06560 VALBONNE -FRANCE.

Summary

EPICLERUS NOMOCERUS (MASI) (HYM., TETRACAMPIDAE), A NEW PARASITOID OF LIRIOMYZA TRIFOLII BURGESS (DIP., AGROMYZIDAE) IN GLASSHOUSE CULTURE.

A thelytokous line of **Epiclerus nomocerus** is sometimes entering tomato glasshouses of Southeastern France, where it parasitizes **Liriomyza trifolii. Tetracampidae** is a poorly known family. So, biology of this species is partially established. Some behavioural and reproductive features are described or quantitatively assessed, more specially fertility and successive times of adult life, from this strain perfectly stable under culture. Alone it proves to be unable to control **L. trifolii**, but it would be coupled with an effective beneficial insect, such as **Diglyphus isaea.**

1. Introduction

La biologie des **Tetracampidae** est à peine connue. On ne sait rien de leurs exigences écologiques et l'utilisation éventuelle de ces chalcidiens en lutte biologique ou en lutte intégrée n'a jamais été envisagée.

Plusieurs Tétracampides ont été récoltés comme parasitoïdes de Diptères dont les larves vivent en mineuses des feuilles, notamment des mouches mineuses de la famille des **Agromyzidae.** Depuis une dizaine d'années environ, nous observons la présence occasionnelle d'une espèce de cette famille, dans les serres et sous tunnel plastique, en culture de tomate hébergeant **Liriomyza trifolii** Burgess (Diptère, **Agromyzidae**). Cet hyménoptère a été trouvé dans le Sud-Est de la France, dans les cultures de tomate du département des Alpes-Maritimes (Antibes, Grasse) essentiellement, mais aussi dans celles du bord de l'Etang de Berre (département des Bouches-du-Rhône). Les quelques observations concernant ce chalcidien dans cette culture protégée, révèlent son action

parasitaire sur **L. trifolii** au cours de deux périodes de l'année : en fin de printemps et durant l'automne.

Depuis quelques années, la souche en provenance d'une serre de tomate située à Grasse, est élevée en insectarium, sur **L. trifolii** multiplié sur haricot (**Phaseolus vulgaris** L.).

Nous avons voulu établir trois catégories de données sur cet insecte.

Premièrement, connaître si les populations de cet entomophage en culture sous abri, résultent d'une importation fortuite en France, vers 1980. Dans ce cas, il s'agirait d'une acclimatation effectuée en dehors du programme de mise au point de la lutte biologique contre la Mouche serpentine des serres (**L. trifolii**), programme qui avait débuté vers 1980, avec des chalcidiens différents de celui-ci.

Deuxièmement, nous avions la possibilité d'étudier quelques caractères biologiques du parasitoïde. Comme il n'y a pas d'étude biologique sur les Tétracampides, c'était une occasion de s'intéresser à cette famille de chalcidiens, quelle que soit son utilité économique ou scientifique.

Troisièmement, ces caractères donnent une première information sur l'importance agronomique éventuelle du Tétracampide. Actuellement, la protection biologique en serre de tomate est pratiquée chez les maraîchers, par lâcher de **Diglyphus isaea** Walker (Hyménoptère, **Eulophidae**). Est-ce que ce Tétracampide peut avoir quelque avantage économique, complémentaire de l'intervention biologique contre **L. trifolii**? Il se trouve spontanément en serre à deux périodes de l'année (mentionnées plus haut). Vers 1985 dans le Sud-Est, la production de tomate sous tunnel plastique, a été remplacée par celle en serre vitrée, avec la plantation au mois de novembre et culture jusqu'en juillet de l'année suivante.

2. Identification et gamme d'hôtes du nouveau parasitoïde

Cette espèce a été identifiée comme étant **Epiclerus nomocerus** (Masi). Le genre **Epiclerus** est représenté dans de nombreuses régions du globe et ses espèces sont mentionnées comme parasitoïdes d'Agromyzides (BOUCEK, 1988). Les espèces - hôtes sont précisées pour certains **Epiclerus** seulement. On ne dispose pas d'autres données biologiques, en particulier sur le milieu environnant où subsistent ces Hyménoptères et sur le stade de mouche-hôte dans lequel ils se développent. Aucun élevage de Tétracampide ne semble avoir été entrepris. Par conséquent, c'est le potentiel biotique de toute une famille d'insectes auxiliaires qui reste non évalué, en tant qu'auxiliaire de l'agriculture ou dans l'optique de l'aménagement d'un agrosystème pour conserver des insectes intervenant spontanément en protection des plantes.

BOUCEK (1958) donne une description précise des deux sexes d'**E. nomocerus**. En se basant sur cette diagnose de

l'espèce, nous avons voulu vérifier si les individus récoltés sur tomate en serre correspondent morphologiquement, aux individus vivant en plein air dans notre pays.

En effet, les populations naturelles présentent des mâles, alors que celles en condition artificielle (culture protégée) n'en ont jamais. En serre de tomate, elles sont parthénogénétiques (thélytoquie). Ne disposant pas d'individus du milieu naturel, vivants, nous n'avons pas essayé de croiser les mâles avec les femelles d'élevage.

Ainsi, **E. nomocerus** pose un problème de biosystématique, qu'on ne peut pas considérer comme résolu par les observations biologiques que nous avons entreprises. Toujours est-il que le changement de mode de reproduction en fonction du milieu où vit le stade adulte ou larvaire, est plus ou moins connu chez les chalcidiens. Nous citerons deux cas qui ont pu être mis en évidence chez un certain nombre d'espèces de chalcidiens. Premier cas : par exemple, **Aphycus apicalis** (Dalman) (**Aphycus albicornis**) bisexué au Japon (MURAKAMI, 1960, 1961) quand il parasite **Phenacoccus aceris** Signoret (**Phenacoccus pergandei**), parthénogénétique en France quand il parasite la même cochenille (PANIS, 1969). Cette modification du mode reproducteur peut survenir même dans des populations sympatriques. C'est le deuxième cas. Par exemple, **Anaphes diana** Girault, avec coexistence dans les pays méditerranéens, d'une lignée parthénogénétique et de populations bisexuées qui ne peuvent plus se croiser avec cette lignée (AESCHLIMANN, 1990).

Nous n'avons pas comparé les femelles d'élevage à celles de collections. L'analyse morphologique et numérique de microstructures d'**E. nomocerus** venant de diverses régions ne peut donc pas venir compléter nos observations. Après avoir vérifié la conformité des individus au statut de l'espèce, l'étude biologique a été orientée vers l'acquisition de données utilisables en lutte biologique.

BOUCEK et al. (1968) confirment l'identité taxonomique du Tétracampide trouvé auparavant par différents entomologistes. Par conséquent, les quelques données recueillies avant 1968, se rapportent bien à **E. nomocerus**. MASI (1934) a découvert cet Hyménoptère sous climat méditerranéen aride (Maroc: Ksar-es-Souk) où il parasite l'Agromyzide **Phytomyza horticola** Goureau sur pois (**Pisum sativum** L. ssp. sativum) [l'hôte n'est pas **Phytomyza atricornis** Meigen comme mentionné par MASI, mais **Ph. horticola** (SPENCER, 1973)]. Dans ce milieu écologique, l'espèce est bisexuée. CAMERON (1939) a obtenu **E. nomocerus** de **Phytomyza ilicis** Curtis, une mouche mineuse des feuilles de houx (**Ilex aquifolium** L.) en Grande-Bretagne. BOUCEK (1958) mentionne son existence dans plusieurs pays d'Europe Continentale, notamment en France (départements de l'Isère et du Var: hôte inconnu).

Nous avons obtenu **E. nomocerus** bisexué, de pupes

d'Agromyzide sur feuille de luzerne en arbre (**Medicago arborea** L.), plante subspontanée et de jardin ornemental. Le Tétracampide s'y trouve dans un milieu urbanisé (Antibes, Alpes-Maritimes) (Les Issambres, Var). L'hôte est **Liriomyza strigata** (Meigen). Son identification est basée sur les mines foliaires des larves (SPENCER, 1973) [cet auteur mentionne la difficulté de distinguer sur les adultes, **L. strigata** de **Liriomyza bryonae** (Kaltenbach)].

Le mâle obtenu de **L. strigata** est identique à l'unique exemplaire d'**E. nomocerus** de la collection du Service Faunistique du C.I.R.A.D. à Montpellier (département de l'Hérault: Grabels, 3 août 1984, G. DELVARE coll., détermination 1990). Enfin, la femelle disponible et issue de **L. strigata** correspond à la description de BOUCEK (1958).

Des commentaires précédents, il résulte que, malgré cette diversité d'hôtes et une large répartition sous climat méditerranéen, toutes ces populations se rapportent à la même espèce.

En conclusion, les populations parthénogéntiques qui parasitent **L. trifolii** en serre de tomate, sont issues très probablement des populations indigènes et bisexuées de plein air.

3. Caractères biologiques d'E. nomocerus en élevage

3a. Caractères qualitatifs

Ce Tétracampide est un parasitoïde de pupes. En fin de développement, la larve de **L. trifolii** sort de sa galerie pour se pupifier sur la feuille qui lui a donné naissance. La pupe est légèrement collée à la face supérieure du limbe foliaire qu'**E. nomocerus** va explorer avec ses antennes, à la recherche de son hôte. Les pupes sont réceptives au chalcidien, dès qu'elles sont formées.

En prenant possession d'une pupe, un comportement de prédation précède toujours la ponte. La femelle du parasitoïde se met à cheval sur la pupe et la perfore avec sa tarière, comme si elle pondait. Puis elle se retourne pour absorber de l'hémolymphe au niveau du point de piqûre. Ensuite, elle se met en posture de ponte, à cheval sur la pupe exactement comme précédemment. Elle enfonce sa tarière au même point de piqûre, mais plus doucement que la première fois. L'oeuf est déposé dans le corps de la pupe.

L'ensemble des trois séquences (exploration antennaire d'une pupe, prédatisme, ponte) dure environ 55 minutes dans les conditions d'étude mentionnées au paragraphe 3b.

Ce comportement est lent, tout comme les déplacements du parasitoïde à la recherche des pupes dans une cage d'élevage. Cela pourrait être un indice de faible aptitude à la recherche

de l'hôte et une cause de diversification vers le parasitisme de plusieurs espèces d'Agromyzides. Cependant, le chalcidien quitte facilement le feuillage, pour aller parasiter des pupes tombées par terre. D'autre part, les dissections montrent que la souche étudiée est celle d'un parasitoïde solitaire: la femelle dépose toujours un seul oeuf par pupe de **L. trifolii.** L'absence de superparasitisme, liée à la localisation de pupes situées à des niveaux différents, pourrait être un indice d'utilisation maximale des ressources pour assurer la descendance de l'espèce. Ceci pourrait compenser le manque de rapidité du chalcidien.

D'après ces caractères qualitatifs et sous réserve d'essais concluants, cet auxiliaire pourrait nettoyer les plants de tomate et le sol, des pupes de mouche mineuse restant après l'action d'un parasite larvaire.

3b. Caractères quantitatifs

Cinq caractères de la biologie parasitaire sont mesurés. Ce sont la fécondité, la longévité ainsi que chacune des trois parties de la longévité ou durée de la vie imaginale. Ces trois parties sont la durée de la pré-oviposition correspondant au temps de maturation ovarienne (mesurée comme le nombre de jours précédant celui de la ponte du premier oeuf), la durée de la ponte, la durée de la post-oviposition (nombre de jours suivant celui de la ponte du dernier oeuf jusqu'au jour de la mort de la femelle). Fécondité, durée de la pré-oviposition et durée de la ponte sont des critères intéressant la pratique d'un élevage et de lâchers de l'auxiliaire.

L'étude est faite dans les mêmes conditions que l'élevage de la souche d'**E. nomocerus** en insectarium: température constante de 25°C ; hygrométrie relative de l'air de 70-80 % ; éclairement de 16 heures par jour, avec 4 tubes au néon (2 de type "lumière blanche", 2 de type "lumière du jour") placés à un mètre environ au dessus des enceintes d'observation du Tétracampide ; pupes issues de feuilles cotylédonaires de haricot (ces deux feuilles, les premières développées après germination, sont les plus réceptives pour la ponte de **L.** trifolii) ; ces feuilles portent 30 à 40 pupes.

La tige de haricot est sectionnée et elle passe à travers un trou percé dans le bouchon d'un pillulier en matière plastique. La tige est plantée dans du sable humide contenu dans le pillulier. L'enceinte d'observation est une boîte en plastique transparent (longueur 27 cm, largeur 13 cm, hauteur 8 cm), aérée par des fenêtres de toile fine de nylon et dont le couvercle constitue le plancher de l'enceinte.

Quelques gouttes de miel sont déposées sur la paroi. Le

	DL	SCE	CM	F
FEC				
LOT	4	23236	5809	2,405
RES	36	86909	2414	(NS)
TOT	40	110145	2754	
LON				
LOT	4	418,0	104,5	0,263
RES	36	14322,2	397,8	(NS)
TOT	40	14740,2	368,5	
PRE				
LOT	4	15,846	3,962	0,973
RES	36	146,642	4,073	(NS)
TOT	40	162,488	4,062	
PON				
LOT	4	271,9	68,0	0,233
RES	35*	10229,2	292,3	(NS)
TOT	39	10501,2	269,3	
POS				
LOT	4	453,6	113,4	1,021
RES	35*	3887,6	111,1	(NS)
TOT	39	4341,2	111,3	

TABLEAU 1. Analyse de variance de chacun des 5 caractères pour les 5 lots d'**Epiclerus nomocerus** (Masi) (8,3,10,10 femelles). Signification des abréviations: CM=carré moyen, DL=degrés de liberté, F=rapport des variances RES/LOT, **FEC**= fécondité, LON=longévité, LOT=source de variation entre lots, **(NS)**=F non significatif au seuil 1% ; durées de: **PRE**=la pré-oviposition, **PON**=la ponte, **POS**=la post-oviposition ; RES=source de variation résiduelle, SCE=somme des carrés des écarts, TOT=total, *=1 donnée manquante, non corrigée.

	N	MOY	MIN	MAX	EM
FEC	41	74,9268	0	208	8,1952
LON	41	39,5122	9	91	2,9980
PRE	41	3,2927	1	9	0,3148
PON	40*	30,2250	-	-	2,5627
POS	40*	6,9000	0	62	1,6425

TABLEAU 2. Analyse statistique des 5 caractères biologiques d'**Epiclerus nomocerus** (Masi). FEC=fécondité, durée de la LON=longévité, PRE=pré-oviposition, PON=ponte, POS=post-oviposition, N=nombre de femelles observées, *=1 femelle manquante, -=donnée manquante, MOY=moyenne, MIN=minimum, MAX= maximum, EM=écart-type.

végétal avec son pillulier est posé sur le couvercle. Une femelle de l'hyménoptère est introduite dans l'enceinte, avant de la fermer. Toutes les pupes sont formées depuis plusieurs heures, un jour au maximum. La femelle de chalcidien vient d'émerger d'une pupe prélevée dans l'élevage en insectarium. L'exposition au parasitoïde dure 24 heures. Le haricot avec ses pupes est enlevé et remplacé chaque jour. Toutes les pupes enlevées de l'enceinte sont disséquées pour dénombrer les oeufs endoparasites.

Les cinq caractères biologiques sont quantifiés à partir de 41 femelles d'**E.** nomocerus. Toutefois, pour des raisons pratiques, l'observation est échelonnée dans le temps, suivant 5 lots (ou séries) totalisant les 41 femelles. Il y a successivement un lot de 8, puis 10, 3 et 10 femelles (ou répétitions). Il faut donc vérifier qu'il n'y a pas de variation biologique d'un lot à un autre, induite par cet échelonnement de l'étude. Le **tableau 1** donne le résultat de l'analyse de variance: pas de différence significative entre lots. Par conséquent, cet échelonnement n'a pas introduit de biais numérique: c'est comme si les 41 femelles avaient été observées en même temps. Le **tableau 2** donne le résultat de l'analyse statistique des cinq caractères biologiques.

Cette étude quantitative amène trois remarques. Premièrement, le Tétracampide présente une grande variabilité de la fécondité (0-208 oeufs), comme beaucoup de chalcidiens en élevage. La moyenne (75 oeufs) n'est pas élevée mais normale pour une longévité de 39,5 jours, compte tenu du temps que met le chalcidien pour rechercher et prendre possession de son hôte, même avec des pupes en abondance (30-40 pupes immédiatement disponibles).

Deuxièmement, l'échelonnement de la ponte sur 30 jours est assez long pour éliminer des pupes éparses dans une serre (reliquat de **L. trifolii** après traitement biologique).

Troisièmement, pour son élevage et son utilisation, on dispose d'un délai de pré-oviposition de 3 jours (1-9). C'est relativement pratique pour recycler des adultes en insectarium et pour les lâchers dans un délai qui n'affecte pas le potentiel biotique de l'insecte auxiliaire.

4. Conclusion

E. nomocerus contraste avec les autres parasitoïdes utilisés à travers le monde contre **L. trifolii**, par la lenteur de ses déplacements à 25°C et le temps consacré à la prise de possession d'une pupe. Il ne réagit pas au facteur densité de l'hôte. Cette absence de réaction à la densité de l'hôte et son parasitisme pupal rendent incertaines, ses chances de juguler des pullulations de mouches mineuses, malgré son

exploration assez complète du milieu où subsistent des pupes. Au contraire, il économise celles-ci, en pondant au point de piqûre alimentaire. Sa gamme d'hôtes s'étend probablement à d'autres Agromyzides que ceux qui sont connus (**L. trifolii**, **L. strigata**, **Ph. horticola**, **Ph. ilicis**). Il reste à déterminer s'il s'agit de la biologie de l'ensemble de l'espèce ou uniquement, d'une lignée adaptée aux serres de tomate et faiblement réceptive à **L. trifolii**. Cette lignée n'est peut-être pas isolée définitivement des populations naturelles. La possibilité de retour à la bisexualité a été prouvée pour la première fois chez un chalcidien parasitoïde de mouches, **Muscidifurax raptor** Girault & Sanders (LEGNER, 1987).

D'un point de vue pratique, sa répartition climatique (climats tempérés chauds, pré-saharien et méditerranéen; climats tempérés froids) peut suggérer des essais d'utilisation en culture maraîchère, dans plusieurs zones du globe où sévissent des **Liriomyza** et **Phytomyza**. L'expérimentation en condition de laboratoire montre que la femelle de **D. isaea** détruit 74% (73-82%) des larves de **L. trifolii** par prédatisme et parasitisme (FRANCO et al, sous presse). L'association de **D. isaea** avec **E. nomocerus**, renforcerait le contrôle biologique de la Mouche serpentine.

Références bibliographiques

AESCHLIMANN J.P., 1990. Simultaneous occurence of thelytoky and bisexuality in hymenopteran species, and its implications for the biological control of pests. Entomophaga 35: 3-5.

BOUCEK Z., 1958. Revision der europäischen Tetracampidae (Hym. Chalcidoidea) mit einem Katalog der Arten der Welt. Acta ent. Mus. nation. Pragae 32: 41-90.

BOUCEK Z., 1988. Australasian Chalcidoidea (Hymenoptera). A biosystematic revision of genera of fourteen families, with a reclassification of species. C.A.B. Internation. Ed.: 832 p.

BOUCEK Z. & ASKEW R.R., 1968. Index of world Tetracampidae. In V. DELUCCHI & G. REMAUDIERE eds. Index of entomophagous insects. Le François Ed.: 19 p.

CAMERON E., 1939. The holly leaf-miner (Phytomyza ilicis Curt.) and its parasites. Bull. ent. Res. 30: 173-208.

FRANCO E., BEITIA F., LYON J.P., ONILLON J. & ONILLON J.C. Prédation et parasitisme: deux composantes de l'efficacité de Diglyphus isaea (Hymenopt., Eulophidae) parasite de Liriomyza

trifolii (Dipt., Agromyzidae). I. Action de la température. Joint Experts' Meeting "Practical application of integrated control in protected crops", Antibes, France, 16-18 October 1989 (sous presse).

LEGNER E.F., 1987. Transfer of thelytoky to arrhenotokous Muscidifurax raptor Girault & Sanders (Hymenoptera: Pteromalidae). Can. Entomol. **117**: 383-389.

MURAKAMI Y., 1960. Seasonal dimorphism with Encyrtidae (Hymenoptera, Chalcidoidea). Acta Hymenopterologica **1**: 199-204.

MURAKAMI Y., 1961. Supplementary note on the seasonal dimorphism in the Encyrtidae (Hymenoptera, Chalcidoidea). Mushi 35: 71-73.

PANIS A., 1969. Aphycus apicalis (Dalman) et Leptomastidea bifasciata (Mayr) (Hym. Encyrtidae), parasites de Phenacoccus aceris (Signoret) (Hom. Pseudococcidae) dans les Alpes-Maritimes. Entomophaga **14**: 383-391.

SPENCER K.A., 1973. Agromyzidae (Diptera) of economic importance. Junk Ed.: 418 p.

LUTTE BIOLOGIQUE : -I-. Essai d'utilisation de *Phytoseiulus persimilis* ATHIAS-HENRIOT (*Acarina, Phytoseiidae*) contre *Tetranychus urticae* KOCH (*Acarina, Tetranychidae*) sur une culture protégée d'aubergine.

CHERMITI Brahim
Laboratoire de Zoologie, Ecole Supérieure d'Horticulture de Chott-Mariem. 4042 Sousse Tunisie

RESUME

Dans le cadre d'un programme de lutte integrée en cultures protégées, un essai d'utilisation de **Phytoseiulus persimilis** pour lutter contre **Tetranychus urticae** a été réalisé en serre d'aubergine fortement attaquée par les tétranyques. La multiplication des populations du ravageur a été contrôlée 5 semaines après la deuxième introduction du prédateur

INTRODUCTION

Les tétranyques et notamment **Tetranychus urticae** KOCH trouvent dans les conditions de la serre un micoclimat très favorable à leur multiplication. Leurs dégâts observés essentiellement sur cucurbitacées (concombre, melon, courgette) mais également sur aubergine, haricot, voire fraisier sont spectaculaires : après apparition puis généralisation de petites taches blanchâtres sur le limbe foliaire, il ya envahissement progressif des parties jeunes du végétal avec ralentissement de la croissance du végétal. Très rapidement les feuilles sont recouvertes de toiles tissées par les acariens et se dessèchent. Au stade ultime, les toiles envalissent toute la plante et des amas de jeunes adultes s'apprêtent à quitter le végétal desséché apparaissent aux extrémités des feuilles et tiges (PRALAVORIO et **al.**, 1975 - 1983).

La lutte chimique préconisée dès son origine contre ces ravageurs en serre s'est heurtée à de nombreux problèmes et, particulièrement, à l'apparition de souches résistantes aux pesticides. Peu de produits restent efficaces et utilisables en serre du fait de ce phénomène de résistance et des accidents phytotoxiques. Aucun acaricide n'est utilisable contre les tétranyques en période de récolte dans les cultures maraichères.

L'acuité du problème posé par la pullulation de ces ravageurs en serre a amené les chercheurs, dès 1961, à s'intéresser à la lutte biologique. Un acarien prédateur **Phytoseiulus persimilis** ATHIAS-HENRIOT, appartenant à la famille des **Phytoseiidae**, a été éxperimenté en serre dès cette époque en Europe et s'est avéré être un agent de lutte très efficace. (CHANT, 1961 ; BRAVENBOER et DOSSE, 1962 ; VOGEL, 1965 ; BOHM, 1966 ; GOULD, et **al.** ,1967 ; BRAVENBOER, 1967 ; BEGLIAROV, 1967).

L'acarien prédateur **Phytoseiulus persimilis** ATHIAS-HENRIOT présente des caractéristiques très favorables à son utilisation en serre : son développement plus rapide que celui des tétranyques (BEGLIAROV,1967) peut avoir lieu dans une large gamme de températures (DOSSE,1958; PRALAVORIO et **al**., 1980) ; le taux intrinsèque d'accroissement du prédateur (0,219 individus par jour et par femelle) est nettement plus élevé que celui de sa proie (0,143) à une température moyenne de 20,3°C (LAING, 1968 - 1969). Par ailleurs, il est doué d'une excellente efficacité prédatrice vis-à-vis de tous les stades des tétranyques.

Le développement de la lutte biologique contre les tétranyques en Europe à l'aide de l'acarien prédateur **Phytoseiulus persimilis** nous a amené à effectuer des lâchers en serre d'aubergine en Tunisie (E.S.H. Chott-Mariem) et à élaborer un programme de lutte intégrée sur cette culture. Par cet essai nous avons voulu tester la capacité de l'acarien prédateur **P.persimilis** à contrôler une forte attaque de l'acarien : **T. urticae** sur une culture d'aubergine.

MATERIEL ET METHODES

L'experimentation a eu lieu au domaine de l'Ecole Supérieure d'Horticulture de Chott-Mariem dans un tunnel plastique de 585 m2. Deux variétés d'aubergine (F1 BONICA et FABINA) ont été plantées le 26 septembre 1987 sur 6 rangées à raison de 3 pour chaque variété. L'écartement est de 1 mètre entre les lignes et de 0,5 mètre entre les plants. La culture a été menée normalement mais sans aucune intervention chimique.

Les conditions climatiques ont été suivies à l'aide d'un thermohygrographe placé au milieu du tunnel plastique.

L'évolution des populations de **T. urticae** et ultérieurement celle de **P. persimilis** a été suivie sur 40 pieds (20 de chaque variété) répartis régulièrement dans le tunnel plastique, le dénombrement a été effectué chaque semaine et n'a conserné que les femelles des deux espèces d'acariens. .

Les lâchers de **P. persimilis** ont été effectués le 5 janvier 1988 à très faible dose et le 10 février dans la proportion du 1/10 du nombre d'adultes de **T. urticae** observés lors du plus récent comptage.

RESULTATS ET DISCUSSION

Le premier comptage a été effectué le 24 novembre 1987 et a révelé que le ravageur **Tetranychus urticae** a été bien installé sur la culture avec une moyenne de 48,23 individus par plant. Au cours des semaines suivantes et suite à des conditions climatiques favorables, notamment une température moyenne de l'ordre de 19° C, les populations de ravageur ont

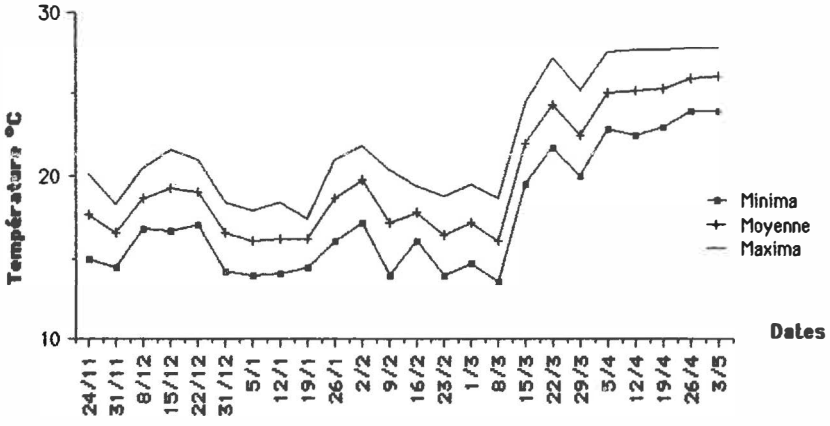


Fig.1: Evolution hebdomadaire des températures (minima, moyenne et maxima)

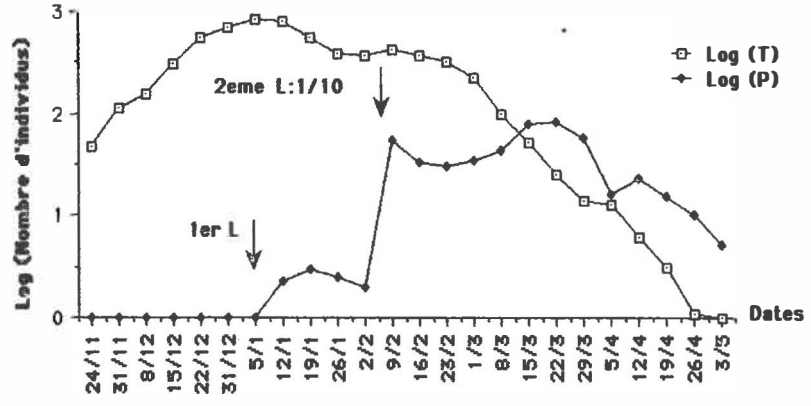


Fig.2: Evolution temporelle des populations de T. urticae (T) et de son prédateur P. persimilis (P)

augmenté considérablement pour atteindre leur maximum le 5 janvier 1988 avec une moyenne de 843,65 individus par plant (figure 2). A cette même date le premier lâcher du prédateur **Phytoseiulus persimilis** a été effectué à une très faible dose en raison de la petite quantité d'acariens prédateurs reçue de la Station de Zoologie et de Lutte Biologique d'Antibes.

A partir de la semaine suivante (le 12 janvier), la population de **T. urticae** a accusé une baisse spectaculaire suite certainement aux opérations répetées d'effeuillage opérées en raison des attaques importantes de la culture par **Verticillium dahliae**. En plus du 31 décembre au 19 janvier la température moyenne était de 16°C accusant une baisse de 3°C par rapport aux semaines précédentes (figure 1). Quant à l'action du prédateur **Phytoseiulus persimilis**, elle est restée sans doute réduite en raison du faible niveau des populations lâchées le 5 janvier 1988.

La chute de la population du ravageur va continuer jusqu'au 2 février où nous avons noté 364,65 individus de **T. urticae** par plant. Profitant d'une élévation de la température, la population de tétranyques a augmenté sensiblement dès le 9 février (427,15 individus par plant). Cette reprise, coincide avec le deuxième lâcher du prédateur réalisé à la dose de 1 **Phytoseiulus persimilis** pour 10 **Tetranychus urticae**.

A partir de la semaine suivante, on note un déclin net des populations de **T. urticae** qui chutent à 25,35 individus par plant le 22 mars, soit 5 semaines après le deuxième lâcher du prédateur. Corrélativement la population de **Phytoseiulus** d'abord apparamment stationnaire s'est développée à partir du premier mars (34,11 individus par plant) et atteint son maximum le 22 du même mois avec 84,85 individus par plant pour décroitre par la suite. Il est intéressant de noter à ce sujet que la population de **T. urticae** élevée au moment du lâcher a nécessité 5 semaines pour être contrôlée par le prédateur et dès lors il était pratiquement impossible d'assister à une subite recrudescence de la population de **T. urticae**.

Le niveau très élevé de la population du ravageur au moment du premier lâcher et l'insuffisance de la quantité du prédateur distribuée explique le temps relativement long (9 semaines) mis par **P. persimilis** pour contrôler les populations de **T. urticae**. Le contôle de la population du ravageur aurait surement été meilleur et plus rapide si les lâchers avaient été effectués dès les premières semaines de l'attaque comme l'a déjà conseillé PRALAVORIO et **al.**, (1980). Les lâchers précoces sont nécessaires car il faut 15 à 20 jours à **P. persimilis** pour bloquer une attaque de **T. urticae** temps pendant lequel les dégâts continuent d'augmenter.

En tenant compte seulement du deuxième lâcher, les résultats obtenus sont proches de ceux trouvés par PRALAVORIO et **al.**, (1975). En effet, en réalisant des lâchers de **P. persimilis** à la dose d'un prédateur pour 10

ravageurs. Ils ont obtenu un blocage des populations de tétranyques en 2 semaines et leur élimination totale en 5 à 6 semaines.

CONCLUSION

Cet essai qui n'était qu'une première approche, a permis de tester la capacité prédatrice de **Phytoseiulus persimilis** à contrôler une attaque de **Tetranychus urticae** en milieu protégé. Le prédateur a pleinement joué son rôle, surtout lorqu'il a été lâché avec un rapport prédateur-proie de 1 sur 10. Rien que deux introductions ont suffit pour contrôler les populations du ravageur qui était déjà à un niveau élevé et d'éviter de nouvelles recrudescences malgré le retour dès le 8 mars 1988 des conditions de température et d'humidité plus favorables au ravageur qu'au prédateur. Il faut remarquer également que cet essai a été volontairement effectué qu'and les populations de **T. urticae** avaient atteint un développement important.

Cet essai permet de penser que dans un proche avenir, cette méthode de lutte dont l'efficacité et l'inocuité ne sont plus à démontrer en Europe, pourra prendre une extension importante dans les cultures sous abri en Tunisie. Toute fois, cela ne sera possible que lorque l'efficacité du prédateur sera mise à l'épreuve sur d'autres cultures protégées et avec différentes modalités d'emploi.

REFERENCES BIBLIOGRAPHIQUES

BEGLIAROV G. A., 1967. Ergebnisse der Untersuchungen und der Anwendung von ***Phytoseiulus persimilis*** ATHIAS-HENRIOT als biologische Bekâmpfungsmittel gegen Spinmilben in der Sowjetunion. Nachtembl. deutsch.Pflanzenschutzdienst Berlin,**21**,197-200

BRAVENBOER L., DOSSE G., 1962.,***Phytoseiulus riegeli*** DOSSE als Prâdator einiger Schadmilben aus der ***Tetranychus urticae*** Gruppe. **Entomol.exp.appl.5,** 291-304 .

BRAVENBOER L., 1967. Biological control of mites in glasshouses. **Proceed 2nd.Int.Congr.Acarology**, 365-371.

BOHM H, 1966. Ein Beitrag zur biologischen Bekämpfung von Spinmilben in Gewächshausen Pflanzenchutz Ber., **34**. (5-6), 68-77.

CHANT D.A.,1961. An experiment on the biological control of ***Tetranychus telarius*** L. in a greenhouse, using ***Phytoseiulus persimilis*** A. H. **Can.Entomol.,93**, 437-443.

DOSSE G,1958. Uber einige neue Raubmilbenarten ***(Acarina,Phytoseidae)***. Pflanzenschutz Ber., **21**, 44-61.

GOULD H. J., HUSSEY N. W., PARR W. J., 1967. Large scale commercial control of ***Tetranychus urticae*** KOCH on cucumbers by the predators

Phytoseiulus persimilis A. H. **Proceed. 2nd Intern. Congr. Acarology**, 383-388.

LAING J. E., 1968. Life history and life table of ***Phytoseiulus persimilis*** ATHIAS-HENRIOT. **Acarologia, 10**, 578-588.

LAING J. E., 1969. life history and life table of ***Tetranychus urticae*** KOCH. **Acarologia, 11**, 32-42.

PRALAVORIO M., JOURDHEUIL P. et MILLOT P., 1975. Essais d'utiliation de l'acarien prédateur ***Phytoseiulus persimilis*** contre les tétranyques sur diverses cultures florales et maraichères en serre. **Ann. Zool. Ecol. anim.**, 7 (2), 211-226.

PRALAVORIO M. et ALMAGUEL-ROJAS L., 1980. influence de la température et de l'humidité relative sur le développement et la reproduction de ***Phytoseiulus persimilis*** **Bull. O.I.L.B./S.R.C.P. "Lutte intégrée en cultures sous serre"**, 1980/3, 157-162.

PRALAVORIO M., FOURNIER D. et MILLOT P., 1983. Quelques données sur ***Phytoseiulus persimilis*** A.H., prédateur de tétranyques en serre. " **Faune et Flore auxiliaires en agriculture**" ACTA, 4-5 mai 1983, 57-61.

VOGEL W., 1965. Deux années d'expériences pratiques de lutte biologique contre les araignées rouges sur une base commerciale. **Bull. Zool.Agric. Bachic, s. II, 7**, 295-298.

TETRANYCHUS URTICAE (KOCH) CONTROL IN A ROSEBUSH GLASSHOUSE BY USING THE STIRRUP-M PHEROMONE

PAGONA PAPAIOANNOU-SOULIOTI
Benaki Phytopathological Institute
145 61 Kiphissia (Athens) - GREECE

Summary

The results obtained from the treatments are the following: fluvilinate has shown a remarkable acaricide action and a higher efficacy on the moving forms of mites, 91.55% when applied with the pheromone over 80.35%. Dinochlor combined with the pheromone has had a reduced action efficiency (83.77% for the moving forms and 79.88% for the eggs), probably due to the particularities of the formulation that alone, without the pheromone has had a higher action efficiency, 97.08% for the moving forms and 93.84% for the eggs. The combination of the mixture clofentezine + fenbutatin-oxide and the pheromone gave excellent results in both the moving forms of mites 97.28% and the eggs 97.97%.

These encouraging results indicate that stirrup-M pheromone, always in combination with an acaricide formulation, posseses a lot of possibilities for practical application on culture protection against *T. urticae* infestation in selected and integrated control programmes.

1. Introduction

Among various animal enemies able to cause serious problems in floriculture and horticulture by qualitative and quantitative crop degradation Red Spider Mites *Tetranychus urticae* (Koch) and *T. cinnabarinus* (Bois.) are almost at the first place.

Concerning the problems caused by the above species in orchards, these have been faced for years on the basis of the "economic damage threshold", which varies from 45% to 60% of infested plants independently of the number of moving forms per leaf. Furthermore the utilization of selective formulations of low toxicity for beneficial population as well as the recomen-

dation or reminding (by experts of phytopathology programmes) for limitation or rejection of formulations that excite the Red Spider Mites' fertility have been met positively by the growers, resulting in a quite limited number of treatments.

In glasshouses situation is entirely different, as the chosen floricultural varieties as well as the horticultural plants undergo a lot of pesticides and treatments in order to be protected from the large number of animal enemies and diseases that infest them. That results in the known incidences both of developing resistant tribes and disturbing the biological equilibrium.

The Red Spider Mites control in glasshouses is difficult enough, as the large number of generations developping there in addition to the fast development of resistant to acaricides tribes do not allow its control easily.

A research on other techniques for the control of these mites is needed. The utilization of new selective bioacaricide formulations, attractive food substances and beneficial organisms (predators) in the frame of selective or integrated control programmes seems to be the best solution in the case of glasshouses.

Releases of predator *Phytoseiulus persimilis* (Athias - Henriot) fro three consecutive years 1988-1990 in a glasshouse containing rosebushes var. baccara for the control of *T. urticae* populations did not give the expected results. The predator's both establishment and development has been limited. We think that's due more to the sulphur saturated atmosphere within the glasshouse and less to the pesticides being used for the control of enemies and diseases.

Finally in order to estimate the various biotechnological means for *T. urticae* control and their application possibilities we carried out a research in a resebush glasshouse in Attica area. The results obtained are cited briefly in this paper (1,2,3,4,5).

2. Material and Methods

A glasshouse of 1000 m^2 planted with rosebushes var. baccara situated in Marathon, Attica, has been used as an experimental plot. The new formulations used for efficiency tests on the popu-

lation of mites were: fluvalinate (Mavrik), clofendezine (Apollo), dinochlor (Pentac) in its new form (emulsive liquid) and the mixture fenbutatid-oxide + clofendezine (Ventex + Apollo) and the attractive food substance (pheromone) stirrup-M (Fernesol and Nerolidol). Some of the above tested formulations have been put in the market recently, others are under registration.

Spray applications were effected during the mites' population high density period. Table 1 shows treatment dates and doses rate of acaricide formulations used.

For each acaricide and the control were utilized 4 experimental plots (replicates) according to a plan of thoroughly casual groups. Every experimental plot comprised 6 plants. The spray application was effected on a hand-operated spayer and it was a full cover spray until all spray liquid pourred out.

Estimates of acaricide formulations were effected by counting the mites' population on samples of 100 leaves (25 X 4), taken at random throughout the plants foliage a day before and in different periods of time after treatment.

3. Results - Discussion

The results of evaluation tests on the efficacy of various formulations applied against the mites (Table 1) are the following:

At the first test with fluvalinate, 8 days after the spray, the reduction of moving forms has been statistically significant for both cases compared with the control. In 20 days the efficiency of this formulation in combination with the stirrup-M pheromone has shown a remarkable acaricide action on the moving forms with a statistically important differene compared both to the control and the formulation applied alone, of which groups presented an increased infestation on a level statistically not differing from the control.

Fulvalinate in combination with the attractive substance stirrup-M presented a quite satisfactory efficacy on the moving forms of phytophaga. The mites' first infestation concerned 100% of leaves with 13.84 individuals/leaf, that after treatment was reduced to 6.12 individuals/leaf, while the moving forms population level was reduced to 8.44%, and the efficacy of the mixture attained 91,55% over 80.35% when it was applied alone. In both

TABLE 1. Results obtained from application of pheromone stirrup-M in combination with other acaricides for *Tetranychus urticae* (Koch) control

Chemical formulations	Treatment days	g or ml of formulation in 100 lit. of water	Counts of eggs and moving forms of mites/100 leaves before and after treatment					
			before treatment		8 days after treatment		20 days after treatment	
			Eggs	Mov.Forms	Eggs	Mov.forms	Eggs	Mov.forms
TEST A								
1) Fluvalinate E.C.		60	504.00 a[1]	346.00 a	869.25 a	153.00 b	1767.25 a	490.75 a
2) Fluvalinate + Stirrup-M	24/5/88	50 + 40	527,25 a	485,75 a	877,25 a	107,25 b	1324.00 a	77.00 b
3) Control		-	811.00 a	399.05 a	972.05 a	1348.5 a	2191.05 a	718.05 a
TEST B								
1) Dinochlor E.C.		125	512.25 a	715.25 a	132.00 b	51.75 c	199.25 c	27.25 c
2) Dinochlor + Stirrup-M	27/6/88	115 + 40	587.75 a	762.00 a	330.25 b	235.00 b	473.25 b	457.00 b
3) Control		-	581.05 a	697.00 a	2227.25 a	1829.75 a	766.00 a	1682.75 a
TEST C								
1) Fenbutatin-Oxide E.C. + Clofendezine	28/7/88	40	767.75 a	820.25 a	59.00 b	218.5 b	22.0 b	26.75 b
2) Fenbutatin-Oxide+Stirrup-M + Clofendezine	28/7/88	30+40+20	705.75 a	962.00 a	36.00 b	39.00 c	23.5 b	22.25 b
3) Control		-	867.00 a	1269.75 a	2487.75 a	1841.75 a	2331.00 a	1574.25 a

[1] For each column average values marked with the same letter statistically do not differ from each other for P=0.05 according to Duncan's method

cases ovicide action of Fluvalinate has been almost trivial to negative (20.16 eggs/leaf before treatment, 34.77 eggs/leaf after treatment).

Concerning dinochlor, its application without the pheromone presented a remarkable efficacy with a statistically significant difference both in 8 and 20 days after the spray over the mixture and the control of the moving forms and the live eggs. The efficiency of the formulation reduced the level of the moving form populations and the live eggs to 2.91% and 6.15% respectively, while the formulations efficacy went up to 97.08% for the moving forms and 93.84% for the live eggs. The reduced efficiency of this formulation in relation with the pheromone stirrup-M on the moving forms and the eggs, statistically different compared with the first case, is propably due to particularities (way of action) of this formulation on the phytophaga. The efficacy of mixture dinochlor + stirrup-M did not exceed 83.77% for the moving forms nor 79.88% for the eggs.

At the third test the combination of formulations chlofentezine + fenbutatin-oxide + stirrup-M gave excellent results on both moving forms and eggs in 8 and 20 days after spray with a significant defference compared to the control.

Furthermore the mixture showed a remarkable efficiency over the formulation fenbutatin-oxide + chlofentezine as well, particularly in 8 days after the spray with a statistically significant difference on the moving forms. The level of moving form populations and live eggs was reduced to 4.71% and 2.02% respectively, while the formulation efficacy attained 95.28% for the moving forms and 97.97% for the eggs.

The above results obtained from tests finally show that pheromone stirrup-M always in combination with an acaricide formulation increases the efficiency of the formulation and makes it efficacious at doses lower than those recommended by manufacturers making thus their application possible in selective and integrated control programmes too.

Concerning Fluvalinate in combination with the pheromone, it appears to be fairly efficacious, especially when applied on not particularly high populations.

REFERENCES

1. PAPAIOANNOU-SOULIOTIS, P., 1985. Control of *T. urticae* in greenhouses in area of Attiki by *Phytoseiulus persimilis*. *Inter. Meeting "Integrated Control in Protected Crops in Mediterranean Region C.E.E./I.O.B.C.*, Heraklion, Crete, 27-29 April, 1985. Proceeding, p. 175-179.
2. PAPAIOANNOU-SOULIOTIS, P., 1987. The present state of Biological control of mites in Protected Vegetable crops in Greece. *Meeting of E.C. Expert's Group Biological and Integrated Control in Protected Crops, I.O.B.C./C.E.E.*, Gabrils-Barcelona, Spain, 27-29 May. 1987 (in press).
3. PARELLA, M.L., 1990. Biological Control in ornamentals : status and perspectives. *Meeting of the Working Group "Integrated Control in glass houses"*/Copenhagen (Denmark) 5-8 June: 161-168.
4. VACANTE, V. 1985. Acari presenti nelle colture orticole e fioricole nelle serre del ragusano e considerazioni sulle possibilità di lotta chimica, biologica ed integrata. *Tecnica Agricola, Anno XXXVII*, n.34:3-23.
5. WARDLOW, L.R. 1990. Integrated pest management in protected ornamental crops. *Meeting of the Working Group "Integrated Control in glass houses"*/Copenhagen (Denmark) 5-8 June: 161-168.

ESSAI DE LUTTE CONTRE LES Meloidogyne SOUS-ABRIS SERRES PLASTIQUE PAR L'EMPLOI DE VARIETES DE TOMATE RESISTANTES.

S. SELLAMI et A. EDDOUD
Département de Zoologie Agricole
Institut national Agronomique.
EL-HARRACH ALGER ALGERIE.

Summary

A study of the use of résistant tomate cultivars (Tresor, Carpy : Hybrids) against Meloidogyne in the green houses was conducted in the experimental station of institut of Agronomic El-Harrach during the year 1988/1989. Resistant tomate cultivars decrease population of Meloidogyne in the soil and roots • the weight of samples indicated an increase of two at four higher than susceptible cultivars (Tango, Fandongo). The observation of females of Meloidogyne in the roots of resistant cultivars revealed the presence of agressive souche of Meloidogyne. The weeds as host plant were be noted.

1. Introduction

En Algérie, les cultures maraichères ont connu ces dernières décennies un développement spectaculaire particulièrement sous abris-serres plastique. En effet, les superficies qui étaient de quelques hectares au début des années 1970 ont atteint plus de 5000 Ha en 1988. Parallèlement, nous assistons à une recrudescence de parasites parmi lesquels, les nématodes du genre Meloidogyne représentent le principal problème sur cultures maraichères aussi bien en plein champ que sous-abris serres plastique (LAMBERTI et al., 1975).
A titre d'exemple, MOKABLI (1988) rapporte que plus de 65 % des abris serres plastique sont infestés par ces nématodes suite à une prospection menée dans certaines régions d'Alger.
Ces dans ce contexte que, nous avons entrepris une étude en 1989 portant sur l'utilisation de variétés de tomate résistantes qui constitue un moyen de lutte efficace et économique (FASSULIOTIS, 1976).

2. Matériels et Méthodes

Notre étude a été menée à la station expérimentale de l'Institut National Agronomique d'El-Harrach (Alger) durant la campagne 1988/1989 dans 2 abris-serres plastique : l'une (A) avec précédent cultural de variété de tomate sensible (degré d'infestation en fin de culture 2,6) et l'autre (B) avec un précédent de variété résistante (saine).
L'essai a été réalisé selon un dispositif en bloc aléatoire complet avec 5 répétitions.

Chaque bloc est constitué de 4 parcelles élémentaires et chaque micro-parcelle renferme une variété et comprend au total 20 plants. Le matériel végétal utilisé comprend 4 variétés : 2 sensibles (**T**ongo et **F**andongo) et 2 résistantes (**C**arpy et **T**résor : Hybrides). L'analyse granulométrique a montré que le sol des 2 abris-serres plastique à une texture limono-argileuse avec un pH de 7,2. Au cours de cette expérimentation, des relevés de température de l'air et du sol ont été notés.
Les principaux paramètres expérimentaux retenus pour apprécier l'influence des variétés résistantes dans la lutte contre les Meloidogyne sont liés d'une part à la culture (production, indice de vigueur, indice de galle) et d'autre part à l'éffectif des populations du parasite dans le sol et dans les racines.

3. Résultats et Discussion

3.1. Influence des différents traitements sur la réaction de la plante

1. Sur la vigueur de la plante.

Les résultats représentés dans le tableau n°1 montrent qu'en cours de cultuture, l'indice de vigueur ne varie pas pour l'ensemble des traitements. En revanche en fin de culture, la vigueur des plants des traitements résistants sur sensibles ou résistants sur résistants est nettement supérieur à celui des traitements sensibles sur sensibles.

3.2. Sur l'indice de galle

D'après **B'CHIR** et HORRIGUE (1983) l'indice de galle est un excelent paramètre pour évaluer le degré d'infestation réel du sol. Il permet d'apprécier le rôle des variétés résistantes dans la lutte contre les **M**eloidogyne. Les valeurs consignées dans le tableau n° 1 montrent que l'indice de galle des variétés résistantes est nettement inférieur (0,21 et 0,28) par rapport à celui des variétés sensibles avec précédent sensible (2,19 et 3,45).

Tableau n° 1 : Influence des différents traitements sur la réaction de la plante.

	SERRE A				SERRE B			
	T	C	To	F	T	C	To	F
Indice de vigueur en cours de culture	3,73	2,56	2,49	2,83	2,83	2,45	2,64	2,88
Indice de vigueur fin de culture	3,32	3,11	0,77	0,77	3,63	3,11	2,15	2,72
Indice de galle fin de culture	0,01	0,05	3,45	2,19	0,00	0,02	0,28	0,20

T : Trésor ; **C** : Carpy ; **To** : Tongo ; **F** : Fandongo

3.3. Sur la production

Les résultats pondéraux des fruits indiquent que la production des variétés résistantes est largement supérieure à celle des variétés sensibles, particulièrement pour la variété trésor (Fig. 1). Les variétés résistantes restent productives jusqu'à la dernière récolte ce qui n'est pas le cas pour les variétés sensibles.
De même, nous avons relevé que le calibre des fruits des variétés resistantes dépasse celui des variétés sensibles ; il est respectivement de 7 à 7,4cm pour Trésor et Carpy (sensibles) et de 6 à 6,8cm pour Tongo et Fandongo (résistantes).

3-2 Sur les populations de Meloidogyne dans le sol et les racines

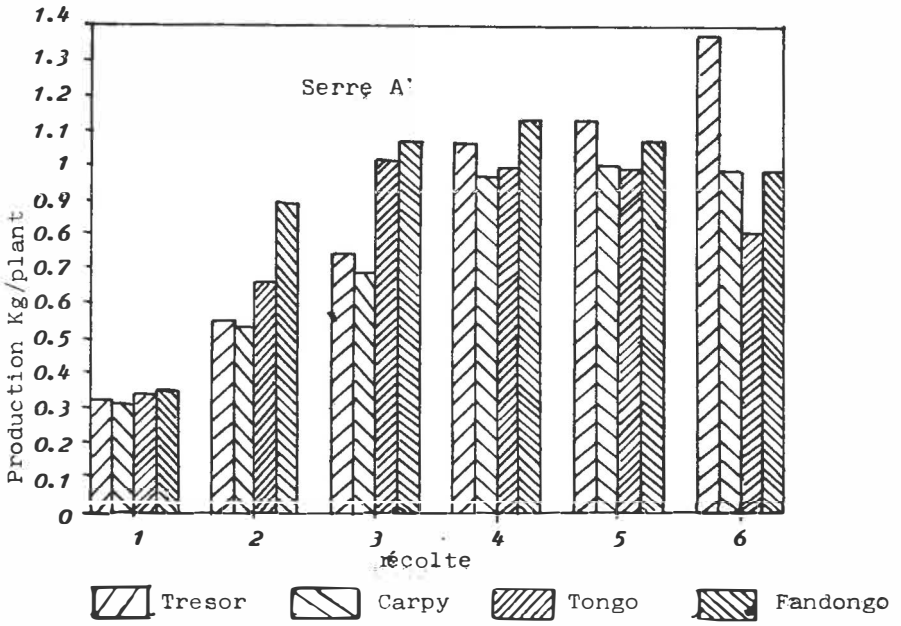
Les analyses nématologiques au niveau du sol et des racines montrent la présence des Meloidogyne aussi bien dans les variétés sensibles que résistantes. Cependant, chez ces dernières le niveau de population relevé est plus faible en comparaison avec les variétés sensibles (Tableau n°2).

Tableau n°2 : Effectifs des populations de Meloidogyne dans les racines et dans le sol.

	SERRE A				SERRE B			
Meloidogyne	T	C	To	F	T	C	To	F
par 100g/sol en fin de culture log (x + 1)	1,79	2,22	2,21	2,27	1,61	1,81	1,82	1,91
Meloidogyne par g/racines en fin de culture log (x + 1)	1,93	1,91	3,15	3,03	1,66	1,82	1,98	1,88

T. Trésor, C : Carpy ; To ; Tongo ; F : Fandongo

Les analyses statistiques par le test de student ont montré des différences significatives pour les facteurs variété et précédent. Les observations occasionnelles des galles au niveau du système racines de quelques plants des variétés résistantes dans les 2 abris serres peuvent être attribuées soit à la présene d'un biotype. A ce titre, PROT (1984) signale qu'une population spontanée de M. arenaria est capable de briser la résistance des variétés de tomate au Sénégal, soit à une élévation de température. En effet, dans notre étude, la température du sol a atteint 30° à partir de fin Mai.



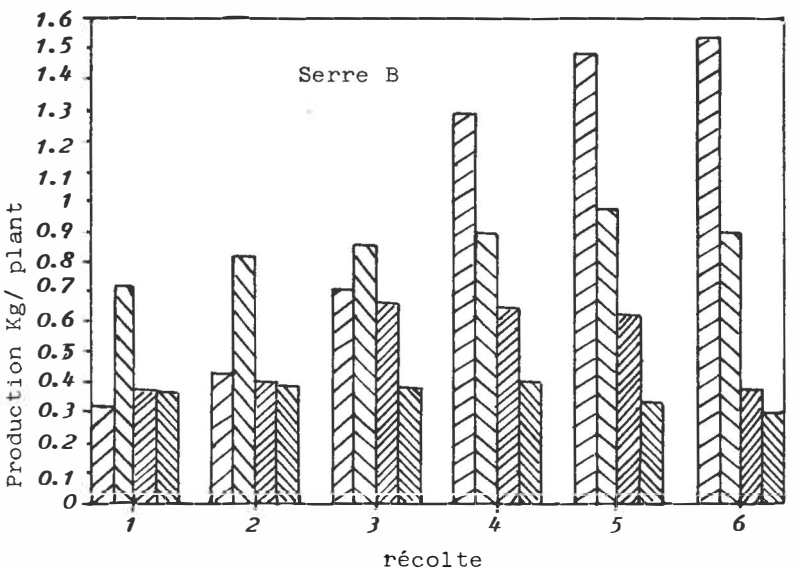


Figure 1 - Production moyenne par plant (Kg)

Néanmoins, ceci reste à confirmer par d'autres travaux. D'après DROPKIN 51969) la température constitue un facteur limitant pour la résistance des plants. De même, plusieurs travaux ont montré que la résistance est brisée avec l'augmentation de la température : cas de la tomate qui perd sa résistance vis à vis de M.incognita à des températures supérieures à 30°C (HOLTSMAN, 1965, PAULSON? 1976 & ZACHEO & ZACHEO, 1984).
Toutefois, nous rapportons qu'au cours de notre essai plusieurs espèces d'adventices présentant des galles ont été resencées (Tableau n°3).

Tableau n°3 : Liste des espèces d'adventices présentant des galles.

Familles	Espèces	Familles	Espèces
Graminées	Setaria verticilata	Chenopodiacées	Chenopodium album
	Setaria viridis	Amaranthacées	Amaranthus angustifolius Amaranthus hybridus
Portulacacées	Portulaca oleracea	Fumariacées	Fumaria capryolata
Legumineuses	Vicia sativa Melilothus indica Trifolium spp	Primulacées	Anagalis arvensis
Convolvulacées	Convolvolus arvensis	Solanacées	Salpicroa origanifolia Solanum nigrum

5. Conclusion

L'étude comparée des variétés de tomate sensibles et résistantes dans la lutte contre des Meloidogyne montrent que ces dernières contribuent à diminuer les effectifs des populations de ces parasites aussi bien dans le sol que dans les racines. Ces résultats concordent avec ceux obtenus par certains auteurs ayant entrepris les mêmes études dans ce domaine (FASSULIOTIS, 1979 ; HORRIGUE, 1983 & ROHINI et al 1984). De même, l'expérimentation a montré que l'installation d'une culture sensible, après une autre résistante donne une récolte nettement supérieure à celle dont le précédent est une culture sensible. Vu les limites de l'emploi des variétés résistantes, une intervention complémentaire (utilisation de champignons nématophages, lutte chimique etc...) est à envisager dans un système de lutte intégrée.

6. Références.

B'CHIR, M.M & HORRIGUE, N., 1983. Etablissement d'un modèle expérimental pour tester l'efficacité des produits nématicides homologués sur les Meloidogyne associés à la culture de Melon (Cucumis melo) sous abri-serre. Ann. INRAT. 55 (3) : 20.

DROPKIN, V.H., 1969. The necrotic reaction of tomatses and other hosts resistant to Meloidogyne : recersal by temperature. Phytopathology, 59 : 1632 - 1376.

FASSULIOTIS, G., 1976. Proceedings of the research planning conference on root-knot nematodes, Meloidogyne spp. IMP : 81 - 85.

FASSULIOTIS, G., 1979. Plant breeding of root-knot nematode resistance in : LAMBERTI, F. & TAYLOR AL.L, 1978. Root-knot nematodes Meloidogyne species. Ed. Acad. Press. London : 245 - 254.

HOLTZMAN, O.V., 1965. Effet of soil temperture on resistance of tomatoto root-knot nematode (Meloidogyne incognita). Phytopathology, 55 : 990 - 992.

HORRIGUE, N., 1981. Contribution à la recherche d'une méthode de lutte intégrée contre les Meloidogyne en utilisant des variétés de tomates résistantes. Mem. 2è Cycle. INAT : 32.

LAMBERTI, F., GRECO, N.L. & ZAOUCHI, H., 1975. A nématological survey of date palm and other major crop in Algeria. Plant Prot. Bull. F.A.O. 23 : 156 - 160.

MOKABLI, A., 1988. Principaux facteurs qui déterminent l'importance et l'agressivité des Meloidogyne sous abris-serres en Algérie. Thèse Magister. Inst. Nat. Agro. El-Harrach. Alger 69.

PAULSON, R.E., 1976. Changes in cell structure induced by Meloidogyne incognita and Meloidogyne hapla (Nematoda) in susceptible and resistant tomato (Lycopersicon esculentum) roots. Dissert. Absts., 36 : 4276.

PROT, J.C., 1984. A naturally occuring resistance breaking biotype of Meloidogyne arenaria on tomato. Reproduction and pathrogenicity on tomato cultivars Roma and Rossol. Revue Nematol. 7 (1) : 23 - 28.

ROHINI, H.M. & EKANAYAKE, K. & DIVITO, M., 1984. Response of lines and varieties of tomato to root-knot nematode infection. Nemat. Medit. 12 : 207 - 212.

TAYLOR, A.L. & SASSER, T.?., 1978. Biology, identification and control of root-knot nematodes (Meloidogyne species). A cooperative publication and united states Agency for international Development Nort. Carolina state Univ. Graphices : 111.

ZACHEO, G. & ZACHEO, B.T., 1984. Influence of different temperatures on resistance of tomato plants to Meloidogyne. Nemat. Medit. 12 : 221 - 230.

"SOIL SOLARIZATION" AND METHYL-BROMIDE ALTERNATED TREATMENTS AS NEW METHOD IN THE DISINFESTATION OF SOIL IN PROTECTED CROPS

C. CALABRETTA (1), A. COLOMBO (1), S. NUCIFORA (1), S. PRIVITERA (2)

(1) Istituto di Entomologia agraria dell'Università di Catania
Via Valdisavoia, 5, 95123 - CATANIA - ITALY

(2) Osservatorio per le malattie delle piante
Corso Umberto, 144, 95024 - ACIREALE (CT) - ITALY

Summary

The experimental results obtained on tomato "Vemar F1" protected crop grown on solarizated soil with or without treatment with phenamiphos, employed at different quantities, are reported. Precedently in the same soil, treated at rate of g 80/m^2 methyl-bromide, a tomato crop was grown. The variation on the presence of root-knot nematodes in the untreated and variously treated soil was tested. In all thesis the occurrence of nematode galls was limited only in the bordering plants, without significant differences between chemically treated and untreated thesis. The possibility to alternate the methyl-bromide and solarization methods without to apply other chemicals has confirmed.

1. Introduction

Solarization has been studied as alternative method to soil fumigation with chemical substances (KATAN, 1980; KATAN, 1981; CARTIA, 1984) against pathogenic fungi in the soil and against root-knot nematodes. Against the last ones a partial success (CARTIA et al., 1989) was obtained by it. From the recent studies on the effect of soil solarization on root-knot nematodes very different results risen due to the differences in several important factors such as the duration of

the physical treatment, the amount of solar energy, the physical characteristics of the soil, the humidity level of the soil during the treatment, the time and duration of the coltural cycle, the influence that the varying climatic condition can have on plants activity and on the activity of their animal and vegetal parasites (CARTIA, 1989 a). Some cases are known, in which the attack of Meloidogyne spp. has not stopped by solarization and has not slowed down, appearing in an unsatisfactory way.

Recent trials (NUCIFORA, 1989) show how in solarized soil both production and plants growth are highly correlated to the degree of attack of root-knot nematodes against them. By soil solarization different efficacy, even in the same place, in different years has been obtained, due to differences in the above mentioned factors. Due to early infestations of roots nematodes some productions of Vemone Fl in solarized greenhouses have been slightly bigger than the ones recorded from non solarized soil and sensibly smaller of productions coming from greenhouses fumigated with methyl-bromide (NUCIFORA, l.c.).

For such cases it could be usefull to effect complementary chemical treatments to stop or slow down the development of root-knots nematodes, which solarization would not be able to stop. In this way the employment of phenamiphos in small and localized rates, applied after transplant, has been sperimented without success (NUCIFORA et al., 1989).

The possibility of employing soil solarization, alternating in with the employment of methyl-bromide, has been suggested by Garibaldi and Gullino (1988) and by Cartia et al., (1988).

To verify such possibility, applying the solarization by itself or adding phenamiphos on soil previously fumigated with methyl-bromide, the trials reported in this paper were carried out.

2. Materials and methods

We employed the hybrid "Vemar Fl", known for its weakness against root-knot nematodes. As control the crop grown on solarized soil without the use of nematocide was used. The other thesis had been solarized and treated after the transplant with phenamiphos. The quantity employed of the chemical varied from thesis to thesis crop.

The experiment wanted to rivaluate both the efficacy of solarization to avoid root-knot nematodes infestation and the possible integrative action of phenamiphos for such a purpose. Solarization was applied on soil fumigated with methyl-bromide before applying the previous crop.

Pratically we wanted to see what possibility there was to employ in an alternate way fumigation and soil solarization and in what ways the post-transplant adding of phenamiphos can improve both its disinfe-

stant effect and the productive capability of the crop.

Therefore 10 thesis with various doses of phenamiphos was set out to compare with the control crop.

The experiment took place during 1988 in a cold greenhouse of 1200 m^2 , in the area of Ragusa. The greenhouse was covered with a plastic film of P.E., which is changed every year.

The soil had 93% of sand, 5,8% of lime, 1,2% of clay and 0,78% of organic matter.

The greenhouse had previously been used for a spring-summer cycle of tomato "Arlette", transplanted on soil fumigated with methyl-bromide (g 80/m^2). The production of the "Arlette" crop was good and at the end of the cycle the roots of all the plants did not show the presence of Meloidogyne knots. After the plant extirpation the soil was solarized for 50 days, from the 10th of july to the 30th of august. Previous to the "Arlette" crop, there had been a crop of tomato "Vemone Fl" in an autumn-winter cycle, during which there had been a considerable development of root-knot nematodes and it had therefore been necessary to fumigate the soil (methyl-bromide g 80/m^2) before the new Arlette spring-summer crop.

The solarization was effected inside a closed greenhouse, following the procedures suggested for the success of the practice itself (CARTIA, 1989 b). The "Vemar Fl" was transplanted in the greenhouse on the 1th of october 1988. The transplant was effected in double rows, leaving a distance of 50 cm between the double rows, a distance of 100 cm between each of the pair rows and a distance of 33 cm between the plants in each row. In total there were 3 plants per square meter.

Irrigation and fertilization processes were effected with hose a drip delivery. The fertilization of base was done using mineral fertilizers only without making use of dung. During the cycle both fertilization and all other agronomical practices were done following the local practice.

We followed a simple randomized scheme, with three repetitions of 34 plants each. Ten thesis and the control was formed. The control was repeated eleven times, in order to verify the main hypothesis of the experiment: to check whether soil solarization, applied under the above mentioned circumstances, would have been able by itself to control the infestation level of Meloidogyne. In order to confront the results together with the other ten thesis, we only considered three test succession, closen for this purpose. The ten thesis crops differed between them in the amount of phenamiphos applied or, for the some amount, in the technique with which the phenamiphos was applied. In such a way we employed an application inside a superficial furrow for the thesis 1 to 5 with the doses of 2.3, 3.5, 4.6, 7.0, 10.5 g/plant of commercial product at 4.8% of a.i. respectively; for the thesis 6 to 10 we employed a plant localized distribution with the same ratios as the first five thesis.

We effected a soil sample 36 days after transplant. This was

done in order to check the eventual presence of root-knot nematodes in the 11 thesis. An hundred days after transplant a macroscopic and microscopic analysis of the roots was effected, pulling up some randomly chosen plants from each ripetition and analysing their root system in the laboratory. The microscopic analysis has been effected with the Cobb's method for extration of nematodes from soil (THORNE, 1961), and incubation's technique (ZANGHERI and PELLIZZARI SCALTRITI, 1981) for the extration of nematodes from vegetables tissue. At the end of the cycle we proceded to the evaluation of the production, counting and weighing the fruits, once they were picked.

3. Results and discussion

In the planimetrical map (fig.1) the level of attack to the roots at the cycle end was emphasized. The tables 2-4 show the average unitary yield, the average number of fruits/per plant and the average unitary weight of the fruits. Table 1 shows the results of the soil analysis reporting the relative quantity of nematodes present in the various thesis. It clearly shows how at 36 days from the transplant the quantity of nematodes was not very consistent, and it was similarly present in all the thesis without direct proportionality to the doses of nematocide employed. Over all it was higher in the control even if there was no significant difference between the control and some of the thesis where the application inside the furrow had been used. Significant was the difference between the control and the thesis where the localized applications had been used. Never the less in both cases the presence in the soil of root-knots nematodes did not lead to the presence of knots in the roots of any of the plants of the 11 thesis.

The presence of root-knots appears only on some of the plants close to the sides of the greenhouse, where the solarization effect had been smaller due to the well known heat dispersions. High levels of attack, reaching the top level of the figurative scale 0-5 (CALABRETTA et al., 1989), are pointed out. As shown in the planimetry of fig.1, there was no behavioural difference in the 11 thesis with regard to this attack, which shows the inefficacy of phenamiphos, when used with the above distribution techniques. As well, there was no negative difference in the cumulative yield (tab.2), or in the number of fruits per plant (tab.3), or in the average unitary weight of the fruits (tab.4). In all the cases and for all the thesis the results we achieved did not show statistically significant differences. The presence of root-knots in the plants shows what was the potentiality of the attack and what levels of infestations would have been reached if the soil solarization would not have been effective, as indeed wasn't in the peripheric areas of the greenhouse, due to the well known edge effects. The results of the microscopic analysis of the roots,

effected 100 days after transplant, did not show a significant presence of root-knot nematode larvae in any of the thesis.

4. Conclusions

We can draw the following conclusions from what has been said up to now:

1 - the employment of phenamiphos as integrative to solarization, administered after transplant inside a furrow or in plant localized distributions, neither improves the yield of the crop, nor it stops the appeareance of root-knots;

2 - the employment of solarization inside a closed greenhouse, on soil which had been fumigated with methyl-bromide before the previous crop, was able by itself to avoid the formation of root-knots except in the peripheric zone of the solarized area;

3 - at least in Sicily, there is a real possibility to successfully alternative soil solarization in summer time with soil fumigation employing methyl-bromide in winter time. This means that we are at the moment able to half the impact of this chemical with the enviroment, in such a way to achieve the results which the law of the italian M.A.F. is expecting to achieve in this and in many other sectors of integrated pest management.

References

CALABRETTA C., COSENTINO S.L., NUCIFORA A., SORTINO O., 1989. Valutazioni di tipi di pomodoro coltivati in serra fredda resistenti all'attacco di nematodi galligeni.
Informatore fitopatologico 39 (6): 43-48.

CARTIA G., 1984. Impiego della pastorizzazione solare nei confronti di parassiti ipogei di solanacce in serra.
Atti Giornate Fitopatologiche 1984. 1: 463-472.

CARTIA G., 1989 a. La solarizzazione del terreno: esperienze maturate in Sicilia.
Informatore fitopatologico 39 (5): 49-52.

CARTIA G., 1989 b. La solarizzazione: tecnica di applicazione.
Atti 3° Incontro sulla difesa della ortofloricoltura protetta. Parte II: 5-7.

CARTIA G., GRECO N., CIRVILLERI G., 1988. Solarizzazione e bromuro di metile nella difesa dei parassiti del pomodoro in ambiente protetto.
Atti Giornate Fitopatologiche 1988, 1: 437-448.

CARTIA G., NOTO G., NUCIFORA A., PARATORE A., 1989. Effetti agronomici e fitosanitari della solarizzazione su pomodoro coltivato in serra.
Colture protette 4: 73-77.

GARIBALDI A., GULLINO M.L., 1988. La lotta integrata contro le malattie fungine delle piante ortensi in coltura protetta.
Informatore fitopatologico 38 (11): 13-20.
KATAN J., 1980. Solar pasteurization of soil for disease control: status and prospects.
Plant Disease 64: 450-454.
KATAN J., 1981. Solar heating (solarization) of soil for control of soilborne pests.
Ann. Rev. Phytopathol. 19: 211-236.
NUCIFORA A., COLOMBO A., PECORELLA C., 1989. Solarizzazione e phenamiphos a dosi ridotte non bloccano lo sviluppo di Meloidogyne spp.
Informatore fitopatologico 39 (6): 39-42.
NUCIFORA S., 1989. Varietà resistenti e solarizzazione del terreno per il controllo dei nematodi galligeni in serra.
Tesi sperim. di laurea. Ist. di Ort. e Flor. Univ. di Catania.
THORNE G., 1961. Principles of nematology.
Mc. Graw-Hill Book Company, Inc. London: pp. 553.
ZANGHERI S., PELLIZZARI SCALTRITI G., 1981. Parassitologia animale dei vegetali.
Cleup ed. Padova: pp. 198.

Table 1 - Number of nematodes (Meloidogyne spp.) for 100 g^{-1} of dry earth recorded at 36 days from the transplant on soil solarized and treated with Nemacur at 4,8% of phenamiphos in the quantities reported in table, variously distributed (*) (**), 7 days after transplant (Donnalucata, 1988).

Nemacur (g/plant)	Number of Meloidogyne spp. for 100g^{-1} of soil (*)	(**)	Mean
0	97.1	92.4	94.75
2.3	27.6	27.5	27.55
3.5	82.7	52.3	67.5
4.6	85.9	21.4	53.65
7.0	67.5	55.3	61.4
10.5	21.4	42.9	32.15
Mean	58.1	50.9	

	DMS	
Significant effects	P= 0.05	P= 0.01
Method of distribution	-	-
Dose	27.6	37.4
Dose x Method of distr.	39.06	-

(*) (**) see table 4

Table 2 - Mean yield/plant (g), cumulated at the end of production cycle, of tomato crop "Vemar F1" on soil solarized and treated with Nemacur at 4,8% of phenamiphos in the quantities reported in table variously distributed (*) (**), 7 days after transplant (Donnalucata, 1988).

Nemacur (g/plant)	Mean yield/plant (g) (*)	Mean yield/plant (g) (**)	Mean
0	2759.9	2720.1	2740.0
2.3	2945.1	2701.8	2823.4
3.5	2746.9	2367.0	2556.9
4.6	2846.4	2567.5	2706.9
7.0	2530.9	2649.7	2590.3
10.5	2610.6	2596.2	2603.4
Mean	2711.1	2587.0	

Significant effects	DMS P= 0.05	DMS P= 0.01
Method of distribution	-	-
Dose	-	-
Dose x Method of distr.	-	-

(*) (**) see table 4

Table 3 - Mean number of fruit/plant, cumulated at the end of production cycle, on tomato crop "Vemar F1", on soil solarized and treated with Nemacur at 4,8% of phenamiphos in the quantities reported in table, variously distributed (*) (**), 7 days after transplant (Donnalucata, 1988).

Nemacur (g/plant)	Mean number of fruit/plant (*)	(**)	Mean
0	16.0	16.5	16.25
2.3	17.1	15.5	16.3
3.5	15.7	13.9	14.8
4.6	17.1	15.3	16.2
7.0	15.4	15.3	15.35
10.5	15.5	15.2	15.35
Mean	16.0	15.2	

Significant effects	DMS P= 0.05	P= 0.01
Method of distribution	-	-
Dose	-	-
Dose x Method of distr.	-	-

(*) (**) see table 4

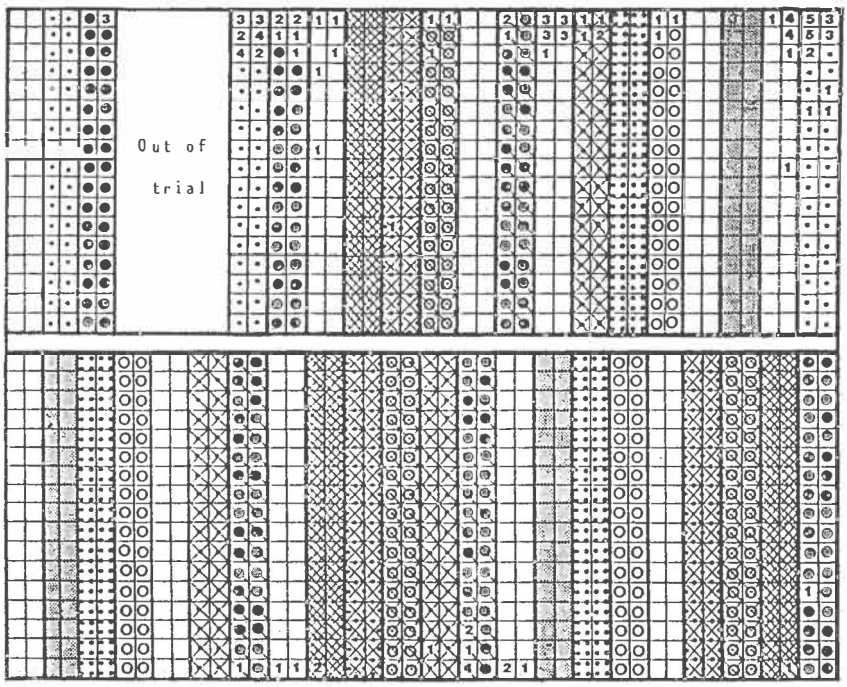
Table 4 - Unitary mean weight of the fruits (g) on tomato crop "Vemar F1" grown on soil solarized and treated with Nemacur at 4,8% of phenamiphos in the quantities reported in table, variously distributed (*) (**), 7 days after transplant (Donnalucata, 1988).

Nemacur (g/plant)	Unitary mean weght of the fruit (g) (*)	(**)	Mean
0	172.1	165.0	168.55
2.3	172.6	174.1	173.35
3.5	174.7	170.0	172.35
4.6	166.3	168.2	167.25
7.0	163.8	173.3	168.55
10.5	167.9	170.2	169.05
Mean	169.2	170.4	

Significant effects	DMS P= 0.05	P= 0.01
Method of distribution	-	-
Dose	-	-
Dose x Method of distr.	-	-

Tables 1-4 (*) = Distribution of Nemacur along the row.
(**) = Distribution of Nemacur concentrated in three sites around the plant.

Figure 1 - Plan of plant distribution and Meloidogyne spp. attack. Every little square of the plan is a test-plant, while numerals inside the square show the degree of attack of Meloidogyne spp. on the roots according to the range 0-5 (Calabretta et al., 1989). The square without number in each repetition represents a plant without attack.



Control with only soil solarization

Thesis with chemical distributed along the row.

- soil solarization + g 2.3 of c.p.
- soil solarization + g 3.5 of c.p.
- soil solarization + g 4.6 of c.p.
- soil solarization + g 7.0 of c.p.
- soil solarization + g 10.5 of c.p.

Thesis with chemical distributed around every plant.

- soil solarization + g 2.3 of c.p.
- soil solarization + g 3.5 of c.p.
- soil solarization + g 4.6 of c.p.
- soil solarization + g 7.0 of c.p.
- soil solarization + g 10.5 of c.p.

c.p. (commercial product) = Nemacur at 4,8% of phenamiphos.

EFFECTS OF SOIL SOLARIZATION ON LARVAE OF MELOIDOGYNE SPP. IN SOIL AND ROOT OF TOMATO "NOVI F1" IN COLD GREENHOUSE

C. CALABRETTA (1), A. COLOMBO (1), S. COSENTINO (2), E. SCHILIRO' (3), O. SORTINO (4)

(1) Istituto di Entomologia Agraria - Università degli Studi di Catania - Via Valdisavoia 5 - 95123, CATANIA (ITALY)
(2) Centro di Studio sulle Colture Precoci Ortive in Sicilia del C.N.R. c/o Istituto di Agronomia Generale e Coltivazioni erbacee - Università degli Studi di Catania
Via Valdisavoia 5 - 95123, CATANIA (ITALY)
(3) Osservatorio delle malattie delle piante di Acireale (CT) del MAF Corso Umberto 144 - 95024, Acireale (CT) ITALY
(4) Istituto di Agronomia Generale e Coltivazioni erbacee - Università degli Studi di Catania - Via Valdisavoia 5, 95123 CATANIA (ITALY)

Summary

To verify the validity of the introduction of soil solarization among the agronomic practices in protected cultivation, in 1988 a research has been carried out in cold greenhouse in Sicily (S. Croce Camerina - RG - 36°48' N, Lat 2°55' E Long) applying a solarization treatment, in comparison to a treatment with methyl bromide and to an untreated control, on tomato 'Novi F1' nematode resistant. The amount of nematodes (Meloidogyne spp.) in soil resulted, in the average, higher in control (2.9 nematodes g^{-1} of soil) compared to the other two treatments (0.9 and 0.6 nematodes g^{-1} of soil in the solarization and bromide treatments respectively). The number of nematodes in root was, irrespective of the date of analysis much higher in control than in bromide and solarization treatments (486, 70 and 16 nematodes g^{-1} d.m. of root, respectively). At the third harvest the solarization treatment gave an accumulated production of 13.7 t ha^{-1} which resulted higher than control (t ha^{-1} 6.2) and lower than bromide treatment (t ha^{-1} 22.0). At the end of cycle the accumulated production of the sterilised treatments (the methyl bromide and the solarization), were not significantly different (61.3 and 58.4 t ha^{-1} respectively) but gave a higher production than control (50.5 t ha^{-1})

1. Introduction

Soil disinfestation by means of methyl bromide is at present the most widely used practice in greenhouses along the coastal region of Ragusa province to control the impoverishment of fertility of the substrates especially from the phitosanitary point of view (CALABRETTA

and PRIVITERA, 1985). Its favourable action which is carried on especially on the control of the activity of fungal parasites and of the root-knot nematodes (Meloidogyne spp.), arouse, however, some uncertainty in relation to the environmental risks and the possible residues of bromine in the products of plants cultivated on treated soil (FOTI and LA MALFA, 1989).

In order to limit the environmental damages caused by the use of this type of fumigants some alternatives were indicated like the use of resistant tomato varieties (CALABRETTA et al., 1989), the introduction in crop rotation of species other than solanaceae (FOTI et al., 1989; MAUROMICALE et al., 1989) and not last the use of soil solarization (KATAN, 1981; CARTIA, 1984; 1989). This latter practice assumes particular interest in the mediterranean environment since, connected to simple techniques, represents one of the possible use of the solar energy in agriculture.

In this context is placed the present research which has the aim to study the effects of soil solarization on the dynamics of the larvae of nematodes in soil and in root of tomato hybrid 'Novi Fl' resistant to nematodes.

2. Materials and methods

The research was carried out in a typical greenhouse area of Sicily (Italy) near to S.Croce Camerina - Ragusa - (36°48' N Lat 2°55' E Long) in cold greenhouse on an almost totally sandy soil. On tomato cv. 'Novi' hybrid, resistant to nematodes, two types of soil treatments were studied. Compared to an untreated control, a solarization treatment (50 days) and a treatment with methyl bromide (80 g m^{-2}) were applied. The plants were transplanted on October 10th, 1988, with a plant density of 3 plants m^{-2} (m 1 x 0,33); the crop technique was the one routinely adopted in the surrounding areas.

Togheter with the soil temperature during the solarization treatment the following data were collected:

- the temperature of the internal air (fig.1);
- height of the plant at 90 days after transplanting;
- weight and number of fruits in the subsequent harvests;

The harvest started the 8th of march 1989 and gone ahead until the 22/5/1989 regarding the first four trusses.

The number of larvae of nematodes was measured on soil samples, close to the plants and between the rows (25 cm depth), according to the Cobb's method (THORNE, 1961) and on root samples with the incubation technique (ZANGHERI and PELLIZZARI SCALTRITI, 1981), in the following dates: 7/11/1988 (only soil samples), 5/12/1988, 8/2/1989 and 13/6/1989 (soil and root samples).

Data were subjected to the analysis of variance. Where the F was significant an LSD (p=0.05) was calculated.

3. Results

During the solarization treatment which lasted 50 days (1200 hours), the soil temperature raised, in the average, by 10°C than the control both at 15 cm and 30 cm of deepness (fig.2). In the solarization treatment the five-day mean temperature, at 15 cm of deepness ranged between 44°C (5-10 July) and 37.6°C (15-20 September); at 30 cm between 39.7°C (10-15 July) and 36.1°C (5-10 September).

The number of larvae of nematodes in soil, resulted in the average of sampling dates and positions, higher in control (2.9 nematodes g^{-1} of soil) followed by methyl bromide (0.9 nematodes g^{-1}) and solarization (0.6 nematodes g^{-1}) treatments, while in the average of sampling dates the amount of nematodes was higher near the plants than between rows (1,95 vs. 1.06 nematodes g^{-1} of soil, respectively) (tab.1).

Tab.1 - Number of nematodes (number g^{-1}) in the soil in relation to the studied treatments and to the sampling site

Treatments	Along the rows	Between the rows	Mean		LSD p=0.05
Control	3.7	2.3	2.88	treatment (t)	0.71
Solarization	0.9	0.3	0.62	site (s)	0.50
Bromide	1.2	0.6	0.88	(t) x (s)	--
Mean	1.95	1.06			

However, the significance of the interaction "sampling date x treatment" testifies that from the third soil sampling ahead (5/12/1988) there where not statistical difference between the control and the two soil treatments (fig.3).

The number of larvae of nematodes in the root was, in the average of sampling dates, significantly higher in control than in the bromide and solarization treatments (476, 70 and 16 nematodes g^{-1} of dry matter of root, respectively) (fig.4). The significance of the "treatment x sampling date" interaction, shows a different behaviour of the treatments in the subsequent sampling dates. In the last sampling date (13/6) the control resulted much more higher than the other two treatments (fig.5).

Plant height at 90 days after transplanting was significantly higher in the bromide treatment than solarization treatment and control (216.2 cm, 196.5 and 197.7 cm respectively) (fig.6).

At the third harvest the solarization treatment gave an accumulated production of 14 t ha^{-1} which resulted higher than control (6.2 t ha^{-1}) and lower than bromide treatment (22 t ha^{-1}). The number of fruit per plant accounted for this difference in the yield (7.5,

5.1 and 2.3 respectively for bromide, solarization and control) (tab.3).

At the end of cycle the accumulated production of the sterilisation treatments (methyl bromide and solarization) were not significantly different (61 and 58 t ha^{-1} respectively) but produced more than the control (50 t ha^{-1}). Also in this case the difference is to ascribed to the different number of fruit per plant (18.9, 19.4 and 16 for the three treatments) than to the fruit weight.

Tab.3 - Cumulated production, number of fruit per plant and fruit weight at the third harvest and at the end of cycle

Treatments	Yield (t ha^{-1})	fruit $plant^{-1}$ (n.)	fruit weight (g)
	At the third harvest		
Control	6.2	2.3	92.2
Solarization	13.7	5.1	89.6
Bromide	22.0	7.5	97.9
Mean	13.97	4.96	93.2
LSD (p=0.05)	5.30	2.80	--
	End of cycle		
Control	50.5	16.0	105.2
Solarization	58.4	19.4	100.2
Bromide	61.3	18.9	108.0
Mean	56.73	18.1	104.5
LSD (p=0.05)	6.97	2.7	--

4. Conclusions

The analysis of the results of the present research, even if limited to a one-year trial, allowed to ascertain the following indications:

- the number of larvae of nematodes in soil and in root of the tomato 'Novi' hybrid was significantly lower in the sterilisation treatments (methyl bromide and solarization) than in untreated control;
- the untreated control produced significantly less than the other two treatments both at the third harvest and at the end of cycle. This differences could not be ascribed to the action of nematodes also for the specific resistance of the tomato hybrid. That could be

probably explained by the action of the sterilization treatments (methyl bromide and solarization) on the microrganism responsible for the nitrogen cycle in the soil.

In conclusion, the soil solarization treatment, at least at the condition of this trial, was able to control the larvae of nematodes in soil and allowed to give a productive result similar to that of the methyl bromide treatment.

References

CALABRETTA C., COSENTINO S., NUCIFORA A., SORTINO O., 1989. Valutazioni di tipi di pomodoro coltivati in serra fredda resistenti all'attacco di nematodi galligeni.
Informatore fitopatologico, 39 (6): 43-48.

CALABRETTA C. and PRIVITERA S., 1985. Considerazioni sullo stato attuale della lotta contro i nematodi galligeni delle piante orticole in coltura protetta e prospettive reali di interventi alternativi.
Tecnica agricola, XXXVII, 3-4: 243-257.

CARTIA G., 1984. Impiego della pastorizzazione solare nei confronti di parassiti ipogei di solanacce in serra.
Atti Giornate Fitopatologiche, 1: 463-472.

CARTIA G., 1989. La solarizzazione del terreno: esperienze maturate in Sicilia.
Informatore fitopatologico, 39 (5): 49-52.

FOTI S. and LA MALFA G., 1989. Problemi della scelta di colture innovative.
Riv. di Agr., 4: 307-326.

FOTI S., MAUROMICALE G., COSENTINO S., 1989. Effects of supplementary lighting on the biological and agronomic behaviour of snap bean, cucumber and summer squash in cold greenhouse.
Acta Horticulturae, (in press).

KATAN J., 1981. solar heating (solarization) of soil for control of soilborne pests.
Ann. Rev. Phytopathol., 19: 211-236.

MAUROMICALE G., COSENTINO S., FOTI S., 1989. Effects of sowing date on the production of phaseolus vulgaris L. in cold greenhouse.
Acta Horticulturae, (in press).

THORNE G., 1961. Principles of Nematology.
Mc. Graw-Hill Book Company, Inc. London, pp. 553.

ZANGHERI S. and PELLIZZARI SCALTRITI G., 1981. Parassitologia animale dei vegetali.
Cleup. ed. Padova, pp. 198.

Fig. 1 - Maximum and minimum temperature of the air in the greenhouse (ten-day value)

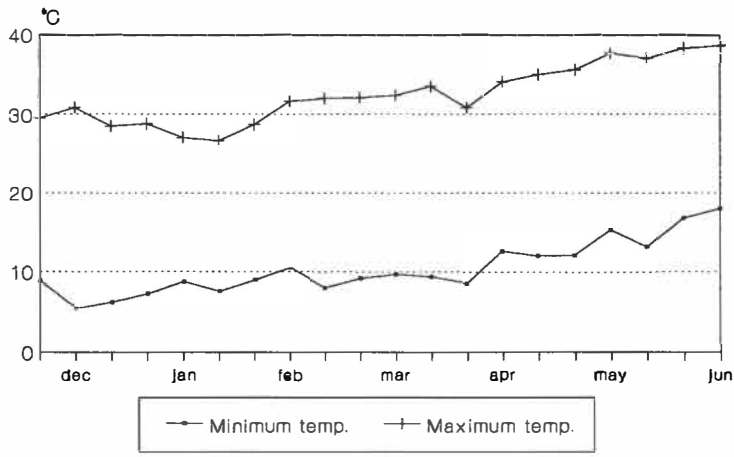


Fig.2 - Five day mean soil temperature during solarization treatment at different soil deepness

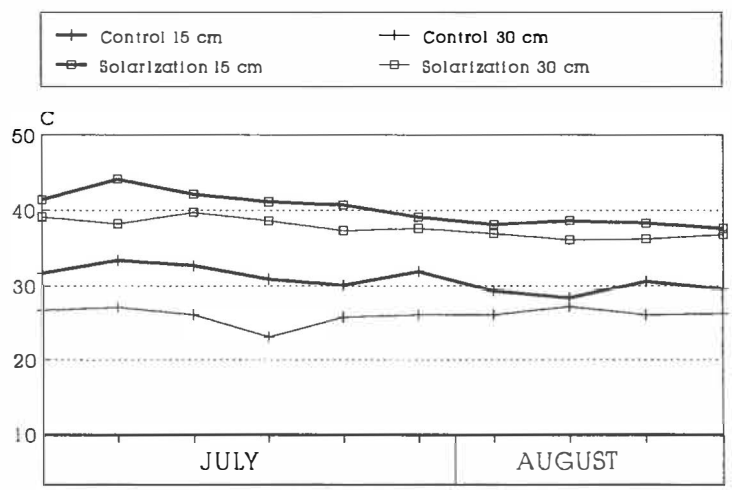
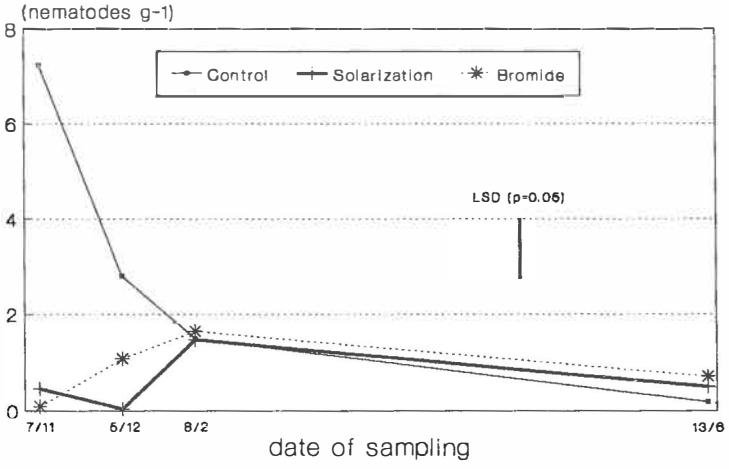


Fig.3 - Dynamics of larvae of nematodes in soil in relation to the studied treatments



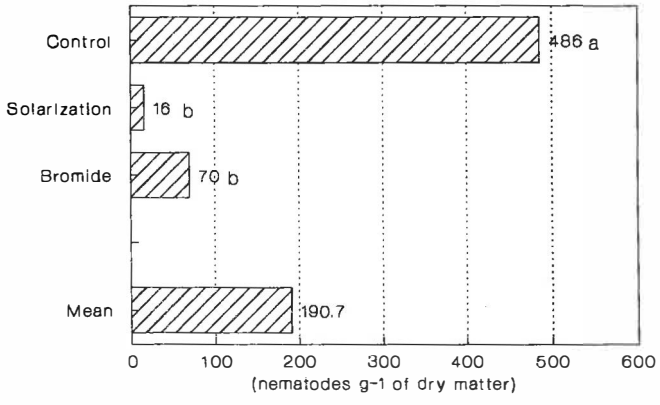


Fig.4 - Larvae of nematodes in root in relation to treatment in the average of sampling date. (values with equal letter do not differ significantly at p=0.05)

Fig.5 - Dynamics of larvae of nematodes in root in relation to the studied soil treatments

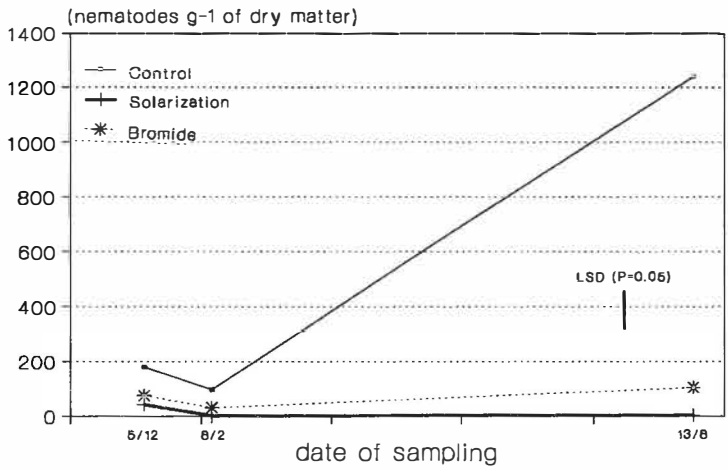
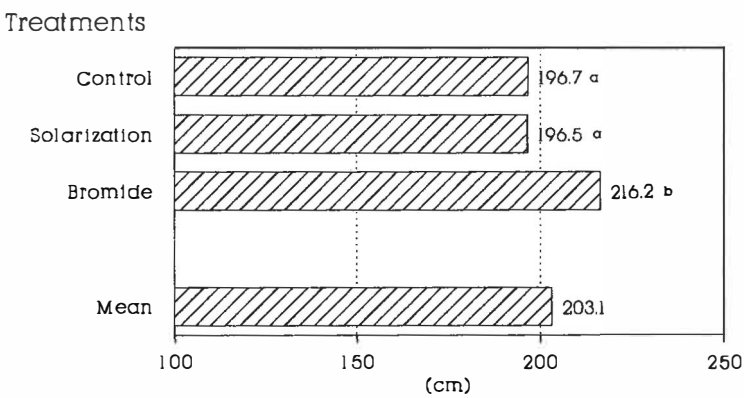


Fig.6 - Plant height at 90 days after transplanting (Values with equal letters do not differ at p=0.05)



LUTTE CONTRE LA POURRITURE BRUNE DES RACINES DE TOMATE EN SERRE PAR LA SOLARISATION DU SOL

BOURBOS V.A. et M.T. SKOUDRIDAKIS
Institut des Plantes Subtropicales et de l'Olivier
Laboratoire de Pathologie Végétale
Chania 73100, Crète, Grèce

Résumé

La pourriture brune des racines de tomate en serre due au complexe parasitaire Colletotrichum coccodes (Wallr.) Hyghes, Fusarium oxysporum Schlecht. f. sp. radicis-lycopersici Jarvis et Shoemaker, F. solani (Mart.) Sacc., Pyrenochaeta lycopersici Gerlach, Pythium debaryanum Hess et Rhizoctonia solani Kuhn, provoque à l'heure actuelle des dégâts importants. La possibilité de la lutte contre cette maladie a été étudiée en utilisant la solarisation du sol. Pour l'application de cette technique le sol testé a été couvert pendant 10 semaines à l'aide d'une feuille plastique transparent de 0,05 mm épaisseur. Dans le sol solarisé on a constaté une forte diminution de 83,5 - 100% de la présence quantitative des composants parasitaires par rapport au témoin. Cette diminution du potentiel infectieux du sol a été extériorisée par une augmentation de la production de l'ordre de 126,2% pour le sol solarisé.

Introduction

La culture de tomate en serre elle-même suivie pendant plusieurs années, la désinfection du sol par les fumigants et la fertilisation chimique parfois démesurée ont profondement déséquilibré la synthèse de la microflore tellurique. Des phénomènes écologiques desagreables comme la fatigue du sol cultivé (Bouhot, 1980) et l'échange des maladies (Davet, 1981) commencent à paraître dans les regions serricoles.

Cette modification profonde de la biocénose du sol de serre a augmenté dernièrement en Crète les dégâts causés par la pourriture de racines de tomate (Bourbos, 1983). En Crète on a constaté que les champignons Pyrenochaeta lycopersici Gerlach, Fusarium solani (Mart.) Sacc., F. oxysporum Schlecht f.sp. radicis-lycopersici Jarvis et Shoemaker, Rhizoctonia solani Kuhn, Colletotrichum coccodes (Wallr.) Hyghes et Pythium debaryanum Hess sont les principaux composants du complexe parasitaire (Bourbos et Skoudridakis, 1988).

La lutte chimique contre cette maladie par utilisation des fumigants, au delà des consequences défavorables déjà référées, ne peut plus contrôler efficacement le Pyrenochaeta lycopersici et F. solani qui se développent en dehors du spectre d'action de ces produits. De plus, la lutte chimique à l'aide des bioctones a été demontrée inefficace contre le F. oxysporum f.sp. radicis-lycopersici.

La solarisation du sol, une méthode physicobiologique, est largement utilisée pour lutter contre les maladies telluriques des plantes cultivées (Bourbos et Skoudridakis, 1988; Drame, 1985; Stapleton et DeVay, 1986). Cette méthode est basée sur la modification physique, chimique et biologique qui subit le sol couvert par une feuille plastique en polyéthylène transparente pendant 4-10 semaines en période estivale sous l'action de l'énergie solaire.

En effet a été constaté que l'action hygrothérmique permanente tue ou inhibe le développement de nombreux champignons pathogénes et favorise la microflore antagoniste.

La dite méthode a été utilisée dans divers pays du monde pour lutter contre la pourriture brune des racines de tomate (Bourbos et Skoudridakis, 1988; Bourbos et Skoudridakis, 1989; Garibaldi et Tamietti, 1983; Katan, 1984; Tzamos, 1983).

Materiel et Méthodes

Les essais pour lutter contre la pourriture brune des racines ont été effectués pendant deux périodes culturales consecutives. Des sols gravement infestés par cette maladie ont été utilisés pour la réalisation de ces essais. Le dispositif expérimental comprenait deux traitements (sol témoin, sol solarisé) en 10 répétitions. La surface de l'unité d'essai était presque 25 m². On a utilisé la varieté de tomate Early Pack 7 sensible aux pathogénes résponsables de la maladie.

La solarisation du sol a été appliquée en période estivale pendant 10 semaines. Pour la couverture du sol on a utilisé des feuilles plastiques en polyéthylène transparent d'une épaisseur de 0,05 mm. Le sol testé était bien laboré et arrosé avant sa couverture par le plastique. Un nivellement attentif de la surface du sol était nécéssaire pour un fin contact des feuilles plastiques à la surface édaphique. Pour les mêmes raisons les films ont été périferiquement enterrés jusqu' à une profondeur de 15 cm. Le contact du film avec la surface édaphique facilite la transmission de la plupart de radiations solaires chauffant le sol.

L'évaluation de l'efficacité de la solarisation contre la maladie a été basée sur:

* L'analyse quantitative et qualitative des composants du complèxe parasitaire. Pour cette analyse on a prélevé à l'aide d'une sonde pédologique 5 échantillons par parcelle-serre d'une profondeur de 2-30 cm. Deux prélevements ont été effectués. L'un avant la couverture du sol par le film plastique et l'autre après la solarisation. L'étude de la présence quantitative et

qualitative des champignons responsables de la maladie a été realisée à l'aide de la technique "suspensions - dilutions" (Waksman, 1927).

* L'application du test biologique décrit par Bouhot (1980). Pour ce bioessai on a utilisé des plantules de tomate de 5 cm de longeur.

* L'éstimation de la production totale obtenue.

* L'éstimation après la recolte des plantes dont le système racinaire était infesté par la maladie.

Resultats

Dans les parcelles non solarisées on a constaté une augmentation de la présence quantitative des composants du complexe parasitaire Colletotrichum coccodes (10,1%), Fusarium oxysporum f.sp. radicis-lycopersici (34,6%), F. solani (31,3%) et Rhizoctonia solani (74,6%). Au contraire les champignons Pyrenochaeta lycopersici et Pythium debaryanum ont présenté une diminution de 0.7% et 9,5% respectivement. Chez les sols solarisés on n'a pas pu isoler les éspeces Colletotrichum coccodes, Pyrenochaeta lycopersici, Pythium debaryanum et Rhizoctonia solani. Les champignons Fusarium oxysporum f.sp. radicis - lycopersici. et F. solani ont été representés par un taux de colonies/gr très faible (Table 1).

Table 1. Evolution quantitative des composants du complèxe parasitaire de la pourriture brune des racines de tomate dans le sol

Especes	Sol témoin	Sol témoin après 10 semaines	Sol solarisé
Colletotrichum coccodes	1,28	1,41	0
Fusarium oxysporum f.sp. radicis-lycopersici	1,56	2,10	0,32
Fusarium solani	2,11	2,77	0,34
Pyrenochaeta lycopersici	1,40	1,39	0
Pythium debaryanum	0,42	0,34	0
Rhizoctonia solani	0,63	1,10	0

En examinant le potentiel infectieux du sol témoin on a observé un pourcentage très élevé de plantes infestées par la maladie arrivant à 96,3% (Table 2) pour le test biologique, et 98,6% pour les plantes agées (Table 3).

Table 2. Resultats obtenus par utilisation du test biologique chez le sol testé.

Cas	% plantes avec les symptômes de la pourriture brune
Sol témoin avant solarisation	96,6
Sol témoin 10 semaines après	96,3
Sol solarisé	0,4

Table 3. Efficacité de la solarisation contre la pourriture brune des racines de tomate en serre

Cas	% plantes avec des symptomes
Sol témoin	98,6
Sol solarise	0,9

La production par plante dans le cas du sol solarisé a presenté une augmentation de l'ordre de 126,2% par rapport au sol-témoin (Table 4).

Table 4. Production (kg/plante) obtenue dans les parcelles d'essai

Cas	Production
Sol témoin	2,437
Sol solarisé	5,513

Discussion

L'application de la solarisation du sol infesté par la pourriture brune de tomate en serre à l'aide des feuilles plastiques en polyéthylène transparent de 0,05 mm épaisseur et pendant la période estivale paraît qu'elle peut contrôler efficacement la dite maladie.

L'analyse quantitative du complèxe parasitaire démontre une forte diminution de la présence de ces composants dans le sol solarisé. Cette diminution s'extériorise par un taux des plantes infestées très bas et une production totale considerablement élevée.

On peut donc penser que l'action hygrothermique permanente dans le sol solarisé exerce une action léthale ou sous-léthale sur les parasites, favorise les antagonistes thérmophiles et ameliore les proprietés physicochimiques du sol.

Bibliographie

BOUHOT, D., 1980. Le potentiel infectieux des sols (soil infectivity). Un concept, un modéle pour sa mésure, quelques applications.
Thèse Univers. Nancy I: 105.

BOURBOS, V.A., 1983. Contribution à l'étude de la mycoflore du sol de culture de tomate en serre non chauffée.
Thèse, Paris VI: 106.

BOURBOS, V.A. et SKOUDRIDAKIS M.T., 1988. La solarisation du sol contre les maladies telluriques de la tomate en serre. Comptes Rendus de la 2ème Conférence Internationale sur les maladies des plantes: 535-545.

BOURBOS, V.A. and SKOUDRIDAKIS M.T., 1988. Soil solarisation with plastic for the control of the brown root rot of the greenhouse tomato.
5th National Phytopathological Congress (11-13 October) Thessaloniki, Greece.

DAVET, P., 1981. Effects non intentionnnels des traitements fongicides sur les microflores aérienne, tellurique et acquatique.
IIIème Colloque sur les effets non intentionnels des fongicides: 41-59.

DRAME, A., 1985. Etude des possibilités d'utilisation de la solarisation dans la lutte contre les maladies du sol.
Thèse 3ème cycle, Univ. INA, Grignon: 70.

GARIBALDI, A. and TAMIETTI, G., 1983. Attempts to use soil solarization in closed glasshouse in northern Italy for controlling corky root of tomato.
Acta Horticulturae 152: 237-243.

KATAN, J., 1984. Soil solarization. In: Second International Symposium on soil disinfestation.
Acta Horticulturae 152: 227.

STAPLETON, J.J and DEVAY, J.E., 1986. Soil solarization: a non chemical approach for management of plant pathogens and prests.
Crop Protection 15(3): 190-198.

TZAMOS, E.C., 1983. Control of Pyrenochaeta lycopersici by combined soil solarization and low dose of methol bromide in Greece.
Acta Horticulturae 152: 253-258.

WAKSMAN, S.A., 1927. Principles of soil microbiology.
Baltimore. Williams and Wilkins Co.

SOILS SUPPRESSIVE TO PHYTOPHTHORA CRYPTOGEA IN ITALY: PRELIMINARY RESULTS (*)

C.PASINI (1), M.CASSINI (1), F.D'AQUILA (1) and A.GARIBALDI (2).

(1) Istituto Sperimentale per la Floricoltura, Sanremo - ITALY.
(2) DI.VA.P.R.A., Sezione di Patologia Vegetale, Università di Torino - ITALY.

Summary
Among 62 soil samples collected on the Western Riviera coast, a few are suppressive against Phytophthora cryptogea, agent of foot rot of Gerbera. The suppressiveness is correlated with the presence of antagonistic microorganisms in these soils.

1. Introduction

Foot rot, incited by Phytophthora cryptogea, is the most severe disease in gerbera cultivations in Italy. Serious economic losses are commonly observed, despite application of control measures. Conventional control measures include soil disinfection and chemical soil drenches after planting. Although these treatments decrease incidence, often the level of control achieved is not satisfactory (Pasini et al., 1984). Moreover, varieties resistant to P.cryptogea are not known: this complicates breeding programmes aimed at obtaining resistant varieties and is also interesting from a commercial point of view.
The availability of alternative control measures therefore looks promising. Soils suppressive to several species of Phytophthora have been described (Ko and Nishijima, 1985; Ko and Shiroma, 1989). In these soils, suppressiveness has been related to the presence of antagonists and/or to physical/chemical properties of the soil (Kao and Ko, 1986).
The aim of the present work was to investigate the presence on the Italian Riviera of soils suppressive to Phytophthora cryptogea.

2.Materials and methods

The experiments were carried out in a glasshouse located at the Istituto Sperimentale per la Floricoltura di Sanremo (Im), under conditions favorable to the development of the disease. In 1990, 62 soils samples (listed under tables 1 and 2) were tested

---

(*) Work supported by grants from Regione Liguria and C.N.R. (Malattie delle piante da fiore ed ornamentali).

Table 1 - Incidence of foot rot on Gerbera in tested soils (first trial).

SOIL n°	DISEASE INDEX (0-100) 1st crop	2nd crop	SOIL n°	DISEASE INDEX (0-100) 1st crop	2nd crop
1	100 a (*)	100 a	16	30 eg	50 de
2	90 ab	100 a	17	0 g	0 g
3	70 ad	100 a	18	80 ac	90 ab
4	40 df	90 ab	19	50 bf	100 a
5	100 a	100 a	20	20 fg	100 a
6	100 a	90 b	21	70 ad	100 a
7	80 ac	70 bd	22	40 df	100 a
8	90 ab	100 a	23	40 df	100 a
9	60 ae	100 a	24	20 fg	90 ab
10	20 fg	10 fg	25	100 a	100 a
11	90 ab	80 ac	26	60 ae	80 ac
12	60 ae	100 a	27	40 df	100 a
13	100 a	80 ac	28	90 ab	100 a
14	20 fg	30 ef	29	90 ab	100 a
15	100 a	100 a	30	60 ae	100 a

(*) The means followed by the same letter are not significantly different, according to Duncan's test (P=0,05).

Table 2 - Incidence of foot rot on Gerbera in tested soils (second trial).

SOIL n°	DISEASE INDEX (0-100)	SOIL n°	DISEASE INDEX (0-100)
31	60 ad (*)	47	50 ad
32	40 bd	48	50 ad
33	70 ad	49	40 bd
34	20 d	50	70 ad
35	30 cd	51	80 ac
36	100 a	52	70 ad
37	50 ad	53	60 ad
38	80 ac	54	60 ad
39	70 ad	55	60 ad
40	60 ad	56	80 ac
41	80 ac	57	90 ab
42	50 ad	58	70 ad
43	70 ad	59	30 cd
44	70 ad	60	80 ac
45	60 ad	61	100 a
46	50 ad	62	30 cd

in order to test their potential suppressiveness against Phytophthora cryptogea. The soils were collected from various fields, cultivated or not. Ten pots (20 cm diameter) were filled with each soil: pots were artificially inoculated by mixing 0.5 g/pot of the pathogen, grown on autoclaved hemp grains and wheat kernels. Each pot was then planted, two weeks after the inoculation with the pathogens, with one gerbera plant (cv Terrafame). Observations on disease severity were carried out, at fortnight intervals, by using a disease index from 0 (healthy plant) to 100 (dead plant). Isolations from diseased plants were carried out in order to confirm that diagnosis was correct. In trial 1, a second crop was planted in the same soil.

3. Results

The development of P.cryptogea was different in the various soils (tables 1 and 2). A low incidence of foot rot was observed in the case of soils 10-14-17-34-35-59-62 (table 1 and 2). Particulary, in the soil 17 all plants were healthy at the end of the experiment. On the contrary, in the case of some soils (5-6-13-15-25-28-29-36-61) disease index was very high (table 1 and 2). Isolations carried out from infected plants grown in these soils confirmed the presence of P.cryptogea.

The investigation permitted to detect the presence of soils suppressive to P.cryptogea on the Western Riviera Coast. The microbiological origin of this suppressiveness has been demonstrated (Garibaldi and Gandolfo, under press): isolates of Trichoderma obtained from soil 17, when introduced in a conducive soil , are able to induce suppressiveness to this soil.

4. References

KAO C.W. and W.H.KO, 1986. Suppression of Pythium splendens in a Hawaiian soil by calcium and microorganisms. Phytopathology, 76, 215-220.

KO W.A. and S.S. SHIROMA, 1989. Distribution of Phytophthora cinnamomi- suppressive soil in nature. J. Phytopathology, 127,75-80.

KO W.H. and K.A. NISHIJIMA, 1985. Nature of suppression of Phytophthora capsici in a Hawaiian soil. Phytopathology, 75, 683-685.

PASINI C., D'AQUILA F., BIANCHINI C., 1984. Prove di lotta contro il marciume basale (Phytophthora cryptogea) della Gerbera. Atti giornate Fitopatologiche, 1, 495-502.

ANTAGONISTIC ACTIVITY OF SOME MICRORGANISMS AGAINST POWDERY MILDEW (SPHAEROTHECA FULIGINEA) OF ZUCCHINI: PRELIMINARY RESULTS *

GIOVANNI MINUTO, ANGELO GARIBALDI and M.LODOVICA GULLINO

Dipartimento di Valorizzazione e Protezione delle Risorse agroforestali - Sezione di Patologia vegetale, Via Giuria 15, 10126 Torino, Italy

Summary

Some fungal and yeast isolates obtained from zucchini leaves infected by powdery mildew (Sphaerotheca fuliginea), showed a good antagonistic activity against this pathogen when tested on potted cucumber plants. In greenhouse trials carried out on the Riviera Ligure (Northern Italy), the positive effect of an isolate, identified as Cladosporium sp., was confirmed on zucchini plants: weekly applications of this antagonist at the concentration of 10^7 - 10^8 CFU/ml protected zucchini plants, reducing disease incidence by 60-90%.

1. Introduction

Powdery mildew, incited by Sphaerotheca fuliginea, is an important disease of zucchini grown under greenhouse conditions in Northern Italy (Matta and Garibaldi, 1981). Control of this pathogen often requires a high number of chemical sprays, reaching ten/season. Although highly effective fungicides against powdery mildew are currently available, the exclusive use of chemical control measures cannot be recommended for several reasons. First of all, a reduction of chemical input is particularly needed in the case of crops such as zucchini where harvest lasts several months: under these conditions, respecting the required intervals between treatment and harvest is very difficult. Secondly, repeated use of some fungicides, especially sterol demethylation inhibitors (DMI), can lead to selection of resistant populations of the pathogen. This phenomenon has already been observed under greenhouse conditions, where populations of S.fuliginea resistant to some DMIs developed after intensive use of some fungicides belonging to this group (Schepers, 1985).

---

* Work supported by grants from Ministero Agricoltura e Foreste (Progetto finalizzato: Lotta biologica e integrata, Sottoprogetto: Colture protette) and from Regione Liguria.
The first author carried out the experiments, the second and third planned the work and wrote the text.

Biological control has long been attempted against S.fuliginea: Ampelomyces quisqualis, known since a long time as hyperparasite of powdery mildews (Blumer, 1967), has been tested against cucumber powdery mildew (Sundheim, 1982; Malathrakis, 1985; Sztejnberg et al., 1989). Moreover, parasitism of cucurbit powdery mildews by other fungi (i.e. Tilletiopsis minor, Cladobotryum varium, Paecilomyces farinosus, Acremonium alternatum, Scopulariopsis brevicaulis) has been reported (Hijwegen, 1988).

The use as biocontrol agents of microrganisms already adapted to the environment where they need to be active is frequently preferred to introduction of organisms originating from other areas. Our work was aimed to evaluate the presence of possible antagonists of powdery mildew and to test their antagonistic activity against S.fuliginea, under the cultural and environmental conditions of the Riviera ligure (Northern Italy).

2. Materials and methods

a) Isolation of microrganisms. Zucchini leaves infected with powdery mildew were collected and examined for the presence of dark areas. Isolations were carried out from these areas, which are generally characterized by the presence of hyperparasites of the pathogen. Possible antagonists were obtained with a needle from brown areas of leaves within 24 hours of collection and transferred onto PDA containing 50 mg/l of terramycin in order to reduce development of bacteria. The possible antagonists were transferred on PDA, coded and kept at 5 ^{0}C.

b) Screening of potential antagonists. Antagonistic activity of the microrganisms isolated was evaluated on cucumber plants (cv. Marketer, 2 plants/pot) grown in climatic cells at 25^{0}C, 12 hour light/day (5,000 lux). Plants were inoculated at the two leaf stage with S.fuliginea by spraying with a conidial suspension (10^{3} - 10^{4} conidia/ml) prepared by scraping naturally infected cucumber leaves.
Potential antagonists were grown on Petri dishes at 25^{0}C; then conidial or cell suspensions (10^{7} - 10^{8} CFU/ml) were prepared by scraping agar surfaces with a needle, then diluting conidia and yeast cells to the desired concentration in distilled water after filtration with cheese-cloth and sprayed on leaves 72 hours after inoculation with the pathogen. Twenty pots (40 plants) were used for each potential antagonist. All experiments were repeated at least twice.
Disease incidence was evaluated by using McKinney index after 5-8 days.
Microrganisms showing the best activity were chosen for further trials.

Table 1 - Activity of different antagonists against S. fuliginea evaluated on potted cucumber plants.

Isolate	% infected leaf area in trial 1		2		3	
--	100	(38)*	100	(30)	100	(28)
1 (yeast)	30		52		66	
2 (Cladosporium)	58		75		75	
4	78		50		78	
7	55		77		n.t.**	
8 (yeast)	62		22		64	
9	43		50		64	
10	58		62		72	

* Between brackets actual attack in control plants
** n.t. = not tested

Table 2 - Influence of four antagonists on severity of S. fuliginea attacks, evaluated on zucchini grown under greenhouse. Treatments were carried out at weekly intervals.

Treatment *	% infected leaf area in tunnel 3	4
--	22 c **	50 c
Isolate 1 (Yeast)	22 c	42 bc
Isolate 2 (Cladosporium)	2 a	4 a
Isolate 8 (Yeast)	5 a	31 bc
Isolate 9	11 b	29 b

* Number of treatments: eight
** Values of the same column followed by the same letter are not significantly different, following Duncan's Multiple Range test (P = 0.05).

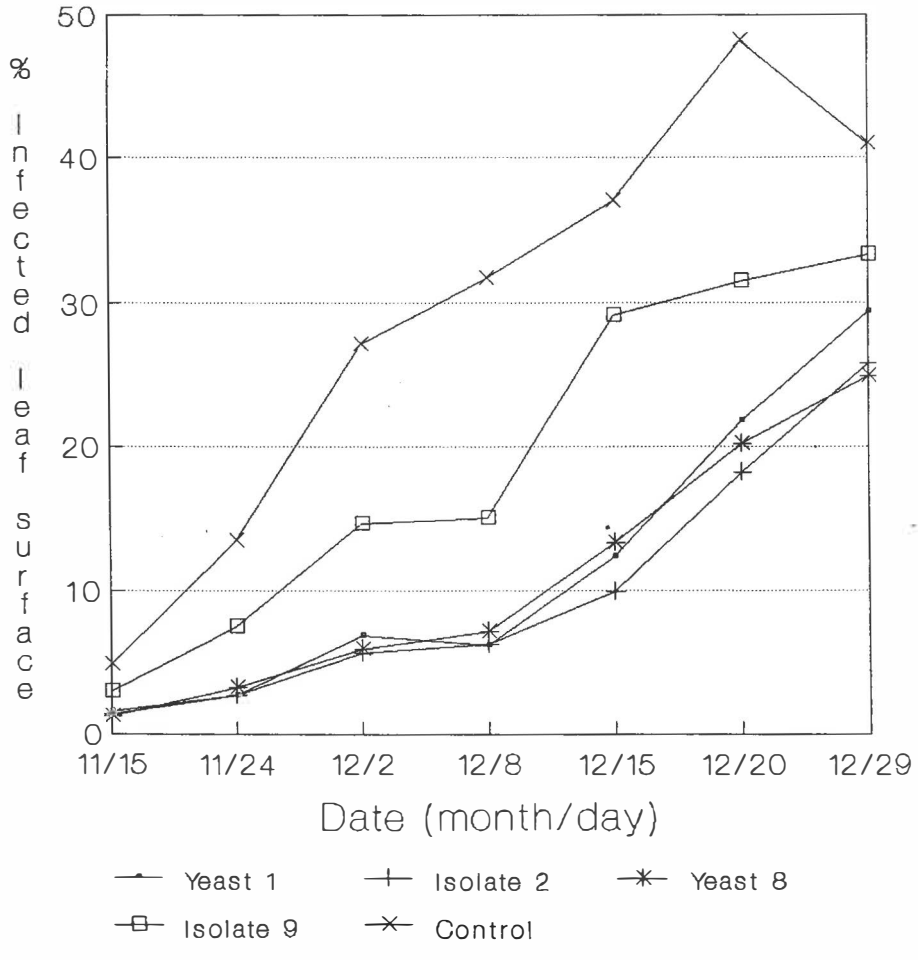


Figure 1 - Development of S. fuliginea infections on zucchini plants treated with different antagonists.

c) Greenhouse trials. Two trials were carried out in 1990 under plastic tunnels at the Centro orticolo sperimentale belonging to the Chamber of Commerce of Savona, located at Albenga (Riviera coast). Zucchini plants (cv Ibis, 30 plants/plot) were grown by using the techniques adopted by local growers. Starting at appearance of the first symptoms of powdery mildew on leaves, plants were sprayed at weekly intervals with a suspension of conidia (strains n.2 and 9) or of yeast cells (strain n. 1 and 8) at the concentration of 10^7 - 10^8 CFU/ml.
The effectiveness of the biocontrol agents was evaluated by counting the percentage of infected leaf area of plants sprayed or not with antagonists at fortnightly intervals.

3. Results and discussion

Hundreds of microrganisms where obtained from dark lesions of zucchini leaves. Twelve of them, chosen among those showing a good growth and/or sporulation, were screened for their antagonistic activity against S.fuliginea on cucumber. This screening led to seven isolates characterized by a good activity. The results obtained in the trials carried out in growth chambers on cucumber plants show that treatments with some fungi and yeasts significantly reduced disease severity of powdery mildew (table 1). Some of these microrganisms, sprayed on greenhouse grown zucchini plants, significantly reduce S. fuliginea incidence (figure 1). The positive effect of some antagonists, particularly of isolate n. 2, identified as Cladosporium sp., was confirmed on zucchini in two trials carried out under tunnels during the spring 1990 (table 2). This isolate showed a good activity also in the presence of a high disease incidence, as observed in tunnel 4 (50% of infected leaf area in control plots) (table 2). Also two other isolates (n. 8 and 9) partially controlled zucchini powdery mildew (table 2).

The present work shows that some microrganisms, isolated from zucchini leaves infected by powdery mildew, show antagonistic activity against S.fuliginea. Particularly, an isolate of Cladosporium sp. looks a promising biocontrol agent against the pathogen. The ability of this fungal genus to sporulate profusely is a positive feature. Conditions which can favor the antagonistic activity of Cladosporium sp. are at present under investigation, as well as compatibility of this antagonist with different pesticides used on zucchini grown under protection.

4. References

BLUMER, S., 1967. Echte Mehltaupilze (Erysiphaceae). Gustav Fischer, Jena.

HEIJWEGEN, T., 1988. Effect of seventeen fungicolous fungi on sporulation of cucumber powdery mildew. Neth. J. Pl. Path., 94: 185-190.

MALATHRAKIS, N.E., 1985. The fungus Acremonium alternatum Linc: Fr., a hyperparasite of the cucurbits powdery mildew pathogen Sphaerotheca fuliginea. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz, 92: 509-515.

MATTA, A & Garibaldi, A., 1981. Malattie delle piante ortensi. Edagricole, Bologna, 248 pagine.

SCHEPERS, H.T.A.M., 1985. Changes over a three-year period in the sensitivity to ergosterol biosynthesis inhibitors of Sphaerotheca fuliginea in the Netherlands. Neth. J. Pl. Path., 91: 105-118.

SUNDHEIM, L., 1982. Control of cucumber powdery mildew by the hyperparasite Ampelomyces quisqualis and fungicides. Plant Pathology, 31: 209-214.

SZTEJNBERG, A., GALPER, S., MAZAR, S. & LISKER, N., 1989. Ampelomyces quisqualis for biological and integrated control of powdery mildews in Israel. J. Phytopathology, 124: 285-295.

LUTTE INTEGREE CONTRE LES MALADIES CRYPTOGAMIQUES DE LA TOMATE AU MAROC

M. BESRI
Institut Agronomique et Vétérinaire Hassan II
B.P. 6202 Rabat-Instituts - Maroc -

Résumé
Au Maroc, la tomate est cultivée sous tunnel plastique et en plein air. Elle constitue la deuxième culture exportée après les agrumes. L'incidence de plusieurs agents pathogènes tels que *F. oxysporum* f.sp.*lycopersici*, *V. dahliae*, *L. taurica*, *B. cinerea*, *D. lycopersici*, *P. infestans*, *A. solani*, *C. michiganense* etc.... peut être, dans certaines conditions, très élevée. Différentes méthodes de lutte (résistance variétale, lutte chimique, solarisation du sol et des tuteurs, pratiques culturales etc...)sont utilisées. Cependant, de nombreuses maladies continuent encore à poser de sérieux problèmes à cause de l'appation de nouvelles races d'agents pathogènes, de souches résistantes aux pesticides, de la non disponibilité de variétés résistantes, de l'utilisation irraisonnée des pesticides etc..

1. Introduction.

La tomate est l'une des cultures les plus largement distribuée au Maroc. Elle est atteinte par de nombreuses maladies qui peuvent, lorsque les conditions d'environnement sont favorables, entrainer des pertes considérables. A cause de sa haute rentabilité, la protection phytosanitaire est très intense.

La culture reçoit 20 à 25 traitements phytosanitaires pendant les 6 mois de végétation. De nombreux hybrides résistants ainsi que de nombreuses techniques culturales visant à réduire l'incidence des maladies sont utilisés. Cependant, malgré cette intense protection, de nombreuses maladies continuent à sévir très sérieusement (BESRI, 1988).

2. Fusariose et Verticilliose vasculaires.

La Fusariose (*Fusarium oxysporum* f.sp. *lycopersici*) et la Verticilliose (*Verticillium dahliae*) vasculaires sont largement distribuées. Dans certaines régions, la culture de la tomate est devenue impossible à pratiquer à cause de la forte infestation des sols due à l'absence de rotations culturales (BESRI 1975).

Fusarium et *Verticillium* se rencontrent tous les deux sous abris plastiques. Cependant, l'incidence du deuxième agent pathogène est plus importante que celle du premier. Dans près de 95% des cas, le flétrissement est dû au *Verticillium* (BESRI 1980). Cette situation est la conséquence des températures prévalent pendant la saison de culture. Les températures moyennes de l'air et du sol varient entre 12 et 20°C. Ces températures sont plus favorables au développement de *Verticillium* qu'à celui de *Fusarium* (BESRI et ZROURI 1982).

Pour contrôler ces deux agents pathogènes, plusieurs méthodes de lutte sont utilisées:

a. Résistance variétale

Tous les hybrides de tomate actuellement utilisés au Maroc sont résistants à la fois au *Fusarium* et au *Verticillium*. Cependant, malgré cette résistance, les deux parasites continuent à provoquer des dégâts importants. Il a été démontré que des facteurs de nature biotique et abiotique sont responsables de la cassure de la résistance.

- Apparition de nouvelles races de *Fusarium* et de *Verticillium*

Tous les hybrides de tomate utilisés sont résistants au *Verticillium* . Cependant, dans certains tunnels, l'incidence de cet agent pathogène peut atteindre les 100% . Une nouvelle race de l'agent pathogène, la race 2, a été identifiée dans nos conditions (BESRI et al. 1984). Près de 60% des isolats obtenus à partir d'hybrides résistants appartiennent à cette race. Actuellement, aucun hybride résistant à cette nouvelle race n'est disponible sur le marché.

Quelques hybrides de tomate sont résistants à la fois à la race 1 et à la race 2 de *Fusarium*. Ces deux races existent au Maroc. La race 3, rapportée dans certains pays (USA, Australie etc...) n'a pas encore été rencontrée au Maroc.

- Salinité du sol et des eaux d'irrigation.

La salinité de l'eau d'irrigation varie entre 0,2 et 6g/l. Il a été démontré que l'augmentation de la salinité de l'eau augmente la sensibilité des plantes au *Fusarium* et au *Verticillium*. Les hybrides de tomate résistant à la race 1 de *Verticillium* deviennent sensibles à cet agent pathogène lorsque la teneur en sel des eaux d'irrigation est élevée (BESRI 1981).

- Interactions avec les nématodes

Dans les parcelles fortement infestées par les nématodes, les hybrides résistants au *Fusarium* et au *Verticillium* deviennent sensibles (ABBAD ANDALOUSSI 1982).

b. Utilisation de semences saines.

Toutes les semences utilisées en culture de tomate sous abris sont certifiées et donc théoriquement indemnes de tout agent pathogène. Cependant, l'analyse de plusieurs lots de semences importées a révélé la présence, dans des proportions importantes de *Corynebacterium michiganense* (FATMI 1981).

Pour la culture de plein air, certains agriculteurs continuent à utiliser leur propre semence. Il a été démontré que ces semences sont fortement infectées par plusieurs agents pathogènes dont *F. oxysporum* f.sp. *lycopersici* (BESRI 1978).

c. Rotation des cultures.

Les tunnels plastiques sont déplacés tous les 2-3ans. Après le déplacement de l'armature métallique, l'agriculteur change la couverture plastique. Par conséquent, la tomate revient sur elle-même pendant au moins 2 à 3 années consécutives. Le taux d'inoculum de plusieurs agents pathogènes augmente donc dans le sol, et l'incidence des maladies augmente également d'année en année.

Après le déplacement du tunnel, la parcelle est cultivée avec des céréales (orge, blé). Ces plantes, immunes au *Fusarium* et au *Verticillium*, sont recom-

mendées dans la rotation pour réduire le taux d'inoculum dans le sol.Cependant, les champs de céréales sont infestées par plusieurs mauvaises herbes qui sont hôtes de *V. dahliae*. Par conséquent, la rotation ne peut avoir d'effet que si elle est accompagnée de traitements herbicides (ZEDDOUK 1986).

d- Solarisation du sol.

La solarisation du sol pendant les mois chauds de l'année avec un film en polyéthylène transparent réduit considérablement la sévérité et l'incidence de *Fusarium* et de *Verticillium* , augmente la vigueur et le rendement des plantes (BESRI 1988).

3. Oïdium

L'Oïdium de la tomate dû à *Leveillula taurica* est l'un des parasites les plus importants sur tomate au Maroc. Cette maladie était peu fréquente avant 1978. Après cette date, de nombreux hybrides performants mais sensibles à l'Oïdium ont été introduits. L'introduction de ces hybrides a coincidé avec une longue période de sécheresse, ce qui a favorisé le développement de la maladie (HORMATALLAH 1984).

La maladie est plus sévère en plein air que sous abris. Seule la lutte chimique avec des produits tels que le triadiméfon et le propiconazole peut être utilisée (BESRI et HORMATALLAH 1985).

4. Pourriture grise.

La pourriture grise due à *Botrytis cinerea* est particulièrement sévère sur tomate cultivée sous abris plastiques. La maladie est contrôlée par application de fongicides tels que la procymidone et la vinchlozoline. Le Bénomyl, le méthylthiophanate ne sont pas efficaces à cause de l'apparition de souches résistantes à ces produits (BESRI et DIATTA 1984). Certaines pratiques culturales telles que l'aération des tunnels, la protection des blessures causées par les opérations d'effeuillage et d'ébourgeonnage, et l'élimination des restes des cultures sont largement appliquées (DIATTA 1984).

5. Mildiou

Il est très difficile de contrôler le développement du Mildiou (*Phytophthora infestans*) une fois la maladie installée. Par conséquent l'utilisation de fongicides tels que Métalaxyl + Manèbe, Métalaxyl + Mancozèbe, Cymoxanil, Mancozèbe etc...doit être préventive.

P. infestans attaque également la pomme de terre. Cette culture ne doit pas entrer dans la rotation.

Les tunnels plastiques doivent être aérés et les feuilles basales enlevées (STIKI 1983).

6. Chancre à Didymella.

Didymella lycopersici est particulièrement sévère sur les cultures de plein air . L'agent pathogène se conserve dans les roseaux (*Arundo donax*) et les piquets d'*Eucalyptus* utilisés comme tuteurs. Le chancre à *Didymella* apparaît d'abord au point de contact entre la tige et le tuteur. La lutte chimique contre cet agent pathogène ne donne pas de résultats satisfaisants (BESRI 1982).

Une excellente désinfection des tuteurs a été obtenue par solarisation. Les tuteurs de tomate sont placés pendant les mois chauds de l'année dans des

tunnels plastiques ne portant pas de cultures. Les températures élevées (supérieures à 50°C) éliminent l'agent pathogène conservé dans les tuteurs. Cette nouvelle technique d'application de la solarisation est largement utilisée au Maroc (BESRI 1982, BESRI et DIOP 1985).

7. Conclusion :

Laconnaissance approfondie de la biologie des parasites de la tomate a été indispensable pour la mise en place d'un programme de lutte intégrée contre les maladies de la tomate au Maroc. L'utilisation rationnelle des pesticides, des techniques culturales (type de tunnel, aération, effeuillage, ébourgeonnage, rotation des cultures, utilisation de semences indemnes de maladie, choix des variétés en fonction de la salinité des eaux d'irrigation, solarisation du sol et du matériel agricole etc...) sont parmi les principales méthodes de lutte visant à réduire l'incidence des maladies de la tomate de plein air et sous tunnels plastiques.

Références bibliographiques

ABBAD ANDALOUSSI, F., 1982. Efficacité de la solarisation et des traitements chimiques du sol dans la lutte contre les nématodes à galles (*Meloidogyne* spp) associés à la tomate sous tunnels plastiques.
Thèse, IAV Hassan II, Rabat, Maroc.

BESRI, M. 1975. Les principales maladies des Solanacées observées au Maroc.
Hommes, Terre et Eaux 16: 73-78.

BESRI, M., 1978. Phases de la transmission de *Fusarium oxysporum* f.sp. *lycopersici* et de *Verticillium dahliae* par les semences de quelques variétés de tomate.
Phytopathol. Z. 93: 148-163.

BESRI, M., 1980. Influence de la température du sol et de l'air sur la Fusariose et la Verticilliose de tomate d'automne et de printemps au Maroc.
Phytopathol. Z. 98:97-107.

BESRI, M., 1981. Qualité des sols et des eaux d'irrigation et manifestation des trachéomycoses de la tomate au Maroc.
Phytopathologia Mediterranea 20: 107-111.

BESRI, M. & M. ZROURI, 1982. Température et manifestation des trachéomycoses de la tomate cultivée en plein air et sous tunnel plastique au Maroc.
Comptes-rendus de la conférence sur l'agrométéorologique au service de la protection des plantes. Genève, 8-10 Mars 1982. OEPP 13: 127-131.

BESRI, M., 1982. Conservation de *Didymella lycopersici* dans les cultures de tomate par les tuteurs.
Phytopathol.Z. 105: 1-10.

BESRI, M., 1982. Solar heating (solarization) of tomato supports for control of *Didymella lycopersici* Kleb. Stem. Canker.
Phytopathology Z: 939.

BESRI, M. & F. DIATTA, 1984. Résistance de *Botrytis cinerea* Pers., agent de la pourriture grise de la tomate aux Benzimidazoles, Dicarboximides et Sulfamides. Comptes-rendus du symposium OEPP sur la résistance aux fongicides. Bruxelles, 8-9 Nov.. Bulletin OEPP 15:379-386.

BESRI, M., M. ZROURI & I. Beye, 1984. Appartenance raciale et pathogénie comparée de quelques isolats de *Verticillium dahliae* (Kleb.) obtenus à partir de tomates résistantes au Maroc .
Phytopath. Z. 109: 289-294.

BESRI, M. & A. HORMATALLAH, 1985. Manifestation et mode de conservation de *Leveillula taurica*, agent de l'Oïdium de la tomate au Maroc.
Phytopath. Z. 112: 348-354.

BESRI, M. & M. DIOP, 1985. Lutte contre *Didymella lycopersici* de la tomate par stockage de tuteurs dans des tunnels plastiques. Nouvelle application du chauffage solaire ou solarisation.
Revue Hort. Suisse 58: 99-102.

BESRI M., 1988. Nouvelles orientations de lutte contre les maladies des plantes cultivées sous abris serre. Comptes-rendus du colloque sur la "Protection des Végétaux sous serre".
Ribat Al Fath, Rabat, Morocco. 14-15 Septembre 1988.

BESRI, M., 1989. Integrated pest management of tomato diseases in Morocco. Proceedings of the "89 Integrated Pest Management in tropical cropping systems".
Bad Durkheim, R.F.A., February 8-15.

DIATTA, F., 1984. Efficacité de la lutte chimique contre *Didymella lycopersici* et *Botrytis cinerea* et problème de résistance aux fongicides. Thèse IAV Hassan II, Rabat, Maroc.

FATMI, M.B., 1981. Importance et distribution de *Corynebacterium michiganense* sur tomate de plein air et sous tunnel plastique. These IAV Hassan II, Rabat, Maroc.

HORMATALLAH, M., 1984.L'Oïdium de la tomate dû à *Oïdiopsis taurica* gamme d'hôte et méthodes de lutte. Thèse IAV Hassan II, Rabat, Maroc.

STIKI, A., 1983. Recherches sur les Mildiou de la tomate cultivée en plein champ et sous tunnel plastique. Thèse, IAV Hassan II, Rabat, Maroc.

ZEDDOUK, M., 1986. Rôle de quelques céréales, de mauvaises herbes, de la fève et des semences de tomate dans la conservation de *Verticillium dahliae*. Thèse de 3è cycle. IAV Hassan II, Rabat, Maroc.

Effectiveness of several antagonists agents against Botrytis cinerea

N.E. Malathrakis
Technological Education Institute, Heraklio, Crete, Greece

O.E. Kritsotaki and E.J. Klironomou
Plant Protection Institute, Heraklio-Crete, Greece

Abstract

Laboratory and greenhouse experiments were conducted to test Trichoderma, Acremonium alternatum and Penicillium sp. against Botrytis cinerea. Laboratory experiments were conducted on PDA, cucumber discs and young bean plants. All antagonists were very effective in laboratory tests, when applied at least one day before the application of B. cinerea. Their effectiveness was higher at 25 C and reduced gradually at 20, 15 and 10 C. Greenhouse experiments were conducted on tomato plants in a plastic greenhouse where the frequency of applications and the con centration of the spore of the antagonists were tested. Neither Trichoderma nor A. altematum were effective in greenhouse experiments.

1. Introduction

Because of the predomination of resistant strains of Botrytis cinerea to the most effective fungicides, grey mold nowadays has been the most destructive disease for crops grown in plastic greenhouses. As experience so far acquired indicates that fungicides sooner or later fail to control gray mold, an alternative control method should be considered.

Greenhouse environment provides some advantages in applying biological control for some diseases and several authors have tried to apply biological control against grey mold in greenhouse crops (MacCain et al, 1984; Elad, 1991).

In this paper we present data from experiments using Trichoderma, Acremonium alternatum and Penicillium sp. for controlling grey mold.

2. Materials and methods

Experiments were conducted in the laboratory as well as in the greenhouses.

2.1. Laboratory experiments.

Petri dish inoculation: Four Petri dishes with PDA were seeded with 0.5 ml each of a spore suspension of the antagonist, containing 1. 10^6 spores /ml, for five successive days. The fourth day all Petri dishes, already seeded and another four which should be seeded the following day, were centrally inoculated with 0.5cm plugs of fast growing mycelium of B. cinerea. Four Petri dishes without antagonists were inoculated the same day. The same procedure was followed with each antagonist at the same time. The test was replicated at 10, 15, 20 and 25 C.

Three days after artificial inoculation the diameter of the mycelial growth was recorded and the percent inhibition by each antagonist, for each day of application and at each temperature was calculated.

Cucumber disc inoculation: Petri dishes 15 cm large containing seven cucumber discs of a diameter 30-35mm, were used. The discs of one Petri dish for each of seven successive days were seeded with 0.04ml each of a spore suspension of the antagonist containing 1.10^6 spores/ml. The sixth day the discs of all Petri dishes already seeded and the discs of one more Petri dish which should be seeded the following day were centrally inoculated with 0.5 cm plugs of fast growing mycelium of B. cinerea. The same procedure was followed with each antagonist at the same time. One Petri dish without antagonist was inoculated the same day. The experiment was replicated at 10, 15, 20 and 25 C. Two days later the diameter of the affected tissue of each cucumber disc was recorded and the percent inhibition by each antagonist, for each day and at each temperature was calculated.

Young bean plant inoculation: For five successive days seven bean plants (Phaseolus vulgaris) with two fully developed leaves were punctured at five places in each leaf. Two hours later they were sprayed to run off with a spore suspension containing 1.10^6 spores /ml of the antagonist tested. The

fifth day the plants sprayed with the antagonist, were artificially inoculated with a spore suspension of B. cinerea containing 1.10^6 spores /ml. Seven additional plants not treated with antagonist, were similarly inoculated by B. cinerea, while seven more plants were not treated either with antagonist or with B. cinerea. The experiment was replicated at 10, 15, 20 and 25 C. During the experiment plants were kept in growth chambers set at 100% r.h, 12/12 photoperiod and about 5000 lux light intensity. A separate test was conducted for each antagonist.

Records of the infection of each puncture were taken four days after the artificial inoculation, using a 0-5 scale (0=no infection, 5= infection with a diameter of about 1cm). On the basis of the score of each treatment and the control the percent protection was calculated.

2.2. Greenhouse experiments.

First experiment: The effectiveness of Trichoderma and A. alternatum at four or seven day intervals, using spore concentrations containing 1.10^6/ml was evaluated against grey mold of tomato. Iprodione was included as a reference treatment.

Second experiment: The effectiveness of A. alternatum at four and seven day intervals at concentrations containing 1.10^5, 1.10^6 and 1.10^7 spores/ml were evaluated against gray mold of tomato.

Both experiments were conducted in a plastic greenhouse on tomatoes grown from early September to the end of May. Plots were arranged in a complete randomized block design with four replicates. In each plot 15 plants were grown. Spore suspensions were applied with a knapsack sprayer until run off.

3. Results

Results obtained by the laboratory experiments can be summarised as follows:

- All antagonists were more effective when tested on young bean plants followed by the test on PDA and then by the test on cucumber discs.
-The effectiveness of the antagonists was higher at 25 C and decreased gradually at 20, 15 and 10 C.

A 100% effectiveness was obtained when antagonists were applied at least one day before the artificial inoculation with B. cinerea in the test on PDA or three days before in the test on cucumber discs. In both these tests applications made the day of the artificial inoculations or the following day had either negligible effectiveness or were not at all effective. In the tests on bean plants the effectiveness was nearly 100% even if antagonists were applied the day of the artificial inoculation.

Some of the results obtained in the greenhouse experiments appear on Table 1. They indicate that there was no significant statistical difference, with respect of tomato fruit infection, between any treatment and the control.

Table 1.-Effectiveness of Acremonium alternatum and Trichoderma sp. on gray mold of tomato (Botrytis cinerea) in commercial greenhouses.

First experiment			Second experiment		
Treatments		inf.fruit /plant	Treatments		inf.fruit /plant
Trichoderma	1.10^6/ 4 days	7 a	Acremonium	1.10^5/4 days	8 ab
"	1.10^6/ 7 "	6 a	"	1.10^5/7 "	14 a
Acremonium	1.10^6/ 4 "	7 a	"	1.10^6/4 "	7 ab
"	1.10^6/ 7 "	6 a	"	1.10^6/7 "	8 ab
Iprodione	0.05%/15 "	5 a	"	1.10^7/4 "	8 ab
Control (water)	/4 "	5 a	"	1.10^7/7 "	6 b
			Control (water)	/4 "	12 ab

Means followed by the same letter are not significantly different by Duncan's Multiple Range Test (0.05).

4. Discussion

The data obtained during this research indicate that the antagonists tested behaved in different way in laboratory and greenhouse exper iments. This is a common phenomenon in biological control with antagonists (Dubos 1986). Several reasons have been mentioned. In the present case the most reasonable explanation is the low temperature (<20 C) which prevailed in the greenhouses during the period of infection by B. cinerea. Even in the laboratory experiments all antagonists tested showed reduced effectiveness at temperature lower than 20 C. At such temperatures antagonists are probably not well established on the petals of the flow ers of tomato through which B. cinerea enter the fruit. That might be true for Trichoderma and A. alternatum but it could be rather difficult to apply for Penicillium sp.. This is easily isolated from senescent tomato flowers during the winter period from any greenhouse in our area.

References

Dubos, B. 1986. Fungal antagonism in aerial agrobiogeneses pp. 107-131. In: I.Chet (ed.) Innovative approaches to plant disease control. John Willey and Sons, New York.

Elad, Y. 1991. Plant diseases in greenhouses. In: G. Stanhill and H.Z. Enoch (eds). Greenhouse ecosystem. Elsevier, Amsterdam. In press.

MacCain, A.H., Sciaroni, R.H, Welch, R.H. and Pierce, L.E. 1984. Gray mold control of cyclamen using Trichoderma harzianum Rifai and reduced rates of vinclozolin. Flower and Nersery Report, Calif. Univ. Berkley.

EXPERIENCE IN INTEGRATED CHEMICAL - BIOLOGICAL CONTROL OF GREY MOULD (BOTRYTIS CINEREA)

Y. ELAD and G. ZIMAND

Dept. of Plant Pathology, Agricultural Research Organization, The Volcani Center, Bet Dagan 50250, Israel.

Summary

An isolate of Trichoderma harzianum capable of controlling grey mould (Botrytis cinerea) was tested under commercial conditions in vegetable greenhouses and grape vineyards. The biocontrol agent was sprayed alone, in tank mix with iprodione, or alternated with iprodione or diethofencarb + carbendazim. Up to 84% disease reduction was obtained by the biocontrol agent, which was at least as effective as iprodione or vinclozolin. The tank mix of T. harzianum with iprodione tended to be more effective than either of the agents alone. Alternating the biocontrol agent with a fungicide was also effective. It is thus possible to reduce the exposure of B. cinerea populations to fungicides, to reduce fungicides use, and potentially to minimize pesticide residues in the treated agricultural products.

1. Introduction

Grey mould caused by Botrytis cinerea is a damaging disease of table grapes and various protected crops in Israel (ELAD et al., 1988; KATAN, 1982a,b; YUNIS et al., 1990). For the control of grey mould, growers have relied heavily on fungicides, mainly benzimidazoles and dicarboximides. However, the spread of B. cinerea strains resistant to either or both groups of fungicides greatly reduced the latter's effectiveness. Thus, control of grey mould continues to be a problem (GULLINO & GARIBALDI, 1986; POMER & LORENZ, 1982).

The need for efficient agents to replace the non-effective fungicides and the increased demand by the consumer for agricultural products with lower residues of pesticides have encouraged us to develop a biocontrol fungicide for grey mould (ELAD, 1990).

Sample results from experiments which were carried out under commercial conditions are described in this paper in order to elaborate on the possibility of controlling the disease by the biocontrol agent alone or in combination with reduced sprays of conventional fungicides, thus allowing limited exposure of the pathogen population to the chemical agents.

2. Materials and Methods

Trials with cucumber: Experiments were carried out in greenhouses (25 x 60 m) located in central and northern Israel, and covered with 0.15-mm-thick polyethylene, Infrasol 266 ultraviolet absorbing (UVA) + infrared repellent (IR), (Ginnegar, Israel). The soils (alluvial vertisol or sandy loam) were fumigated with methyl bromide (Bromine Compounds, Be'er Sheva, Israel) prior to planting. Plants were placed 0.5 m apart, with 1.25 m between rows. Planting was usually done around 20 October. Each plot contained 10-20 cucumber plants (Cucumis sativus, parthenocarpic cv. Kasem 292, Hazera Ltd., Haifa, Israel). Experiments were laid out in randomized blocks with five replicates. Disease was evaluated on the senescing female flowers (fruits) or stem nodes. Crop treatments were given according to the usual commercial practice in each region. Fungicides and the biocontrol agent aimed against grey mould were sprayed to runoff with a backpack motor sprayer (Echo SHR 200E, Kioriez Corp., Japan) at a calculated volume of 100 L 0.1 ha^{-1}. The spray nozzle type used was

Contribution from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel. No. 3274-E, 1991 series.

a conejet Dx6.

Trials on grapes: A vineyard in central Israel (Judean mountains) was selected for the experiments because of the history there of grey mould in previous years (ELAD et al., 1988). Plots of 5-10 vines (Vitis vinifera L. cv. Barlinka or cv. Shami) were arranged in randomized blocks, with five replicates. As soon as the first infected berries were observed in the vineyard, treatments against grey mould were started. The grape bunches were sprayed until runoff with the same equipment described above for cucumber plants.

Fungicides: The fungicides sprayed were iprodione (Rovral 50 WP, Rhone Poulenc, France), vinclozolin (Ronilan 50 WP BASF, AG, Ludwigshafen, FRG), a factory-prepared mixture of diethofencarb (25%) and carbendazim (25%) (Resec, WP, Sumitomo Chemical Co., Japan) or Folpet (Folpan, 50 WP, Makhteshim Chemical Works Ltd., Israel). An isolate of Trichoderma harzianum from cucumber fruits was grown and formulated by Makhteshim Chemical Works Ltd. and sprayed with the above mentioned equipment.

3. Results

The biocontrol agent chosen for wide scale experiments, T. harzianum, was sprayed with regular equipment in plots treated as usual under commercial conditions. Some of the field experiments carried out since 1987 are reported in Tables 1 and 2.

Experiments in cucumber greenhouses: Trichoderma preparation was effective in controlling fruit or stem infections (Table 1).

TABLE 1: Effect of Trichoderma harzianum on infections of cucumber fruits and stems at five locations in Israel.

Treatment[1]	Disease incidence (number of infections/10 plants)							
	Ara		Herut	Gadish		Ibtan		Ahituv
	Fruit	Stem	Fruit	Fruit	Stem	Fruit	Stem	Stem
None (control)	33.3	12.3	174.7a	15.7a	12.0a	34.3a	48.0a	3.75a
Vinclozolin (0.5g/L)	18.3	4.3	-	-	-	-	-	-
Iprodione (0.5g/L)	-	-	88.0ab	5.5b	4.8b	13.4b	16.8b	1.5ab
T-39 (2g/L)	10.8	2.0	-	-	-	-	-	-
T-39 (4g/L)	-	-	14.1b	3.8b	5.5b	15.0b	24.0b	2.0ab
T-39 (4g/L) mixed with iprodione (0.5g/L)	-	-	15.0b	2.8b	1.5c	15.4b	15.3b	0.2b
T-39 (4g/L) alternated with iprodione (0.5g/L)	-	-	-	-		12.5b	22.0b	-

[1]Sprayed at a volume of 1000 L/ha. [2]Numbers of each experiment followed by a common letter are significantly not different ($P=0.05$) according to Duncan's Multiple Range Test.

Up to 84% reduction in disease incidence was achieved by 0.2-0.4% of the T. harziarum preparation. Results were positive when low or high inoculum pressure of B. cinerea was present in the greenhouses. Tank mixtures of Trichoderma with iprodione sometimes improved the performance of the agents as compared with either of them alone. Alternating the biocontrol agent with iprodione resulted in control similar to either of the agents alone (Table 1).

Similar results were obtained with the same agents in tomato greenhouses and in strawberry fields (data not presented).

Experiments in grape vineyards: Examples of the results of experiments with table grapes are presented in Table 2. The control achieved by each of the

tested agents did not differ significantly. A tank mix of Trichoderma with iprodione was slightly better than iprodione alone. Alternating Trichoderma with the fungicide mixture diethofencarb + carbendazim was as effective as the chemical agent alone. Effectiveness of treatments was also extended to post harvest storage (Table 2).

TABLE 2: Effect of Trichoderma harzianum sprayed in the vineyard on grey mould of table grapes.

Treatment[1]	Disease incidence (number of infections/10 vines)			
	cv. Barlinka[2]	cv. Barlinka[2]	cv. Shami[2]	cv. Shami[3]
None (control)	80.0a[4]	6.2	20.3a	5.6
T-39 (4g/L)	31.0b	2.8	13.3ab	2.7
Folpet (0.5g/L)	-	1.8	-	-
Iprodione (0.5g/L)	32.0b	-	8.6ab	2.3
Diethofencarb + carbendazim (0.25g/L each)	-	-	11.3	0.3
T-39 + iprodione	16.0b	-	3.0b	1.3
T-39 alternated with a mixture of diethofencarb + carbendazim	-	-	11.0ab	3.0

[1]Sprayed at a volume of 1000 L/ha. [2]Tested in the vineyard. [3]Tested 7 days after harvest. [4]Numbers followed by a common letter are significantly not different (P=0.05) according to Duncan's Multiple Range Test.

Similar results were obtained in various experiments carried out in vineyards in several countries (data not presented).

4. Discussion

The results presented here point to the fact that a T. harzianum preparation is an excellent alternative to fungicides for the control of grey mould. Biological control of grey mould has been tested for at least 45 years (BLAKEMAN, 1985; BLAKEMAN & FOKKEMA, 1982; DUBOS & BULIT, 1981; FOKKEMA, 1976). NEWHOOK (1957) sprayed tomato plants with isolates of Cladosporium herbarium and Penicillium spp. and reduced the amount of decayed fruits. REDMOND et al. (1987) controlled grey mould on rose flowers and WOOD (1950) controlled the disease on lettuce leaves, each with epiphytic microorganisms. TRONSMO & DENNIS (1974) and TRONSMO & YSTAAS (1980) reported the control of B. cinerea on strawberry and apple fruits by Trichoderma. Trichoderma was also tested for its ability to control grey mould by various researchers (DUBOS et al., 1982; GULLINO et al., 1985; McCAIN et al., 1985) and others, but reports on the commercial use of a biocontrol agent against this disease were limited to Bulgaria and the Soviet Union (LYNCH, 1988).

There has been an increase in awareness of the negative side effects of fungicides on the ecosystem, and growing interest in pesticide-free agricultural products. Biocontrol and fungicidal treatments should be considered in terms of the most effective means of disease control in relation to the ecological damage which may result from their use.

An increasingly strict legislative and environmental climate has raised substantially the cost and the time-scale of development of new fungicides. In fact, many agrochemical and biotechnology companies are investing in R&D of disease biocontrol, with the intention of incorporating it into integrated crop management programs. However, another major justification for development of disease agents is to extend the crop protection weaponry where no chemical agent

exists. There are also possibilities for minor uses, where industry has found it difficult to justify the cost of R&D and registration of a fungicide.

Biological methods are a realistic aim for control of foliar diseases, but their success will depend on a thorough understanding of their behaviour and interactions in the microenvironment of the host surface, together with a detailed knowledge of the properties of the pathogen and its physiology (ELAD, 1990).

The side effects and toxicology of biological products must also be tested. In this regard microorganisms producing antibiotics, toxic compounds or lytic enzymes will probably be unacceptable. The toxicological tests customarily used for chemical products should be applied for such biological products. If simple competitition is the sole mode of action, the requirements for registration should perhaps be more lenient, provided that the antagonist of choice does not present any health risk and is not a genetically modified microorganism.

Finally, our results show that the biocontrol agent Trichoderma is useful for controlling grey mould and for reducing the use of fungicides against the disease. Thus, pressure towards development of resistance against fungicides in the pathogen can be reduced and pesticide residues in the agricultural products can probably be elimintated.

5. Acknowledgements

This work was conducted with the help of Prof. I. Chet, the Hebrew University of Jerusalem, Rehovot. It was partially supported by Marks and Spencer. The authors dedicate the considerable help of A. Cohen, H. Abir and the field advisors of Makhteshim Chemical Works Ltd., and the cooperation of the farmers in the various experimental plots.

6. References

BLAKEMAN, J.P., 1985. Biological succession of leaf surface microorganisms in relation to biological control on the phylloplane. Pp. 6-30 in: Windels, C.E. and Lindow, S.E. [Eds.] Biological Control on the Phylloplane. The American Phytopathological Society, St. Paul, MN.

BLAKEMAN, J.P. & FOKKEMA, N.J., 1982. Potential for biological control of plant diseases on the phylloplane. A. Rev. Phytopath. 20:167-192.

DUBOS, B. & BULIT, J., 1981. Filamentous fungi as biocontrol agents on aerial plants surfaces. Pp. 353-367 in: Blakeman, J.P. [Ed.] Microbial Ecology of the Phylloplane. Academic Press, London.

DUBOS, B., JAILLOUX, F. & BULIT, J., 1982. L'antagonisme microbien dans la lutte contre la pourriture grise de la vigne. Bull. EPPO 12:171-175.

ELAD, Y., 1990. Reasons for the delay in development of biological control of foliar pathogens. Phytoparasitica 18:99-105.

ELAD, Y., SHABI, E. & KATAN, T., 1988. Negative cross-resistance between benzimidazole and N-phenylcarbamate fungicides and control of Botrytis cinerea on grape. Plant Pathol. 37:141-147.

FOKKEMA, N.J., 1976. Antagonism between fungal saprophytes and pathogens on aerial surfaces. Pp. 487-506 in: Dickinson, C.H. and Preece, T.F. [Eds.] Microbiology of Aerial Plant Surfaces. Academic Press, London.

GULLINO, M.L. & GARIBALDI, A., 1986. Resistance to fungicides in Botrytis cinerea: present situtation. Notiz. Mall. Pl. 17:63-71.

GULLINO, M.L. & GARIBALDI, A., 1987. Control of Botrytis cinerea resistant to benzimidazoles and dicarboximides with mixtures of different fungicides. Meded. Facul. Landouwwet. Rijksuniv., Gent 52:895-900.

GULLINO, M.L., MEZZALAMA, M. & GARIBALDI, A., 1985. Biological and integrated control of Botrytis cinerea in Italy. Experimental results and problems. Proc. Eighth Botrytis Symposium (Alba, Torino, Italy) pp. 299-308.

KATAN, T., 1982a. Resistance to 3,5-dichlorophenyl-N-cyclic imide ('dicarboximide') fungicides in the grey mould pathogen Botrytis cinerea on protected crops. Plant Pathol. 31:133-141.

KATAN, T., 1982b. Persistence of dicarboximide-fungicide resistance in populations of Botrytis cinerea in a warm, dry temperate agroclimate. Phytoparasitica 10:209-211.

LYNCH, J.M., 1988. Biological control of plant diseases: achievements and prospects. Brighton Crop Protection Conference - Pests and Diseases. 7A-2:587-596.

McCAIN, A.H., SCIARONI, R.H., WELCH, K.E. & PIERCE, L.E., 1985. Gray mold control of cyclamen using Trichoderma harzianum Rifai and reduced rates of vinclozolin. University of California, Berkeley, CA. Flower and Nursery Report for Commercial Growers, Fall and Winter, p. 1.

NEWHOOK, F.J., 1957. The relationship of saprophytic antagonism to control of Botrytis cinerea Pers. on tomatoes. N.Z. J. Sci. Tech. A 38:473-481.

POMER, E.H. & LORENZ, G., 1982. Resistance of Botrytis cinerea Pers. to dicarboximide fungicides. A literature review. Crop Prot. 1:221-230.

REDMOND, J.C., MAROIS, J.J. & MacDONALD, J.D., 1987. Biological control of Botrytis cinerea on roses with epiphytic microorganisms. Pl. Dis. 71:799-802.

TRONSMO, A. & DENNIS, C., 1974. The use of Trichoderma species to control strawberry fruit rots. Neth. J. Pl. Path. 83:449-455.

TRONSMO, A. & YSTAAS, J., 1980. Biological control of Botrytis cinerea on apple. Pl. Dis. 64:1009.

WOOD, R.K.S., 1950. The control of diseases of lettuce by the use of antagonistic organisms. I. The control of Botrytis cinerea Pers. Ann. Appl. Biol. 38:203-216.

YUNIS, H., ELAD, Y. & MAHRER, Y., 1990. Effects of air temperature, relative humidity and canopy wetness on gray mold of cucumbers in unheated greenhouses. Phytoparasitica 18:203-215.

GREY MOLD OF GREENHOUSE-GROWN TOMATOES: DISEASE CONTROL BY CLIMATE MANAGEMENT ?

P. NICOT and D. ALLEX.
I.N.R.A., Station de Pathologie Végétale,
Domaine Saint Maurice, B.P. 94,
F-84143 MONTFAVET Cedex, FRANCE

Summary

As conventional methods are becoming increasingly inefficient in controling grey mold of tomato in greenhouses, more and more growers are resorting to costly dehumidification schemes to avoid conditions favorable to the disease. In order to propose a "climate management strategy" that would limit the dehumidification interventions, a study was undertaken to determine the precise water requirements for *Botrytis cinerea* Pers. to induce disease on tomato plants. Preliminary results are presented in this report on the effect of wetness duration and wounding on the germination of *B. cinerea* spores on the surface of tomato leaves. On intact leaflets, conidia failed to germinate in absence of free water and germination remained very low for leaf wetness durations of up to 24 hours. In the presence of wounds created with a scouring pad, dry conidia germinated without addition of free water. However, in presence of water, the germination rates increased sharply with wetness duration up to 7 hours, above which they remained stable. Lesions developed after inoculation on leaves wounded with a scouring pad and maintained wet for 24 hrs, but not on intact or on carborundum-wounded leaves incubated in similar conditions.

1. Introduction

Grey mold, caused by the ubiquitous fungus *Botrytis cinerea* Pers., is a very serious disease of protected vegetable crops. On greenhouse-grown tomatoes, the fungus can attack all aerial parts of the plant and is often responsible for catastrophic yield losses (Messiaen et al., 1991). None of the commonly-grown varieties of tomatoes are resistant to the disease, and although biological control methods have been sought and certain potential biocontrol agents identified (Dubos, 1987, Gullino & Garibaldi, 1990, Gullino et al., 1990), no commercial formulation has been released to this date. The control of this disease, which has relied heavily on the use of benzimidazoles and dicarboximides, has become increasingly difficult with the increasing prevalence of strains of *B. cinerea* that are resistant or tolerant to both groups of fungicides (Gullino & Garibaldi, 1986, Northover & Matteoni, 1986, Messiaen et al., 1991).

In southern France, the disease is particularly prevalent during the late winter and early spring months, when weather conditions and cultural practices may result in high relative humidity inside the shelters and the presence of free water on plant surfaces. Such conditions have long been recognized as favorable to the development of grey mold, and recommendations to growers for

avoidance of the disease include ventilation and heating of the greenhouses to reduce relative humidity and to avoid condensation (Jarvis, 1989, 1990). In a pre-oil crisis study, Winspear et al. (1970) showed that dehumidification of a tomato greenhouse with a humidistat set at 75% relative humidity (RH) resulted in an incidence of fruit blemishes less than 5% of that in a control greenhouse without dehumidification. In the current economic context, however, such systematic dehumidification of a greenhouse is a costly endeavor and more information is needed on the water requirements of the fungus to determine precisely what humidity conditions should be avoided.

In several host-fungus systems with *B. cinerea* or *B. squamosa*, it has been shown that high relative humidities may not be sufficient to result in infection and lesion development. In several cases, a wetness period was necessary, and the frequency of infections increased with the duration of the wetness period (Bulger et al., 1987, Ramsey & Lorbeer, 1986, Salinas et al., 1989). In 1990, a study was undertaken to determine the precise water requirements for *B. cinerea* to induce disease on tomato plants. This report presents preliminary results on the effect of wetness duration and wounding on the germination of *B. cinerea* spores on the surface of tomato leaves. Part of these results have been presented elsewhere (Allex & Nicot, 1990).

2. Materials and methods

Isolate BC8 of *B. cinerea*, maintained on malt agar (MA) medium (Difco), was used throughout this study. Spores obtained from 12-15 day old colonies on MA medium were used as inoculum. Their germination rates determined after 24 hours incubation at 20°C on water agar medium and MA medium were 0.0% and 97.5%, respectively.

The upper sides of tomato leaflets from *ca* 6-week old plants were inoculated either with dry spores blown from a sporulating colony, or with a 4×10^5 cell/ml water suspension sprayed with a CF_2Cl_2 Desaga sprayer (Heidelberg). The plants were cultivar Monalbo unless otherwise indicated.

To study the effect of wounding of the host on the germination of the spores, wounds were created by gently rubbing the leaves with carborundum ("microwounds") or with a scouring pad ("macrowounds") 15-30 minutes before the inoculation. The carborundum-wounded leaflets were rinsed with distilled water to remove the abrasive particles.

Inoculated plants were placed inside a small growth chamber with temperatures of 22°C (16 hours light) and 18°C (8 hours darkness). A layer of free water (ca 3 cm deep) was maintained on the floor of the chamber to ensure that relative humidity remained near saturation throughout the duration of the experiments. Actual RH, mesured with a hair hygrothermograph, was 95-98% during the night and 85-90% during the day.

In an attempt to reduce the growth chamber space and plant material needed for these experiments, similar tests were conducted on

leaflets cut off from the plants: Inoculated leaflets were detached from the plants and placed in 9cm diameter Petri plate covers. To ensure nearly saturated RH, the covers were placed inside 14cm diameter Petri dishes containing a layer of free water. The large Petri plates themselves were placed in a small growth chamber as described above.

To obtain wetness periods of desired durations on the leaflets, plant material was removed from the humid chambers at appropriate times and allowed to dry. The leaflets were dry after *ca* 1 hour and the plants were again placed in the humid chamber for the rest of the incubation period.

To monitor the germination of spores on the leaves, clear adhesive tape was applied on the surface of the leaflets and peeled carefully. The tape was then mounted on a microscope slide and observed under phase contrast. For each leaflet, a minimum of 100 spores were observed. Results were expressed as proportions of germinated spores. The transformation $Y = \text{Arcsine } (X^{-1/2})$ was applied to the data prior to statistical analysis. Throughout the study, a minimum of 3 replicate leaflets were examined for each treatment.

3. Results

Comparison of germination frequencies on detached and non-detached leaflets. In absence of free moisture, virtually no germination occurred on the surface of non-detached leaves, even after 96 hours, while over 35% germination was observed after 72 hours on detached and non-detached leaflets (Fig. 1). Large differences between germination on detached and non-detached leaflets were also observed with wetness duration ranging from 4 to 24 hours and in the presence or absence of wounds (Tables 1 and 2).

In view of these results, the following experiments were conducted on whole plants and the data presented herafter will concern non-detached leaflets unless otherwise stated.

Effect of wetness on spore germination on the leaf surface. On intact and micro-wounded leaflets, the presence of free water for several hours was necessary to observe germination (Table 2). In the presence or absence of wounds, the frequency of germination increased with increasing wetness duration. However, the increases in germination frequency were not statistically significant for more than 7 hours of wetness (Table 2).

While free water on the leaf surface was necessary to observe germination in absence of wounds, it may not always be sufficient: in a second experiment, germination rates remained below 6% after 96 hours incubation, even on leaves maintained wet for 24 hours (Fig. 2).

Effect of the presence of wounds on spore germination on the leaf surface. The presnece of wounds on the surface of the leaves had significant effects on the frequency of spore

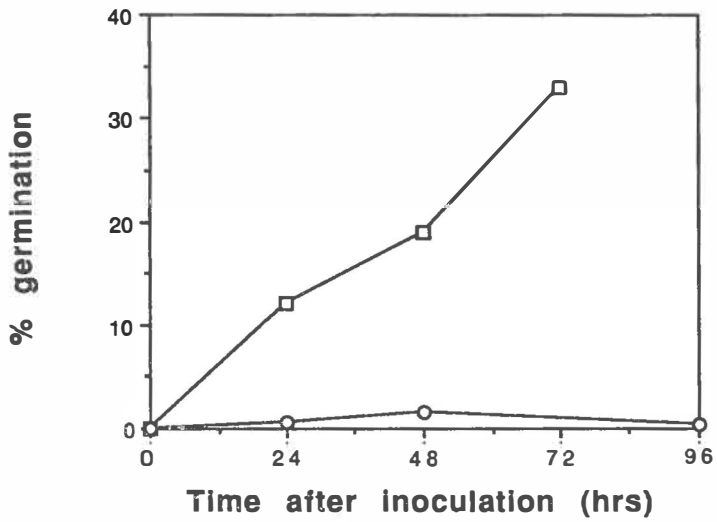


Figure 1: Evolution over time of the frequency of germination of dry spores of *Botrytis cinerea* on the surface of tomato leaflets detached (□) or not detached (○) from the plants and incubated in nearly saturated relative humidity.

TABLE 1: Effect of leaf wetness duration and presence of wounds on the frequency of germination of Botrytis cinerea spores 24 hrs after inoculation on tomato leaflets detached from the plants.

	Leaf wetness duration (hours)		
	0	4	24
intact leaflets	6.4 a	15.0 a	8.9 a
micro-wounded	3.8 a	47.3 b	44.1 b

Numbers shown are percentages of germinated spores, averaged over 3 leaflets per treatment. Averages followed by different letters are significantly different ($p<0.05$) based on the Newman-Keuls multiple comparison procedure

TABLE 2: Effect of leaf wetness duration and presence of wounds on the frequency of germination of Botrytis cinerea spores after 24 inoculation on tomato leaflets not detached from the plants.

	Leaf wetness duration (hours)			
	0	4	7	24
intact leaflets	0.0 a	0.0 a	14.6 b	18.1 b
micro-wounded	0.5 a	11.0 b	16.9 b	22.3 b
macro-wounded	24.2 b	55.3 c	78.1 d	84.8 d

Numbers shown are percentages of germinated spores, averaged over 5 leaflets per treatment. Averages followed by different letters are significantly different ($p<0.05$) based on the Newman-Keuls multiple comparison procedure

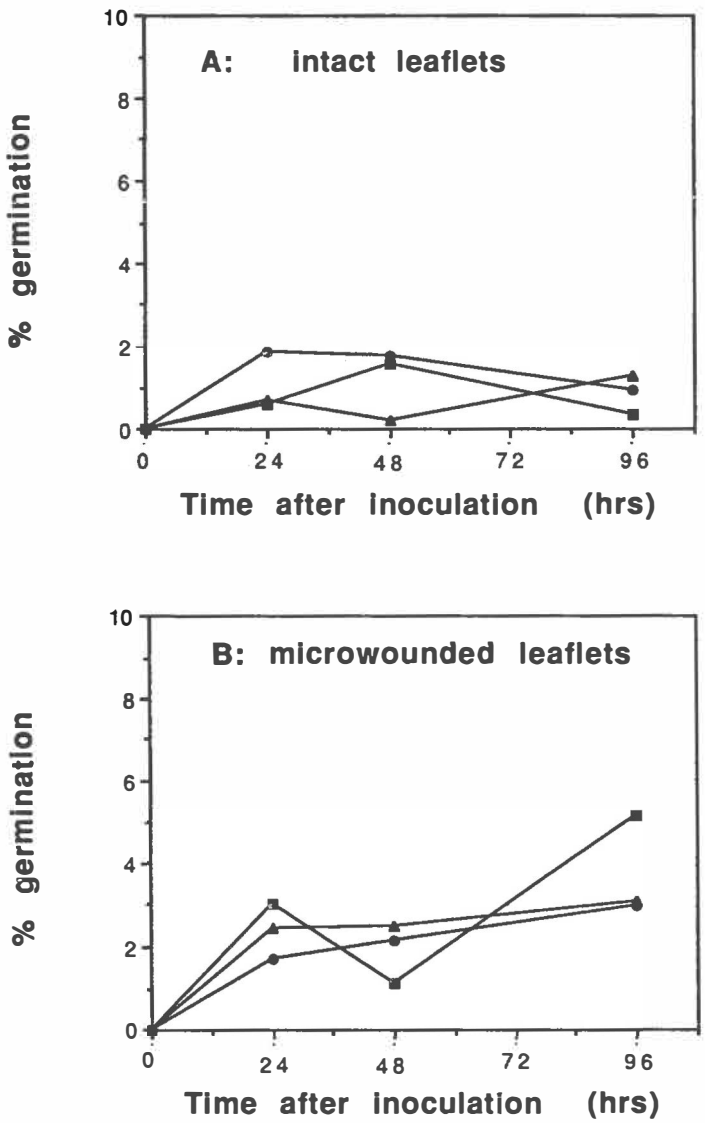


Figure 2: Evolution over time of the frequency of germination of dry spores of *Botrytis cinerea* on the surface of tomato leaves maintained dry (■), wet for 4 hours (●) or wet for 24 hours (▲). The leaflets were not detached from the plants and were intact (**A**) or microwounded (**B**) with carborundum prior to inoculation.

germination. Dry spores were able to germinate in large numbers on the surface of macro-wounded leaves and the germination frequency increased significantly with increasing degree of wounding for any given leaf wetness regime (Table 2, Fig.2, Fig. 3).

When observations were made beyond 24 hours after inoculation, the germination rates remained stable over time (Fig. 3), with plateaus at *ca* 6%, 15% and 58% germination for unwounded, micro-wounded and macro-wounded leaflets, respectively. These results suggest that spores that had not germinated by 24 hours after inoculation did not germinate in the following 3 days of the experiment.

Effect of host variety. In addition to cultivar Monalbo, germination tests were conducted on three tomato cultivars commonly grown in southern France. On macro-wounded leaflets maintained wet for 24 hours, germination rates were not statistically different 24 hours after inoculation, with averages (5 replicate leaflets examined per cultivar) of 90.1%, 83.7%, 86.3% and 89.1% for cultivars Monalbo, Larma, Prisca and Rondello, respectively. Similarly, no statistical differences were detected when the tests were conducted on leaflets detached from the plants, microwounded, and maintained wet for 6 hours after inoculation (Fig. 4).

Symptom expression. Following observation of spore germination, plants were kept in the growth chambers up to 7 days after inoculation. On leaves maintained wet for 24 hours after inoculation, lesions developed on 93.8% of the macrowounded leaflets and none of the microwounded or intact leaflets. Similar observations were made on plants maintained dry and on plants maintained wet for 4 hours after inoculation.

4. Discussion

From the time a spore of *B. cinerea* lands on the surface of a tomato leaf, the process leading to the development of a detectable lesion includes spore germination, growth of the germ tube into an infection hypha, penetration of the host, colonization of host tissue and symptom expression. The completion of the whole process necessitates that conditions be met for the successful conclusion of each successive step. The results obtained by previous researchers for *B. cinerea* on strawberry and gerbera (Bulger et al., 1987, Salinas et al., 1989) and for *B. squamosa* on onion (Ramsey & Lorbeer, 1986) suggest that one or more of these steps require the presence, for an appropriate length of time, of free water on the host surface. The work presented here constitutes a first trial in a projet to characterize the water requirements of the fungus for each of the stages of the infection process.

Although preliminary, our results clearly showed that the presence of free water for a duration of *ca* 7 hours on the surface of intact tomato leaves was necessary for germination to proceed. These results merit confirmation as they suggest that Botrytis attacks on intact tomato leaves could be avoided by preventing the occurence in shelters of 4 to 7 hours of wetness on the foliage - a

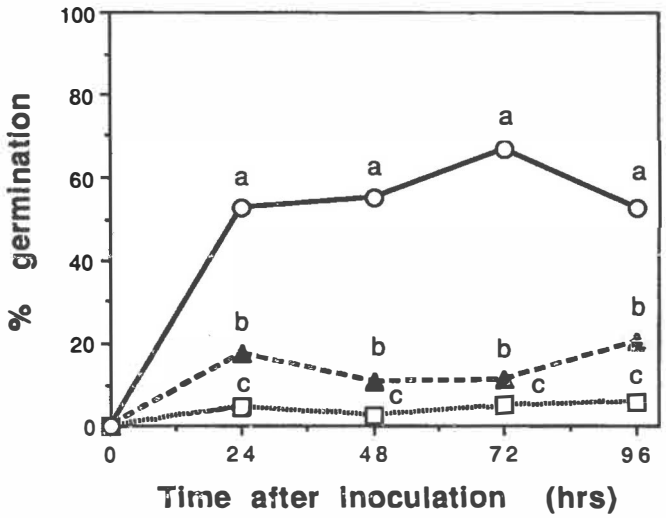


Figure 3: Evolution over time of the frequency of germination of dry spores of *Botrytis cinerea* on the surface of tomato leaves maintained wet for 24 hours. The leaves were not detached from the plants and were intact (□), microwounded with carborundum (▲) or macrowounded with a scouring pad (○) prior to inoculation. Points followed by different letters indicate a significant difference ($p<0.05$) based on the Newman-Keuls multiple comparison procedure.

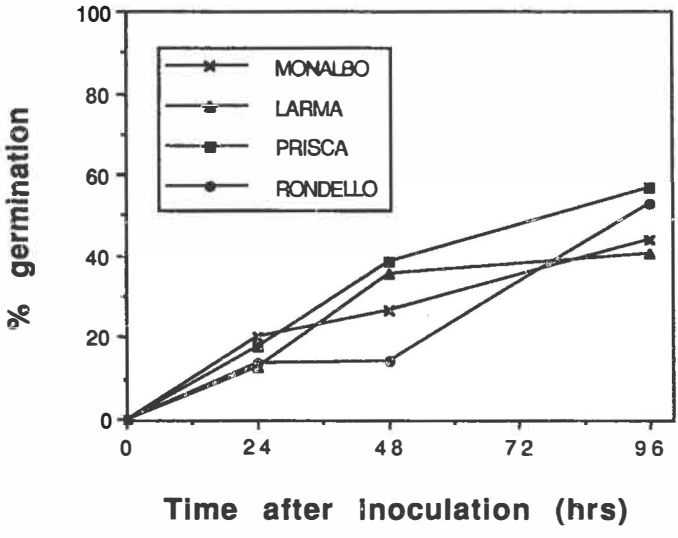


Figure 4: Evolution over time of the frequency of germination of dry spores of *Botrytis cinerea* on the surface of tomato leaflets of 4 different varieties. The leaflets were detached from the plants, microwounded, and maintained wet for 6 hours after inoculation. Each point represents the average from 5 replicate leaflets.

condition much less difficult and costly to attain than 75% relative humidity.

A complicating factor in commercial greenhouses may be the presence of wounds on the leaves: superficial wounds caused by pests such as white flies, aphids and mites, or deep wounds, cuts and bruises caused by leaf miners or the frequent handling of the plants. In our study, the presence of wounds on the leaves had two distinct consequences: (1) a reduction in the duration of the wetness period required for the onset of spore germination and (2), an increase in the proportion of germinating spores (Table 2).

The very low germination rates observed on intact leaves, even in the presence of 24 hours of wetness, are in agreement with reports on the strict nutrient requirements for the germination of *B. cinerea* spores (Blakeman, 1980) and their limited availability in tomato leaf leachates (Chou, 1972). These phenomena also suggest that the observed effect of wounds on spore germination could result from additional moisture and nutrients leached from the bruised cells. This hypothesis is supported by the parallel increase in wound severity and germination rates obserbed in the present study (Table 2). It is also compatible with the correlation noted in somes shelters between the presence of honeydew due white fly infestations and the presence of Botrytis lesions on the leaves.

The present study provides encouraging information in view of our objective to develop a climate management strategy to control grey mold in tomato greenhouses. It clearly needs to be repeated, with consideration given to the possible role of parameters such as the age of the leaves (rather than that of the plants), the age of the spores and possible differences among strains of the fungus. Other plant organs such as flowers, stems and young fruit, that are commonly attacked by the fungus, should also be taken into account. Fianlly, other steps in the infection process may have requirements even more constraining for the fungus than germination - as suggested by the lack of lesion development on intact and micro-wounded leaflets in our study - and the possibility of preventing the disease by blocking these stages will need to be explored.

5. References

ALLEX, D. and NICOT, P.C. 1990. Effect of leaf wetness and wounds on the germination of conidia of *Botrytis cinerea* on the surface of tomato leaves. Proc. 2nd Congress French Soc. Phytopath. Montpellier 28-30 November 1990. Supplement to the Bulletin of the French Soc. of Phytopathology. Page T5-A1.

BLAKEMAN, J.P. 1980. Behavior of conidia on aerial plant surfaces, *in* Coley-Smith J.R., Verhoeff K. and Jarvis W.R. eds., *The Biology of Botrytis*, Academic Press, London, pp 115-149.

BULGER, M.A., ELLIS, M.A. and MADDEN, L.V. 1987. Influence of temperature and wetness duration on infection of strawberry flowers by *Botrytis cinerea* and disease incidence of fruit originating from infected flowers. Phytopathology 77:1225-1230.

CHOU, L.G. 1972. Effect of different concentrations of carbohydrates, amino acids, and growth substances on spores germination of *Botrytis cinerea*. Phytopathology 62:1107.

CHOU, L.G. 1972. The effect of leaf and plant leachates from five tomato cultivars varying in résistance to *Botrytis cinerea* on spore germination of *Botrytis cinerea*. Phytopathology 62:750

DUBOS, B. 1987. Fungal antagonism in aerial agrobiocenoses. *In*: *Innovative approches to plant disease control*, John Wiley & Sons, pp 107-135.

GULLINO, M.L. and GARIBALDI, A. 1990. Selection of *Trichoderma* with enhanced biocontrol capacities. Proceedings of the 8th Congress of the Mediterranean Phytopathological Union - Agadir, Morocco, 1990.

GULLINO, M.L. and GARIBALDI, A. 1986. Fungicide resistance monitoring as an aid to tomato grey mold management. 1986 British Crop Protection Conference - Pests and Diseases pp 499-505.

GULLINO, M.L., MORENO, E. and GARIBALDI,A. 1990. Prove di lotta chimica e biologica contro la muffa grigia su pomodoro allevato in serra. Atti Giornate Fitopatologiche 2:225-232.

JARVIS, W.R. 1989. Dewpoint from the speaking plant. Grower, August 17th 1989, pp 14-17.

JARVIS, W.R. 1990. In the greenhouse; Manage climate to control disease. American Vegetable Grower, March 1990, pp 98-101.

LEROUX, P. and CLERJEAU, M. 1985. Resistance of *Botrytis cinerea* Pers.and *Plasmopara viticola* (Berk. & Curt.) Berl. & de Toni to fungicides in French vineyards. Crop Protection 4:137-160.

MESSIAEN, C.M., BLANCARD, D., ROUXEL F. and LAFON, R. 1991. Les maladies des plantes maraîchères. INRA, Paris, 552 pp.

NORTHOVER, J. and MATTEONI, J.A. 1986. Resistance of *Botrytis cinerea* to benomyl and iprodione in vineyards and greenhouses after exposure to the fungicides alone or mixed with captan. Plant Disease 70:398-402.

RAMSEY, G.R. and LORBEER, J.W. 1986. The role of temperature and free moisture in onion flower blight. Phytopathology 76:612-616.

SALINAS, J., GLANDORF, D.M.C., PICAVET, F.D. and VERHOEFF, K. 1989. Effects of temperature, relative humidity and age of conidia on the incidence of spotting on gerbera flowers caused by *Botrytis cinerea*. Neth. J. Pl. Path. 95:51-64.

WINSPEAR, K.W., POSTLETHWAITE, J.D. and COTTON, R.F. 1970. The restriction of *Cladosporium fulvum* and *Botrytis cinerea* attacking glasshouse tomatoes, by automatic humidity control. Ann. Appl. Biol. 65:75-83.

INTEGRATED CONTROL OF GREY MOULD OF TOMATO

M. LODOVICA GULLINO *, CLAUDIO ALOI ** and ANGELO GARIBALDI *

* Dipartimento di Valorizzazione e Protezione delle Risorse agroforestali - Sezione di Patologia vegetale, Via Giuria 15, 10126 Torino, Italy
** Centro Esperienze e Ricerche - SIAPA, Galliera, Italy

Summary

The integration of cultural, biological and chemical control measures was attempted for controlling grey mould (Botrytis cinerea Pers.) of tomato grown under greenhouse in Northern Italy. In the presence of higher amount of nitrogen fertilization and reduced ventilation, disease incidence was higher: under such conditions, only chemical sprays, carried out with the mixture procymidone + thiram, used alone or in alternation with carbendazim + diethofencarb, satisfactorily controlled grey mould. In ventilated greenhouse, in the presence of a lower amount of nitrogen fertilization, also the alternation of chemical and biological treatments (carried out with Trichoderma spp.) did offer a good control of grey mould. Also the use of formulated Trichoderma preparations alone resulted in partial disease control. The results obtained show that the integration of different control measures permits a good control of B.cinerea and reduces the number of chemical sprays.

1. Introduction

Grey mould, incited by Botrytis cinerea Pers., is the most serious foliar disease of tomato grown under protection. Under favorable environmental conditions, the number of sprays normally carried out in commercial greenhouses can be more than six/season. In Italy, as well as in many other countries, management of this disease is complicated by the presence of populations of the pathogen resistant to benzimidazoles and dicarboximides (Bozzano et al., 1990) and by restrictions in the number of effective available fungicides. Under these conditions, availability of

* Work supported by grants from Ministero Agricoltura e Foreste (Progetto Finalizzato: Lotta biologica e integrata. Sottoprogetto: Colture protette) and from Regione Liguria.
First and last authors planned the experiments and wrote the manuscript, the second carried out the experimental work.

alternative control strategies, environmentally safer, looks very promising. Unfortunately, the biocontrol agents (mostly Trichoderma spp.) up to now investigated (Elad, 1990) and the cultural methods, especially in the case of protected crops, used separately do not always satisfactorily control the pathogen.

The results obtained by integrating cultural, biological and chemical measures in order to effectively manage grey mould on tomato grown under greenhouse on the Riviera Coast will be described in this paper.

2. Materials and methods

The two trials described were carried out during the spring 1990 at the Centro Orticolo sperimentale of the Chamber of Commerce of Savona, located at Albenga (Northern Italy). Tomato plants (cv Candela) were grown under two polyethylene tunnels equipped with overhead irrigation. The level of nitrogen fertilization was different in the two tunnels: in tunnel 1, a fertilizer containing $N:P_2O_5:K_2O$ at a ratio of 1:2:3 was used, while in tunnel 2 the ratio of $N:P_2O_5:K_2O$ was 4:1:1. Moreover, tunnel 1 was ventilated during the day and left open during the night if the temperature was higher than 7°C. Tunnel 2, on the contrary, was ventilated only when temperature was higher than 20 °C and kept always close overnight. All other cultural practices were those followed by local growers.

Plants were artificially inoculated twice at flowering with conidial suspensions (10^6 conidia/ml) of B.cinerea, containing 90% sensitive (S) and 10% benzimidazole and dicarboximide resistant (RBD) spores, as previously described (Garibaldi et al., 1989).

Treatments were carried out at 7 day intervals, starting at first open flowers. Fungicides and Trichoderma (at dosages reported under table 1) were applied by means of a hand-operated knapsack sprayer. Trichoderma IPV (Gullino et al., 1990) was applied as spore suspension (10^{10}/l); Trichoderma IPV F (T 5/2 RDB 11, SIAPA, Bologna, Italy) and MTR 39 (Makhteshim, Beersheva, Israel) were used respectively at the dosages of 1.6×10^{10} and 4×10^{10} cfu/l as formulations. Each treatment was applied to three replicate plots (16 plants/plot) in a randomised block layout. At harvest, rotted and healthy fruit were counted and weighed.

3. Results and conclusions

Disease severity resulted high in both tunnels, with attacks being, however, higher in tunnel 2, due to the higher amount of nitrogen and to the reduced ventilation (table 1). The effect of the tested treatments was different in the two tunnels. In tunnel 2, in which environmental conditions and fertilization were favourable to grey mould, only chemical sprays, carried out with the mixture procymidone+thiram, used alone or in alternation with carbendazim+diethofencarb, satisfactorily controlled grey mould (table 1). Also in tunnel 1 the best results were shown by the same chemical sprays, but, in this case, also the alternation of chemical and biological treatments and the use of formulated biocontrol agents alone offered a partial control of B.cinerea

Table 1 - Effectiveness of different treatments against grey mould of tomato (cv. Candela).

Treatment*	g or cfu/l	Number rotted fruit/plot	
		Tunnel 1	Tunnel 2
1) Control	--	34 d **	41 b
2) Procymidone+thiram/***	0.25+1		
Trichoderma IPV	10^{10}	12 bc	34 b
3) *Trichoderma* IPV	10^{10}	34 d	50 b
4) *Trichoderma* IPV F	1.6×10^{10}	17 c	44 b
5) *Trichoderma* MTR 39	4×10^{10}	19 c	48 b
6) Procymidone+thiram	0.25+1	5 ab	9 a
7) Carbend.+diethof./***	0.25+0.25		
procymidone+thiram	0.25+1	1 a	4 a

* Total number of sprays carried out: 5
** Values of the same column, followed by the same letter, do not significantly differ, following Duncan's Multiple Range Test (P = 0.05).
*** Treatments carried out in alternation.

(table 1). Number of healthy fruit/plot, considered as cumulative data of different harvests, was not significantly affected in tunnel 1 by the different treatments, while in tunnel 2 treatments carried out with *Trichoderma* IPV did show a positive effect. From a general point of view, yield did not resulted severely affected by disease (table 2).

By considering the evolution of grey mould attacks at different harvests (figure 1), it is possible to observe that the disease in tunnel 1 spread slowly in comparison with tunnel 2. This phenomenon might have practical consequences, since it lead to a much lower disease incidence during the first harvests, corresponding to higher tomato prices.

Reduced amount of nitrogen fertilization and adoption of simple cultural practices such as increased ventilation, in order to reduce the persistence of water films on leaves, complemented well the other control measures. Under conditions less favorable

Table 2 - Effectiveness of different treatments carried out against grey mould of tomato on yield, evaluated as number and weight of healthy fruit (the data reported are the total of different harvests).

Treatment *	Healthy fruit/plot			
	Number		Kg	
	Tunnel		Tunnel	
	1	2	1	2
1) Control	218 a**	221 bc	34.4 a	34.6 a
2) Procymidone+thiram/*** *Trichoderma* IPV	236 a	252 ab	39.3 a	38.8 a
3) *Trichoderma* IPV	195 a	261 a	31.9 a	37.6 a
4) *Trichoderma* IPV F	198 a	237 abc	32.4 a	38.9 a
5) *Trichoderma* MTR 39	218 a	218 cd	35.1 a	33.1 a
6) Procymidone+thiram	205 a	208 d	35.3 a	38.0 a
7) Carbendaz.+diethof./*** procymidone+thiram	235 a	207 d	38.3 a	37.1 a

* Treatments carried out as reported under table 1
** and *** see table 1.

to disease development, also biocontrol agents partially controlled the pathogen. It is interesting to observe that the best results were obtained with formulations of *Trichoderma* (treatments 4 and 5): this is probably due to a better survival of formulated *Trichoderma* due to substances present as coformulants. The alternation of fungicides and biocontrol agents, in combination with cultural measures, did permit further reduction of disease incidence (table 1). This result is particularly interesting, because it permits an overall reduction of the number of chemical sprays.

In conclusion, although needing further confirmation, the results obtained show that the integration of different control measures permits a good control of grey mould and reduces the number of chemical sprays. In the future probably biocontrol agents might play a major role but, at present, fungicides are still necessary for management of tomato grey mould.

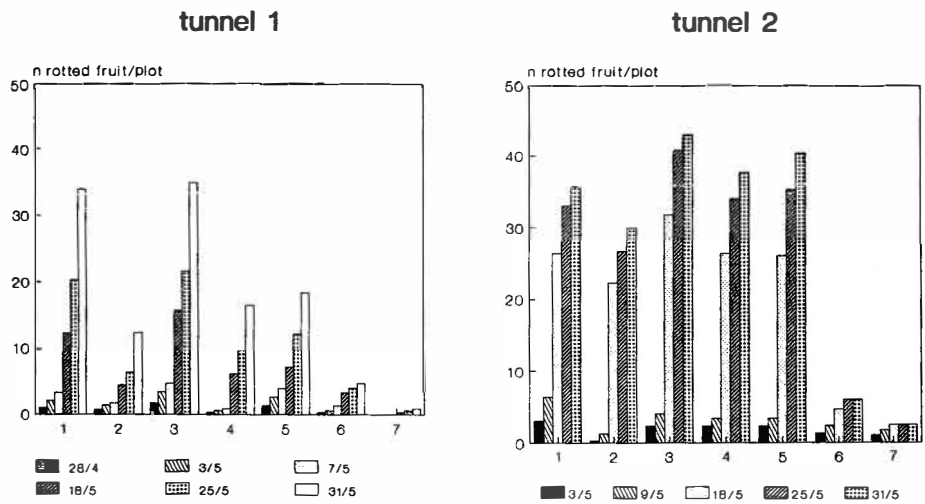


Figure 1 - Evolution of grey mould attacks at different harvests (for explanation of treatments 1-7, see table 1).

4. References

BOZZANO, G., MINUCCI, C. & GULLINO, M. L., 1990. Monitoring fungicide resistance in Botrytis cinerea on greenhouse tomato, in press.

ELAD, Y., 1990. Reasons for the delay in development of biological control of foliar pathogens. Phytoparasitica 18: 99-105.

GARIBALDI, A., ALOI, C. & GULLINO, M.L., 1989. Evolution of Botrytis cinerea populations on strawberry and tomato under the influence of different spray strategies. Med. Fac. Landbouww. Rijksuniv. Gent, 54: 651-656.

GULLINO, M.L., MORENO, E. & GARIBALDI, A., 1990. Prove di lotta chimica e biologica contro la muffa grigia su pomodoro allevato in serra. Atti Giornate fitopatologiche, 2: 225-232.