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PROGRES EN LUTTE INTEGREE EN CULTURES SOUS VERRE

PROGRESS IN INTEGRATED CONTROL IN GLASSHOUSES

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INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
CONTROL OF NOXIOUS ANIMALS AND PLANTS

WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES
REPORT OF THE MEETING HELD FROM 5 TO 7 MAY 1976
AT THE STATION DE ZOOLOGIE ET DE LUTTE BIOLOGIQUE, INRA, ANTIBES, FRANCE

GROUPE DE TRAVAIL LUTTE INTEGREE EN CULTURES SOUS VERRE
RAPPORT DE LA REUNION TENUE DU 5 AU 7 MAI 1976
A LA STATION DE ZOOLOGIE ET DE LUTTE BIOLOGIQUE, INRA, ANTIBES, FRANCE

BULLETIN SROP
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INTRODUCTION

This Bulletin contains the papers presented during the third meeting of our Working Group "Integrated Control in Glasshouses", held from 5 to 7 May, 1976, at the INRA "Station de Zoologie et de Lutte Biologique" at Antibes, France. Biological control plays a major part in developing a better balanced pest control system in glasshouse crops. Consequently it is not surprising that the reports presented here deal almost exclusively with various aspects of biological control, or that a good deal of attention is given to pesticide selectivity, with the aim of avoiding unwanted interference of pesticide applications with introduced parasites and predators.

This Bulletin should be seen as a follow-up to IOBC/WPRS Bulletin 1973/4, "Integrated Control in Glasshouses". Comparing the two documents will give an excellent idea of the progress made in this particular field in the past three years. I would like to congratulate the various members of the Working Group for their contribution to this achievement and thank them very much for their collaboration in our organization's activities.

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STATUS OF INTEGRATED CONTROL IN THE US GREENHOUSE INDUSTRY

by

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In the United States, progress in achieving integrated control of greenhouse pests has been minimal. This is due to a combination of factors, which are outlined below.

A. The US greenhouse industry is relatively small and scattered.

The exact acreage is difficult to determine, because of the expansion in the number plastic covered structures. According to Cravens (1974), there were approximately 2,900 acres (1,180 ha) used for vegetable production. Of this total, about 50 percent was plastic covered. In recent years, the glass acreage has tended to remain the same, while that covered with plastic is increasing.

As a consequence, there are no large centers of greenhouse pest control research (as in the UK, The Netherlands, etc.) in the US, because the demand has not been localized.

B. The relatively large number of pests attacking greenhouse vegetables.

In addition to the greenhouse whitefly and two spotted spider mite, other pests such as the vegetable leafminer (Liriomyza sativae Blanchard),(Diptera: Agromyzidae) potato tuberworm (Phthorimaea operculella), and tomato pinworm (Kieferia lycopersicella) (both Lepidoptera: Gelechiidae) are serious pests of tomatoes. Leafminers and the "French-fly" Tyrophagus sp. have become pests of cucumbers.

The shipment of produce across the country (and from Mexico), the proximity of many greenhouses to outdoor growing areas, and the fact that many growers have crops in some stage of growth inside the greenhouse virtually all year, contribute to rather severe outbreaks of one or more of the above pests.

This has complicated efforts to achieve a practical integrated control programme. Bacillus thuringiensis, for example, has no effect on either of the Lepidoptera listed above. Naturally, not all of these pests are always present, but they are there often enough to cause problems.

C. Until recently, insecticides have generally been effective in controlling major pests.

D. Registration of "selective" insecticides on greenhouse crops is difficult.

Under the present pesticide registration programme in the US, availability of pesticides for "minor" crops (e.g. greenhouse vegetables and ornamentals), has been severely restricted. Therefore, it is doubtful whether such pesticides as pirimicarb and resmethrin will be legally available to US greenhouse vegetable producers in the near future, even though they are able to be used on certain floricultural crops.

Despite this generally gloomy situation, it is necessary to make an effort to develop a practical integrated control plan for producers of greenhouse vegetables in the US. As mentioned in "C" above, pesticide resistance or phytotoxicity was not a problem until recently. During the past few years, growers have had an increasingly difficult task controlling pests such as white flies and leafminers on tomatoes. Although we have not conducted any studies to determine whether populations of these insects have developed resistance, the experience of other areas of the world suggests that this is the case.

A more critical problem has been the increasing acreage of cucumbers, with the resulting spider mite problem. In grower experience and research trials, it has been difficult to locate the satisfactory combination of an effective acaricide that is not phytotoxic to cucumbers. Plictran might be useful in this regard, if use on young plants can be avoided. Of course, even if a satisfactory material can be located, registration will still be a problem.

Present Projects and Future Outlook

A. Encarsia formosa and Phytoseiulus persimilis

Results from using Encarsia and Phytoseiulus in controlled experiments on vegetables have been similar to those obtained in other areas of the world. What is necessary now is to provide rearing facilities for natural enemy supplies and distribution, plus programmes for grower education. This phase of the system is scheduled to get started in late 1976 and during 1977.

Studies also have been conducted using Encarsia to control whiteflies on short-term ornamental crops such as poinsettias (Helgesen and Tauber, 1974, Lindquist, unpublished). Helgesen and Tauber achieved control on a poinsettia crop in production, but at temperatures that probably were too high for economic and horticultural reasons. During the summer of 1975, I obtained excellent control of whiteflies on poinsettia stock plants with Encarsia (comparable to that obtained with aldicarb), taking advantage of the naturally higher temperatures during this period. Use of Encarsia in this manner may allow a grower to go

into the main poinsettia production season virtually free of whiteflies, and reduce the amount of insecticides needed later in the crop.

Poe (unpublished) has used Phytoseiulus with some success in trials for two spotted spider mite control on roses in Florida.

B. Resistant cultivars

Efforts have been made in several locations to evaluate tomato cultivars and plant introductions for resistance to whiteflies, spider mites, and leafminers. Results indicated either some mechanical resistance due to the presence of hairs, or sticky exudate on leaves, or, that some cultivars were non-preferred as feeding or oviposition sites. However, to-date there does not seem to be anything useful in an active breeding programme.

C. Selective chemicals

As is already known from work in several parts of the world, many pesticides can be utilized in an integrated programme that are less harmful to Encarsia or Phytoseiulus, either in themselves, or by applying them in the proper way or at the proper time.

Part of my work at Wooster is aimed at continuing to locate those materials that would control K. lycopersicella, L. sativae, or T. vaporariorum (adults) on tomatoes, while allowing Encarsia survival. A restriction on those materials chosen was that only compounds which had a possibility of becoming registered were used.

Insecticides included permethrin, chlordimeform, acephate, diazinon, methomyl, endosulfan (applied as high-volume sprays), and pyrethrin (applied as H.V. and U.L.V. sprays). Generally, results were evaluated by applying materials at 10-14 day intervals to a growing system containing whitefly scales and introduced Encarsia, and recording percent parasitism. No special effort was made to avoid periods of parasite activity. Although all were effective against one or more of the above species, only pyrethrin appeared to be of use in an integrated programme. The other materials were either phytotoxic (chlordimeform), or did not allow significant parasitism. Harbaugh (1975) reported that nicotine sulfate and/or resmethrin could be used to keep a whitefly and Encarsia system in balance, provided applications were made during periods of low parasite activity. Since it is unlikely that resmethrin will receive approval for use on food crops in the US, this use will be restricted to ornamentals. Nicotine sulfate, if registration for greenhouse food crops is allowed to remain, may be useful in an integrated programme.

On cucumbers, similar studies have been conducted, attempting to identify materials that will control T. urticae, T. vaporariorum, L. sativae and Bradysia coprophia (Sciaridae), while remaining relatively harmless to P. persimilis. Materials used in this phase of the programme included plictran, permethrin, pyrethrin, acephate, methomyl, oxamyl, zardex

(high-volume sprays), diazinon (E.C. and granules as soil drench). When P. persimilis adults were introduced onto plants 0, 24, or 72 hr after treatment, only plictran, pyrethrin, and zardex allowed much survival.

Therefore, pyrethrin applied as high-volume or ultra-low-volume sprays appears to be the most satisfactory material of those tested.

Probably, several other compounds could be used occasionally, if Encarsia or Phytoseiulus were well-established, if re-introductions could be made, or applications were timed to avoid peak parasite activity.

The above summary, I believe, reflects the present status of integrated control efforts in the US. We hope to use the information gathered by other workers and adapt it to our cropping practice. Hopefully, a practical integrated control programme can then be developed in a minimum amount of time.

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THE DEVELOPMENT OF BIOLOGICAL CONTROL ON CUCUMBERS AND TOMATOES IN THE UK

by

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In the UK much of the early work on biological control in glasshouses had been done on cucumber pests where, because of the problem of acaricide resistance in Tetranychus urticae growers were interested and ready to adopt alternative methods of control.

Following a series of large scale demonstrations of the integrated control of cucumber pests and diseases (Gould 1971) organised on a cooperative basis by the Glasshouse Crops Research Institute (GCRI) and the Agricultural Development and Advisory Service (ADAS), a successful programme for cucumber growers has now been developed in the UK. This programme is summarised in Table 1.

Table 1. Basic Integrated Control Programme for Cucumbers

Pest/Disease	Treatment	Control method
Tyrophagus longior	Parathion bed drench before planting	Selective timing
Tetranychus urticae	Phytoseiulus persimilis	Biological-predator
Trialeurodes vaporariorum	Encarsia formosa	Biological-parasite
Thrips tabaci	Gamma BHC or diazinon bed drench	Selective placement
Aphis gossypii	Pirimicarb spray	Selective aphicide
Sphaerotheca fuliginea	Dimethirimol or benomyl root drench	Selective fungicide

Full details of the methods for introducing the biological agents were described by Parr & Scopes (1971). The most predictable control of red spider mite (Tetranychus urticae) was obtained when each plant was infested with 10-20 mites soon after planting followed by 2 predators onto each alternate plant 10-14 days later. This established an even population of the predator before the plants were infested with naturally occurring populations of Tetranychus urticae from the glasshouse structure. It was also shown that, to obtain

the most reliable control of whitefly (Trialeurodes vaporariorum) (Parr 1970) the crop should first be infested with whitefly at a rate of 2 per plant followed 14 days later by an introduction of Encarsia formosa as parasitized scales at a rate of 20 per plant. In practice growers have not adopted the technique of introducing pests on to their plants and Phytoseiulus persimilis is being used successfully by an introduction as soon as the first symptoms of red spider mite damage are seen on the crop. Similarly other techniques are being used for whitefly control and the parasite is often introduced at regular intervals at a rate of one to 2 parasites per plant from planting until black parasitised scales are established in the crop (Gould, Parr, Woodville & Simmonds 1976). This method assumes that whitefly will infest the crop soon after planting but a drawback is the uncertain forecast of the number and cost of the introductions which will be necessary before the parasite becomes established.

Since 1973 the main cooperative effort by GCRI and ADAS has been in the development of a similar integrated control programme for tomato pests. In the last 3 years the control of whitefly has become more difficult on commercial nurseries and resistance to DDT, resmethrin and malathion (Table 2) has been confirmed.

Table 2. Malathion resistance in glasshouse whitefly LC50s (ppm) of populations from 5 tomato nurseries in S. West England

Nursery	1	2	3	4	5	Susceptible Strain
LC50	404	284	241	43	32	25

Parr, Gould, Jessop and Ludlam (in press) have described different methods of introducing Encarsia formosa for the control of whitefly on tomatoes. The GCRI "Classical" method recommends the establishment of a low, even infestation of whitefly on the crop by introducing one whitefly on every tenth plant at planting followed by the parasite 3, 5 and 9 weeks later, to coincide with the development of 3rd instar whitefly scales at normal growing temperatures. Typical results are shown in Table 3.

Table 3. Biological Control of whitefly on tomatoes GCRI "Classical" method

Sampling date	8/4	7/5	22/5	11/6
No of scales/leaf	14	211	478	1350
% parasitized	50	50	83	98
Plants with 'sooty' moulds	0	0	0	0

Two alternative methods, avoiding the initial introduction of whitefly are currently being used on commercial nurseries. The first depends on the ability of the grower to detect whitefly infestations at an early stage. Parasites are introduced when the whiteflies are first seen, at a rate of one per plant followed by a second similar introduction 14 days later. In the second method, of particular value on nurseries where the pest is known to be a regular problem, parasites (one per plant) are introduced at fortnightly intervals after planting until the first black scales are established in the crop. Typical results are shown in Table 4. Neither method is completely reliable and in the absence of an artificially established even infestation of whitefly, patches of heavily infested plants can occur where, because of the excessive amounts of honeydew secreted on the leaves, the parasite is much less effective (Parr 1972).

With all methods the parasites were introduced as pupae in situ on pieces of tobacco leaf which were distributed throughout the crop on every 50th plant.

Table 4. Biological Control of whitefly on tomatoes
"Routine introduction" method

Planting date 12 January	No of *Encarsia* introductions - 8			First parasitized scale in crop - 3 March			
Sampling date	23/1	15/2	3/3	20/3	3/4	10/4	23/5
% plants - white scales	45	64	72	90	92	100	40
% plants - black scales	0	0	52	80	85	100	100
% parasitism	0	0	5	19	44	61	99
% plants - sooty moulds	-	-	-	-	1	8	4

Work at the GCRI (Hussey & Parr - personal communication) has shown that the parasite is also less effective in the poor light conditions in the early months of the year and in 1976 a series of trials has commenced to investigate the use of the pesticides oxamyl, pirimiphos-methyl and resmethrin for the control of whitefly infestations in January to March followed by the parasite later in the season.

Two methods have been developed for the biological control of red spider mite on tomatoes. The first, based on the introduction of the pest, consists of infesting 20 percent of plants in the propagating stage with red spider mite about 3 weeks before planting followed 10 days later with an introduction of 4 predators per plant. These quickly disperse through the rest of the plants after planting and will protect the crop against reinfestation by ex-hibernating mites for up to 3 weeks. An alternative method of introducing 5-10 predators on every 5th or 10th plant as soon as the first signs of red spider mite damage are seen, has also been used successfully.

Parasites and predators are now available from 2 large commercial producers and several smaller ones in the UK. Encarsia are supplied as pupae, usually on tobacco leaves at a cost of £2.50 per thousand and Phytoseiulus persimilis is sent out on bean leaves or occasionally in small gelatine capsules at a cost of £15 per thousand. All material is dispatched by post and the suppliers do not normally provide a follow up advisory service.

In an attempt to obtain quantitative information on the use of biological control programmes under glass ADAS advisers collected details of growers known to be using these techniques on cucumbers and tomatoes in 1975. The results are summarised in Table 5.

Table 5. Survey of nurseries using biological control on tomatoes or cucumbers in 1975

No or growers	Estimated acreage	P. persimilis acreage	E. formosa acreage	% Satisfactory Control Red spider mite	Whitefly
137	195	90	138	94%	65%

The results suggest that biological control was being used on at least 10 percent of the cucumber and tomato acreage. However as the data refer only to those growers known to the Advisory Service the result is probably an underestimate of the true position. Information received from the two main suppliers of parasites and predators suggest that they produced sufficient material to treat a total of 300 acres of tomatoes and cucumbers. The results of the Advisory Service Survey also show that most growers were able to obtain good results with P. persimilis but the control of whitefly with the parasite Encarsia formosa was less satisfactory.

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PROGRESS OF INTEGRATED CONTROL OF PESTS UNDER GLASS IN NORWAY

by

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The biological control agents in practical use in Norway are Phytoseiulus persimilis to control two-spotted spider mite on cucumber and tomatoes, and Encarsia formosa to control greenhouse whitefly (Trialeurodes vaporariorum) on tomatoes.

Successful integrated control is obtained with Phytoseiulus against spider mite combined with diazinon drench against thrips.

Control experiments of spider mite on ornamental plants have been carried out in an effort to try to expand the utilization of P. persimilis and the susceptibility of P. persimilis against pesticides for use in greenhouses has been tested.

P. PERSIMILIS IN SPIDER MITE CONTROL

Methods

The experiments with P. persimilis to control spider mite were carried out on mother plants of croton (Codiaeum variegatum), 4 experiments and Diffenbachia sp., 2 experiments. The temperature varied between 20° and 24°C. The predatory mite was introduced at different densities of the spider mite (Table 1), 2-4 predators were released at each introduction spot. One introduction spot was used per square metre in the experiments 1, 2, 3 and 6. Experiment 3 was sprayed with tetradifon before the predator was released. In experiment 4, four introductions were used per square metre and in experiment 5, one introduction per 2 square metres. Each experiment was carried out in three replicates. The spider mite and P. persimilis were counted on 100 leaves per replicate.

Results and discussion

None of the experiments showed spider mite damage of economic importance, on the mother plants or on the cuttings. The results are shown in Table 1.

The population growth in the spider mite varied between the experiments, but in all cases complete control was obtained 50-60 days after introduction of the predator.

Table 1. Experiments with Phytoseilus persimilis to control Tetranychus urticae on motherplants of Codiaeum variegatum & Diffenbachia sp.

Experiments	m^2 mother-plants	N° prey/ leaf before introd. of predator	N° introd. spots 1/ m^2 of plants	Population increase of prey days from introduction to max. prey population	Population increase of prey rate, max. popul.:popul. at introd.	Complete control days after introduction
C. variegatum						
1	50	0.12	1	40-50	8 X	60
2	41	1.62	1	20-30	2.6	60
3	30	3.02	1 2/	20	1.2	50
4	11	12.40	4	-	-	50
Diffenbachia						
5	64	0.87	0.5	20	1.9	60
6	35	3.95	1	20	1.4	60

1/ One introduction spot represents 2-4 predators.

2/ Sprayed with tetradifon before introduction of predator.

Experiment 1, which had lower attack of spider mite at time of introduction but higher ratio of predator/prey than experiment 2, gave the longest period of spider mite increase and accordingly also the highest population increase of spider mite before the predator was able to reduce the prey population. These differences are probably due to the difficulties of the predator in finding the prey at low spider mite population.

Experiment 3, which was sprayed with tetradifon before the introduction of the predator, had only slight increase in the prey population before the population decreased. This shows the value of tetradifon in an integrated programme, where it prevents increase in the prey population.

Experiment 4, with four introduction spots per square metre and the highest initial spider population (12.4 mites per leaf), showed no marked increase in the population of the spider mite 14 days after introduction of the predator.

Comparison between experiments 5-6 and 1-2 shows that the spider mite population did not increase at the same rate on Diffenbachia and C. variegatum. This is probably due to lifferences in the reproduction rate of the spider mite on the two plants.

SUSCEPTIBILITY OF P. PERSIMILIS TO PESTICIDES

Materials and methods

Table 2 lists the pesticides used in the experiments and the dosages or concentrations normally applied. The normal dosage or concentration will be referred to in the following as N.

Table 2. Pesticides used in experiments with the predatory mite Phytoseiulus persimilis

Pesticides	Normal dosage or concentration
Fumigants	
Chinomethionate	14.4 g/100 m^3
Dichlorvos	8 g/ "
Lindane	4 g/ "
Nicotine	10 g/ "
Sulfotep	3 g/ "
Spray	
Chinomethionate	0.0125 %
Chloranilformethan	0.0100 %
Cyhexatin	0.0250 %
Mevinphos	0.0240 %
Pirimicarb	0.0250 %
Pyrazophos	0.0200 %
Pyrethrum	0.0100 %
Tetradifon	0.0150 %
Triforine	0.0200 %

Both the initial and residual effect of the pesticides on the predatory mite were investigated. Test plant was dwarf bean (Phaseolus vulgaris var: nanus) 'Saxa'.

Testing of initial effect. Eggs of different ages were transferred to bean leaves and treated immediately. For each pesticide dosage or concentration there were five replicates of fifty eggs. The eggs that hatched were considered to have survived.

The mobile stages of the predatory mite were transferred to bean plants which had already been infested with spider mites. There were four replicates of 30 to 100 predatory mites for each treatment. Surviving mites were counted after two days.

Testing of residual effect. Bean plants were infested with spider mites and then treated with pesticides. After 24 hours, 30 eggs of the predatory mite were transferred to the plants. All surviving predatory mites were counted when those on untreated plants had reached adult stage. There were four replicates of each treatment.

The results are presented as relative numbers, with the number of predatory mites on untreated plants being set at 100.

Results and discussion

The effects of chinomethionate, dichlorvos, lindane, nicotine and sulfotep are found in Table 3.

Table 3. Effect against Phytoseiulus persimilis of various pesticides as "smokes"

Pesticides	Dosage a.i.	% surviving P. persimilis		
		Initial effect		Residual effect
		Eggs	Mobile stages	Untreated = 100
chinomethionate	28.8 g/100 m^3	29.7	0	0
"	14.4 g/ " (=N)	50.4	0	0.7
dichlorvos	10.0 g/ " (=N)	77.7	0.7	95.0
lindane	8.0 g/ "	90.0	0	65.9
"	4.0 g/ " (=N)	98.5	5.1	99.2
nicotine	20.0 g/ "	99.0	0.9	100
"	10.0 g/ " (=N)	93.4	16.1	100
sulfotep	6.0 g/ "	100	0	100
"	3.0 g/ " (=N)	-	0	-
untreated	-	99.0	100	-

Chinomethionate was applied in dosages of 14.4 (i.e. N) and 28.8 g/100 m^3. After treatment 50.4 percent and 29.7 percent of the eggs survived, respectively. The mobile stages did not survive either dosage. On the residue, 0.7 percent of the predatory mites survived the lower dosage, while none survived the higher dosage.

Though only half of the eggs are killed initially by the normal dosage of chinomethionate, the residue will still greatly reduce the population after hatching.

Dichlorvos was vaporized at the normal dosage of 10 g/100 m^3. The result was 77.7 percent egg survival and 0.7 percent survival of the mobile stages. The treatment had no residual effect.

Earlier experiments with dichlorvos spraying (Bøhm 1970, Binns, et al. 1971) at normal concentration showed 100 percent mortality of both mobile stages and eggs. This would indicate that dichlorvos as a smoke, is less harmful to P. persimilis than spraying. The relative low toxicity of Dichlorvos vapour in the present experiment and the absence of any residual effect, makes it clear that the predatory mite population has considerable chances of surviving a treatment.

Lindane was used in dosages of 4 (i.e. N) or 8 g/100 m^3. Comparison with untreated plants showed that those dosages had no effect on eggs. After treatment with the lower dosage, 5.1 percent of the mobile stages survived direct treatment, whereas none survived the higher dosage. The residual effect was low as 99.2 percent and 65.9 percent survived on the two dosages.

The experiments indicated that normal dosages of lindane smoke spared the eggs but killed most larvae and adult mites. As the pesticide is without residual effect, it will only partly reduce the numbers of predatory mites.

Nicotine was tested in dosages of 10 g (i.e. N) and 20 g/100 m^3. Both dosages were nontoxic to the eggs, whereas 16.1 percent and 0.9 percent of the mobile stages survived the lowest and highest dosages, respectively. The treatments had no residual effect.

Of the fumigants tested, nicotine was the least toxic to the mobile stages, besides having no effect on eggs and no residual effect.

Sulfotep was used in dosages of 3 (i.e. N) and 6 g/100 m^3. These treatments had no initial effect on eggs, but killed mobile stages. The treatments had no residual effect. The results showed that one treatment will provide partial reduction of the population of P. persimilis.

Table 4 shows the effect of the pesticides cyhexatin, mevinphos, pirimicarb, pyrethrum and tetradifon.

Cyhexatin was tested in four different concentrations, from 0.00625 percent to 0.05 percent (N. = 0.025 percent). Even the highest concentration was without effect on eggs of P. persimilis. At the lowest concentration, 90 percent of the mobile stages survived and at the highest, 4.1 percent survived, while N concentration gave 46.3 percent survival of the mobile stages.

Table 4. Effect against Phytoseilus persimilis of various pesticides after spraying

Pesticides	Concentration % a.i.	% surviving P. persimilis		
		Initial effect		Residual effect
		Eggs	Mobile stages	Untreated = 100
cyhexatin	0.05	99.0	4.1	0
	0.025 (=N)	100	46.3	0
	0.0125	100	47.2	5.2
	0.00625	100	90.0	10.0
mevinphos	0.024 (=N)	25.6	-	-
	0.012	48.0	0	21.2
	0.006	43.6	0	65.9
	0.003	58.4	0	61.7
pirimicarb	0.1	-	1.7	49.4
	0.05	4.0	25.4	83.3
	0.025 (=N)	59.0	64.7	100
	0.0125	91.0	-	-
pyrethrum	0.01 (=N)	14.5	0	5.3
	0.005	85.4	10.5	14.9
	0.0025	97.0	6.5	33.1
	0.00125	100	-	37.6
tetradifone	0.06	99.4	91.7	100.0
	0.03	98.0	90.4	91.3
	0.015 (=N)	100	-	100
untreated	-	98.0	98.0	-

On the residue there were no survivors at the two highest concentrations, while 5.0 percent to 10.0 percent of the population survived the two lowest concentrations.

There were no two-spotted spider mites on the plants at the end of the experiment. The fact that there were few or no P. persimilis present should therefore probably be attributed to insufficient food supply rather than the toxicity of the pesticide. This is supported by earlier studies (McClanahan 1970) showing cyhexatin selective towards P.persimilis

Cyhexatin can be used to reduce a population of two-spotted spider mites in proportion to predatory mites, for which purpose it should not be applied in concentrations higher than 0.0125 percent.

Mevinphos was tested in four different concentrations, from 0.003 percent to 0.024 percent (i.e. N). At direct application, 58.4 percent of the eggs survived the lowest concentration as opposed to 25.6 percent for the highest. All concentrations gave 100 percent kill of the mobile stages. The residue killed 61.7 percent of the population at the lowest concentration, and 21.2 percent at 0.012 percent mevinphos.

In earlier studies (Binns et al. 1971, Böhm 1970) mevinphos has been found highly toxic to P. persimilis. These findings agree with the present results, where 100 percent toxicity against mobile stages occurred with spraying at 1/8th normal concentration. The eggs were more resistant, but still 75 percent were killed at normal concentrations. The residue, moreover, was also toxic, and mevinphos should therefore be considered as harmful to P. persimilis at normal concentration.

Pirimicarb was tested in four concentrations from 0.0125 percent to 0.1 percent (N = 0.025 percent). Direct spraying with 0.0125 percent spared 91 percent, and spraying with 0.05 percent concentration spared 4.0 percent of the eggs. Mobile stages survived at the rate of 64.7 percent at the 0.025 percent and 1.7 percent at the 0.1 percent concentration, survival of the population was 100 percent and 49.4 percent respectively.

In earlier studies (Helgesen and Tauber 1974) found that 0.015 percent pirimicarb was without effect on eggs and mobile stages. Table 4 shows that the normal concentration (0.025 percent pirimicarb) was not toxic as residue, but gave about 40 percent kill of eggs and mobile stages. Used at this dose, this pesticide may be considered relatively nontoxic to P. persimilis.

Pyrethrum was tested in four concentrations, from 0.00125 percent to 0.01 percent (N). At the lowest concentration, 100 percent of the eggs survived. With increasing concentration, percentage of survivors decreased, being 14.5 percent at the highest concentration. The highest concentration killed all the mobile stages, while 10.5 percent and 6.5 percent of the mobile stages survived at concentrations of 0.05 percent and 0.025 percent, respectively. Survival of the mite population on pyrethrum residue ranged from 87.6 percent at the lowest concentration to 5.3 percent at the highest concentration.

The results show that pyrethrum is toxic to P. persimilis. At the normal dose (0.01 percent pyrethrum) most eggs and all mobile mites are killed by spray, and the population was further reduced through residual effect.

Tetradifone was tested in three concentrations, from 0.015 percent (N) to 0.06 percent. It appears from Table 4 that tetradifon in the concentrations applied was not toxic to P. persimilis, either initially or residually.

Earlier investigations (Böhm 1970 and McClanahan 1970) have also shown tetradifon to have little effect on P. persimilis.

The effects of the fungicides chinomethionate, chloranilformethane, pyrazophos and triforine are found in Table 5.

Table 5. Effect against Phytoseiulus persimilis of various fungicides after spraying

Pesticides	Concentration % a.i.	% surviving P. persimilis		
		Initial effect		Residual effect
		Eggs	Mobile stages	Untreated = 100
chinomethionate	0.025	31.0	2.0	2.5
	0.0125 (=N)	26.0	14.0	9.2
	0.00625	54.4	16.0	38.1
	0.003125	64.5	51.0	67.1
chloranilformethane	0.0514	94.8	43.0	12.2
	0.01285 (=N)	96.0	63.0	23.5
	0.00642	-	-	55.3
	0.00321	-	70.0	91.8
pyrazophos	0.0656	96.3	0	17.9
	0.0328	95.6	1.4	37.6
	0.0164 (=N)	97.0	1.4	89.3
	0.0082	95.2	10.2	-
	0.0041	-	77.1	-
triforine	0.08	97.0	31.7	100
	0.04	98.8	44.2	100
	0.02 (=N)	99.0	41.2	99.6
	0.01	100	49.9	100
untreated	-	98.0	38.0	-

Chinomethionate was applied in four concentrations, from 0.03125 percent to 0.025 percent (N = 0.0125 percent). With these concentrations, the survival rate ranged from 64.5 percent to 26.0 percent of the eggs, and from 51.0 percent to 2.0 percent of the mobile stages with direct spraying. Survival on the residue ranged from 67.1 percent at the lowest to 2.5 percent of the population at the highest concentration. At the normal concentration, 26 percent of the eggs and 14 percent of the mobile stages survived the spray and 9.2 percent of the population survived on the residue.

The results show a marked reduction in the population of P. persimilis at the normal concentration, which is in agreement with earlier investigations (McClanahan 1970, Binns et al. 1971).

Chloranilformethan was applied in four concentrations, from 0.00321 percent to 0.0514 percent (N = 0.01 percent). The eggs were resistant. Of the mobile stages, 70.0 percent survived the lowest concentration and 43.0 percent the highest. On the residue, 91.8 percent of the population survived the lowest concentration, and 12.2 percent survived the highest. At the concentration of 0.0128 percent, 63 percent of the mobile stages survived spraying and 23.5 percent survived the residual effect.

The tests revealed that this pesticide has a comparatively weak initial effect on predatory mites, but a rather high residual effect. At normal concentration, at least some of the population will survive the treatment.

Phyrazophos was applied in five concentrations, from 0.0041 percent to 0.0656 percent (N = 0.02 percent). None of these had initial effect against eggs. At the lowest concentration, 77.1 percent of the mobile stages survived, while only 1.4 percent survived the 0.0164 percent concentration. There was 89.3 percent surviving on the residue of 0.0164 percent and 17.9 percent of the population survived the 0.0656 percent pyrazophos residue.

The experiments showed that pyrazophos in an integrated programme certainly should not be used in concentrations higher than 0.016 percent. At that concentration it was relatively nontoxic as a residue, however it killed most larvae and adult mites, but not the eggs.

Triforine was tested in four concentrations from 0.01 percent to 0.08 percent (N = 0.02 percent). The fungicide was without effect on eggs, while 31.7 percent to 49.9 percent of the mobile stages survived at the described concentration range. There was no residual effect.

Of the pesticides listed in Table 5, triforin resulted in the least overall reduction of P. persimilis. Applied at the normal concentration, it will nevertheless result in a certain reduction of the population, as about 60 percent of the mobile stages will be killed.

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STUDIES AND EXPERIENCES ON THE BIOLOGICAL CONTROL OF THE MOST IMPORTANT PESTS ON GLASSHOUSE CULTURES IN FINLAND

by

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Research on the biological control of pests in glasshouse cultures started in Finland in 1965 when the first experiments were carried out to test the efficiency of the predatory mite (Phytoseiulus persimilis) in the control of the two-spotted spider mite (Tetranychus urticae). The control of this pest in commercial cultures began in 1970.

The biological control of the greenhouse whitefly (Trialeurodes vaporariorum) by the parasitic chalcid wasp (Encarsia formosa) started in 1973 after testing research results obtained in other countries with a few experiments in commercial cultures.

For some years intensive research has been carried out in the possibilities for biological control of aphids, especially of Myzus persicae, Macrosimphum euphorbiae and M. rosae. In experiments, also in commercial cultures, results on the efficiency have been quite promising with the ladybeetles (Coccinella septempunctata and Adalia bipunctata), the predatory midge (Aphidoletes aphidimyza) and the lacewing (Chrysopa carnea), however, these control agents are not yet being used by farmers.

Research on the biological control of the onion thrips (Thrips tabaci) started this spring.

Biological control of the two-spotted spider mite - "pest in first" or "natural infestation" method

When the biological control of the two-spotted spider mite commenced in 1970 22 per-cent of the 500 farmers growing glasshouse cucumbers used the predatory mite on a total area of 11 hectares. In 1974 and 1975 70 percent of the farmers were users of the predatory mite, and it was used on a total area of 31 hectares. All the farmers based their control on the "natural infestation" method by introducing one predatory mite against each ten

two- spotted spider mites in initial stages of infestation. Subsequently the stand is inspected weekly and predatory mites are transferred if required to such places of the stand which show too high number of two-spotted spider mites. The farmers have learned the method well and almost always a complete control has been obtained. Use of pesticides has been unnecessary.

The last meeting in Littlehampton in 1973 agreed that an experiment should be carried out both in Finland and in France to compare results obtained by the "pest in first" and the "natural infestation" methods.

In Finland the experiment was carried out in 1974 during the growing season. Two 1000 m^3 glasshouses were used, each with 630 plants. The "pest in first" method was tested according to instructions received from Dr. N.W. Hussey by letter. Eight days after planting each plant was infested with 20 females of two-spotted spider mite or altogether 12 600 mites were used. When the stage of damage was 0.4 (Hussey and Parr 1963) two predatory mites were put on every second plant, or a total of 630 mites in all.

The "natural infestation" method was tested by putting one predatory mite against 10 two-spotted spider mites as soon as these were seen. When this happened 52 plants were infested by two-spotted spider mites and 450 predatory mites were put on the plants accordingly. The predators were transferred five times during the growing season to such places where they were low in numbers.

Both methods resulted in equally good and complete control. The number of two-spotted spider mites and predatory mites was well balanced during the whole growing season from the beginning of March till the end of September. The "pest in first" method, however, proved more expensive than the "natural infestation" method. The "pest in first" method required more predatory mites and infestation of plants with two-spotted spider mites was more time consuming than the weekly inspection of the stand and transfer of predatory mites in the "natural infestation" method. A summary of the research results is in the press (Markkula and Tiittanen 1976).

Based on this research a conclusion was drawn that the "pest in first" method will not be recommended to Finnish farmers as it would not be of any advantage to the farmers, which have learned well and become used to the "natural infestation" method. The Finnish farmers purchase the predatory mites from Kemira Ltd at a cost of 52 mk or about 63 French francs per 100 individuals at present. The farmers themselves place the predatory mites into the stand as soon as the first symptoms of damage by the two-spotted spider mite appear. The farmers also know well how to transfer the predatory mites and the two-spotted spider mites into necessary places to maintain the balance.

So far the biological control of the two-spotted spider mite is practised only in cucumber cultures. Its use has been tested also in ornamental plants, primarily in rose and chrysanthemum cultures. Both positive and negative results have been obtained in these tests. During the first part of the growing season or from February till mid-April the temperature is too low for the predatory mite. During the period of the worst damage of the two-spotted spider mite or from May through August the predatory mite gets on well, however, during this period the regular control of aphids with insecticides also destroys predatory mites.

The biological control of the greenhouse whitefly

The biological control of the greenhouse whitefly was started with a few commercial tomato and cucumber cultures in 1973. Kemira Ltd already took care of the mass rearing of predatory mites and the sales to farmers, and now the same firm imported into Finland parasitic wasps from England and the Netherlands. The first experiences were so positive that testing was expanded and in 1975 Kemira Ltd started the mass production of parasitic chalcid wasps as well. At this stage 100 vegetable farmers, half growing tomatoes and half cucumbers, obtained parasitic chalcid wasps through Kemira Ltd. According to an enquiry sent to the farmers on the efficiency of the control, 78 percent of the tomato growers had obtained good results, 7 percent satisfactory and 14 percent reported that the results were poor. Amongst cucumber growers the results were somewhat less satisfactory with 35 percent good, 42 percent satisfactory and 21 percent with poor results.

From the very beginning the "natural infestation" method has been applied also in the biological control of the greenhouse whitefly. The parasites are placed into the stand as black scales as soon as the farmers observe the first flying greenhouse whiteflies. Recommended "dose" is 6 parasites/m^2 and the aim is to introduce them in two or three lots at weekly intervals.

The biological control of aphids

Control of aphids has been studied by working out the most suitable ration of abundance between the control agents and the prey in the beginning of the control. Adalia bipunctata, C. septempunctata and Aphidoletes aphidimyza have been used in these studies. Another line of research has been to solve problems involved in mass production of these organisms.

It seems not to be possible to establish a stable and continuously reproducing population of ladybeetles in glasshouses. The best result has so far been obtained by introducing large numbers of ladybeetle eggs or larvae into the stand soon after the first aphids have been seen, and adding more predators whenever the aphids have appeared again. Thus the procedure has been similar to chemical control.

Because the transfer of larvae into the plants requires much work it is more practical to place eggs of ladybeetles into the stand. In cultures the ladybeetles lay their eggs on the leaves of plants or on filter papers. Pieces of leaves or paper with eggclusters are then placed on the plants to be protected. In the development of mass production of ladybeetles the main study has been to find out a suitable artificial diet. This was considered necessary because mass production with live aphid diet does not seem to be economically feasible. The development of artificial diet was started already in 1973.

Up till now the best suited mixture for ladybeetle diet is composed as follows:

water 220	one chicken egg
wheat germs 5 g	french beef liver 50 g
brewer's yeast 7 g	honey 10 g
salt mixture 1 g	vitamines B, C and E
casein 3 g	inhibitors of fungi and bacteria

When the larvae of A. bipunctata were fed on aphids or on artificial diet, 90–95 percent and 75–80 percent became adults, respectively. Adults grown on artificial diet did not lay eggs if their feeding continued with the same diet as used for larvae. However, these adults laid fertile eggs when fed on aphids (Kariluoto et al. 1976). Later on it has been noticed that the adults lay eggs even if they do not get any aphids at all, but a diet consisting of 70 percent of fresh liver and 30 percent of sucrose which is more simple than that given to the larvae. Egg laying adults must be fed daily to maintain a continuous egg production. Experiments have shown that a high humidity of the environment (75–90 percent RH) in the larval cultures caused more larvae to become adults.

The artificial diet was developed especially for A. bipunctata. However four other ladybeetles species have been developed into adults with the same composition of artificial diet. The species and percentages that became adults are: Hippodamia tredecimpunctata 50–60 percent, Adalia decempunctata 10–30 percent, Coccinella transversoguttata 30–40 percent and C. septempunctata 30–50 percent.

As to the use of the predatory midge in the biological control of aphids, a stable midge population develops in glasshouses and prevents the aphids to increase in numbers. We have not been able to eradicate the midges in all of our glasshouses irrespective of innumerable treatments with demethoate, malathion and mevinfos. They make their appearance regularly in our aphid cultures during February when there is light enough.

A sufficient number of midges was obtained rapidly in experimental glasshouses on roses and green peppers by introducing three predatory midge pupae per each ten peach aphids on their feeding grounds at a very early stage of aphid infestation. If less predatory midges were distributed the aphids had time to increase and started to cause damage before the effect of midges started to be prominent.

It has been able to develop such a simple mass production method for predatory midges that it is easy to apply for "industrial production".

The predatory midge is at present the most promising agent in control of aphids because it rapidly develops into a stable population in glasshouses and its mass rearing is easy.

The biological control of thrips

Onion thrips is known to have numerous natural enemies, parasites, predators and pathogens. Studies have been made at least on the efficiency of predators and pathogens in the biological control, but the results have not yet been used in practice (e.g. Carl 1972 and 1975). Studies have started this growing season in Finland to clear up the role of native predatory species of thrips, how they thrive, and what is their efficiency in the control of onion thrips in glasshouses.

Conclusions

Biological control of the two-spotted spider mite has come to stay in practice. Predatory mites are used to control the two-spotted spider mite by 70 percent of the farmers growing glasshouse cucumbers. Farmers growing ornamentals are ready to use predatory mites as soon as the biological control of aphids is possible.

The practical control of greenhouse whiteflies has started. During the last growing season 5 percent of the 2000 tomato and cucumber growers used parasitic chalcid wasps to control greenhouse whiteflies on a total area of 9 hectares.

The biological control of aphids in commercial glasshouse cultures can be started as soon as a sufficiently economical solution is available for the mass production of control agents.

After the good experience in the use of predatory mites the Finnish glasshouse farmers are ready to experiment with any new biological control agent and use it in commercial scale. They have learned to believe and trust in biological control.

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PROGRESS IN BIOLOGICAL CONTROL IN GLASSHOUSES IN SWEDEN

by

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Swedish growers of glasshouse crops began to discuss biological control of pests about ten years ago. Growers of cucumbers had especially great problems with severe attacks of red spider mites in their cultures. So, when the possibility to control this pest with a predatory mite showed a possible solution to the problems, this matter was enthusiastically discussed. Some introductory experiments with the predatory mite Phytoseiulus persimilis were made but organised activity in this field was begun first in 1971. The situation then was very precarious for many growers. It was almost impossible to control spider mites with permitted pesticides because of resistance to these compounds. Also demands from the public for vegetables with the smallest possible residues of pesticides and stricter rules concerning the use of these chemicals necessitated united efforts to solve the problems with red spider mites on glasshouse cucumbers. For this purpose a committee was established in 1971 with representatives of the growers, the Advisory Service, the Agricultural College of Sweden, Horticultural section and The National Swedish Plant Protection Institute.

As no one was working on biological control of glasshouse pests in Sweden, this was the only way to carry this matter. The committee started experiments for control of spider mites on cucumbers with the predatory mite Phytoseiulus persimilis in 1972. These experiments were made on a practical scale with the growers. Ten experiments using different modes of applying predatory mites in different numbers on the cucumber plants were made. The predatory mites for this purpose were reared on bean plants in small glasshouses. The results of these experiments were very good and a report on this was submitted by Mr. G. Svensson, of The National Swedish Plant Protection Institute at the conference at Littlehampton in September 1973.

The next step of the committee was to arrange for a large scale production of Phytoseiulus persimilis for commercial use.

Everybody concerned agreed on the convenience of having large scale rearing of predatory mites within the country. These discussions resulted in the commissioning of a private firm, AB Anticimex, to manage the rearing and distribution of Phytoseiulus persimilis on the behalf of the Swedish growers of cucumbers. Anticimex is a firm which produces pathogen-free mice for medical research at institutes mainly in Europe and in the United States. Anticimex is also the only firm in Sweden which executes eradication of pests in storehouses and homes. In 1974, in Stockholm, this firm started rearing predatory mites on bean plants in closed chambers illuminated with artificial light and ventilated with filtered air. Predatory mites were distributed to about 10 ha of glasshouse cucumbers. The results in practice were very good and interest in controlling spider mites with Phytoseiulus persimilis increased considerably. In 1975, Anticimex distributed predatory mites to 15 ha of glasshouse cucumbers, but results were not as good, and some failures occurred. This was partly due to the extremely hot summer, with temperatures of more than 30° C in the glasshouses for long periods. These temperatures are not suitable for Phytoseiulus persimilis which move to the lower parts of the plants leaving the spider mites at the top of the plants. Another reason for the poor result in 1975 was that the firm Anticimex had moved the production of predatory mites to other rooms, less suitable for that purpose. The result of this was, that some of the predatory mites produced were in bad condition or dead when they reached the growers. A third reason for the bad result could also be in some cases impatience and stinginess on part of the growers. In some cases, they were not able to wait long enough for the predatory mites to do their work and they also put too few predatory mites on the plants.

At the prospect of 1976 the committee proposed that the firm Anticimex should move the production of predatory mites to southern Sweden where the main growing of cucumbers is situated. The firm agreed and now the production of Phytoseiulus persimilis is performed by Anticimex in rented glasshouses in South Sweden, not far from the branch station of the National Swedish Plant Protection Institute.

This year the distribution of predatory mites is entirely handled through the growers cooperative in Helsingborg, situated on the west coast of Southern Sweden. The cooperative has the sole right of selling predatory mites and Encarsia formosa in Sweden. There are two different systems of selling predatory mites for members of the cooperative. In both systems a basic fee is paid by all members of the cooperative based on the quantity of cucumbers delivered from respective growers to the cooperative (0.3 Skr per 100 kg cucumbers delivered). For the remaining fee two alternatives are possible. The growers may come to an agreement called "full service" with Anticimex. This means that the growers are assisted by the firm's adviser when predatory mites are put into the glasshouses for the first time. If necessary, the adviser makes two or three further inspections in these

glasshouses and at the same time supplies more predatory mites when needed. The total cost for this service, including predatory mites is, besides the basic fee 0.50 Skr per m^2 glasshouse area.

According to the second alternative of paying, the growers, besides the basic fee, pay 0.25 Skr per unit.

Growers, who are not members of the cooperative, do not pay the basic fee but are charged 0:42 Skr per unit. The smallest number of predatory mites delivered is one thousand.

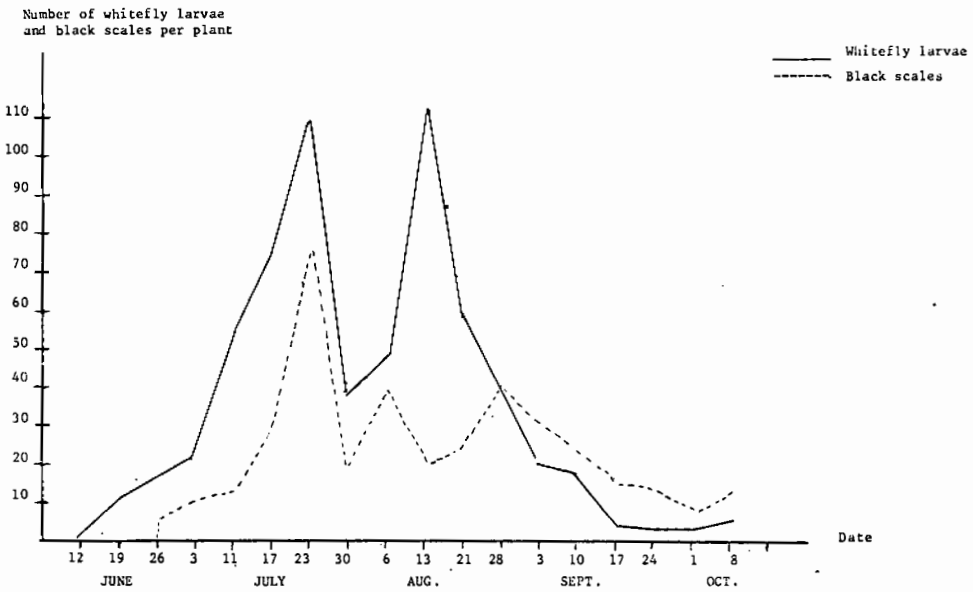
Predatory mites are put into the glasshouses only when a natural infestation of red spider mites has occurred. An intentional infestation with red spider mites followed by an introduction of predatory mites later on has been tried in 1974 with rather good results but it is almost impossible to get the growers to intentionally infest their cultures with red spider mites.

Biological control of whiteflies

Under the direction of the committee, experiments with biological control of whiteflies in tomato growing using the parasite Encarsia formosa were begun in 1974. Six experiments were done on a practical scale. In most cases ten black scales of Encarsia formosa per m^2 were put into the glasshouses on two occasions. The first introduction was made as soon as a few whiteflies per 100 m^2 were observed. In one case, however, a heavy infestation existed already when the experiment begun. No fewer than 1,100 whiteflies per 100 m^2 occurred in one glasshouse. In spite of three introductions, each of 10 black scales per m^2, it was not possible to prevent a strong development of the whitefly population resulting in heavy occurrence of sooty moulds. The other experiments were, however, on a whole successful. A typical development of the populations of whiteflies and Encarsia formosa is illustrated in diagram 1. This illustrates the development in one of the successful experiments. Ten black scales on each occasion were introduced in the glasshouse on the 12th and on the 26th of June. On the 12th of June the number of adult whiteflies was 6–7 per 100 m^2.

Diagram 1. The development of the two insect populations in one of the experimental glasshouses.

(Andersson, K. & Ekbom, Barbara 1975. Växtskyddsnotiser 39, 114-119)



As can be seen two peaks in the development of whitefly population occurred, one in the middle of July and the other one month later. Then the whitefly attacks diminished and were of little consequence until the culture was cleared in October.

The reason for the second peak may be that the number of parasites became too large in proportion to the number of the fourth larval stage of the whiteflies. In such a situation the parasites will also attack the younger larval stages which are not suitable for survival. These results in a diminishing number of Encarsia formosa and an increasing number of whiteflies.

The successful experiments resulted in a great interest in control of whiteflies with the parasite Encarsia formosa and the committee commissioned the firm Anticimex to rear also Encarsia formosa on behalf of the Swedish growers. This production was begun in 1975 in Stockholm. Black scales have been imported from Holland when this production was insufficient.

From this year, even the production of Encarsia formosa has been moved to South Sweden. For this purpose the firm has hired glasshouses at the Agricultural College at Alnarp, near Malmö.

As mentioned before the distribution of black scales is also entirely handled by the growers cooperative. Only one pricing of black scales occurs. Members of the cooperative pay 0.10 Skr per unit and others pay 0.12 Skr per unit. The smallest number of black scales delivered is three thousand.

Special problems

Special problems, besides those occurring when biological and chemical control are combined in an integrated control programme, include first of all the great need of advise and information to the growers. This may be difficult to supply. The best solution is probably, that those producing predators and parasites could also supply the advisory work concerning the integrated control in question. This is also what the firm Anticimex partly has assumed in regard to those growers who make use of the so called "full service" agreement.

Another problem in our country is found in those glasshouses where cucumbers and tomatoes are grown on mineral wool. In this substrate especially, the plants may be very heavily attacked by fungus diseases which necessitates an intensive control-programme with fungicides further complicating the integrated control-programme.

Being short of scientists working with biological control in glasshouse crops, we had to rely on scientists from abroad in the beginning of our work in this field. We are especially indebted to Dr. L. Bravenboer and his colleague Dr. J. Woets of the Glasshouse Crops Research and Experiment Station at Naaldwijk. Their help and their advice has been of very great value to us and I herewith wish to offer the committee's thanks to them for this and as well as for the invitation to this conference.

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BIOLOGICAL AND INTEGRATED CONTROL IN GLASSHOUSES IN POLAND

by

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During the last years dynamic development of glasshouse production took place in Poland. Several big glasshouse farms have been built, in which the area of glasshouses amounts to 6-16 ha. Increasing the area of glasshouse crops needs the elaboration of modern methods of protection of these crops against pests and diseases. Among the methods applied in Poland for the protection of glasshouse cultures the introduction of biological methods to the practice of plant protection is of great importance. The proof of this is the construction this year of a special glasshouse (300 sqm of area) with additional laboratory spaces, designed for mass rearing of beneficial insects. With the increase of the area of glasshouse crops where biological control is applied the construction of further glasshouses for mass rearing of entomophagous organisms is provided for.

The activities carried out in Poland concern research upon the biological and integrated methods of control of red spider mites (Tetranychus sp.), glasshouse white fly (Trialeurodes vaporariorum Westw.) and aphids.

Biological control of red spider mites (Tetranychus sp.)

Biological control of red spider mites in glasshouses is based on the use of the predatory mite (Phytoseiulus persimilis). This method is applied specially in the production of glasshouse cucumbers on many horticultural farms. The recommended practice of predator application is a weekly control of all the plants in the glasshouse and placing the predators on the plants, on which red spider mites are found. This method ensures effective control of red spider mites, and the number of predators introduced to the glasshouse during vegetative season amounts to 6-10 individuals per 1 sqm.

The research carried out so far showed lower usefullness in Poland of the method of predator application elaborated in England (Hussey and Bravenboer, 1971). Under Polish conditions the cucumbers are planted in the glasshouse in the period from mid January till the end of March, and main appearance of red spider mite takes place from mid May till the end of June, and the protection of the plants against red spider mite immediately after cucumber planting is not of significant importance. Moreover the increased amount of manpower, the unequal development of red spider mite and Phytoseiulus persimilis on the plants and the need for repeated introduction of predators after about two months since the beginning of control were observed.

P. persimilis is more and more used for the control of red spider mites on roses. The same method of predator application is used as on cucumber. On roses unfavourable conditions for P. persimilis development occur during the period June till August (high temperature, low relative humidity) and at that time individual chemical treatments are recommended in order to reduce red spider mite populations. For these treatments preparations of low toxicity for the predator are used: Roztoczol extra 8 (active ingredient tetradifon), Milbex 50 WP and Kelthane.

P. persimilis is also used for the control of red spider mites on tomatoes and potted plants: Croton, Diffenbachia, Cissus and Anthurium (Pruszyński, 1976).

For aphid control in the presence of P. persimilis the selective aphicide Pirimor, and for disease control all the fungicides except Morestan, are recommended.

Biological control of glasshouse white fly (T.vaporariorum)

Biological control of the glasshouse white fly by using Encarsia formosa Gahan is experimentally carried out in production glasshouses.

Best results in the control of glasshouse white fly have been obtained on spring growing of glasshouse tomatoes, grown in Poland from December till mid July. Permanent introduction of the parasite from the moment of glasshouse white fly appearance, during three months, can stop the development of the pest and reduce its number to initial density.

The research results have shownthat for the following factors are of great importance for the effective introduction of Encarsia formosa: 1 - initial density of glasshouse white fly, 2 - adequate number of Encarsia formosa and 3 - correct timing of introduction and length of introduction period.

The introduction of adults of E.formosa on glasshouse tomatoes has given the most satisfactory results. This method of introduction was most effective, it ensured immediate activity and allowed for effective control.

The introduction of E.formosa was started at the moment of first appearance of glasshouse white fly, when the mean number of adults amounted to 0.1 - 1.5 per plant. The number of introduced individuals of E.formosa varied according to pest density and amounted to 1-5 adults of the parasite per one tomato plant. The control effect was positive, when the initial ratio of parasite adults to white fly adults was about 1:2 at the early stage of introduction and 1:1 at later stages. The distribution of the parasites at the moment of introduction in the glasshouse was very important for effective control. Best results have been obtained in the case of weekly introductions of E.formosa in the glasshouse in the following proportions: about 20 percent of total number of individuals in the first weeks

of introduction (March), about 45 percent in next 4-5 weeks (April) and about 35 percent in next 4-5 weeks (May and the beginning of June). E.formosa introduced at too low numbers in the first period does not ensure good control results even in the case of introductions of high numbers of parasites at a later period. In the cases of late and scarce appearance of greenhouse white fly on tomato cultures, 1 to 1.5 E.formosa adults per plant were sufficient. The development of parasitization in the glasshouse can be presented by a simplified formula: $P = a.b^n$, where P = the degree of parasitization, a = initial density of introduced parasites, b = coefficient of population development, n = number of generations. The number of generations is one of the factors determining the effectiveness of control. Maximum parasitization of T.vaporariorum larvae is in most cases observed at 75 days after first introduction, when the fourth generation of E.formosa starts to parasitize. Our research shows less effectiveness of E.formosa in the control of glasshouse white fly in the case of mass appearance of the pest, and also on autumn tomatoes and Gerbera plants, when the conditions (temperature and light) are unfavourable for the development of E.formosa. In these cases chemical or integrated control of glasshouse white fly is recommended (Kowalska and Szczepańska 1969, 1975, 1976).

Results of research on the toxicity of chemical preparations for E.formosa showed that some pesticides are practically non-toxic for the development stages of the parasite inside the host larvae. The fungicides Dithane, Benlate and Morestan and the aphicide Pirimor showed selective action. The pesticides belonging to the group of pyrethroids: Bioresmetrine, Bioresmetrin PB, Decis PB and K Othrine showed low toxicity to the eggs and larvae of E.formosa and were non-toxic for the pupae. Bioresmetrine PB, however, applied 2, 3 or 4 times during the complete development cycle of the parasite (at weekly intervals) stopped the development of E.formosa. Insecticides containing dichlorfos and malathion were of medium toxicity to E.formosa, Actellic 50 EC, however, was very toxic. Research on the populations of E.formosa which survived chemical treatments, as well as research on further generation (F_1) showed, that characteristics like adults longevity, degree of parasitization of T.vaporariorum larvae, dynamics of development of next generation and the emergence of adults are somewhat reduced but they do not differ significantly from control populations. The results obtained will be the basis for the elaboration of integrated control of glasshouse white fly. This year the experiments on biological control of glasshouse white fly on glasshouse cucumbers have begun.

Biological aphid control

For many years research is carried out on the effectiveness and possibilities of use in biological aphid control in glasshouse cultures of the following aphidophagous insects: Aphelinus asychis Walker (Hymenoptera, Eulophidae), Diaeretiella rapae McInt. (Hymenoptera, Aphidiidae), Aphidoletes sp. (Itonididae) and Chrysopa carnea and other species of golden-eyed fly (Neuroptera, Chrysopidae). Experiments are carried out on asparagus, tomatoes and

cucumbers. Good results have been obtained in the control of green peach aphid (Myzus persicae) using Diaretiella rapae on tomatoes. The parasite maintained itself very well in the environment and it parasitized the aphids in considerable degree. On asparagus best results were obtained through introduction in the glasshouse of eggs of golden-eyed fly, and especially of Chrysopa perla L.

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CB .6222

PROGRESS REPORT ON THE INTEGRATED PEST CONTROL IN GLASSHOUSES IN HOLLAND

by

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Glasshouses in the Netherlands cover an acreage of 7900 ha (4700 ha with vegetables, 3100 ha with flowers and 100 ha with fruit trees). In vegetable growing there is a main cropping period (6— 8 months) of tomatoes, cucumbers, sweet peppers, followed by autumn crops (3 months) such as cucumbers, tomatoes and lettuce. In winter, the glasshouse is ecologically an uninhabited island. The windows are premanently closed and outdoors it is cold. Biological control is mainly done in the main crops because of the advantages of the isolated situation during several months.

The main crops of tomatoes, gherkins, cucumbers and sweet peppers cover together 80 percent of the glasshouse vegetable acreage (including non-heated tomatoes).

Tomato

The main crop acreage in 1975 covered 2060 ha. Night temperature in winter is 15° C, in day time it is 22° C and is allowed to increase proportional to the radiation intensity. On 600 ha Encarsia formosa controlled the greenhouse white fly successfully, i.e. on 30 percent of the acreage of heated tomato houses (table 1). The application is usually done in four fortnightly introductions of black scales, at least 1250 scales per introduction per 1000 m^2 (1975). The decision factor for success is a good timing of the first introduction when the first young larvae of the pest are present (Van Alphen, these proceedings). The timing is decided upon by the grower and dealer together (Woets, 1973). These larvae are offspring of the first generation of white flies that usually are introduced into the glasshouse as larvae or pupae on the young plants. The introduced Encarsia-scales, delivered on cucumber leaves, are dispersed through the whole glasshouse in small numbers of pieces of leaf and put down on the young plants, upside down. The results of the system are satisfactory and independent of the month of introduction (van Lenteren, these proceedings). In several cases a fifth introduction or an extra dose is given for security reasons. Due to the good information and guidance of the grower by the produoer and his dealers the number of failures is remarkably small.

TABLE 1. Acreages in (ha), on which successful biological control was achieved with Phytoseiulus in cucumbers and sweet peppers and with Encarsia in tomatoes in dutch glasshouses.

	Cucumber			Tomato *			Paprika		
	planted before June	with Phyt.	in %	planted before June	with Enc.	in %	planted before June	with Phyt.	in %
1969	860	25	2	2200	-	-	-	-	-
1970	870	200	25	2380	-	-	-	-	-
1971	750	75	10	2430	4	-	70	-	-
1972	840	100	12	2290	20	1	75	-	-
1973	790	150	20	2040	120	5	150	10	7
1974	785	150	20	2090	400	20	160	20	12
1975	782	150	20	2060	600	30	160	20	12

* non-heated houses excluded

Red spider control by Phytoseiulus persimilis A.-H. on tomatoes is not as good as on cucumbers, possibly due to different climatic conditions and different population development of red spider. In nearly all cases Encarsia in tomatoes is integrated with dicofol against red spider.

The control of tomato leafminer (Liriomyza bryoniae Kalt.) can be the limiting factor for biological control. From year to year the amount of damage caused can vary considerably. Several organo-phosphorous compounds are used, but none of them is harmless to the parasites, neither the adults nor the ones in the scales. During propagation sulfotep can be smoked, but it is impossible to apply this insecticide after planting in a glasshouse in which Encarsia is going to be introduced, because there is an adverse effect on the adults for at least 3 weeks after the application of sulfotep. Some growers dust malathion twice a week as a prevention during the first 3-4 weeks after planting, as is advised by the producer. Others pick off the leaves with fresh mines; this gives good results, but is mostly considered as too labourious. The number of cases where the leafminer causes trouble after Encarsia introduction is increasing which causes considerable concern. A way out on short terms could be a soil drench with an OP-compound to kill the pest in the soil (at population and at hatching).

Vasates lycopersici Massee (tomato gall mite) has not been recorded since its appearance in 1973 (30 holdings) and 1974 (3 holdings).

Integrated scheme for tomatoes, 1976

greenhouse white fly	-	Encarsia formosa
red spider	-	cyhexatin (Plictran), dicofol (Kelthane), fenbutatinoxide (Torque), Phytoseiulus
tomato leaf minor	-	malathion dust before Encarsia picking off leaves with smaller mines, (organo-phosphorus compounds)* in nursery: sulfotep (Bladafum)

* integration impossible

Cucumber

The temperature regime in day time is at least 23°C, rising in proportion to the radiation input, and at night 18°C. The application of Phytoseiulus is stable for some years already amounting to 20% of the main crop acreage (150 ha, table 1). This is due to several factors. Till now good acaricides are available for the control of the red spider mite. The new all-female cultivars are more susceptible to damage of red spider mite, as a consequence the economic damage threshold has become lower, having less room for population fluctuations of the red spider mite and thus for biological control. During a warm summer period stronger ventilation is needed. Resulting in a lower humidity in the top of the crop which induces the predator to avoid the upper leaves. It is then necessary to spray the tops with selective chemicals as cyhexatin (Plictran), fenbutatinoxide (Torque) or propargite (Omite).

The greenhouse white fly is controlled by hydrocyanic gas. Only a few growers introduce Encarsia. They have long term success only after timing the introduction at very low numbers of white fly larvae. High doses of Encarsia are required as in the English system after planned pest introduction (Hussey and Bravenboer, 1971). The control of Thrips tabaci Lind. by organo-phosphorus compounds was a limiting factor for Phytoseiulus application. Now it is clear that the predator population can survive application of sulfotep and dichlorvos. This is understandable as resistance against some compounds of the OP-goup (parathion, demeton-s-methyl, mevinfos, diazinon) has been found (Schulten, Van de Klashortst and Russell, 1970). Cotton aphid is controlled by Pirimicarb.

The only problems with fungicide integration concern the BCM group. Till now there are three mildew-controlling fungicides, which do not harm the predator. Two of them are OP-compounds and are expected to interfere if Encarsia is introduced.

Integrated scheme for cucumbers, 1976

red spider	-	Phytoseiulus, as supplement: cyhexatin, (Plictran), fenbutatinoxide (Torque, propargite (Omite)
greenhouse white fly	-	hydrocyanic gas
mildew	-	pyrazofos (Curamil), Plondrel, triforine (Funginex)
Thrips tabaci Lind.	-	diazinon, nicotine, dichloorvos * sulfotep (Bladafum)*
cotton aphid	-	pirimicarb, diazinon

* integration is possible if applicated carefully

Sweet pepper

The temperature in February-March is at least 23°C during day time and 18°C at night. This crop gives a good example of limiting factors for biological control caused by minor pests. Thrips tabaci Lind. and Hemitarsonemus latus Banks (broad mite) are the most important ones. The last one is new in vegetable growing. Myzus persicae is controlled by Pirimicarb, other pests which occur frequently are Lygus pabulinus L. and Liocoris tripustulatus F. and caterpillars (Diataraxia oleracea L.), which are well controlled by tricholorfon (Dipterex) and carbaryl. The lesser susceptibility of Phytoseiulus for OP's is a favourable factor for its increased use.

Integrated scheme for sweet peppers, 1976

red spider	-	Phytoseiulus, as supplement: cyhexatin (Plictran), fenbutatinoxide (Torque)
Thrips tabaci Lind.	-	diazinon, dichloorvos, ** sulfotep (Bladafum) **
Hemitarsonemus latus Banks (broad mite)	-	(dicofol) *, cyhexatin (Plictran),
Lygus pabulinus L.	-	(trichlorfon (Dipterex)) *
Diataraxia oleracia L.	-	(carbaryl) *

* integration impossible

** integration possible if application is timed carefully

Gherkins

This crop covers nearly 300 ha and this acreage includes many non-heated glasshouses. Application of Phytoseiulus started in 1974 and 1975 by cooperation of several growers, extension officers and the producer of natural enemies. The BCM-fungicides can be integrated with Phytoseiulus if the application is carelly planned as a drench.

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CB .6223

OBSERVATIONS ON THE PREDACIOUS BEHAVIOUR OF PHYTOSEIULUS PERSIMILIS

by

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Among predacious species belonging to the family Phytoseiidae Phytoseiulus persimilis is distinguished by high prey demands and high voracity. Many factors, however, influence on the number of prey consumed by P. persimilis and knowledge about these can be of great importance for more effective and economic use of the predator in biological control of red spider mites.

Influence of development stage of predator on the number of prey consumed by P. persimilis

Based on various observations it can be stated, that the larvae of P. persimilis practically do not feed, and the trials in the consumption of red spider mite eggs are in most cases unsuccessful (Laing 1968). Proto- and deutonymphs of P. persimilis are characterized by considerable mobility and the ability of food searching, they feed on the eggs and larvae of red spider mite. Laing (1968) stated, that the protonymphs of the predator eat on an average during 24 hours 4.4 and the deutonymphs 6.0 eggs of the red spider mite.

In our own investigations the number of prey eaten by the adults of P. persimilis in various periods of their life has been determined (Table 1).

TABLE 1. The feeding of females during various periods of their life-cycle and of P. persimilis males on various development stages of Tetranychus urticae

T. urticae stage	Female						Male	
	Preoviposition period		Oviposition period		Postoviposition period			
	Range	Average	Range	Average	Range	Average	Range	Average
Eggs	0-27	13.0	6-41	22.2	2-12	6.3	1-21	11.9
Larvae	0-23	7.8	1-39	20.9	2-14	6.2	1-16	6.1
Protonymphs and Deutonymphs	3-17	6.9	12-30	17.6	-	-	1-10	4.8
Adults *	-	-	2-12	6.0	-	-	-	-

*/ Adults less than 24 hr old to avoid egg deposition

The experiments were carried out at 21°C and in each combination about 140 observations were made (10 specimens of predator during two weeks, everyday control and prey supplement).

In these experiments the highest number of prey was eaten by P. persimilis females during the oviposition period, a lower number of prey was consumed by the females during the preoviposition period then by the males, and the lowest number - by the females during the postoviposition period.

Similar observations were made by Laing (1968), who also observed considerable differences in female feeding before, during and after the period of egg laying. Red spider mite eggs were used, as prey and it was stated, that the females ate 7.3, 14.3 and 3.9 eggs during 24 hours, respectively.

Influence of temperature and relative humidity on the number of prey consumed by P. persimilis

An experiment in which female deutonymphs of red spider mite were used as prey was carried out at 17, 21 and 26°C and at 6 levels of relative humidity.

The results obtained show, that an increase of temperature and a decrease of relative humidity cause an increase of the number of prey consumed by the females of the predator (Table 2). The difference in the number of prey consumed at different humidities was 5.7 deutonymphs at 17°C, and 2.8 deutonymphs at 21 and 26°C. The differences in the number of prey consumed at various temperatures fluctuated depending on the relative humidity between 1.6 and 5.7 deutonymphs.

TABLE 2. Influence of temperature and relative humidity on the number of deutonymphs consumed by P. persimilis females

Relative humidity	17°C		21°C		26°C	
	Range	Average	Range	Average	Range	Average
18%	11-15	12.5	6-15	13.5	10-15	14.6
45%	8-15	12.6	4-15	13.7	12-16	14.2
60%	5-13	8.5	4-15	12.1	5-17	13.2
75%	7-10	8.8	2-14	12.7	9-16	13.5
85%	6-10	7.5	6-14	11.1	4-15	13.2
95%	0-10	6.8	7-13	10.7	5-14	11.8

The results presented are confirmed in the works of other authors. Mori and Chant (1966) in their investigations observed higher number of red spider mite females eaten by the predator at low relative humidity. In the Soviet Union Plotnikov and Sadkovskij (1972) stated an increase in the number of red spider mite eggs (from 3.2 to 5.8) eaten by P. persimilis females in the case of a rise of temperature from 21-22°C to 24-25°C. The difference in the number of eggs eaten, at relative air humidities of 60, and 90% amounted to 21 eggs at 21-22°C and 22 eggs at 24-25°C. Uscekov and Beglarov (1968) stated that at 25°C and a relative humidity of 50-70% one female of P. persimilis consumes 21-23 specimens of red spider mite. whereas at the same temperature, but at a relative humidity of 98% - only 11 specimens are eaten.

The majority of investigations on the influence of temperature on the number of prey consumed by P. persimilis is carried out at temperatures varying from 20-30°C. No data are available about the feeding of the predator at temperatures above 30°C. Our own observations show that red spider mite survives better a rise of temperature above 30°C than P. persimilis at about 35°C P. persimilis females stop to feed.

Influence of the period of starvation on the number of prey consumed by P. persimilis

Mori and Chant (1966) in their investigations found no difference in the number of prey consumed by females well fed and after a period of starvation. They observed, however, that the females after a period of starvation fed longer and often a second time on the same prey.

The observations made by us confirm the results obtained by Mori and Chant (1966). In an experiment, in which 2 hrs observations were made on the feeding of females without and after 24 hrs of starvation no differences in the number of prey consumed have been noted. The period over which feeding occurred changed however considerably. Non-starved females fed from 5 to 19 min. on an average, whereas the period of feeding of starved females amounted to 45 min. on an average.

Though, the period of starvation influences the intensity of feeding, it does not cause, however, an increase in the number of prey attacked and consumed by the predator.

Food searching by the predator

In the observations made by us particular patternsin predator searching behaviour have not been noted. In order to determine the way of food searching by the predator (except of accidental contact) an experiment was carried out, in which the females of the predator were placed on a leaf-disc (5 cm of diameter) with eggs of the red spider mite. In the first combination the web has been left, in the second it was removed (Figure 1). Meantime

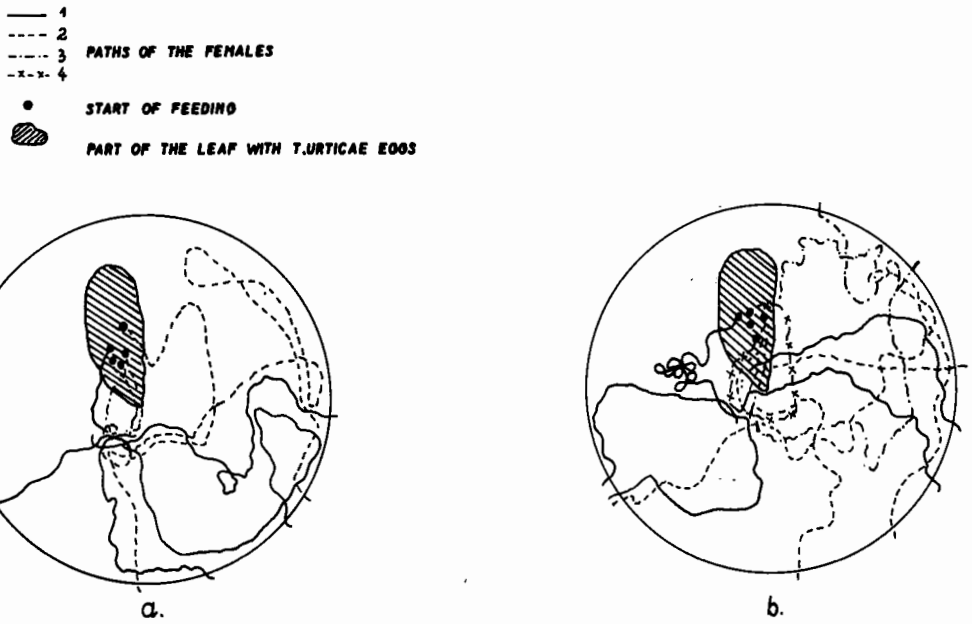

Figure 1. Food searching by P. persimilis females in the case, when the web has been left on the leaf (a) and after its removal (b). Distances covered by 5 females are presented.

necessary for egg discovery by the females of P. persimilis was in the case of web leaving 219.6 sec., and in the case of web removing 432.4 sec., In the presence of a web the females discovered the eggs in general after their second release on the disc, in the lack of the web after the third release. The web spun by red spider mites thus seems to facilitate considerably food searching by the predator.

Migrations of P. persimilis females from the leaves

It has often been observed that the predator females migrate from the leaves before complete destruction of the red spider mites. Plotnikov and Sadkovskij note (1972), that according to their observations the females start to migrate from the leaves, when the proportion of predator to the prey amounts to 1:1.1 and to 1:1.2.

Our own experiment was made on bean plants with two leaves and on each leaf different development stages of the red spider mite were present. The females of predator could easily pass from one leaf to another. In all the cases an excess of red spider mites on the leaves was observed.

The results obtained (Figure 2) show, that the females of P. persimilis preferred more differentiated stages of the red spider mite. In all cases the females migrated from the leaves, when they found only one development stage of the red spider mite.

Thus, apart from the number of prey present, the cause of migration of P. persimilis females from the leaves and plants seems to be the early destruction of part of the development stages of red spider mite. This migration from the leaves is at the same time proof of a considerable adaptation of the predator to the predacious mode of life. Red spider mite left on the leaves serves as the food for emerging and developing larvae of the predator.

The results presented here are part of a larger programme of research on P. persimilis in Poland. In other experiments the influence of various plant species on the development of P. persimilis, the behaviour of the predator, and the influence of number of prey on the development of the predator (Pruszyński 1973) are studied.

Final results will be used to develop the best method of predator application.

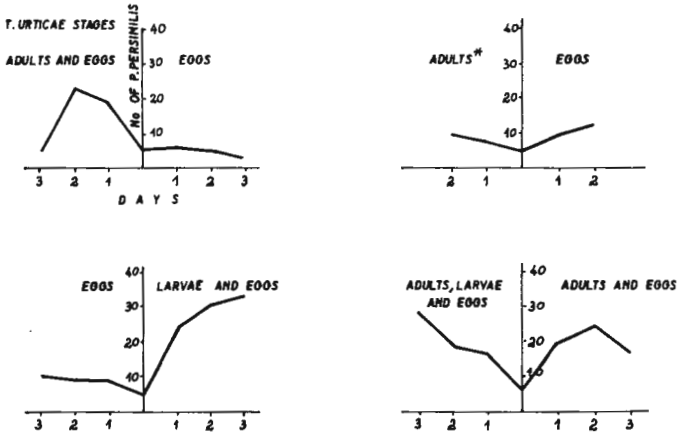

Figure 2. The development of P. persimilis on bean leaves on which red spider mite occurred in various development stages.

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CB .6224

ETUDE DE LABORATOIRE CONCERNANT LA TOXICITE DES PRODUITS PHYTOSANITAIRES POUR *PHYTOSEIULUS PERSIMILIS*

par

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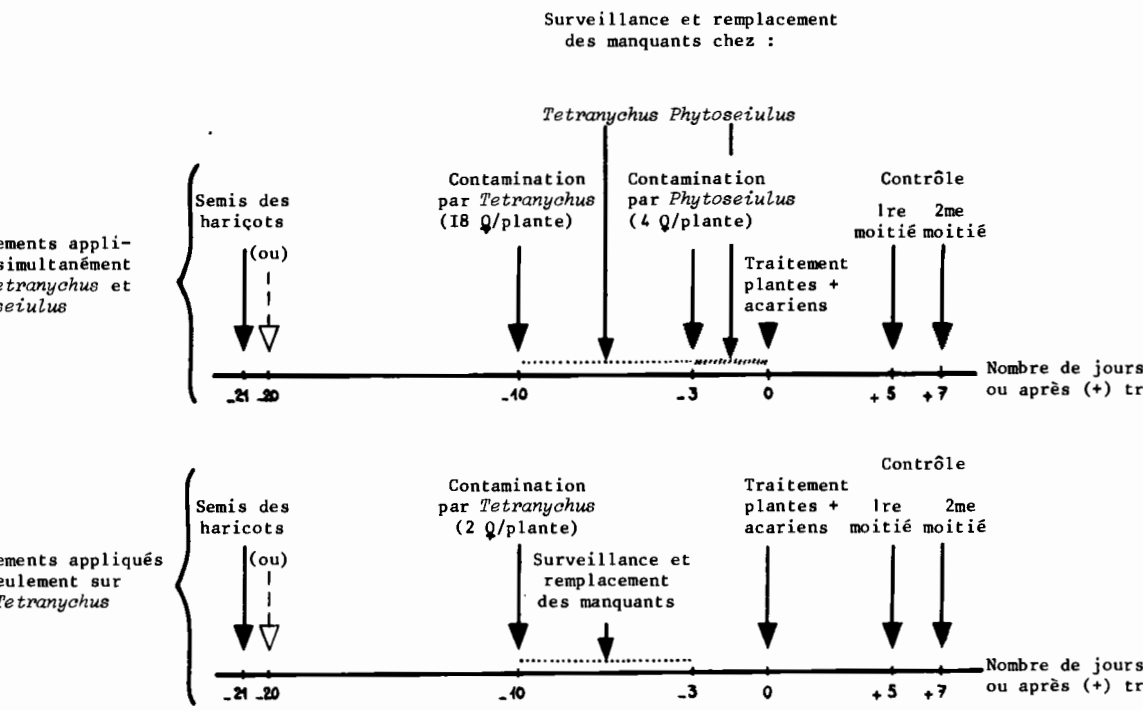
Lorsque nous nous sommes préoccupés en 1972 du problème posé par l'emploi des produits phytosanitaires en présence de *Phytoseiulus persimilis*, nous avons cherché à mettre sur pied une méthode dans laquelle les substances, comme dans les conditions naturelles, auraient la possibilité d'agir par les mécanismes les plus divers et dans laquelle le matériel biologique présenterait, avec celui de la pratique, le maximum d'analogies. Nous avons de ce fait été amenés à concevoir et à mettre à l'épreuve, une méthode consistant pour l'essentiel à appliquer les produits à tester sur plantes entières, contaminées par tous les stades de *Tetranychus* et de *Phytoseiulus*, et à apprécier les effets avec le maximum de recul possible. Jusqu'en 1975 tous les produits ont été testés sur des populations maintenues en permanence sur plantes traitées. Depuis cette époque, et pour essayer de répondre à la question de savoir ce qui se passerait pour des prédateurs traités ayant, après traitement, la possibilité de migrer sur des supports propres contaminés par une nourriture non polluée, nous associons systématiquement à la méthode ancienne une méthode dans laquelle, aussitôt après traitement, cette possibilité de quitter les plantes traitées est offerte aux prédateurs.

I - ACTION DES APPLICATIONS DE PRODUITS PHYTOSANITAIRES SUR DES POPULATIONS DE PREDATEURS MISES DANS L'IMPOSSIBILITE DE QUITTER LES PLANTES TRAITEES

Cette partie du travail a fait l'objet d'une première communication lors du Congrès International de la Protection des Plantes tenu à Moscou en septembre 1971 (1). Rappelons-en l'essentiel.



E 1 - Principales opérations réalisées dans l'étude de l'effet des traitements phytosanitaires sur *Phytoseiulus persimilis* (Température : 23,5 ± 1,5 ; Hygrométrie 75 ± 5 % ; Durée d'éclairement 14 heures/jour)

METHODE

La chronologie des principales opérations réalisées dans ce type d'essai est indiquée dans la figure I. Les plantes destinées à servir de supports communs aux proies et prédateurs sont des haricots nains cultivés isolément en godets de 8 cm de diamètre sur du sable stérilisé et humidifié, lorsque cela est nécessaire, par de l'eau du robinet. Un anneau de glu placé sur la tige de chaque plante au niveau de l'insersion cotylédonnaire empêche la fuite des acariens introduits sur le feuillage.

Pour que les prédateurs puissent disposer d'une nourriture suffisante jusqu'à la fin des essais, il est commode de faire multiplier à l'avance les tétranyques servant de proies : des études préliminaires assez longues nous ont amenés à considérer comme correct, dans les conditions de contamination fixées par la figure I, le rapport de 16 femelles de *Tetranychus* pour 4 femelles de *Phytoseiulus* par plante, rapport que nous avons cru devoir porter à 18/4 au vu des résultats obtenus dans les premiers essais. Etant donné l'importance que revêt la suffisance ou l'insuffisance de nourriture dans la formation et le maintien d'une population de prédateurs sur une surface limitée, il est nécessaire d'apporter toute son attention à la formation de la population de tétranyques et de s'assurer, par un contrôle journalier, que les femelles mises à pondre n'ont pas disparu et sont apparemment en bon état. Les prédateurs sont introduits 3 jours avant traitement parmi les tétranyques ; ils sont alors soumis comme précédemment à des vérifications journalières et éventuellement remplacés en cas de manque ou de mortalité. La constitution des populations au moment de l'intervention est indiquée dans le tableau I. Rappelons que dans les conditions de nos essais, la durée du cycle de développement de *Phytoseiulus* est d'environ 5 jours et que la durée d'incubation des oeufs varie entre 2 jours à 2 1/1 jours. Pour *Tetranychus urticae* ces délais sont respectivement d'environ 10 jours et de 4 à 5 jours.

Les traitements sont réalisés par pulvérisation au moyen d'un pulvérisateur électrique, type pulvérisateur à peinture, et ce sur la totalité de chaque plante contaminée, d'une dilution aqueuse de la substance à essayer. La pulvérisation est arrêtée lorsque le dépôt liquide paraît atteindre 4 à 5 mg par cm^2 de

TABLEAU I

Nature et importance des populations d'acariens (proies et prédateurs) préparées pour l'étude d'activité des pesticides sur *Phytoseiulus persimilis*
Cas de populations maintenues en permanence sur les mêmes plantes

ence de série ssais	Type de population formée	Animal considéré	Femelles déposées initialement sur chaque plante	Période précédant la date du traitement (jours)	Population existant sur chaque plante à l'époque du traitement (4)		Contrôle (6 jours après tra	
					Formes post embryonnaires vivantes	Oeufs d'apparence viables	Formes post embryonnaires vivantes	d'a v
I	Acariens phytophages seuls	*Tetranychus urticae*	I6 (1)	IO	7I3	650	2255 (2)	
	Acariens phytophages + acariens prédateurs	*Tetranychus urticae*	I6	IO	528	240	222 (2)	
		Phytoseiulus persimilis	4	3	I7	28	79 (2)	
II	Acariens phytophages seuls	*Tetranychus urticae*	I8 (1)	IO	II64	940	3286 (3)	
	Acariens phytophages + acariens prédateurs	*Tetranychus urticae*	I8	IO	7I2	5I9	567 (3)	
		Phytoseiulus persimilis	4	3	I7	33	95 (3)	I

nsité uniquement utilisée pour la présentation des résultats ; densité réelle = 2 femelles/plante
yennes de 11 essais avec 6 répétitions répartis sur 6 mois
yennes de 20 essais avec 6 répétitions répartis sur 21 mois
yennes correspondant aux nombres d'acariens observés lors des contrôles et calculées d'après les rapports entre populati
terminés dans 4 essais (série I) et 9 essais (série II)

TABLEAU 2

Activité de divers pesticides sur *Phytoseiulus persimilis*
Effet produit par les traitements sur la densité des prédateurs

Substances utilisées	Concentrations d'emploi * (g MA/hl)	Réduction (%) du nombre des prédateurs *** à dose moyenne d'emploi	Réduction (%) du nombre des prédateurs *** au quart de la dose moyenne	Dose ramenant la densité des prédateurs à la densité lors du traitement (g MA/hl)	Rapport entre dose moyenne d'emploi et dose ci-contre
Phosphoré expérimental CIBA	25 ± 5*****	100	99,98	0,8	31,2
Stanneux expérimental BAYER	40 ± 10*****	100	99,70	2,2	18,2
Métidathion	60 ± 20	100	99,65	< 0,1	> 600
Dichlorvos	100	100	99,33	3,8	26,0
Binapacryl	50	100	99,28	2,6	19,2
Mancozèbe	160	100	98,69	16,1	9,9
Dicofol	50 *****	100	97,2	5,4	9,2
Bioéthanométhrine synergisée	5,5 ± 0,5	100	?	< 1,6	> 3,4
Chinométhionate	10 ± 2,5	99,93	86,4	2,1	4,9
Bénomyl	30	99,91	98,2	1,3	23,1
Naled	100	99,62	97,5	3,2	31,2
Chlorfensulfide + chlorfenetol	75	99,53	86,9	14,0	5,3
Phosalone	60	99,28	97,1	1,4	42,9
Parathion éthyle	22,5 ± 2,5	99,20	80,9	5,2	4,3
Fenbutatin oxyde	50	95,8	85,8	8,6	5,8
Pirimicarbe	37,5	94,8	44,0	19,4	1,9
Cyhexatin	30	94,5	62,7	14,7	2,0
Méthylthiophanate	59,5 ± 24,5	94,2	83,5	14,0	4,2
Proclonol	45 ± 5*****	91,2	74,2	18,9	2,4
Dienochlore	60	90,3	50,0	40,6	1,5
Mevinphos	37,5 ± 2,5	88	74,2	14,0	2,7
Tetradifon	16	85,3	80,9	5,7	2,8
Dodemorphe acétate	100	67,3	33,5	> 200	< 1/2
Isolane	8 ± 2	50,0	24,9	52,4	1/6,6
Ditalimfos	40 ± 10	43,6	27,4	> 200	< 1/5
Thirame	335 ± 15	< 20	?	> 400	< 1/1,2
Drazoxolon	40	< 15	?	> 50	< 1/1,25
Folpel	150	# 0	# 0	> 20	< 1/1,3

* Concentrations prévues en applications foliaires contre acariens, pucerons, aleurodes, cochenilles, oïdium et maladies s'attaquant aux cultures légumières, florales et ornementales

*** Réductions du nombre des formes postembryonnaires vivantes constatées 6 jours après traitement et par rapport aux populations non traitées examinées à la même date

***** Doses probables d'emploi

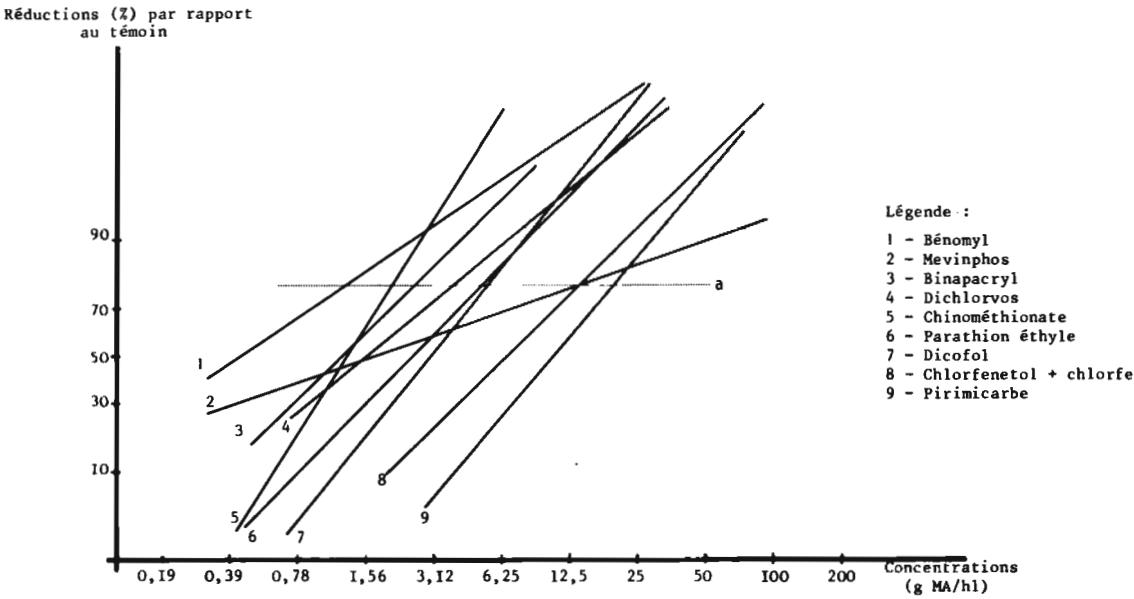


FIGURE 2 - Action de divers pesticides sur *Phytoseiulus persimilis*. Réductions du nombre des formes postembryonnaires vivantes constatées 6 jours après l'application des produits à l'issue d'un contact permanent entre animaux traités (prédateurs et proies) et végétaux traités (Rapport entre proies et prédateurs initialement utilisé 16/4) - a : réduction ramenant la population à une densité identique à celle du jour de l'application

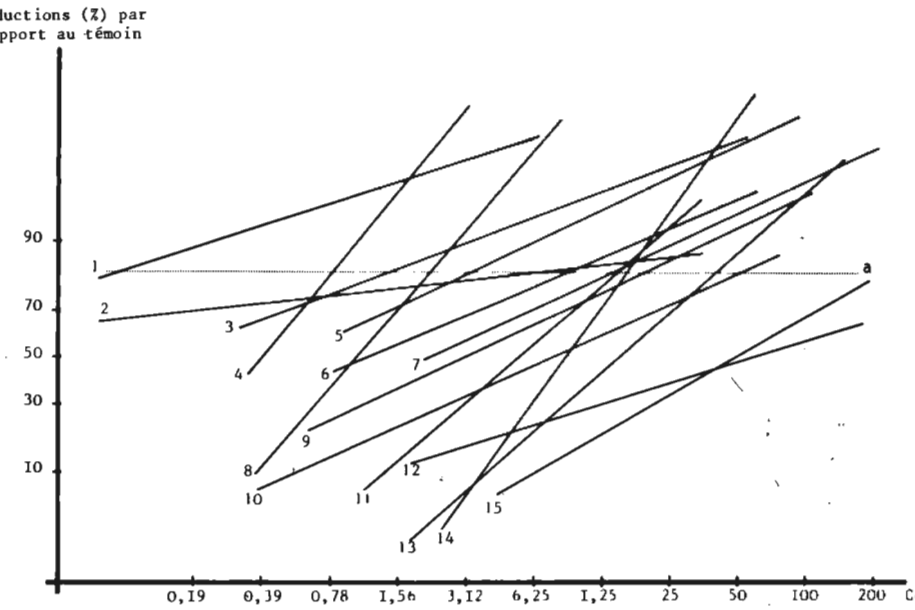
surface foliaire, dépôt vérifié par pesée, avant et après traitement, d'un papier filtre exposé à la pulvérisation. Chaque dose est essayée sur 4 plantes et chaque produit testé à 4 doses formant entre elles une progression géométrique de raison 4. La dose la plus forte est alors égale au multiple ou au sous-multiple de 100 le plus proche de la dose moyenne prévue pour les applications pratiques.

Une moitié des plantes est contrôlée après 5 jours, l'autre moitié après 7 jours. Cette manière d'opérer permet d'alléger le travail de vérification mais permet surtout d'obtenir des informations complémentaires concernant en particulier le sens de variation du nombre de prédateurs et la viabilité des oeufs observés lors du 1er contrôle. Tout le travail de vérification est fait sous binoculaire et consiste à dénombrer les formes vivantes ou mortes de *Phytoseiulus* ainsi que les formes mobiles de *Tetranychus* restées vivantes.

A chaque essai sur *Phytoseiulus* est associé un essai sur *Tetranychus* seul (figure I et tableau I) destiné à faire apparaître l'effet purement acaricide de la substance mise en étude. Il faut cependant mentionner que cet effet est probablement légèrement différent de celui qui se manifeste sur les tétranyques épargnés par les prédateurs, car dans ce cas la population d'acariens phytophages se trouve déjà nécessairement modifiée quantitativement et qualitativement par la présence des *Phytoseiulus* (tableau I).

RESULTATS

Pour simplifier la présentation, nous ne prendrons en considération que la moyenne des résultats obtenus 5 et 7 jours après l'application et concernant exclusivement les formes postembryonnaires vivantes. Les réductions observées dans les densités de populations sur plantes traitées par comparaison avec les densités de populations sur plantes non traitées sont exprimées, en fonction des concentrations essayées, dans les figures 2 et 3. La construction de droites de régression n'a en fait d'intérêt que dans la mesure où elle offre la possibilité de corriger les résultats individuels, mais surtout, dans la mesure où elle donne le moyen de prévoir l'effet des applications à des concentrations qui ne sont pas celles utilisées dans les essais. Les résultats obtenus dans des conditions qui nous paraissent être celles communément rencontrées dans les traitements de cultures sous abris et calculés selon le procédé qui vient d'être mentionné sont présentés dans le tableau 2.



GURE 3 - Action de divers pesticides sur *Phytoseiulus persimilis*. Réductions du nombre des formes postembryonnaires viva constatées 6 jours après l'application des produits, à l'issue d'un contact permanent entre animaux traités (pr teurs et proies) et végétaux traités (Rapport entre proies et prédateurs initialement utilisés 18/4)
a - réduction ramenant la population à une densité identique à celle du jour de l'application

Comme on le voit, la plupart des traitements freinent considérablement le développement de *Phytoseiulus persimilis*. S'il est vrai que des fongicides comme le thirame, le drazoxolon et le folpel ou qu'un aphicide dit spécifique comme l'isolane occupent une place qui peut paraître logique parmi les produits les moins nocifs, on retrouve tout aussi bien des fongicides comme le mancozèbe et le bénomyl ou des aphicides comme le pirimicarbe parmi les produits à forte toxicité. Il en est de même pour des acaricides spécifiques dont la nocivité reste cependant toujours appréciable. Cette forte toxicité apparente de la quasi totalité des substances employées tient évidemment d'abord à la dose utilisée. Une réduction de la concentration d'emploi pourrait théoriquement améliorer les résultats mais il faudrait (tableau 2) que cette réduction soit dans la plupart des cas de plus de moitié pour que la densité des *Phytoseiulus* soit la même 6 jours après traitement que le jour même de l'application. Cette forte toxicité apparente des produits tient surtout à la méthode d'essai pratiquée et au fait que de nombreux facteurs pouvant jouer contre le prédateur, et notamment la suppression plus ou moins rapide des proies par les traitements, se trouvent réunis. La figure 4 indique assez bien qu'une forte action acaricide va de pair avec une forte régression des prédateurs, mais elle montre également que ce facteur n'est sûrement pas suffisant pour expliquer l'activité dépressive aux concentrations d'emploi, de traitements réalisés avec des fongicides comme le mancozèbe, le bénomyl ou le méthylthiophanate et avec des insecticides comme l'isolane ou le naled qui font preuve vraisemblablement d'une certaine toxicité directe vis-à-vis de l'espèce de prédateur considérée. Pour nous résumer, et utiliser un mode d'expression peut être plus familier pour les amateurs de dynamique de populations, on peut dire que parmi les 28 substances étudiées groupant insecticides ou fongicides appartenant à des groupes chimiques variés et utilisés à des doses considérées comme des doses moyennes d'emploi, les substances apparemment les moins nocives se répartissent comme suit : cinq permettent à la population de *Phytoseiulus* de s'accroître de plus du donble dans les 6 jours qui suivent le traitement : le folpel, le drazoxolon, le thirame, le ditalimfos et l'isolane ; une permet à la population de s'accroître dans la proportion de 1 à 1 nombre compris entre 1 et 2 : le dodemorphe acétate ; et enfin trois ne permettent de retrouver au mieux qu'environ la moitié de la population : le tétradifon, le mévinphos et le diénochlore. Rappelons qu'en l'absence de traitement l'accroissement des populations se réalise dans la proportion de 1 à 5-5,5.

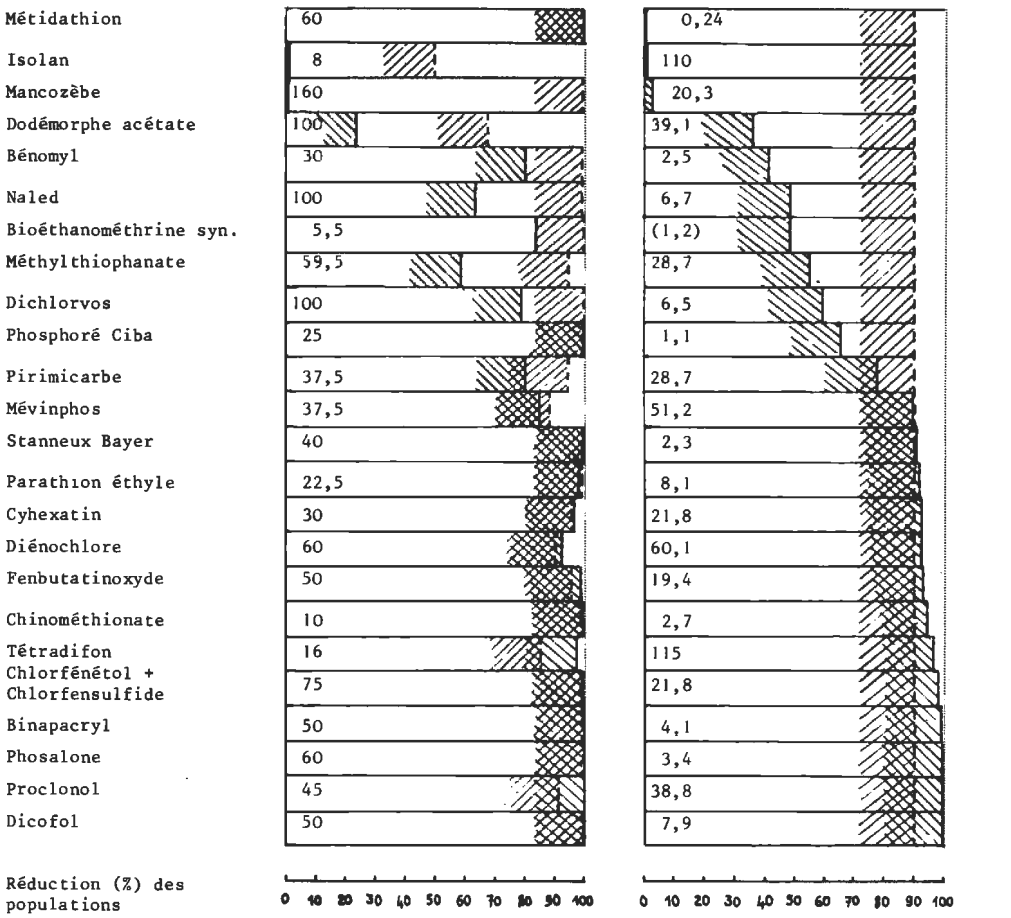


FIGURE 4 - Effets comparés de divers traitements sur *Phytoseiulus persimilis* associé à *Tetranychus urticae* et sur *Tetranychus urticae* seul. (Les concentrations correspondant aux résultats exprimés dans la figure sont indiquées en g MA/hl en face de chacune des substances concernées)

TABLEAU 3

Nature et importance des populations d'acariens (proies et prédateurs) préparées pour l'étude d'activité des pesticides sur *Phytoseiulus persimilis*
Cas de populations ayant ou non la possibilité de migrer sur plantes propres à partir de l'époque du traitement

Type d'essai	Type de population formée	Animal considéré	Femelles déposées initialement sur chaque plante	Période précédant la date du traitement (jours)	Population existant sur chaque plante à l'époque du			
					Traitement (4)		Contrôle (6 jours après traitement)	
					Formes post embryonnaires vivantes (3)	Oeufs d'apparence viables	Formes post embryonnaires vivantes	Oeufs d'apparence viables
Population ne pouvant pas quitter la plante d'origine	Acariens phytophages seuls	*Tetranychus urticae*	22 (1)	10	1502	-	3595 (2)	-
	Acariens phytophages + acariens prédateurs	*Tetranychus urticae*	22	10	2253	-	408 (2)	
		Phytoseiulus persimilis	4	4	27 (2)	37 (2)	118 (2)	120 (2)
Population pouvant quitter la plante d'origine	Acariens phytophages + acariens prédateurs	*Tetranychus urticae*	22	10	1153	-	-	-
		Phytoseiulus persimilis	4	4	27 (2)	37 (2)	163 (2) (69 + 94) (4)	202 (2) (96 + 106)(4)

(1) Densité uniquement utilisée pour la présentation des résultats
(2) Moyennes de 6 essais avec 4 répétitions répartis sur 9 mois
(3) Les moyennes des populations de *Tetranychus* sont rapportées aux moyennes observées après 6 jours en tenant compte des variations de densité calculées dans 4 ou 5 essais entre la date du traitement et la date du contrôle
(4) Parties de la population sur plante d'origine et sur nouvelle plante contaminée elle-même 10 jours avant la date du traitement par 16 tétranyques.

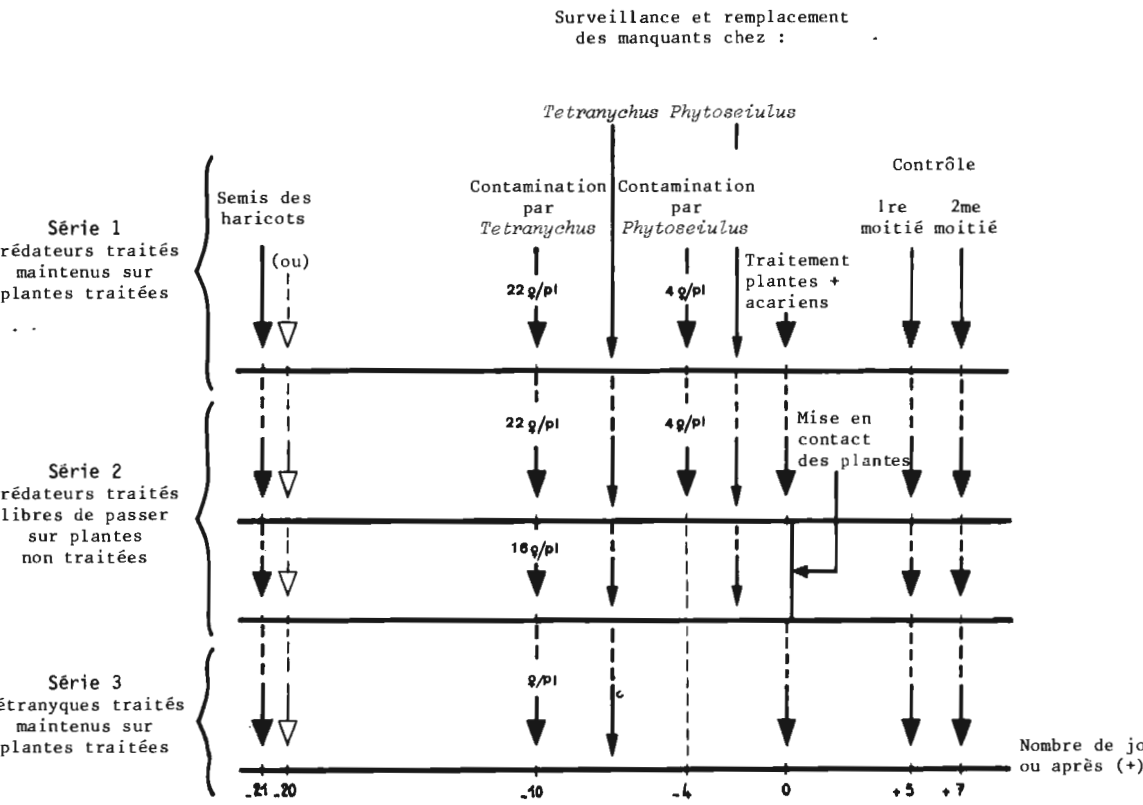


FIGURE 5 - Principales opérations réalisées dans la méthode d'essais modifiée utilisée pour l'étude de l'effet des traitements phytosanitaires sur *Phytoseiulus persimilis*

II - ACTION DES APPLICATIONS DE PRODUITS PHYTOSANITAIRES SUR DES POPULATIONS DE PREDATEURS AYANT, APRES TRAITEMENT, LA POSSIBILITE DE PASSER SUR PLANTES PROPRES ET D'Y TROUVER UNE NOURRITURE NON POLLUEE. COMPARAISON AVEC LE CAS DE POPULATIONS N'AYANT PAS CETTE POSSIBILITE

Nous avons évoqué au début de cette communication, l'intérêt d'une méthode d'essai dans laquelle l'effet indirect provoqué sur *Phytoseiulus* par la réduction ou la pollution des proies serait limité et qui correspondrait mieux à ce qui peut se passer en serres ou même dans la nature, dans le cas de traitements localisés.

METHODE

La figure 5 résume l'ensemble des opérations entrant dans le cadre des essais comparatifs que nous réalisons maintenant systématiquement pour toute substance nouvelle. L'innovation réside essentiellement dans le fait que la moitié des plantes contaminées par le couple prédateurs-proies (série n° 2 de la figure 5) sont, immédiatement après traitement, accolées à des plantes propres elles-mêmes infestées par des tétranyques non traités. L'accolement se fait de telle manière que les feuilles primaires des haricots se trouvent superposées, les feuilles traitées étant toujours au-dessous des feuilles propres pour éviter que la contamination des plantes propres ne se produise par simple chute des prédateurs. La figure 5 montre qu'une amélioration a été apportée également dans la constitution des populations de *Phytoseiulus persimilis*, l'introduction des prédateurs se faisant maintenant 4 jours avant la date d'intervention dans une population de tétranyques que nous avons été évidemment amenés à renforcer. Le tableau 3 résume les principales données concernant l'évolution des populations en cours d'essai.

En raison du volume de chaque expérience, 2 concentrations sont essayées pour chaque substance : la concentration paraissant être la concentration moyenne d'emploi et la concentration moitié.

TABLEAU 4

Action de divers pesticides sur *Phytoseiulus persimilis* selon la possibilité, laissée au prédateur, de quitter ou non les plantes traitées

Substances et concentrations d'emploi (g MA/hl)	Nombre d'individus vivants, pour 100 individus traités, retrouvés 6 jours après un traitement							
	à dose d'emploi				à demi-dose			
	(Prédateurs maintenus sur plantes traitées) (1)		(Prédateurs non maintenus sur plantes traitées) (2)		(Prédateurs maintenus sur plantes traitées) (1)		(Prédateurs non maintenus sur plantes traitées) (2)	
Bupirimate (25)	71	(85,9)(3)	166	(73,5)	338	(33,0)	348	(44,5)
Soufre mouillable (600)	23	(93,7)	I83	(70,0)	37	(89,9)	183	(70,0)
Dicofol (50)	22	(95,6)	221	(62,4	26	(94,9)	321	(45,4)
Endosulfan (60)	6	(98,7)	33	(95,1)	79	(82,7)	133	(80,6)
Produit expérimental Fisons (30)	3	(99,5)	196	(64,3)	20	(96,4)	266	(51,6)
Binapacryl (50)	0	(100)	19	(96,5)	0	(100)	21	(96,2)

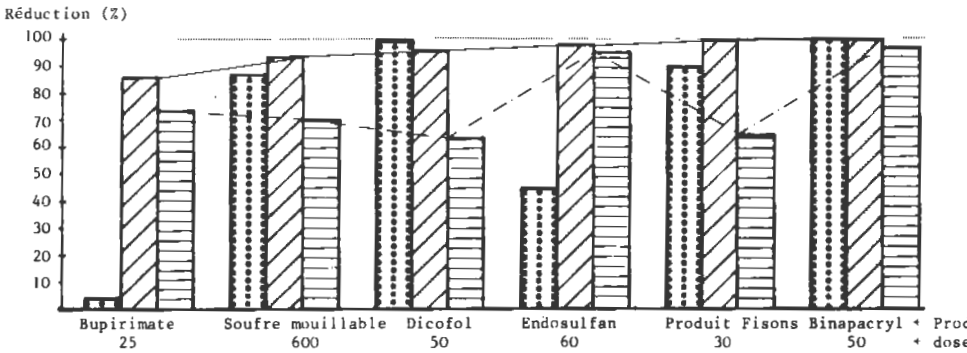
1) Nombre moyen de prédateurs obtenus en l'absence de traitement : 451
2) Nombre moyen de prédateurs obtenus en l'absence de traitement : 600
3) Les nombres entre parenthèses correspondent aux pourcentages de réduction de la population calculés par rapport aux témoins non traités observés à la même époque

RESULTATS

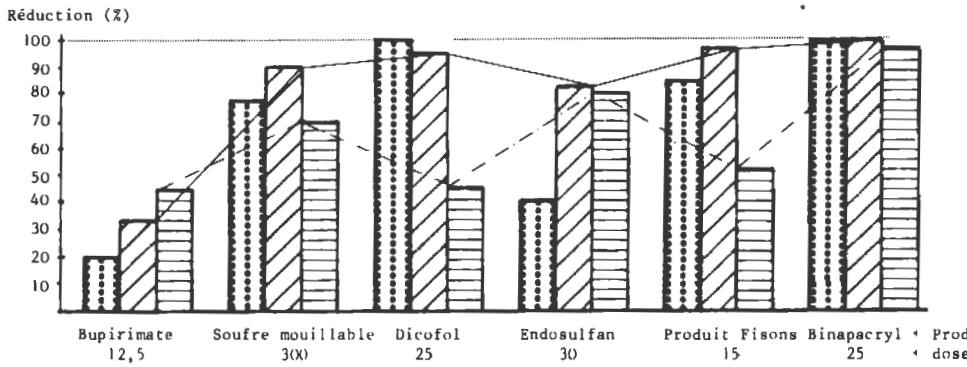
Nous donnons dans le tableau 4, et pour les deux types de méthodes appliqués simultanément, les nombres de prédateurs vivants observés 6 jours après traitement et correspondant à 100 individus traités.

On peut constater d'abord qu'en l'absence de traitement un apport complémentaire de nourriture à des prédateurs ayant pourtant une ration suffisante pour éliminer le risque de cannibalisme, améliore nettement la croissance des populations, la densité des animaux vivants augmentant en effet dans ce cas dans le rapport de 1 à 6 au lieu de 1 à 4,5 dans l'autre. On peut noter également qu'un traitement apparemment violent comme celui réalisé au moyen du binapacryl à concentration normale, permet cependant à un certain nombre de prédateurs normalement voués à disparaître lorsqu'ils sont maintenus sur plantes traitées, de survivre s'ils peuvent passer sur plantes demeurées propres et y trouver de surplus une nourriture demeurée saine. Cette réduction de la toxicité des traitements pour *Phytoseiulus* dans le cas d'applications "localisées" est d'ailleurs générale mais, comme on pouvait le prévoir, elle est loin de se manifester avec la même importance pour tous les produits.

Si la toxicité de l'endosulfan, du binapacryl et à un moindre degré du bupirimate ne se trouve que peu affectée par le changement de conditions auquel est soumis le prédateur (figure 6), la nocivité du dicofol, du produit Fisons et du soufre mouillable est en revanche considérablement réduite par l'application des produits sur une partie seulement du feuillage laissé à la disposition de *Phytoseiulus*. Ceci peut se comprendre si l'on admet que pour les 3 premières substances l'essentiel de la toxicité apparente est probablement due à la toxicité proprement dite à l'égard du prédateur alors que pour les autres produits cette toxicité est modifiée par la présence ou l'absence, selon le cas, d'une toxicité indirecte due simplement à la suppression ou à la pollution de la nourriture par les traitements chimiques précédemment réalisés. On peut donc dire que la classification des substances d'après la nocivité apparente qu'elles manifestent à l'égard de *Phytoseiulus* varie avec la méthode utilisée. Si l'on ne s'intéresse qu'à la seule évolution du nombre de prédateurs dans les jours qui suivent l'application chimique, on peut d'ailleurs compléter les informations données par le tableau 4 et la figure 6 en disant qu'en 6 jours, et à la suite d'un traitement à



ostances utilisées
la dose d'emploi



ostances utilisées
à la moitié de
la dose d'emploi

IGURE 6 - Réduction (%) du nombre d'individus vivants obtenue 6 jours après l'application de diverses substances sur populations de *Phytoseiulus* ▨ ou de *Tetranychus* ⁝⁝⁝ maintenues sur plantes traitées ou sur populations de *Phytoseiulus* ▤ libres de quitter les plantes après traitement

la dose d'emploi que nous appellerons traitement "localisé", la densité des *Phytoseiulus* se trouve multipliée par un facteur supérieur à 2 pour le dicofol, voisin de 2 pour le produit Fisons et le soufre mouillable, compris entre 2 et 1,5 pour le bupirimate et enfin inférieur à 0,5 pour l'endosulfan et le binapacryl (facteur moyen d'accroissement en l'absence de traitement : 6,0) ; dans le cas d'un traitement appliqué à la seule surface foliaire mise à la disposition du prédateur et de sa proie, les facteurs d'accroissement sont respectivement compris entre 1 et 0,5 pour le bupirimate, entre 0,5 et 0,25 pour le soufre et le dicofol et inférieur à 0,25 pour les autres produits (facteur moyen d'accroissement en l'absence de traitement : 4,5).

III - DISCUSSION ET CONCLUSION

La présentation des travaux sur la toxicité des produits vis-à-vis des populations de *Phytoseiulus persimilis* fait apparaître une fois de plus l'importance que revêt la méthodologie dans l'appréciation d'un certain type d'activité manifestée par les substances testées. Ceci doit nous contraindre à demeurer à l'écoute des praticiens de la lutte intégrée de manière que les substances à essayer puissent être sélectionnées dans des conditions aussi proches que possible des conditions normales de leur application. Les méthodes que nous utilisons actuellement présentent l'inconvénient d'être relativement complexes, longues et de mettre en oeuvre un matériel biologique dont les caractéristiques sont nécessairement sujettes à variations. Dans la mesure où nous souhaitons obtenir au laboratoire des résultats traduisant plus l'activité d'un traitement que le mode d'action d'un produit, il nous paraît difficile sinon risqué de simplifier et d'alléger la méthodologie décrite précédemment. Nous rapportons d'ailleurs dans le tableau 5 les résultats obtenus comparativement dans des tests simples, appliqués à des stades précis du prédateur, et permettant d'apprécier l'activité des produits par le critère classique de la mortalité, et les résultats obtenus dans les expérimentations décrites dans cette communication et réalisées sur populations. Comme on peut le constater, la destruction d'un stade particulier du prédateur est loin de refléter l'effet dépressif constaté sur population. Le soufre, le chinométhionate ou le produit Fisons ne provoquent par exemple aucune mortalité des femelles de *Phytoseiulus* et pourtant leur effet sur la densité des prédateurs est important, mais il est alors la conséquence de toute une série de mécanismes qui incluent, pour le soufre notamment la destruction des larves à la naissance. Le bénomyl est une des substances qui, à dose normale d'emploi, paraît plus

TABLEAU 5

Effets comparés, à dose moyenne d'emploi, de divers pesticides sur populations ou stades déterminés de *Phytoseiulus persimilis*

Substances (et concentrations en g MA/hl)[*]	Mortalités (%) affectant les			Réductions (%) du nombre d'individus vivants (rappel) dans des :	
	Oeufs[***]	larves néonates[*****]	femelles adultes[*******]	Populations libres de quitter les plantes traitées	Populations maintenues sur plantes traitées
Métidathion (60)	96,4	100	100		100
Dichlorvos (100)	98,9	0-10	100		100
Binapacryl (50)	4,3	90-100	65,3	96,5	100
Mancozèbe (100)	45,2	65-75	27,7		100
Bioéthanométhrine + synergiste (5,5)	19,0	80-90	99,9		100
Dicofol (50)	0	70-80	71,0	62,4	95,6-100
Chinométhionate (10)	0,4	40-50	0		99,9
Bénomyl (30)	4,5	55-65	33,3		99,9
Produit expérimental FISONS (30)	0	10-20	0	64,3	99,5
Parathion éthyle (22,5)	2,8	0-10	14,6		99,2
Endosulfan (60)	0	0-10	25,0	95,1	98,7
Pirimicarbe (37,5)	5,5	0-10	4,0		94,8
Soufre mouillable (600)	0	100	0	70,0	93,7
Proclonol (45)	0	55-65	14,7		91,2
Dienochlore (60)	0,8	40-50	4,2		90,3
Bupirimate (25)	8,6	20-30	7,7	73,5	85,9
Dodemorphe acétate (100)	0,9	0-10	2,2		67,3
Ditalimfos (40)	0,4	0-10	25,7		43,6

[*] Les noms en caractères gras réduisent de plus de 85 p.cent la densité des tétranyques vivants

[***] Oeufs de 0 à 24 heures laissés après traitement sur le support traité et examinés 3 jours plus tard

[*****] Contrôle réalisé en même temps que celui des oeufs

[*******] Femelles isolées du support traité immédiatement après traitement et placées 3 jours sur support propre avec nourriture propre

nocive dans les applications sur populations qu'elle ne semble l'être dans les applications visant des stades isolés ; mais cette substance a, entre autres propriétés, celle d'abaisser considérablement la ponte des femelles traitées et par conséquent de réduire le développement des populations, sans pour autant paraître particulièrement meurtrière pour les individus touchés. On peut dire finalement que les tests simplifiés sont nécessairement insuffisants pour permettre une approche à notre avis correcte de l'activité des traitements dans les conditions normales et qu'ils ne doivent être maintenus que comme tests explicatifs venant compléter utilement les tests pratiqués sur modèles de population.

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LES POPULATIONS APHIDIENNES EN SERRE ET LEUR LIMITATION PAR UTILISATION EXPERIMENTALE DE DIVERS ENTOMOPHAGES

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L'essai de divers insectes aphidiphages en serre au cours de ces dernières années à Antibes a montré que, du fait de la rapidité de multiplication des pucerons, l'on arrivait assez difficilement à leur éradication rapide par lâchers inondatifs et dans les cas où cette éradication était obtenue, la recolonisation par des aphides d'origine extérieure était très fréquente. Quelle que soit la méthode utilisée, on reste donc un certain temps avec des pucerons et des auxiliaires en présence dans la serre, et l'évolution de l'équilibre dépend en grande partie des caractéristiques des populations aphidiennes, extrêmement variables selon les espèces de pucerons présentes, du type de végétal et de la variété cultivée, de l'âge des plantes, des modalités culturales et de l'utilisation éventuelle des produits chimiques.

C'est pourquoi nous exposerons aussi les principaux caractères des populations aphidiennes et les conditions culturales des serres dans lesquelles nous avons travaillé, en insistant principalement sur le cas des cultures maraîchères (essentiellement solanées). En effet, les cultures florales locales sont relativement moins favorables au développement des essais de lutte biologique contre les pucerons, soit que les aphides qu'elles portent soient éliminés parce que sensibles aux traitements chimiques destinés à d'autres ravageurs (c'est le cas de Macrosiphum euphorbiae sur oeillet et de Macrosiphum rosae sur rose), soit que la floraison soit échelonnée sur une période assez longue (rosier) durant laquelle la présence de pucerons, même très limitée, n'est pas admise sur les boutons floraux.

La présence de pucerons relativement plus résistants aux insecticides (Myzus persicae sur Oeillet et Chrysanthème, Aphis gossipyi sur Chrysanthème) pourrait cependant favoriser dans l'avenir le développement de la lutte biologique contre les aphides, dans la mesure où des méthodes biologiques seraient utilisées pour les autres ravageurs (Acariens, Lépidoptères). Il est possible d'utiliser sur Chrysanthème Aphelinus asychis ou Chrysopa perla avec un traitement au pirimicarbe localisé aux sommités florales ou avec un traitement très abondant (0,3 1/m^2) à concentration réduite à la moitié de Bioresmethrine.

CULTURES MARAICHERES

Tomate

La tomate est de toutes les solanées maraîchères de serre la plante la moins réceptive pour les pucerons. Les espèces dominantes sont Myzus persicae SULZ, Macrosiphum euphorbiae THOS et Aphis gossypii GLOV. La méthode de lutte proposée en 1973 (SROP/WPRS Bull. 73/4), associant la suppression des feuilles basses infestées au lâcher précoce de parasites (Diaeretiella rapae + Aphelinus asychis) suffit à maintenir les pullulations à un niveau très faible ou nul, comme l'ont confirmé les essais réalisés ces trois dernières années. Une infestation tardive d'Aphis gossypii, localisée à la face inférieure des feuilles relativement basses, peut intervenir, comme en 1976, sans incidence sur la récolte (Aphis gossypii est moins sensible au parasitisme par A. asychis que les deux autres espèces). Indépendamment du parasitisme les pullulations aphidiennes sont limitées par la pilosité de la plante (poils glandulaires notamment), surtout lorsque les feuilles portent du miellat d'aleurodes. Les pucerons, particulièrement les adultes de Myzus persicae SULZ, et surtout de Macrosiphum euphorbiae THOS, se collent aux poils les plus longs ou bien accumulent les substances visqueuses à l'extrémité de leurs pattes où se développent des fumagines. Ce phénomène limite considérablement les possibilités d'installation et les déplacements des pucerons mais il intervient surtout sur des plantes ayant atteint un certain développement (1 mètre) et principalement au niveau des tiges, où s'accumulent les cadavres de pucerons ou de parasites. La même observation peut être faite sur les aubergines greffées sur tomate, au niveau de la tige du porte-greffe. Les poudrages au soufre micronisé augmentent encore la mortalité des pucerons, le soufre s'accumulant à la base des pattes des adultes. Lorsque la densité d'aleurodes est assez forte, on observe par ailleurs une certaine concurrence interspécifique, les pucerons s'installant moins sur les feuilles portant des adultes en cours de ponte ou des larves. Cette concurrence est nettement plus importante que celle résultant de l'occupation d'une partie de la surface disponible par les aleurodes et elle paraît se manifester surtout au niveau de l'installation des pucerons, lorsque les aleurodes sont les premiers en place.

Dans nos régions, la rapidité du développement de la tomate et la tendance actuelle à limiter sa hauteur à 3 ou 4 bouquets pour les cultures de primeurs, permet souvent d'échapper aux dégâts de pucerons en l'absence de tout traitement si on supprime les foyers des feuilles basses. Un lâcher de parasites dès le début des infestations permet de freiner la multiplication des pucerons et d'éviter à coup sûr tout dommage sur culture de primeurs d'autant que la plante âgée paraît relativement moins réceptive aux infestations tardives. Lorsque la population aphidienne est faible et dispersée, on ne peut descendre au dessous d'une certaine densité de parasites (de l'ordre de 10 au m^2) et on a intérêt à assurer leur installation au moyen d'une "unité mobile de production permanente", qui assure le maintien de la souche en serre selon la méthode exposée en 1973 (Bull. SROP 1973/4). Actuellement nous utilisons des cages de plexiglass rondes de 30 cm de diamètre et 50 cm de hauteur,

dont la face interne est recouverte de "Fluon" (polytetrafluoroethylène ou P.T.F.E.) et dont l'orifice supérieur est recouvert d'une toile de nylon dont les mailles assurent le passage des parasites, mais gêne celui des ailés de pucerons. Près de la toile, une rainure circulaire profonde de 5 mm et large de 5 mm à sa bordure supérieure, dont le fond large de 10 mm est garni de glue, empêche les larves et les aptères qui ont pu gravir la paroi verticale malgré le P.T.F.E. de sortir de la cage, tandis qu'une grande partie de parasites peuvent sortir en volant ou sautant (A. asychis) par dessus la rainure.

Dans ces cages, les végétaux (jeunes choux ou petits pois) infestés par Myzus persicae assurent le maintien des parasites qui sont progressivement libérés dans la serre. Il est nécessaire de placer une de ces unités mobiles de production permanente pour 100 m^2 de serre environ, de préférence à proximité des zones où on a repéré les premières infestations, la dispersion d'A. asychis se faisant surtout par course ou petits sauts de plante à plante.

Poivron

Le poivron est très favorable à la multiplication des pucerons et très sensible à leurs dommages, notamment au niveau des fleurs et des feuilles (miellat).

Sur poivron, on retrouve les trois espèces dominantes des solanées.

1. Myzus persicae, qui colonise les jeunes plants très précocement et dont les populations sont très dispersées sur l'ensemble du feuillage et des fleurs.

2. Macrosiphum euphorbiae qui s'installe juste après Myzus persicae et dont les colonies infestent plus volontiers les organes jeunes (boutons floraux, jeunes feuilles et tiges) bien qu'on les trouve aussi comme M. persicae sous les feuilles. Ces deux pucerons sont responsables d'une coulure des fleurs.

3. Aphis gossypii qui s'installe souvent tardivement et colonise d'abord les feuilles basses et même sénescentes.

De plus Aulacorthum solani, rencontré occasionnellement sur tomate, se multiplie plus rapidement sur poivron où on le trouve souvent en mélange avec Macrosiphum euphorbiae.

Dans l'étude sur l'évolution de la population sur poivron, nous avons essayé de voir s'il fallait tenir compte de la densité des pucerons par rapport à la surface du feuillage ou par rapport au nombre de feuilles. La surface des feuilles peut être exprimée par la formule Sr = 0,63 L X l (L = longueur, l = largeur de la feuille, sur poivron hâtif d'Antibes, selon la méthode mise au point par J.C. ONILLON sur Agrumes). (Fig. 1)

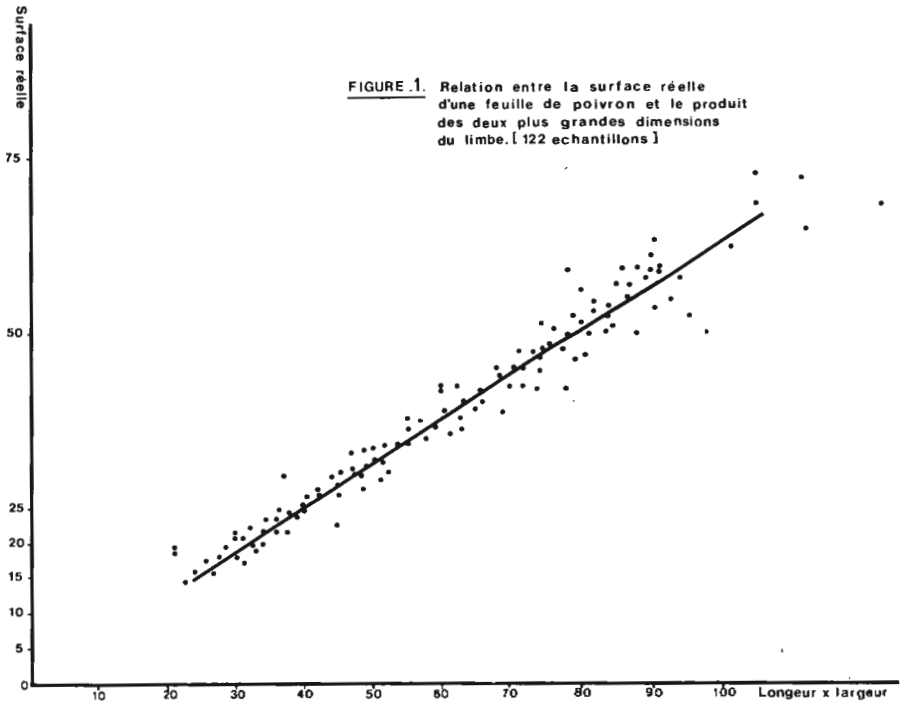


FIGURE 1. Relation entre la surface réelle d'une feuille de poivron et le produit des deux plus grandes dimensions du limbe. [122 echantillons]

Effectivement, les deux courbes indiquant la répartition de la population pour différentes strates en nombre de pucerons par feuilles et en nombre de pucerons par cm^2 montrent que la densité réelle exprimée en fonction de la surface est beaucoup plus forte pour les strates hautes que la densité exprimée en nombre de pucerons par feuille, (Fig. 2 et 3) mais le point le plus important concerne la présence de pucerons (M. persicae et M. euphorbiae) au moment de la floraison et la localisation de ceux-ci sur les fleurs ou à proximité de celles-ci.

En l'absence d'intervention, une population de plus de 100 pucerons par pied à l'apparition des premières fleurs se traduit 40 jours plus tard, par une diminution de moitié de la récolte hebdomadaire effectuée à cette date. Pour une population initiale de 500 pucerons par pied, cette récolte est nulle. Cette perte de récolte peut être partiellement compensée ultérieurement par des récoltes plus fortes mais celles-ci n'auront pas la même valeur marchande que les fruits de primeurs. Il y a donc nécessité d'intervention au seuil de 100 p/pied, en début de floraison.

Il existe des différences variétales, le poivron "Hâtif d'Antibes" étant plus sensible que le poivron type "Lamuyo" par exemple.

Les cultures traitées chimiquement sont plus souvent infestées par Myzus persicae qui présente souvent une résistance plus grande aux insecticides que les autres aphides.

C'est pourquoi nous avons d'abord tenté d'utiliser un parasite spécifique de Myzus persicae, Diaeretiella rapae M'INT, qui donne d'excellents résultats en lâchers massifs au niveau de pépinières de poivrons (graph.)

Des observations similaires ont été faites avec Aphidius matricariae, qui s'introduit spontanément en serre plus couramment que Diaeretiella rapae. Les plants de poivrons, à feuilles lisses, se prêtent bien à l'utilisation d'Hyménoptères Aphelinidae du type Aphelinus asychis qui courent à la surface des feuilles. Aphelinus asychis est utilisé en mélange avec Diaeretiella rapae dans nos essais, comme dans le cas des tomates en raison de sa polyphagie et de son action prédatrice, au moins aussi importante en serre que l'action parasitaire. A. asychis s'attaque à l'ensemble des pucerons du poivron bien qu'Aphis gossypii soit moins parasité que les autres espèces, comme c'est le cas sur la tomate. La répartition spatiale d'A. asychis est souvent différente de celle de D. rapae, l'aphelinide préférant des micro-climats plus chauds et plus humides. Les pucerons parasités par A. asychis tendent à migrer à la pointe des feuilles pendantes de poivron ou à la base de la tige principale où les momies noires s'accumulent en grand nombre.

L'utilisation des unités mobiles de production permanente de parasites a permis l'installation précoce de ceux-ci dans nos serres expérimentales, mais le taux de multiplication des aphides étant beaucoup plus élevé sur poivron que sur tomate, il est apparu préférable de renforcer les populations de parasites par des lâchers massifs localisés sur les foyers présentant une densité de l'ordre de 100 pucerons par plante dès leur apparition.

Les chrysopes (Chrysopa perla) ont été utilisées soit seules (Fig. 2 et 3) (sur une serre de 3.000 m^2 notamment) soit en association avec les parasites lorsque l'installation de ceux-ci paraissait trop tardive ou insuffisante pour maîtriser les pucerons.

Deux techniques sont utilisées:

1. Lâcher inondatif d'oeufs de chrysopes sur bandelettes de cellophane: lorsque les populations aphidiennes sont très faibles (1 oeuf par puceron environ). Les bandelettes sont obtenues par massicotage de la cellophane dont sont tapissées les cages d'élevage. L'éclosion échelonnée des oeufs provenant de 3 à 4 jours de ponte assure le maintien en serre de larves pendant une période de 3 à 4 semaines en condition de jeûne partiel. Une alimentation artificielle d'appoint peut éventuellement favoriser la survie des larves en cas d'alimentation aphidienne insuffisante (milieu de VANDERZANT).

Dans les serres professionnelles de la Vallée du Var où des essais ont été effectués, l'élimination des noctuelles a été assurée par les larves de Chrysopes. (Fig. 2 et 3).

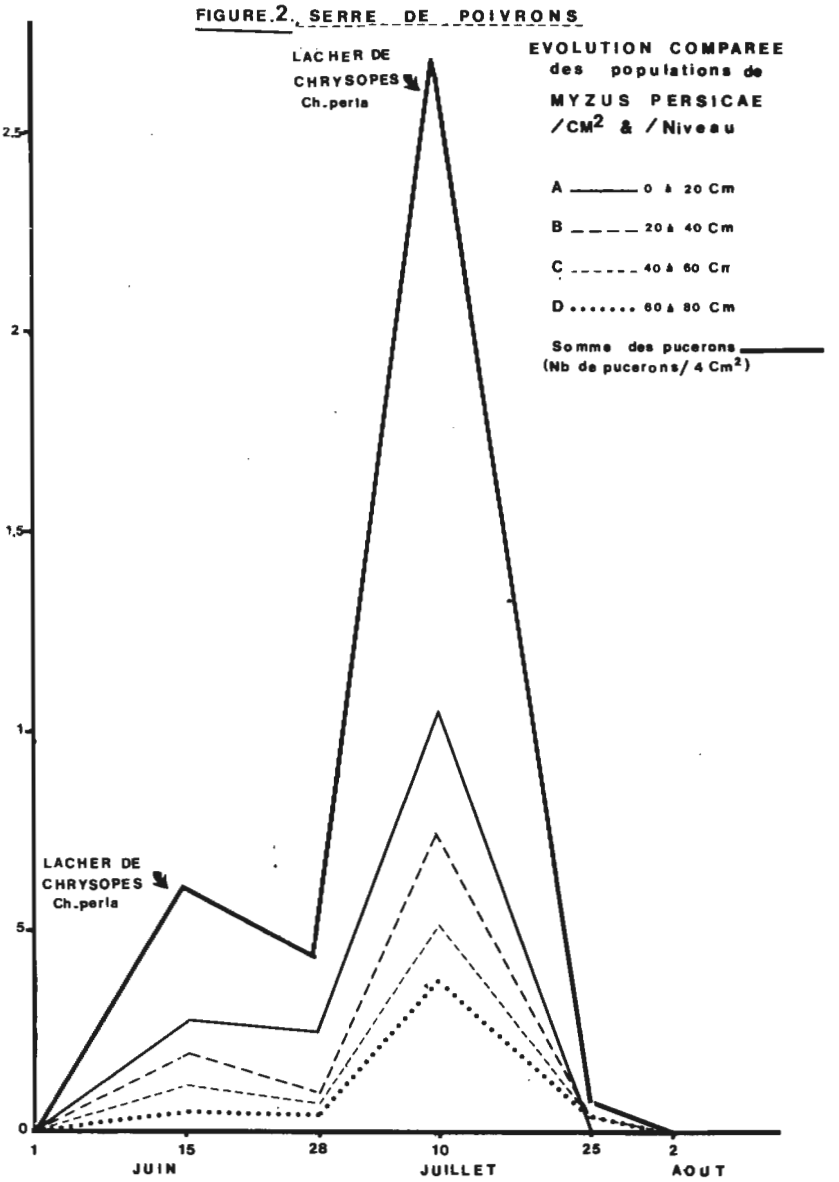
2. Lâcher de larves au 2ème stade à raison de 1 larve pour 10 pucerons environ. Cette technique permet une régression rapide des pullulations présentant déjà un risque pour la plante dans un délai relativement bref (100 pucerons par plante en début de floraison). Si on laisse cette population évoluer, on aboutit à une perte de récolte qui se manifeste 3 semaines à 1 mois plus tard (voir plus haut). En 1974 et 1975, des lâchers répétés de larves ont permis de maintenir la population aphidienne à un niveau à peu près nul tout au long de la culture. Une telle technique est relativement peu économique, car la survie des larves en serre est de l'ordre d'une dizaine de jours seulement, et la production de larves au stade L2 pour la réalisation de lâchers répétés exige un élevage de pucerons plus important que la production d'oeufs (intérêt de l'alimentation artificielle). De plus, l'estimation des populations aphidiennes souvent très hétérogènes est relativement longue à réaliser si on veut éviter un gaspillage excessif de larves (contrôles effectués à raison de 4 feuilles de différents niveaux pour un pied sur dix dans nos essais, pour des populations aphidiennes relativement homogènes). Aussi, des essais de thermothérapie ont-ils été réalisés afin de voir s'il était possible de réduire les pullulations importantes présentant à terme un risque de perte de récolte (plus de 100 pucerons par pied) afin d'effectuer des lâchers sur des populations réduites.

La fermeture des ouvrants de serre par journée ensoleillée permet dans nos régions d'atteindre rapidement 35° à 45°, sous réserve que le toit ne soit pas blanchi à la chaux, auquel cas on dépasse difficilement 35°. En l'absence de miellat, les poivrons résistent bien à des chocs thermiques de 4 heures à 42°-45°. En revanche, les pieds infestés par des populations de 1.000 à 10.000 pucerons par pied et recouverts de miellat présentent des signes de brûlure pouvant aller jusqu'à la chute totale des feuilles. Les plantes ainsi dépouillées reconstituent très rapidement leur feuillage (variétés Hâtif d'Antibes et Lamuyo), mais la récolte peut être fortement diminuée de 18 à 13 fruits par pied en 1972 pour la première récolte sur une serre très fortement infestée de Hâtif d'Antibes.

Durant le traitement une partie des pucerons se réfugient sous les feuilles basses qui traînent sur le sol humide et, dans le cas de M. euphorbiae, à la base du tronc. Ces aphides recolonisent progressivement la plante lorsque la température redevient normale (25° C).

La chute de population enregistrée à 24 heures d'intervalle varie entre 80 et 90 pour cent et est comparable pour Myzus persicae et Macrosiphum euphorbiae excepté dans le cas où cette dernière espèce a pu se réfugier sous des feuilles basses.

FIGURE.2. SERRE DE POIVRONS



Par son feuillage lisse, le poivron favorise l'utilisation des bassinages (associé ou non au choc thermique) pour réduire les populations de pucerons et laver le miellat. Une vigoureuse aspersion de bas en haut provoque la chute des pucerons et notamment de M. euphorbiae. Cependant, l'intérêt du bassinage réside surtout dans l'élimination partielle du miellat; la diminution de la population aphidienne n'excéde pas 50 pour cent, les adultes recolonisant assez rapidement la plante, à moins de poser un manchon englué sur le tronc et d'éliminer les feuilles trainant à terre pour les plantes très infestées constituant des foyers.

Aubergine

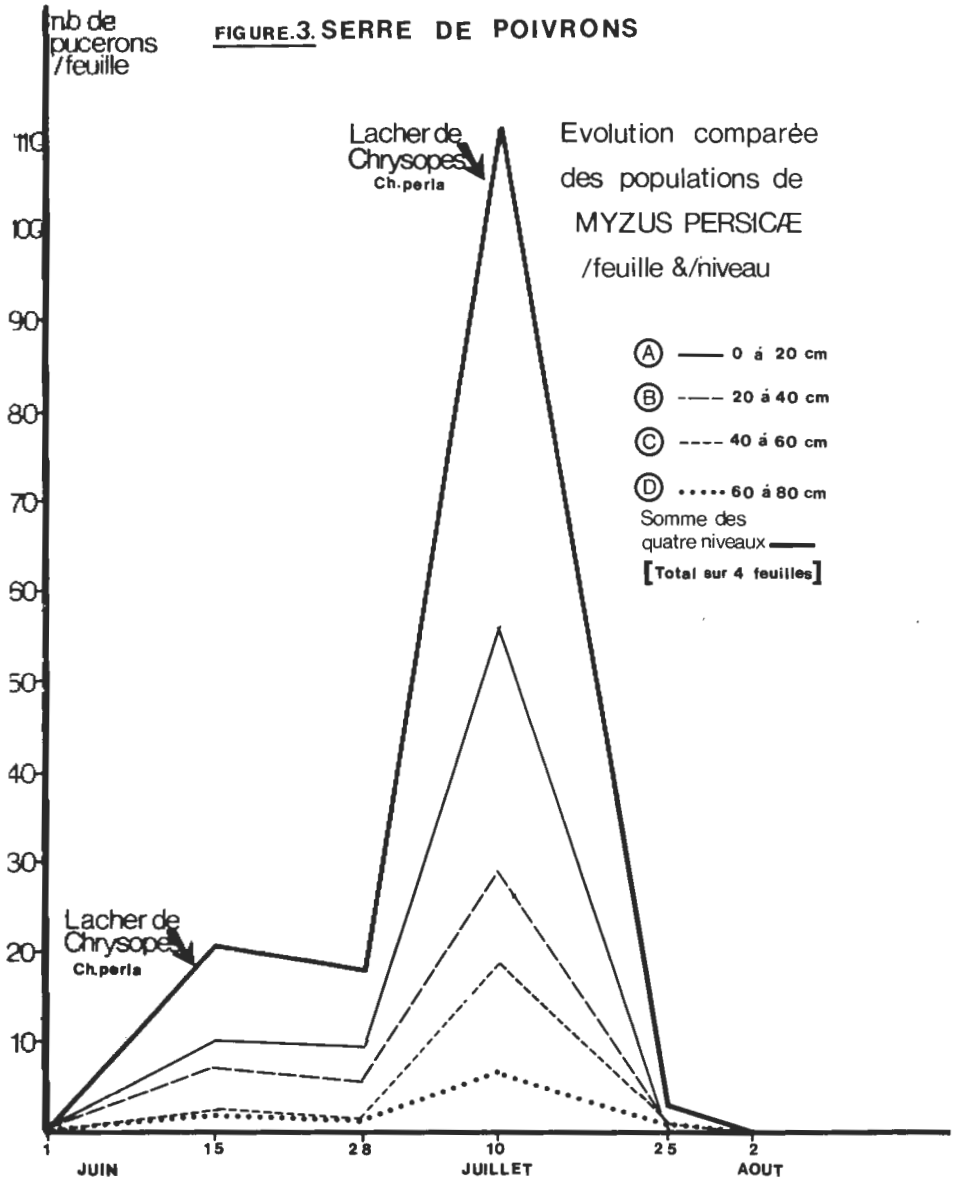
L'aubergine est, comme le poivron, très favorable à la multiplication des pucerons, avec des différences variétales, violette longue étant plus sensible que New York et Baluroi plus sensible que Bonica.

Les espèces dominantes sont les mêmes que sur poivron, l'ordre d'apparition des espèces étant également Myzus persicae, puis Macrosiphum euphorbiae et Aulacorthum solani, et enfin Aphis gossypii. Les deux premières espèces sont les plus à craindre, car elles infestent précocement l'ensemble du feuillage (dessous des feuilles) et des organes jeunes (pousses, boutons floraux). Chez M. euphorbiae, la tendance à coloniser les jeunes feuilles et les fleurs est plus marquée que chez M. persicae qui se multiplie fortement sur feuilles basses. Les principaux dégâts sont liés à la colonisation des fleurs (coulure) des jeunes fruits et à la production de miellat par les pucerons colonisant les parties supérieures de la plante (surtout M. euphorbiae). Les fleurs sont plus résistantes aux pucerons que celles du poivron et la formation du fruit peut se faire avec plus de 70 pucerons par fleur avant la fécondation. Le miellat provoque très rapidement l'apparition de fumagine qui nuit à la présentation des fruits et freine la photosynthèse. Aphis gossypii colonise surtout la face inférieure des feuilles en commençant par les feuilles basses, mais atteint très rapidement une densité considérable avec production de miellat intense.

Sur aubergine les parasites introduits précocement (Diaeretiella rapae M'INT, Aphelinus asychis WALK.) présentent une dispersion moins rapide que sur poivron (la pilosité et la structure de la plante ne paraissent pas très favorables à l'installation d'A. asychis).

L'introduction naturelle d'Aphidius matricariae aboutit à une colonisation assez comparable à celle qu'on obtient avec D. rapae. Toutefois, elle intervient généralement trop tardivement pour empêcher l'infestation des boutons floraux.

Sur Aphis gossypii, Lysiphlebus testaceipes introduit dans le Sud-Est de la France en collaboration avec STARY peut s'installer spontanément à partir des plantes sauvages des maquis voisins (genêt d'espagne infesté par Aphis craccae). Les lâchers effectués sur cultures de concombres voisines des plantations d'aubergine ont permis une bonne installation des parasites sur aubergine, montrant ainsi le grand pouvoir de dispersion de cette espèce.


nb de pucerons /feuille
FIGURE.3. SERRE DE POIVRONS
Lacher de Chrysopes Ch.perla
Evolution comparée des populations de MYZUS PERSICÆ /feuille &/niveau
Ⓐ —— 0 à 20 cm
Ⓑ —— 20 à 40 cm
Ⓒ ---- 40 à 60 cm
Ⓓ ····· 60 à 80 cm
Somme des quatre niveaux ——
[Total sur 4 feuilles]
Lacher de Chrysopes Ch.perla
110
100
90
80
70
60
50
40
30
20
10
1
15
28
10
25
2
JUIN
JUILLET
AOUT

Cette caractéristique pourrait être mise à profit pour compléter l'action de Trioxis sinensis utilisé expérimentalement à Littlehampton et un échange de parasites a eu lieu dans ce but à la demande de cette station de recherches. T. sinensis s'installe et se multiplie rapidement en serre dans nos conditions climatiques mais vole sur place au dessus des plantes et ne semble pas se diffuser très facilement. Nous n'avons pas encore de données suffisantes au sujet de ce parasite.

D'une manière générale, l'installation même précoce de parasites au moyen d'unités mobiles de production ou par lâcher massif précoce ne fait que freiner la multiplication des trois espèces dominantes (M. persicae, M. euphorbiae et A. gossypii), et la diminution des populations aphidiennes n'intervient que si d'autres facteurs entrent en jeu:

- Introduction spontanée de prédateurs tels que Scymnus spp. Harmonia 14-punctata, Coccinella septempunctata, Scaeva pyrastri, Syrphus corollae, Episyrphus balteatus, Hétéroptères prédateurs (Dicyphus errans, Orius sp., Deraecoris sp.), Cecidomyidae, Chrysopa septempunctata, C. formosa, Boriomyia sp.

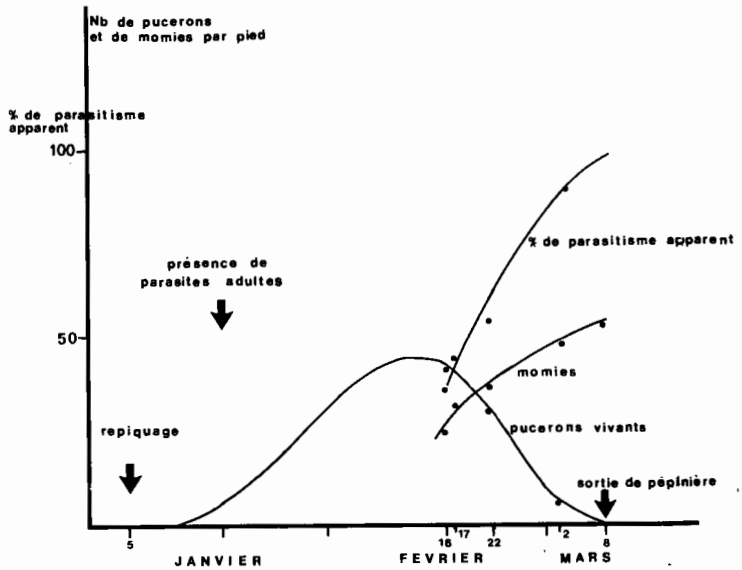
- Températures élevées: en pratique, nous avons constaté chaque année une diminution des populations aphidiennes coïncidant avec l'apparition de températures supérieures à 30° en serre, sauf pour A. gossipyi. Cette diminution est beaucoup plus rapide s'il existe des insectes aphidiphages dont la proportion relative se trouve brusquement augmentée sous l'effet des premières journées chaudes qui limitent la multiplication des aphides.

- Stade des plantes. Les plantes âgées ayant déjà subi des pullulations de pucerons sont moins favorables à l'installation de M. persicae et M. euphorbiae. Ceux-ci colonisent plus volontiers les repousses du porte-greffe (tomate) ou les gourmands et peuvent être éliminés par pinçage. Même les jeunes pousses du sommet de la plante sont moins infestées, en raison peut-être de leur exposition au soleil.

Il semble que sur culture jeune, les parasites ne font que freiner la progression des pullulations aphidiennes, tant que celle-ci est encore dispersée et hétérogène, au moins jusqu'à une densité de l'ordre de 100 à 500 pucerons en moyenne par pied, pour des plantes de 5 à 10 feuilles principales. Par ailleurs, on ne peut trop compter sur l'action prédatrice d'A. asychis qui présente un maximum d'activité aux alentours de 25° et qui s'installe et se diffuse beaucoup plus difficilement sur aubergine que sur poivron.

Les tentatives de lâchers massifs de parasites sur des populations faibles et hétérogènes ont abouti à un gaspillage considérable de ceux-ci (sauf sur pépinières où les plants sont très rapprochés). (Fig. 4).

FIGURE 4 EVOLUTION D'UN COMPLEXE HOTE-PARASITE DANS UNE PEPINIERE DE POIVRONS



Aussi nous orientons-nous actuellement vers des lâchers répétés d'oeufs ou de larves de Névroptères pour compléter l'action des parasites susceptibles d'être installés dès l'apparition des premiers aphides au moyen d'unités mobiles de production. Le complexe Aphelinus asychis-Diaeretiella rapae convient pour les infestations précoces de M. persicae et ultérieurement de M. euphorbiae qui constitue un hôte de prédilection pour A. asychis.

Dans le cas de populations dépassant 100 pucerons par pied en moyenne, nous avons tenté de limiter le nombre d'auxiliaires à lâcher en effectuant préalablement, comme sur poivron, des essais de chocs thermiques et de bassinage.

Dès 35°, on observe pour des chocs thermiques durant 4 heures environ un freinage très notable de la multiplication des pucerons.

L'aubergine résiste bien à des températures de 42° à 45°, maintenues pendant 4 heures, et nous n'avons pas observé, comme sur poivrons, de chute des feuilles couvertes de miellat. En revanche, les pucerons ont des possibilités d'abri à la base du tronc et sous les larges feuilles qui traînent à terre et qui constituent d'importants foyers de recolonisation:

dans ce cas la chute de population observée 24 heures après le début de l'essai est de l'ordre de 60 pour cent seulement alors qu'elle varie de 80 à 90 pour cent sur les pieds ne présentant pas de feuilles basses infestées. La suppression des feuilles basses infestées et la pose d'un manchon englué a permis de piéger une partie des pucerons sur les foyers d'infestation.

Deux essais de bassinage très vigoureux réalisés sur des cultures infestées essentiellement par Macrosiphum euphorbiae ont eu pour effet une réduction de moitié de la population 24 heures après l'essai, avec une dispersion des adultes qui recolonisent rapidement des pieds jusqu'à présent non infestés et notamment les jeunes pousses. La diminution de la quantité de miellat et de mues recouvrant les feuilles des pieds les plus infestés présente cependant un intérêt non négligeable, bien que l'aubergine se prête moins bien que le poivron à ce traitement du fait de sa pilosité. Au niveau de foyers d'infestation localisés, la technique de suppression des feuilles basses et la pose d'un manchon englué améliore le rendement du bassinage et surtout évite la dissémination des pucerons en les empêchant de recoloniser les plantes.

Les essais de lutte biologique étaient conduits sur aubergine avec différentes espèces de chrysopes car les premiers résultats obtenus avec C. perla étaient moins encourageants et plus dépendants des conditions culturales que sur poivron où un véritable "nettoyage" de la plante peut être obtenu lorsque les lâchers sont effectués en fonction de données précises sur l'importance et surtout la répartition spatiale des populations aphidiennes, les déplacements des larves étant limités.

Indépendamment de la pilosité et de la surface des plantes (feuilles très larges sur les plants greffés sur tomate), certains facteurs culturaux peuvent intervenir sur le comportement des larves de Chrysopes: celles-ci se déplacent plus facilement sur un mulch de paille ou sur le film plastique noir du système d'irrigation que sur un sol travaillé.

Chrysopa formosa paraît présenter une activité supérieure à C. perla sur aubergine et se maintient davantage sur les plantes. Elle est en outre susceptible de se multiplier en serre après un lâcher d'oeufs ou de larves et s'accommode des températures élevées (35°). C. septempunctata s'introduit spontanément en serre et peut s'y multiplier.

La polyphagie des chrysopes constitue un élément important dans le choix de ce type de prédateurs, les larves lâchées avec une densité suffisante sur les jeunes plantes (de l'ordre de 10 par pied) jouant un rôle de nettoyage non négligeable vis-à-vis de tous les ravageurs à corps mou (oeufs et jeunes chenilles de lépidoptères, larves, nymphes et adultes d'aleurodes).

Sur aubergine, les chrysopes sont impuissantes à enrayer les pullulations d'aleurodes, mais à plusieurs reprises, nous avons constaté des densités moindres d'aleurodes sur les cultures "traitées" avec C. perla et C. formosa par rapport aux parcelles non traitées.

Chrysopa carnea, qui paraît extrêmement polyphage, n'est pas actuellement utilisée pour les essais à cause du cannibalisme larvaire qui nécessite un élevage en cages individuelles, mais nous n'excluons pas son emploi en raison des excellents résultats obtenus avec FERRAN sur milieu artificiel (55 pour cent de rendement). (Bigler, Ferran et Lyon, 1976, sous presse).

Chrysopa perla a été jusqu'à présent préféré à cause du cannibalisme réduit en élevage massif, de sa plus longue durée de vie larvaire qui permet d'espacer les interventions en assurant la présence de chrysopes jusqu'à 1 mois après lâcher d'oeufs en serre, de la facilité de manipulation des adultes en cage et des oeufs sur cellophane.

Chrysopa formosa présente à peu près les mêmes caractéristiques que C. perla, pond ses oeufs sur végétal infesté et non sur cellophane, mais en revanche se maintient mieux que C. perla sur aubergines et peut se multiplier en serre, et s'adapter à de hautes températures. C. formosa et surtout C. perla font actuellement l'objet d'essais d'alimentation artificielle, le cycle complet ayant pu être obtenu sur milieu de VANDERZANT. (Bigler, Ferran et Lyon, 1976, sous presse).

C. septempunctata présente comme C. perla une longue durée de vie larvaire, une très grande taille et une consommation importante de pucerons avec cannibalisme réduit et manipulation aisée des adultes. Elle a été retenue pour l'expérimentation car elle s'introduit et se reproduit spontanément en serre, mais ne semble pas se prêter aussi bien que C. formosa à une multiplication de masse, dans l'état actuel de nos connaissances.

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THE USE OF CHRYSOPA CARNEA STEPH. FOR BIOLOGICAL CONTROL OF APHIDS IN GLASSHOUSES

by

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The use of the common green lacewing, Chrysopa carnea, for biological control of pests has been studied in many experiments. Many pest species, such as aphids, mealybugs and cutworms have been successfully controlled with lacewings. The green lacewing has been studied also in glasshouses, mostly for aphid control. Most of the experiments have been performed only on laboratory scale. We started our study to examine whether the green lacewing could be used in practical horticulture. The purpose of this report is to give an account of some important problems that appeared during the experiments. Results of the aphid control experiments on the green pepper are available in TULISALO & TUOVINEN (1975).

Mass rearing of the green lacewing

Mass rearing of the green lacewing is quite easy to the amount of some thousands or tens of thousands eggs/day (RIDGWAY et al. 1970). The more extensive use of the green lacewing supposes the production of millions of eggs/day. The production must be very cheap, because great numbers of eggs are needed for successful control. The most difficult problem in mass rearing seems to be the feeding of the larvae. A good artificial diet for adult lacewings is available but none for the larvae. Possibilities of developing a useful artificial diet for larvae seem limited, due to their cannibalistic habits. Isolation of the larvae is very laborious, although a better technique of feeding the larvae has been developed (MORRISON et al. 1975).

We have studied the possibility of feeding the larvae with adult Sitotroga cerealella moths. First results show that adult moths form a quite useful and cheap biomass for larval feeding. The technical arrangements of this method are now under study.

Storage and application of the eggs

Storing the eggs for two weeks at +10°C does not reduce the hatching of the eggs very much. This is important when the future use and commerce of the eggs is considered. Furthermore, cold resistance also makes possible the mailing of eggs over long distances in cool boxes. The cannibalism of the larvae makes that both storing and mailing as well as introducing of the green lacewings is most successful at the egg stage. In the USA a technique for distributing eggs in masses by spraying them mixed with a suitable medium has been investigated (SHANDS et al. 1972), and this seems to be a possible method to distribute eggs also in glasshouses. We have introduced the eggs by placing paper slips containing eggs on the plants. It is quite easy to distribute eggs with this method, also greater egg-masses, but it requires a great deal of work. The larvae quite readily disperse in the crop, so the paper slips could be placed rather sparsely.

Number of eggs needed for control

When the green lacewings are introduced in the glasshouses as eggs, the number of eggs compared to aphids must be quite high. The decrease in egg hatching percentage, cannibalism and egg predators reduce the number of lacewing larvae in the culture. The hatching of eggs takes some days and the aphid population may have increased during that time. This means that the initial ratio of lacewings to aphids changes very much during the control period. In our experiments with green pepper we have got results that suggest to use even a 1:1 ratio of eggs and aphids. That is why control must be started at the initial phase of aphid infestation. However, we must remember that the green peach aphid reproduces very quickly on the green pepper and the control of other aphid species or aphids on other crops may need less eggs.

The black ant preventing control

The black ant (Lasius niger L.) proved to destroy the lacewing eggs very effectively. They found the egg-paper slips before the eggs hatched and carried, in some cases, most of the eggs from the plants. Spraying the eggs scattered onto the plants may save most of the eggs, but it seems necessary to us to destroy the black ants in the glasshouse before starting the control programme.

Continuity of the control

In successful control the lacewing larvae consumed almost every aphid in the crop and so most of the larvae starved to death or disappeared from the glasshouse. That is why only a few adults hatched in the glasshouse, and even they did not lay enough eggs because suitable

food was lacking. It may be possible, however, to feed adult lacewings with artificial diet and thus increase egg laying. In our experiments we had to re-introduce eggs into glasshouses at intervals of about four weeks.

Conclusions

The experiments reported here showed that the larvae of the common green lacewing are quite promising agents for biological control of aphids in glasshouses. They are polyphagous, have a good ability to move on plants, and have a good searching capacity. Furthermore, they have quite a wide adaptability to temperature. The larvae are partly resistant against some insecticides which facilitates integrated control. Concerning the use of the green lacewing in practice only a few problems remain to be solved. The mass production and application of the eggs still need some improvements. We think that this insect can be a usable and economical agent for aphid control.

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MASS REARING AND POSSIBLE USES OF CHRYSOPIDAE AGAINST APHIDS IN GLASSHOUSES

by

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At the Institute of Plant Protection in Poznań research on green lace-wing (Chrysopidae) is carried out to determine their possible use in biological and integrated pest control in glasshouses both by protection of natural populations of Chrysopidae in the agro-ecosystem and by mass rearing and introduction.

In this report the work on mass rearing of Chrysopidae and the results obtained after the introduction of Chrysopidae in glasshouse crops are presented.

Research on mass rearing of Chrysopidae

The research on mass rearing of Chrysopidae presently carried out concerns the development of an artificial diet and the mechanization of rearing process.

A very simple and relatively inexpensive rearing method, based on the modification of Finney's (1950) and Hagen's (1950) method has been developed. Chrysopidae are fed with the eggs of Sitotroga cerealella Ol. that are previously frozen at a temperature of -8 to -18° C. It allows to give the eggs only once, which simplifies the rearing very much. The eggs do not lose their nutritive value after freezing, on the contrary it seems to increase. (Table 1). Freshly collected eggs of Sitotroga cerealella stored in the refrigerator maintain their nutritive value for at least a month.

The quantity of food needed for the development of one Chrysopa carnea larva is about 30 mg; for the larvae of other species of Chrysopidae 50-100 mg of Sitotroga cerealella eggs are needed (Table 2).

TABLE 1. Influence of freezing of eggs on quality of Chrysopa carnea

	TIME OF FREEZE					
	24 h		7 days		30 days	
	FROZEN EGGS	CHECK	FROZEN EGGS	CHECK	FROZEN EGGS	CHECK
Longevity of development cycle in days	18–23	21–23	19–21	19–23	19–22	19–24
Longevity of larval stage in days	8–13	10–12	9–11	11–14	10–12	10–12
Mortality in time of development	44,4	55,0	6,7	50,0	16,7	56,7
Weight of cocoons in mg.	10,0 6,0–14,0	7,2 4,0–12,0	8,6 5,0–13,0	9,0 4,0–12,0	8,5 5,0–12,0	6,1 4,0–12,0

TABLE 2. Influence of quantity of food on breeding results

INDEX OF BREEDING	AMOUNT OF FOOD CONSUMED PER LIFE CYCLE			
	Frozen eggs	Frozen eggs	Frozen eggs	Fresh eggs
	30 mg	50 mg	100 mg	30 mg - check
Longevity of development cycle in days	18–23	18–23	19–22	18–24
Longevity of larval stage in days	7–9	7–9	7–9	7–10
Mortality in time of development	15 %	38,5 %	16 %	33 %
Weight of cocoons in mg.	10,0	7,5	7,0	7,3

Manpower is only needed to place prepared prey eggs in rearing vessels, together with two predator eggs with well visible embryons. Small test-glasses with perforated stoppers facilitating the ventilation are used as rearing vessels. Adults are transferred to glass cylinders of about 20 cm of diameter after emergence. The cylinders contain a small vessel filled with water and food consisting of the yeast hydrolisate, honey, sugar and a small number of aphids. In one cylinder, 30-60 insects are placed. Chrysopidae oviposit on paper bands placed on the walls of the cylinder. The eggs are cut out and transferred to test-glasses. They are stored in containers with a high relative humidity (80-90 percent). Eggs can not be stored for a long time; our average storage period is 1-2 weeks.

The rearing of Chrysopidae is carried out in air-conditioned chambers, in which temperature is maintained at 25-28° C, relative humidity at 70-80 percent and 18 hours of light are given.

Using the above described method we have reared without diapause until now the following species:

43 generations of Chrysopa carnea Steph.
11 generations of C. abbreviata Curtis
8 generations of C. commata Kis et Ujhelyi
7 generations of C. formosa Brauer
5 generations of C. phyllochroma Wesm.
5 generations of C. septempunctata Wesm. and
4 generations of C. perla L. (Table 3-4)

The method is especially useful for rearing of C. carnea which is characterized under these conditions by good biological characteristics such as: high fecundity, low mortality, predominance of females in the populations and speedy development.

The material obtained in the rearings has been used for experiments to study the feasibility of aphid control in glasshouses by introduction of Chrysopidae eggs.

Trials of biological control of aphids in glasshouses

Experiments were carried out in glasshouses with asparagus which were heavily attacked by green peach aphid (Myzus persicae). The area covered by one glasshouse amounted to about 120 sqm. In total 4,800 eggs of C. perla have been introduced, i.e. about 40 per sqm., and the ratio of predator to prey amounted to 1 : 25. The results of experiments were very favourable, during 3 months the culture of asparagus was free of aphids. Greenhouses with chemical control served as a comparison, in these treatments with Nogos G 50 EC were repeated several times.

TABLE 3. Biological index of mass rearing of Green Lacewings

No.	Species	No. of generation breeded without diapauza	Longevity of development cycle	Percentage of emerged eggs	Mortality in percentage	Average fertility of female	Sex - Ratio	Life longevity of adults
1.	Chrysopa carnea Steph.	43	18 - 26	F_{24-25} 62,0 - 99,3 F_{40-41} 33,0 - 47,0	F_{38-42} 79,0 - 82,0 12,3 - 61,0	F_{23} 398,0 F_{38} 141,0	0,50-0,69	86 - 138
2.	Chrysopa perla L.	4	26 - 32	F_{1-3} 23,0 - 77,7 F_4 0	72,8 - 96,5	F_2 342,8 F_4 20,0	0,46-0,50	90 - 175
3.	Chrysopa phyllochroma Wesm.	5	26 - 38	20,0 - 80,0	72,0 - 97,0	121,0-293,7	0,30-0,50	53 - 85
4.	Chrysopa abbreviata Kis et Ujhelyi	11	30 - 42	F_2 83,3 F_{11} 13,7 F_{12} 0	82,0 - 96,0	F_{3-8} 283,0-339 F_{11} 119,0	0,20-0,50	86 - 138
5.	Chrysopa commata Kis	8	30 - 46	F_{1-8} 58,6 - 33,0 F_9 0	70,0 - 82,0	120,0-489,2	0,30-0,40	78 - 137
6.	Chrysopa formosa Brauer	7	22 - 41	25,0 - 63,6	86,0 - 92,0	208,0-342,2	0,50-0,75	60 - 104
7.	Chrysopa septempunctata Wesm.	5	26 - 35	23,0 - 63,4	92,0 - 96,2	207,0-422,7	0,20-0,50	55 - 117

Another series of experiments was carried out in 4 glasshouses with asparagus. In two of them, biological control (introduction of C. carnea eggs) and in the other two, integrated control were applied. Integrated control consisted in the introduction of Chrysopa combined with periodical treatments with Pirimor 0,05 percent at 0,5 kg/ha. This aphicide is relatively non toxic for the larvae of Chrysopidae. It can be used at a relative low dosage and allows for a reduction of the quantity of introduced entomophagous insects. During the experiments, carried out from September till the end of October, 15,000 eggs of C. carnea have been introduced in a glasshouse of about 300 sqm. and 2 g. of Pirimor has been used. In a glasshouse of the same area, however, in which chemical method was applied, 180 g. of Nogos EC and 150 ml. of Pirimor have been used. Thus, the integrated control method considerably reduces the amount of pesticides used, while ensuring excellent aphid control.

In the glasshouses, where biological control was applied from March till the end of June, 24,000 of eggs of Chrysopidae have been introduced to each of them, and good results were obtained, but with a certain delay. This might be explained by a too low number of Chrysopidae in relation to the density of the aphid population.

The detail of the experiments in the two glasshouses were as follows:

Glasshouse	Dates of introduction and observations	Number of aphids per 1 sqm.	Number of introduced C.carnea & C.perla per 1 sqm.	per glasshouse	Notes
1.	7.III.74	286,0	48	2,400	C. carnea
	18.III	332	48	2,400	
	27.III	183,6	26	1,300	
	10.IV	158,0	20	1,000	C. perla
	23.IV	218	-	-	
	2.V	154,4	7,6	380	"
	13.V	89,6	10,0	500	
	23.V	117,4	160	8,000	C. carnea
	5.VI	61,6	76,0	3,800	in control
	21.VI - 30.VIII	0	0	0	172,5 aphids per 1 sqm.
2.	18.III	82,3	7,1	850	C. carnea
	27.III	59,4	5,0	600	
	10.IV	221,7	20,0	2,500	
	23.IV	548,3	8,3	1,000	
	2.V	243,3	9,2	1,100	
	13.V	183,3	12,5	1,500	
	23.V	73,7	66,7	8,000	
	5.VI	18,8	4,2	2,300	
	21.VI	0	-	-	

The above mentioned results show the effectiveness of Chrysopidae in the control of aphids on asparagus.

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IMPORTANCE RELATIVE DE DIVERS FACTEURS INTERVENANT DANS LA TOXICITE MANIFESTEE PAR CERTAINS PESTICIDES A L'EGARD DE *DIAERETIELLA RAPAE M'INTOSH*

R. DELORME *

Diaeretiella rapae est un hyménoptère Aphidiidae parasite dont les possibilités d'utilisation dans la lutte contre les pucerons de serre (*Myzus persicae SULZER* en particulier) ont été explorées par la station de Zoologie de l'INRA depuis quelques années (LYON 1968, 1970, 1971, 1973).

L'utilisation des Aphidiidae comme moyen biologique de lutte contre les pullulations aphidiennes est actuellement étudiée dans de nombreux pays à la suite des premiers succès observés en Amérique du Nord en particulier contre *Therioaphis maculata BUCKT.*

Cependant, outre les problèmes de dynamique des populations et de mise au point des méthodes d'introduction, se pose le problème de leur émploi dans le cadre d'une lutte intégrée aussi bien en serre qu'en plein champ, les informations sur la toxicité des pesticides restant très fragmentaires.

Nous avons entrepris en 1973 l'étude de la toxicité pour *D. rapae* de quelques pesticides à l'aide de tests de laboratoire de longue durée destinés à mettre en évidence l'action des pesticides sur les différents stades, la persistance d'action des résidus pour les adultes et la possibilité pour ces derniers de se reproduire.

Dans un premier temps l'étude a porté sur douze pesticides utilisables en serre sur les parties aériennes des plantes ; parmi ces substances figurent des insecticides (lindane, parathion, phosalone, vamidothion), des

* : Avec la collaboration technique de Andrée GREDT.

aphicides spécifiques (isolane, pirimicarbe), des acaricides (dicofol, tétradifon, mélange chlophénamidine + formétanate) et des fongicides (bénomyl, mancozèbe, dodémorphe acétate).

Cette étude a été complétée dans un deuxième temps par l'examen de la toxicité d'un insecticide systémique, le carbofuran, formulé en granulés incorporables au sol.

PRODUITS UTILISES EN PULVERISATIONS

Ces essais ayant déjà fait l'objet de deux publications (DELORME, 1975,1976) nous nous bornerons à rappeler les résultats principaux.

La toxicité des pesticides pour les stades internes jeunes du parasite (pucerons parasités non momifiés renfermant des oeufs et larves 1 et 2 du parasite) est souvent identique à la toxicité pour l'hôte. Cependant dans le cas du mancozèbe, du dicofol, du tétradifon et du mélange chlorphénamidine + formétanate, une proportion non négligeable de parasites peut émerger après la mort de l'hôte, alors que pour le parathion l'effet inverse s'observe, le produit pouvant dans certains cas pénétrer et détruire les jeunes stades du parasite sans détruire le puceron hôte.

On retrouve d'ailleurs cet effet de pénétration du parathion dans l'application en présence de stades internes âgés du parasite (larves 4, nymphes et adultes prêts à éclore), à l'intérieur des pucerons momifiés ; il est le seul des produits testés à réduire sensiblement les émergences (85 % à la concentration de 25 g MA/hl). La présence du tégument momifié du puceron constitue une barrière physique à la pénétration des produits et explique probablement la remarquable tolérance de ces stades envers la plupart des pesticides.

En ce qui concerne la toxicité initiale et la persistance d'action pour les adultes de *D. rapae* des dépôts formés sur les plantes, aucune action n'est relevée pour le bénomyl, le mancozèbe, le dicofol et le tétradifon. Le parathion, le mélange chlorphénamidine + formétanate, le vamidothion, le lindane et le pirimicarbe provoquent une mortalité supérieure à 90 % à la concentration d'emploi, les plus persistants étant le mélange chlorphénamidine + formétanate, le parathion et le vamidothion.

La possibilité d'obtenir une descendance à partir des parasites traités aux divers stades de développement mentionnés est en général liée à la présence de pucerons non parasités ayant survécu au traitement. Les seuls cas où *D. rapae* n'a pu limiter la reprise des populations aphidiennes ont été observés dans certaines répétitions après des traitements au vamidothion et au parathion.

ETUDE DE LA TOXICITE D'UN INSECTICIDE SYSTEMIQUE, LE CARBOFURAN, UTILISE SOUS FORME DE GRANULES INCORPORES AU SOL.

1° - Méthode

- Insectes mis en oeuvre.

L'hôte choisi pour l'élevage de *D. rapae* est *Myzus persicae*, lui-même élevé sur un mélange pois-fèves à 20°C ± 10 % d'HR et sous une photopériode de 16 heures, l'éclairage étant assuré par des rampes de 4 tubes fluorescents de 40 W situés à 20 cm environ au-dessus du sommet des cages. Dans ces conditions la durée du cycle de *D. rapae* est de 13 à 17 jours suivant le stade de l'hôte (en accord avec BONNEMAISON, 1970), la longévité des adultes de 6,1 jours en moyenne.

- Support végétal utilisé.

Les essais sont conduits sur fèves plantées individuellement en pots sur du sable, substrat choisi afin d'éviter les phénomènes d'adsorption des pesticides au niveau de la matière organique du sol.

Une plaque plastique circulaire laissant passer la tige de la plante surmonte le sol et l'ensemble est recouvert par une housse de mousseline selon le schéma indiqué précédemment (DELORME, 1976).

- Conditions d'application et schéma de l'essai.

Le carbofuran est appliqué sous forme de granulés à 5 % de MA incorporés au sable à une profondeur de 1 cm environ et en 4 points formant les sommets d'un carré de 6 cm de côté, et équidistants de la tige de la plante. 3 doses ont été appliquées correspondant à 150, 300 et 600 g MA/ha,

et à des intervalles de temps différés après le semis. 3 types d'actions ont été étudiées :

- Toxicité pour l'hôte *Myzus persicae*
- Action sur l'évolution conjointe du complexe parasite-puceron
- Toxicité directe pour les adultes de *D. rapae*

Les différentes opérations réalisées sont représentées dans la figure n° 1.

2° - Résultats.

- Pucerons non parasités.

De même que pour les essais de pulvérisation il nous a semblé important de connaître d'abord l'action du carbofuran sur l'hôte *Myzus persicae* non parasité.

Le test est réalisé de la manière suivante : des fèves âgées de 11 jours sont contaminées par une centaine de pucerons de tous stades, la population résultante étant contrôlée 12 jours plus tard ; les traitements sont exécutés à raison de 2 répétitions par dose soit au semis, soit au moment de la contamination, soit 7 jours et 2 jours avant le contrôle.

La toxicité du produit est exprimée par la réduction de population vivante par rapport au témoin. Les résultats sont présentés dans le tableau 1, d'où l'on peut tirer les remarques suivantes :

- le carbofuran est d'autant plus efficace qu'il est appliqué plus tôt.
- bien que l'effet se manifeste dès le 2ème jour après traitement, il faut attendre un minimum de 12 jours pour approcher de l'efficacité totale.

- Evolution du complexe parasite-puceron.

Comme précédemment des fèves âgées de 11 jours sont contaminées chacune par une centaine de pucerons sur lesquels on apporte 5 jours plus tard 5 femelles et 2 mâles du parasite.

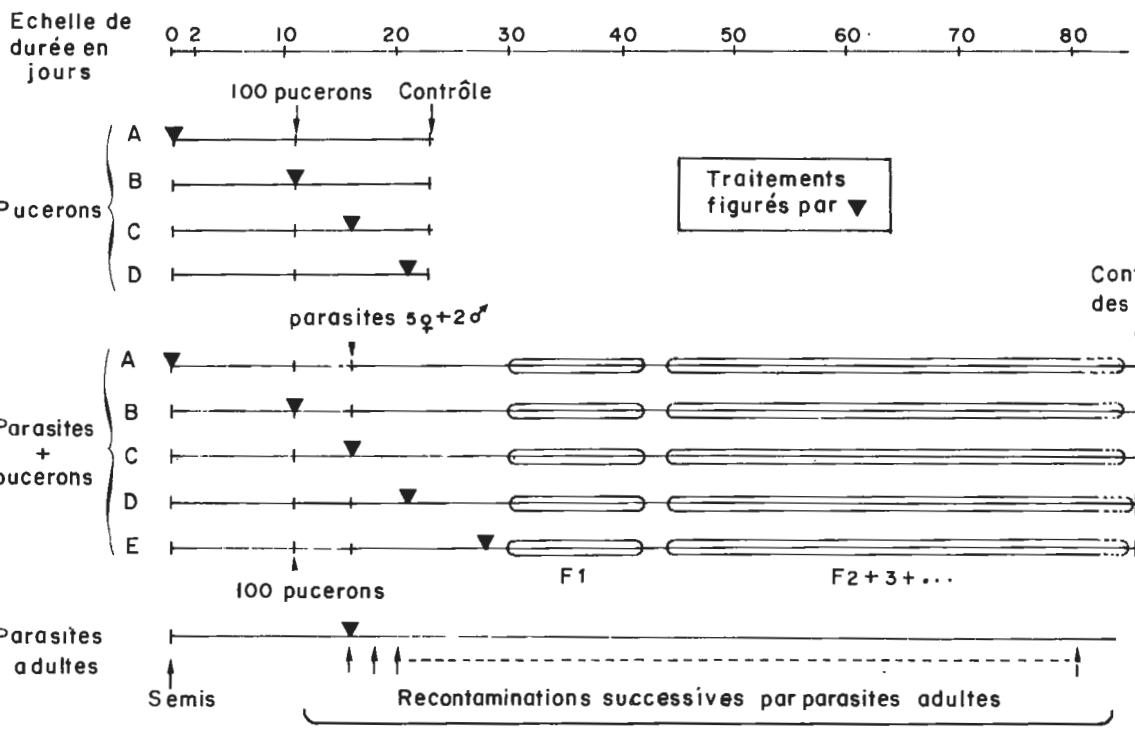

FIG. 1 : SCHEMA GENERAL DE L'ESSAI

TABLEAU I

Réduction des populations de *Myzus persicae* soumises à l'action du carbofuran

Doses en g M.A./ha	Temps entre le traitement et le contrôle des populations			
	23 j (série A)	12 j (série B)	7 j (série C)	2 j (série D)
150	93,3	30,0	70,7	10,5
300	97,5	48,3	76,4	29,0
600	100	97,3	82,7	33,5

TABLEAU II

Réduction des émergences de *D. rapae* à la suite de l'application de carbofuran

Génération	Doses en g M.A./ha	Série A	Série B	Série C	Série D	Série E
F_1	150	100	92,0	67,3	69,0	67,1
	300	86,1	100	72,6	95,2	16,6
	600	100	100	100	42,7	66,0
F_2 + 3	150	100	80,9	82,8	92,5	95,5
	300	100	100	81,1	99,7	75,3
	600	100	100	100	97,8	100

Les émergences de la 1ère génération (F1) commencent 14 jours plus tard et se poursuivent sur 10 à 12 jours. Ces émergences sont contrôlées journellement de même que celles des générations suivantes. Les traitements sont réalisés à raison de 2 répétitions par dose soit au semis, soit au moment de l'apport des pucerons,soit à l'apport des parasites, soit 5 jours plus tard ou enfin 2 jours avant les émergences.

L'effet du carbofuran sur les émergences est apprécié par rapport aux émergences se produisant dans les pots témoins contaminés dans les mêmes conditions.

Les résultats exposés dans le tableau II appellent les remarques suivantes :

- A toutes les doses et quelle que soit la date du traitement, le carbofuran entraîne une réduction notable des émergences des parasites.
- La première génération est d'autant plus réduite que le produit a été appliqué plus tôt.
- L'action sur les générations suivantes est encore plus marquée : à la dose de 600 g MA/ha, on n'observe pratiquement pas de 2ème génération. Aux doses moitié et quart, la réduction des émergences par rapport au témoin est en moyenne de plus de 90 %.

Ces réductions d'émergences semblent imputables principalement à la mortalité des pucerons hôtes. En effet le contrôle des plantes après la fin des émergences, ne montre pas un pourcentage de momies non écloses plus élevé dans les traités que dans les témoins ; aucune action sur les stades internes n'a pu en conséquence être mise en évidence.

- Toxicité directe pour les adultes de *D. rapae*.

Des fèves sont plantées en pots selon le montage indiqué précédemment. Lorsqu'elles ont atteint une hauteur d'environ 15 cm le traitement est effectué et dès cette date on apporte périodiquement sur chaque plante 50 parasites adultes, prélevés dans l'élevage et âgés de 0 à 24 H. Les mortalités sont relevées après 24 heures de contact.

La figure 2 indique les courbes de mortalité obtenues pour les 3 doses en fonction du temps laissé entre le traitement et la contamination.

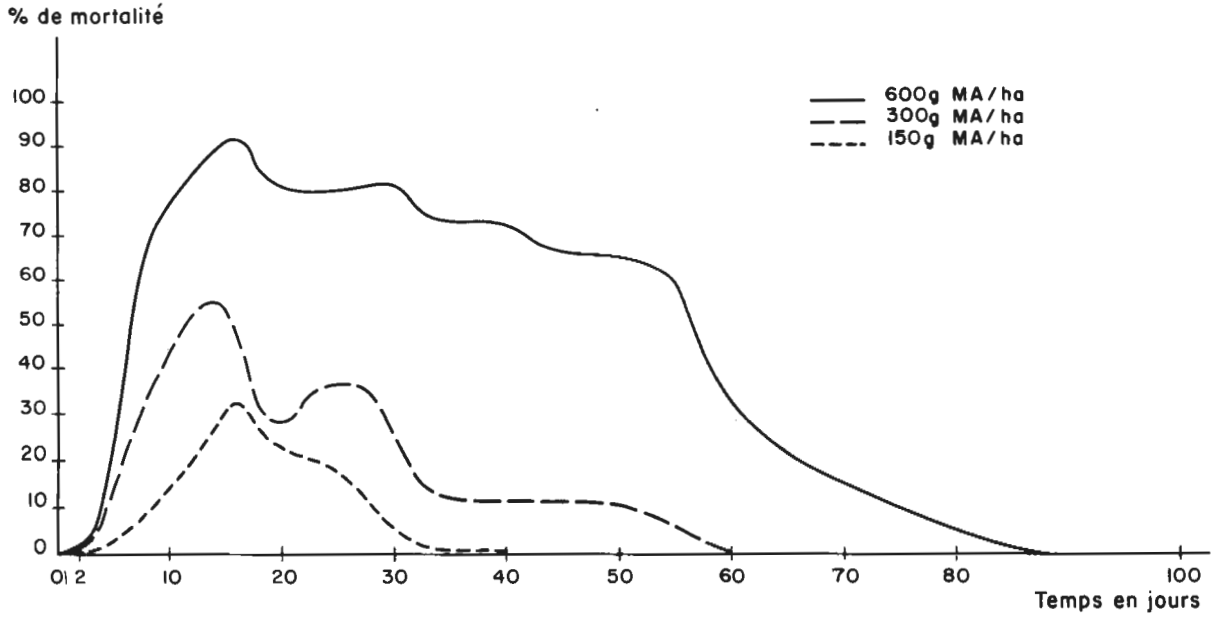

FIG. 2 : TOXICITE DIRECTE DE LA PLANTE POUR LES ADULTES DE *D. rapae*
A LA SUITE DU TRAITEMENT PAR LE CARBOFURAN

Ces courbes représentent les moyennes de deux essais comportant chacun 2 répétitions par dose.

Contrairement à ce qu'affirment de nombreux auteurs indiquant que l'utilisation d'un insecticide systémique appliqué en traitement de sol n'entraîne aucune action directe pour les entomophages ne se nourrissant pas directement de la plante, nous mettons ici en évidence qu'un produit comme le carbofuran utilisé en granulés incorporables au sol présente une toxicité directe très importante pour les adultes de *D. rapae*. En effet à la dose de 600 g de M.A./ha la toxicité devient mesurable dès le 3ème jour après traitement. Elle croît ensuite rapidement, provoquant plus de 90 % de mortalité vers le 15ème jour ; on observe ensuite un palier légèrement décroissant jusque vers le 55ème jour où la mortalité est encore d'environ 60 %, puis une chute assez rapide, l'activité biologique disparaissant vers le 80ème jour.

Les doses moitié et quart montrent également une activité maximum vers le 15ème jour (provoquant respectivement 55 et 35 % de mortalité) ; la phase palier est moins marquée et l'activité biologique disparaît totalement vers le 60ème jour pour la dose moitié et vers le 40ème jour pour la dose quart.

Les mortalités relevées sont dues essentiellement à une action directe de contact, les adultes ne se nourrissant pas de la plante. L'explication semble en être une exsudation d'une partie de la matière active ou de certains métabolites véhiculés par la sève.

DISCUSSION

L'étude des pesticides utilisés en pulvérisation a permis de mettre en évidence différents points responsables de la toxicité ou de l'inocuité relatives des divers pesticides :

- Tous les produits testés présentent une toxicité plus ou moins importante pour l'hôte et par conséquent pour les stades jeunes du parasite se trouvant à l'intérieur du puceron. Cette toxicité agissant de concert sur l'hôte et le parasite peut être bénéfique dans le cas où les parasites peuvent évoluer après la mort du puceron (mancozèbe, dicofol, tétradifon, chlorphénamidine + formétanate), néfaste si le produit peut pénétrer et détruire

le parasite sans détruire l'hôte (parathion), ou indifférente si les mortalités des deux espèces sont identiques. BONNEMAISON (1962) note l'importance du stade de développement atteint par le parasite au moment du traitement sur les possibilités de terminer son développement.

- La grande tolérance aux pesticides du stade momie, notée par de très nombreux auteurs, a été mise en évidence pour la plupart des produits testés. Cependant la généralisation n'est pas possible, comme nous l'avons montré pour le parathion déjà cité par BARTLETT (1958), SHOREY (1963) et BINNS (1967) pour son action sur les momies de divers parasites de pucerons. D'autres insecticides, presque tous organo-phosphorés sont également cités : le malathion (BARTLETT 1958, OBRTEL 1961, BINNS 1967), le déméton (BARTLETT 1958, OBRTEL 1961), le mévinphos (BONNEMAISON 1962, SHOREY 1963), l'endothion (BONNEMAISON 1962), le diazinon (SHOREY 1963); le dichlorvos et le fénitrothion (KOWALSKA et al. 1971) ainsi qu'un carbamate, le mexacarbate (SHOREY 1963).

- Cependant les parasites émergeant des momies traitées sont soumis à l'action des résidus sur les plantes. FOLSOM dès 1927 note lors d'un essai de plein champ que l'arséniate de chaux tue les adultes de *Lysiphlebus testaceipes CRESS.* après l'émergence. La grande sensibilité des adultes des Aphidiidae aux pesticides (WAY 1949, BARTLETT 1958, ZELENY 1965, BINNS 1967, WIACKOWSKI et al. 1968, etc ...) explique les effets létaux des résidus de nombreux pesticides après émergence. La nécessité de disposer de produits perdant leur activité biologique très rapidement est discutée entre autres par BARTLETT (1958) et OBRTEL (1961).

En accord avec ces derniers, il semble que le point le plus important à prendre en considération dans le cas des produits utilisés en pulvérisation soit la persistance d'action des résidus et leur toxicité pour les adultes émergeant après traitement.

Les momies constituent lors de l'application un véritable réservoir de parasites échappant pour la plupart à l'action toxique du pesticide. La période d'émergence des parasites issus des momies traitées ne dépassant guère une semaine, le choix des pesticides employés doit être fait en fonction de leur toxicité initiale, mais surtout de la durée d'activité biologique des résidus qui ne devrait dans aucun cas dépasser une semaine.

L'utilisation de pesticides systémiques en traitement de sol est par ailleurs très séduisante. SHOREY et HALE (1963) note la grande sélectivité des insecticides systémiques appliqués de cette façon, et l'absence de toxicité directe pour les entomophages. Des essais effectués en serre par TAMAKI et al. (1969) n'ont montré aucun effet apparent de l'aldicarbe sur l'activité d'*Aphidius smithi* SHARMA et SUBBA RAO. WAY et al.(1969) pour l'azidithion, TYLER et al,(1974) pour l'acéphate, l'aldicarbe, le carbofuran, le CGA 12658, le disulfoton et le terbufos montrent une réduction marquée du nombre de momies, en relation avec la diminution du nombre d'hôtes disponibles.

Nous avons noté ce fait pour le carbofuran mais de plus nous avons mis en évidence la forte toxicité directe du produit probablement exsudé par la plante pour les adultes de *D. rapae*. La destruction de ceux-ci n'étant pas totale et compte tenu de la raréfaction de l'hôte, il ne semble pas que le carbofuran puisse être considéré comme très toxique pour les parasites de pucerons.

Cependant il faut insister sur le fait que les produits systémiques utilisés en traitement de sol ne sont pas forcément sans action directe sur les entomophages et que certains pesticides de ce type peuvent éventuellement provoquer un déséquilibre des populations défavorable aux parasites ou prédateurs.

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CB. 6229

NOTE PRELIMINAIRE SUR L'UTILISATION DES CHOCS THERMIQUES EN LUTTE INTEGREE CONTRE MYZUS PERSICAE SULZ. EN SERRE

par

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Dans une perspective de lutte intégrée, il est nécessaire d'envisager les possibilités offertes par la régulation climatique des serres pour détruire les insectes.

Des essais réalisés en laboratoire mettent à notre disposition des données importantes sur l'action des fortes températures sur la survie et la fécondité de Myzus persicae SULZ.:

- à température constante, 30°C constitue la limite supérieure de l'espèce: en effet, la fécondité d'insectes élevés à cette température est nulle (BARLOW, 1962; DE REGGI, 1972);
- des femelles virginipares aptères maintenues 48 heures à 30°C donnent une descendance, qui présente des anomalies plus ou moins graves, mais qui n'est pas viable. Ces anomalies n'existent pas en présence d'une thermopériode de 12 heures 30°-10°C (DE REGGI et DELMAS, 1965).

Pour des raisons pratiques et économiques, il semble difficile de maintenir longtemps une température élevée en serre. Par contre, la simple fermeture des ouvrants au cours d'une journée chaude permet d'atteindre économiquement une telle température associée à une forte hygrométrie provoquée par la transpiration des plantes. Il convient donc d'envisager les possibilités offertes par des chocs thermiques de ce type, dans la mesure où leurs conséquences sont négligeables pour le végétal.

Une température de 38,6°C associée à une hygrométrie inférieure à 20 pour cent appliquée pendant une heure à des femelles virginipares aptères isolées du végétal pendant cette période provoque une mortalité de:

- 78 pour cent, la mortalité durant jusqu'au 5ème jour pour une température post-opératoire de 25°C;
- plus de 95 pour cent le premier jour et 100 pour cent le second pour une température post-opératoire de 30°C (DE REGGI, 1968).

Travaillant également sur M. persicae isolé du végétal pendant un choc thermique d'une heure, mais à 60 pour cent d'humidité relative et sur des stades variés, BROADBENT et HOLLINGS (1951) constatent que:

- pendant le choc, la première mortalité apparaît à 38°5C et la mortalité totale à 41°C;
- pour des conditions post-opératoires de 15°C et 70 pour cent H.R., la mortalité totale est atteinte en 24 heures pour un choc à 39°5 et en 48 heures pour un choc à 38°5C.

Sur Chou, la plupart des pucerons se laissent tomber pendant un choc de 30 mm à 42-43°C, mais les individus qui demeurent sur le végétal survivent et se reproduisent normalement. Contrairement à l'opinion de BODENHEIMER et SWIRSKI (1957), ces auteurs considèrent que les jeunes stades sont les plus sensibles.

Notons enfin que, travaillant sur divers insectes différents, MELLANBY (1954) considère que l'acclimatation à des températures élevées modifie peu la température létale.

Les essais de laboratoire ont, pour l'essentiel, porté sur des insectes isolés. Ils ne tiennent donc compte ni de l'influence de l'alimentation de l'insecte et du microclimat offert par le végétal, ni du comportement du puceron, qui peut, soit rechercher le site le moins défavorable, soit se laisser tomber sur le sol.

Cependant, ces données étant encourageantes, nous avons procédé à un essai préliminaire en vraie grandeur dans une serre de 100 m^2 située à Valbonne (A.M.) plantée d'aubergines var. Bonica à une densité de 2 Plants/m^2. Les conditions climatiques étaient suivies à l'aide de thermo-hygrographes à capteurs ventilés disposés à 0,6 et 1m du sol.

Le choc thermique a eu lieu le 15 avril 1975 à midi au cours d'une période pendant laquelle la température était très bien régulée jour et nuit aux environs de 23°C, l'hygrométrie étant fluctuante entre 60 et 100 pour cent. A la fermeture des ouvrants, la température est passée brusquement de 23 à 34°C, puis est montée progressivement à 45°C pendant les deux heures suivantes, où elle s'est maintenue pendant 3 heures. L'hygrométrie est restée à 70-80 pour cent pendant cette période. Le retour à la normale a été brusque à l'ouverture de la serre. Les aubergines avaient 11 étages de feuilles. Elles ont très peu souffert: seules quelques nécroses localisées du limbe ont été notées. Deux bassinages ont été effectués: le soir et le lendemain matin.

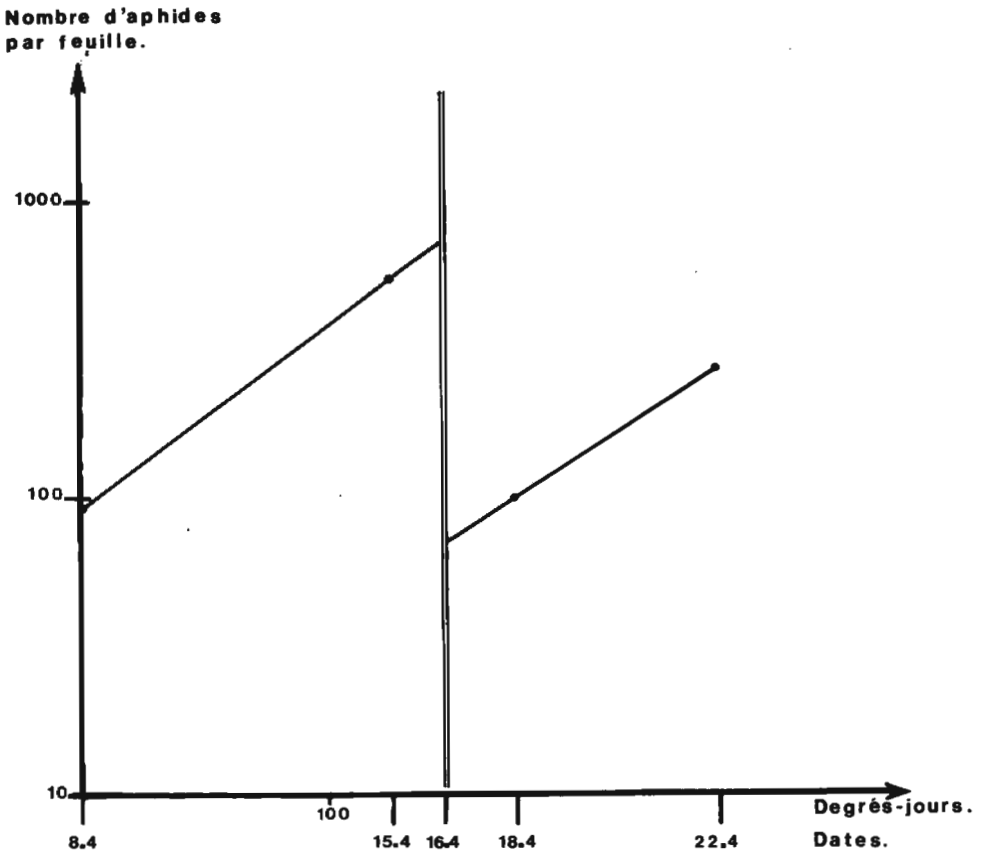
La population de M. persicae a été prélevée à chaque date sur un échantillon composé de trente 8° feuilles de plants régulièrement répartis dans la serre. Du 8 au 15 avril, la structure de la population reste stable; le choc thermique a un effet nettement plus marqué sur les jeunes larves, le pourcentage de ces dernières tendent à se rétablir le 22.4. (Tableau 1).

TABLEAU 1. Structure des populations de M. persicae avant et après choc thermique

Date	L1 - L2	L3 - L4	V.A.	N3 - N4	V.L.
8.4	59,6%	31,6	8,1	0,5	0,3
15.4	57,8	34,1	7,5	0,3	0,2
18.4	47,9	41,1	9,7	1	0,3
22.4	51,9	40,6	5,8	1,4	0,4

V.A.: Femelles virginipares aptères
V.L.: Femelles virginipares ailées
Choc thermique: le 16 avril à midi.

Nous n'avons constaté aucune malformation sur les individus prélevés le 18.4. Ce prélèvement a été effectué deux jours après le choc, c'est-à-dire qu'il porte sur une population stabilisée après les déplacements occasionnés par les hautes températures. Si l'on extrapole les taux d'accroissement observés (selon HUGES, 1963, calculés pour un seuil de développement de 4°C et une durée de stade standard de 30 degrés-jours) pendant les deux périodes encadrant le choc thermique, on constate que la population est passée pendant ce dernier de 20.916 à 2.056 aphides dans l'échantillon (Fig. 1). Enfin, le taux d'accroissement observé du 18 au 22/4 est légèrement inférieur à celui du 8 au 15/4 (0,36 contre 0,43). Dans la mesure où notre échantillonnage est représentatif, nous avons donc constaté une réduction de 90 pour cent des populations aphidiennes plus marquée sur les jeunes stades larvaires.



Les expériences de laboratoire comme l'essai en serre, permettent d'attendre, sur des plantes peu sensibles aux chocs thermiques, une réduction appréciable des populations de M. persicae. Macrosiphum euphorbiae THOM., autre déprédateur important de l'aubergine, paraît être plus sensible que M. persicae à ce type de traitement (BROADBENT et HOLLINGS 1951). Il semble donc possible par ce moyen de diminuer considérablement le coût d'une intervention ultérieure de lutte biologique pour laquelle le nombre d'entomophages à lâcher est directement fonction de la population de phytophages en place.

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SOME ASPECTS OF THE PRACTICAL APPLICATION OF THE PARASITE ENCARSIA FORMOSA FOR CONTROL OF TRIALEURODES VAPORARIORIUM

by

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Encarsia formosa Gahan has been reported as an efficient parasite for control of the greenhouse whitefly (Trialeurodes vaporariorum Westw.) on tomatoes (Lindquist and Spadafora 1971, Parr 1973, Stenseth 1973, Woets 1973). In these earlier experiments, the parasite was introduced into the glasshouses as adult parasite or as parasitised scales. The parasites were released one to six times in the different experiments at 7 to 14 days' intervals.

Burnett (1962) has pointed out the importance of an even age structure in the parasite population at the start of the host-parasite interaction. This counteracts fluctuations in abundance of the host or parasite. The age structure in the parasite population will depend on the occurrence of the parasites from the time of the first release into the houses until hatching of its offspring. Thus planning for parasite introduction as parasitised scales requires knowledge about the time of development of the parasite.

This paper reports on studies on the time of development of Encarsia formosa and gives results of control experiments whereby the parasite was introduced as parasitised scales and released at intervals covering the time of development.

THE TIME OF DEVELOPMENT OF ENCARSIA FORMOSA

Methods

Whiteflies and parasites were cultivated on tomato plants, variety 'Selandia', at 21°-22°C.

Tomato plants were infested with adult parasites 16 days after oviposition of the whiteflies, the parasites were removed after 48 hours and the plants placed at constant temperatures of 18°, 21°, 24° and 27° and fluctuating day and night temperatures of 24°,18°C

TABLE 1. Time of development of Encarsia formosa at different constant and fluctuating day and night temperatures

Temperatures °C	Time of development in days
18	29–39
21	25–35
24	16–24
27	13–17
18/24 (night/day)	22–30
21/27 (night/day)	15–19

and 27°/21°C, twelve hours night and twelve hours day. The experiments were conducted under natural light from March 1 to July 1.

At each temperature regime 500–1500, parasitised host larvae were used. The time of development of the parasite is counted from the middle of the oviposition period till emergence of the adult parasite.

Results and discussion

The time of development of Encarsia formosa at different constant and fluctuating temperatures is shown in Table 1.

Curry and Pimentel (1971) indicate a development time of Encarsia formosa of about 48 days at a constant temperature of 21°C, while Burnett (1949) suggests development periods of 29.5, 22.9, 15.0 and 11.9 days, respectively, at 18°C, 21°C, 24°C and 27°C. Results presented here are largely in correspondence with those of the latter author.

The experiments showed the parasite to have a development period of 22 to 30 days at varying day temperatures, 18°C night temperature and 24°C day temperature, and an emerging period of adults of 8 days. With the anticipated life span of 4 days (Burnett 1949), this ensures the presence and oviposition of the parasites during at least 12 days after introduction of parasitised scales into greenhouses.

Two introductions under conditions of 18°C night temperature and 24°C day temperature at about 12 days' interval should therefore produce a balanced parasite occurrence until the new generation emerges. At the temperature combination 21°C night and 27°C day temperature, the development period of the parasite is 15–19 days. One introduction may possibly suffice in this casethough two introductions at 7–8 days' interval are more likely to provide an even distribution of the parasites.

A comparison of the development period of the parasite from this investigations with that of the greenhouse whitefly (Stenseth 1971) shows constant temperatures of 21°C and 24°C to provide almost coinciding development periods for host and parasite. Fluctuations in the host and parasite populations are likely to be favoured under such conditions in subsequent generations. With the temperature combinations 18°C night and 24°C day, the parasite has a shorter development period than the whitefly. This counteracts fluctuations in the host and parasite populations, and the propagation of the parasite is favoured compared to that of the host. This finding is supported by Milliron (1940), who found higher parasitism at varying night and day temperatures than at constant temperature.

It is well known that the whitefly seeks out the young leaves of sprouting shoots to oviposit (Hussey and Gurney 1960). On the same leaf, the age of the whitefly larvae, therefore, is relatively uniform. As a consequence, the age distribution of the parasite also becomes fairly even, because successful parasitism normally occurs in the 3 and the 4 larval instar (Burnett 1960). By taking into consideration the time of oviposition as well as that of development as seen in Fig. 1, non-parasitised whitefly larvae will start emerging 7 days before the emergence of the parasite. Pruning the plants and removing all the waste material may thus be of some importance to the parasite/whitefly ratio. If the leaves are removed, for instance at 18°C night temperature and 24°C day temperature, before they are 2 weeks old, the parasite is favoured. If 5-6 weeks old leaves are removed, the whitefly is favoured. On leaves more than 8 weeks old the greater part of the parasites have emerged, and their cutting is of no consequence.

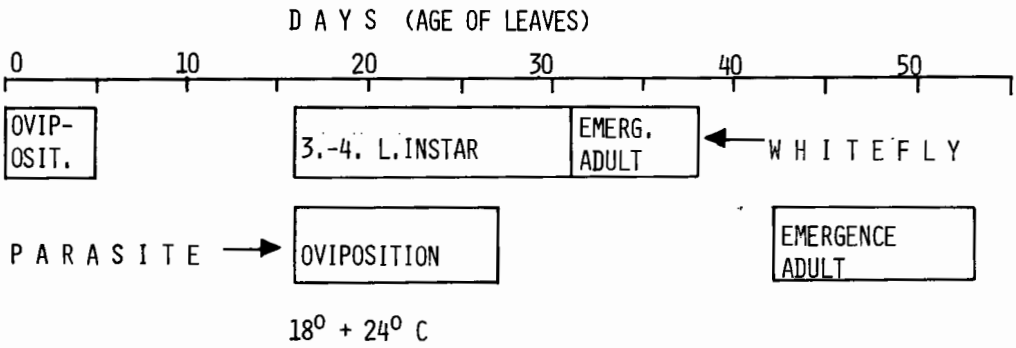

Fig. 1 Development of whitefly and its parasite

CONTROL EXPERIMENTS

Methods

Large-scale trials were carried out at different places in Norway in 1974 and 1975 (Table 2). The glasshouses chosen had natural attacks of glasshouse whitefly on tomatoes. The plants in the experimental houses were cultivated according to the layering method. With the exception of experiment 1, all experiments were carried out in commercial glasshouses.

Table 2 shows the tomato variety used, numbers of plants, and the temperature in the experimental houses. Theromostats were used to regulate the temperature in the houses. The temperatures given in Table 2 are not the actual temperatures, but the temperatures to which the thermostats were adjusted. On sunny days the temperatures, therefore, may have been higher than the data given in Table 2. One exception is experiment 1 where the temperature was measured continuously.

TABLE 2. Place of experiment, tomato variety, number of plants and the temperature in the experimental houses

Experiment No.	Place	Variety	Number of plants	Temperature
1	Ås, Akershus	Extase	72	18°-25°C, average 21°C
2	Jaeren, Rogaland	"	5000	Night: 19°-20°C. Day: 23°-27°C
3	Slagen, Vestfold	Special	2800	" : 18°C " ca.24°C
4	" "	"	2800	" : 18°C " ca.24°C
5	Jaeren, Rogaland	Extase	1400	" : 20°C " ca.25°C
6	" "	"	1500	" : 16°-18°C " 20-25°C

Exp. 2-6, actual temperature not continuously measured, but estimated after thermostat regulation.

The parasite was introduced into the glasshouses as parasitised scales and the parasite emerged during the first 5-8 days after introduction. Percent hatching of the parasitised scales was examined only in some cases (Table 3). The parasite material was applied in regular portions per 40 plants evenly distributed throughout each experimental house. One exception is experiment 2 where the parasites were distributed on the most heavily attacked spots in the second and third introduction.

TABLE 3. Initial population of greenhouse whitefly (Trialeurodes vaporariorum) and introductions of parasites (Encarsia formosa) in the glasshouses used for experiments

Experiment No.	Whitefly numbers larvae per leaf	Whitefly numbers adults per 4 top leaves	Introductions of parasites Dates	Number of parasitised scales introd. per plant	Percent hatching
1.	41.2	1.7	22.3	0.83	94.7
	60.1	5.4	6.4	0.83	94.0
	160	34.7	18.4	0.83	66.0
2.	-	0.1	2.4	0.63	-
	-	1.2	18.4	0.31	-
	-	4.5	2.5	0.31	-
3.	0.94	0.54	3.4	0.89	83.4
	1.55	0.56	16.4	0.89	86.3
4.	1.20	0.14	3.4	0.71	83.4
	0.39	0.50	16.4	0.89	86.3
5.	5.24	0.64	4.7	2.85	-
	6.06	1.04	18.7	2.85	-
6.	-	1.9	30.7	2.66	-
	67.3	7.2	14.8	2.66	-

Table 3 shows the time of the introductions of the parasite in each experiment, the degree of whitefly attack at the time of introduction, numbers of parasitised scales introduced, and the percent emerging adult parasites from the parasitised scales.

The uppermost leaf of twenty plants in each house was tagged with the date once a week. Numbers of parasitised and surviving whitefly larvae were recorded eight or nine weeks after tagging. Black host larvae were registered as parasitised. Adult whitefly were recorded from four apical leaves on each of 50 plants selected at random.

Presentation of the results

The whiteflies prefer young upper leaflets for oviposition. The time of development from oviposition till emergence of the adult whiteflies takes 30 days at alternating temperatures, 18°C by night and 24°C by day (Stenseth 1971), and 3rd and 4th instars are not successfully parasitised (Burnett 1962). To coincide with the instars suitable for parasitism, the real time of parasite introductions were therefore adjusted accordingly; figures 2-4 illustrate the results including the expected number of adult parasites. These numbers refer to parasitised larvae 26 days earlier, as the time of development from oviposition to emergence of adult parasite takes about 26 days at alternating temperatures (18°C+24°C).

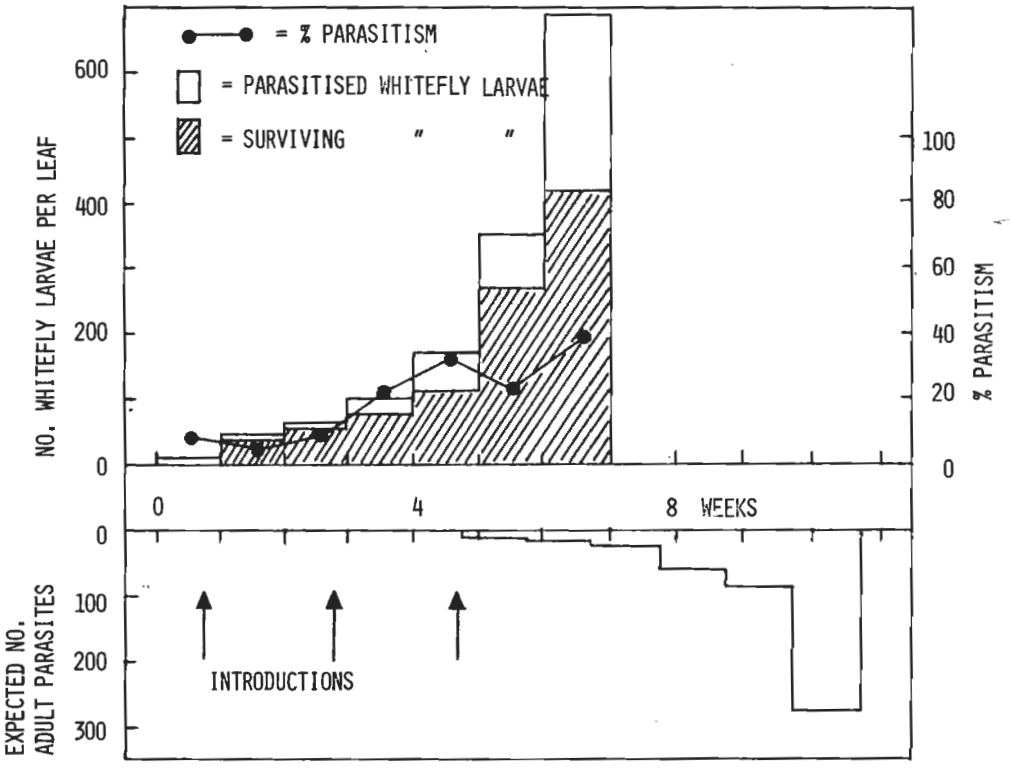

Figure 2. Timing of introduction of parasites and impact on the degree of parasitism. Results of experiment 1 (see table 3 for details).

Results and discussion

Introduction of the parasite Encarsia formosa, on tomato plants attacked by greenhouse whitefly gave four types of situations.

Situation 1. Fig. 2 shows the results from experiment 1. The slope of surviving larvae population was greater than that of the parasitised larval population. After seven weeks the plants were covered with sticky honeydew and sooty moulds and not suitable for further experimental use. It is likely that this development was due to low, 5.9 percent to 22.1 percent initial parasitism.

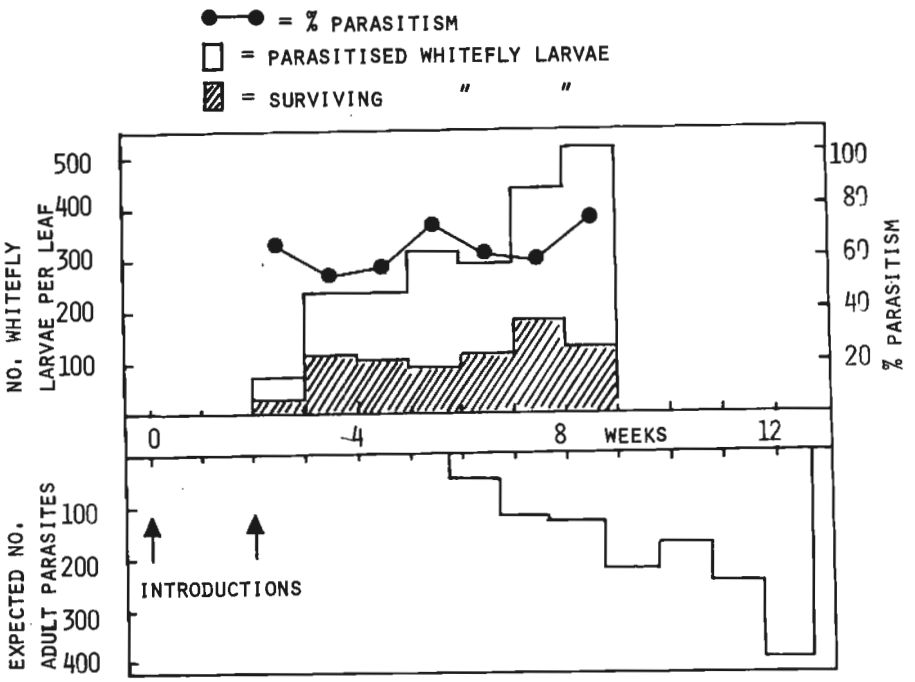

Figure 3. Timing of introduction of parasties and impact on the degree of parasitism. Results of experiment 6 (see table 3 for details).

Situation 2. Fig. 3 shows the results from experiment 6. In this case the total larval population of the whitefly was increasing the following 9 weeks after the first introduction of the parasite, but an initial parasitism (records only for second introduction) of 65 percent and 53 percent and increasing parasite population prevented a corresponding increase in surviving whitefly larvae. The increase in number of whitefly larvae seems to have been stopped by the increase of the parasites.

For practical reasons the experiment had to be terminated after 9 weeks, but the expected population growth of the parasite and the rather stable population of surviving whitefly larvae indicate that the parasite would probably have continued to dominate the host.

Situation 3. Fig. 4 shows the results from experiment 2. Introduction of parasites here resulted in fluctuations in abundance of host larvae and adult parasites. The regulation of the whitefly population was satisfactory all through the experimental time of 25 weeks and no sooty moulds developed.

The total number of larvae showed three peaks about 8 weeks apart, but during the first twenty weeks the number of surviving whitefly larvae was rather constant. The expected number of adult parasites showed three gradually decreasing peaks. The first two peaks corresponded to the low level of larvae. This pattern indicates the findings of Burnett (1962) that more host larvae are killed when the parasite number is high.

When the number of parasites has reached a certain minimum it cannot cope with the whitefly larvae offered and the number of surviving whitefly larvae will increase.

The results given in Fig. 4 indicate two types of fluctuations. One short term fluctuations in number of adult parasites determined by the time of development of the parasite and the mortality of host larvae. Secondly, a long term fluctuation in number of whiteflies. This is partly a result of the short term fluctuations, but greater longevity of adult whiteflies than of parasites might be a stabilizing factor and, in the present case, leading to the long term fluctuation.

Situation 4. In this situation there were no marked or regular fluctuations in abundance of parasite and host during the experimental time of 13 to 25 weeks. Experiment 3, 4 and 5 give the following results:

In all three experiments the whitefly populations were very low when the parasites were introduced. In all cases less than 8 whitefly larvae per leaf were present and less than one adult whitefly per four top leaves. In no experiment did the whitefly population exceed two adult whiteflies per plant all through the season. A general feature was also the declining percent parasitism in the autumn. Fig. 5 shows the results from experiment 4.

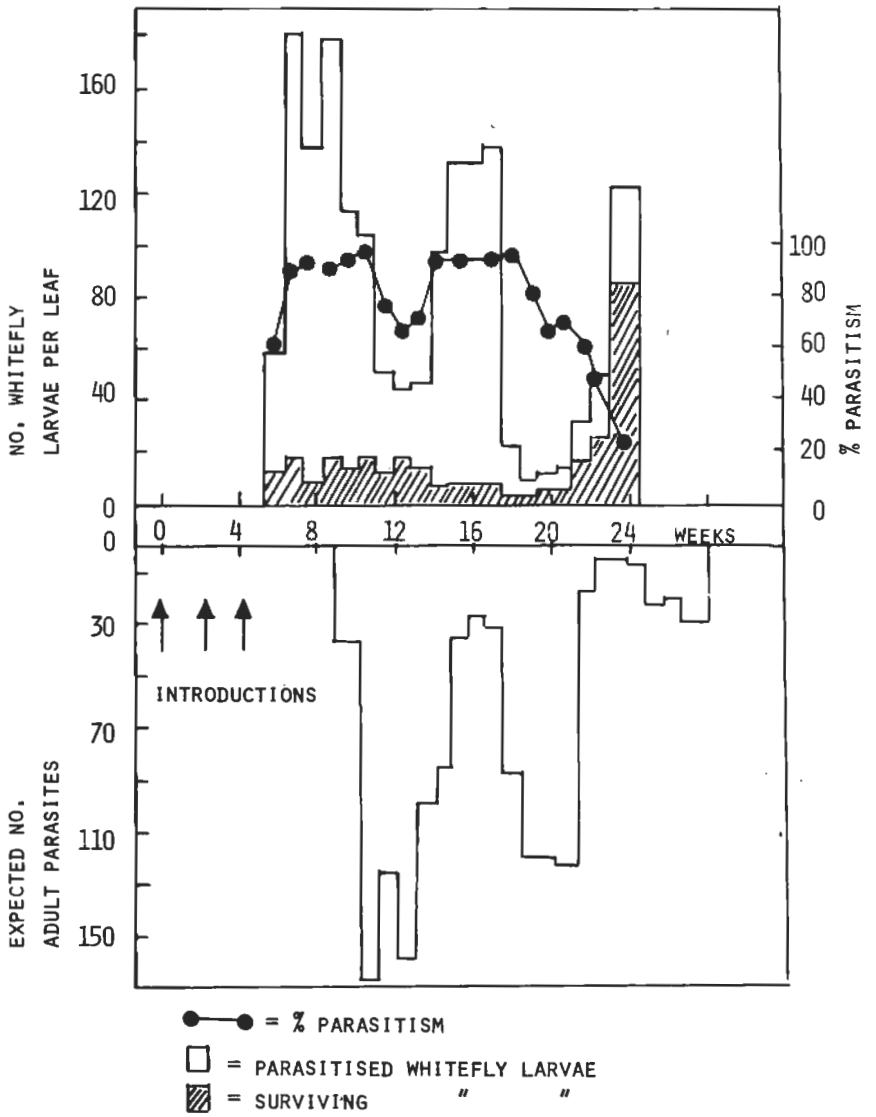

Figure 4. Timing of introduction of parasites and impact on the degree of parasitism. Results of experiment 2 (see table 3 for details).

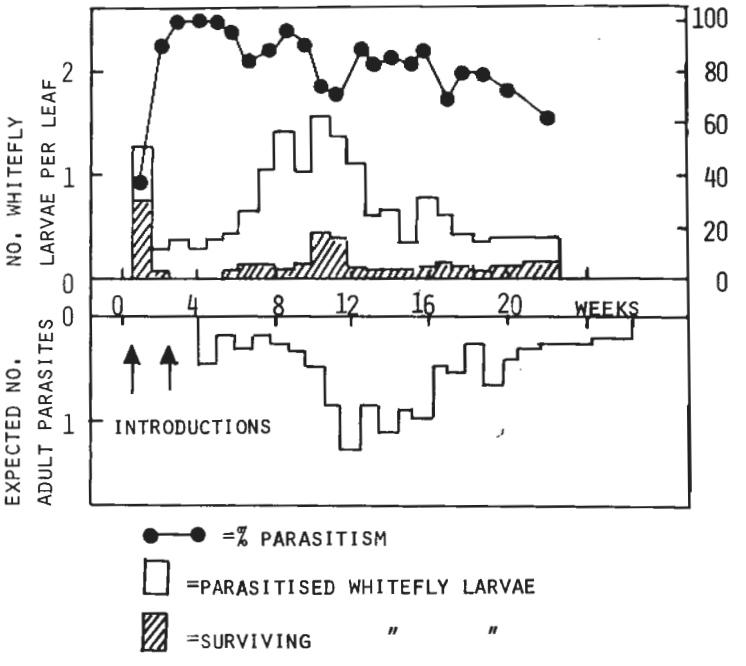

Figure 5. Timing of introduction of parasites and impact on the degree of parasitism. Results of experiment 4 (see table 3 for details).

Conclusions

1. By using the parasitised scale technique two introductions of E. formosa at fortnightly intervals are sufficient for good control of greenhouse whitefly on tomatoes.

2. Parasites introduced at low populations of whiteflies give the best control results.

3. At whitefly populations below one adult per plant, two parasites per plant are a sufficient initial parasite number.

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STUDIES ON THE DISPERSAL OF THE WHITEFLY PARASITE ENCARSIA FORMOSA

by

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SUMMARY

Factors affecting the dispersal of Encarsia formosa are an important feature in designing methods for use of the parasite to control whitefly (Trialeurodes vaporariorum). The results show that adult parasites are capable of detecting quite small foci of whitefly scales within a commercial tomato crop but that once having located them they do not readily move on to other plants. The rapidity with which the parasites detected widely spaced scale infested plants suggests that they are in some way attracted to scales over quite long distances. What this attractant is and how it works is being investigated.

The effects of different light intensities and scale densities on parasite distribution and subsequent parasitization have also been studied.

Experiment 1: To test the effectiveness of the parasites to locate whitefly scales sparcely distributed within a tomato crop, a single tobacco plant infested with about 4000 black, parasitized scales was placed in the centre of a 100' x 24' glasshouse containing 900 tomato plants (var. Eurocross BB) planted in 8 double rows with a single rowalong the glass at each side. Planting was on 9 January at normal commercial spacing. Similar plants in 9" pots infested only with whitefly scales were spaced among the crop at distances varying from between 4½' to 50' ft. from the source of parasite release. In one half of the house, the "target" plants consisted of 11 single, infested plants interspersed amongst the crop plants while in the other half, larger targets comprising six groups of 4 infested plants each were used. The target plants were placed in the crop on 16 January and the parasite plant, from which adult parasites had started to emerge, was introduced on 17 Jan. The target plants together with a proportion of the crop plants were examined every 3 days for the presence of adult parasites. After 2 weeks, all targets were removed and fumigated with DDVP strips to kill-off adult parasites. After a further 2 weeks, during which time all parasitized scales had turned black, a complete assessment of the scale population and degree of parasitism was made (Table 1).

TABLE 1. Dispersal of Encarsia formosa within a tomato crop

Target	Distance from parasite release site in ft.	Adults present on target days after introduction	Total no. adults on target 2 wks after parasite release	Total scales on target plants	% scales parasitized
Single plant	4.5	1-3	11	523	87.6
"	8.5	1-3	29	3030	87.6
"	13.0	1-3	90	NR	NR
"	16.5	3-6	48	4097	57.1
"	18.5	3-6	32	NR	NR
"	27.0	3-6	30	5718	42.8
"	27.5	3-6	23	NR	NR
"	33.5	1-3	39	8330	35.8
"	39.0	6-9	33	NR	NR
"	45.0	3-6	31	2101	72.1
"	50.0	3-6	64	6447	60.3
				Mean/plant	
4 plants	9.0	1-3	116	3120	61.9
"	25.0	3-6	106	NR	NR
"	27.0	3-6	70	3127	63.1
"	36.0	3-6	49	NR	NR
"	48.0	6-9	100	NR	NR
"	48.0	3-6	70	4752	35.6

Note: NR = No record

Results: The adult parasites showed a remarkable ability to search out whitefly scales. As expected, adult parasites were first recorded on the target plants in close proximity (up to 13 ft.) to the parasite plant within 1-3 days, but even the single infested plant 50 ft. away was colonised within 6 days (Table 1). Nor did the size of the target area appear to influence the parasite's searching ability. Only on 34 (4%) of the main, uninfested crop plants were 1 or 2 adult parasites recorded and most of these plants were next to or in close proximity to an infested target plant.

The speed with which the scale-infested plants were colonised by adult Encarsia and their almost complete absence from the main crop plants suggests that there is some attractant by which the parasite is capable of detecting scales on plants at quite

considerable distances. By what means they do so remains to be investigated. Periods of sunshine following parasite introduction is thought to be a stimulus to adult activity and good establishment and it undoubtedly influences its distribution and fecundity. The total hours of sunshine in the 2 weeks following the introduction of the parasites was 32.3 hr. including over 7 hrs on each of the 3rd and 5th days. This may account for the high degree of parasitism achieved among the large scale populations on the target plants.

Experiment 2: Effect of light intensity on dispersal and parasitism of Encarsia formosa

On 10 February, 20 tomato pot plants (18" high) heavily infested only with 2nd and 3rd instar whitefly scales, were placed on the ground of each of two identical glasshouses 16' x 8' arranged in 5 rows of 4 plants each. The rows were 3 ft apart and the plants 15 in. apart in the rows.

House 1 was unshaded and received natural daylight.
House 2 was lined with green polythene sheeting which reduced the daylight intensity by half.

Light meter readings taken at 10.00 and 15.00 hrs daily over the period of the experiment gave the mean light intensity and range as:

Unshaded 475 (70-1000) lumens per sq. ft.
Shaded 230 (30 - 470) " " " "

The glasshouse temperatures during this period ranged from a night minimum of 62°F to day maxima of 76-82°F.

On 12 February, 200 parasitized whitefly scales were introduced from a single point at the south end of each glasshouse. Adult parasites started to emerge on 17 February and from the number of empty scales it was estimated that 160 adult parasites were active in each house. The plants were examined for adult parasites daily for a period of one week after which they were fumigated with DDVP and counts subsequently made of white and black scales on the leaves.

Results: Many more parasites settled on the plants in the shaded than in the unshaded house. Of the 160 adults on the wing in each house, the overall maximum recorded in the shaded house was 74 compared to 33 in the unshaded one (Table 2). Distribution of parasites under both light conditions was poor. Although the first row of plants 1 ft. from the source of parasites was well colonised by adults, particularly in the shaded house, there was a marked fall-off in numbers progressively towards the more distal rows. This confirms the previous findings that once parasites locate a source of scales they do not readily move on to other plants. There was also a corresponding fall-off in the number of

parasitized scales (Table 3) though fair comparisons between shaded and unshaded plants cannot be made owing to the wide differences in the scale populations which occurred between the two sets of plants despite being exposed to the same initial whitefly infestation.

The results of this experiment done at this time of year where even in the unshaded house the intensity of natural daylight did not exceed 1000 lumens per sp. ft. and then only for short periods, tends to confirm the difficulties experienced on commercial nurseries of establishing a satisfactory interaction in the early part of the year. The unaccountable loss of a large proportion of the emergent adult parasites from the introduced material co could, if a common occurrence, be an important factor in establishing suitable rates of parasite introduction to achieve a satisfactory pest/parasite interaction.

TABLE 2. Effect of light intensity on the dispersal of adult Encarsia formosa

Row	Distance from parasite introduction site		No. adult parasites per row					
			Date: 21/2	24/2	25/2	26/2	27/2	28/2
A	1 ft.	Shaded	12	29	49	48	60	57
		Unshaded	19	19	10	10	9	5
B	4 ft.	Shaded	2	5	4	7	7	6
		Unshaded	0	7	9	0	13	20
C	7 ft.	Shaded	1	2	3	3	3	5
		Unshaded	1	2	2	3	1	3
D	10 ft.	Shaded	1	0	0	0	1	0
		Unshaded	0	0	0	1	3	4
E	13 ft.	Shaded	0	1	1	2	3	2
		Unshaded	0	0	0	1	0	1
Overall totals		Shaded	16	37	57	60	74	70
		Unshaded	20	28	21	15	26	33

TABLE 3. Effect of light intensity on parasitism

Row	Distance from parasite introduction site		Mean No. scales per plant		% parasitism
			White	Black	
A	1 ft.	Shaded	1011	606	37.4
		Unshaded	141	291	67.4
B	4 ft.	Shaded	1186	85	6.7
		Unshaded	1261	115	8.4
C	7 ft.	Shaded	1374	61	4.3
		Unshaded	205	47	18.6
D	10 ft.	Shaded	1322	15	10.9
		Unshaded	442	23	5.0
E	13 ft.	Shaded	932	29	3.0
		Unshaded	501	13	2.5
Overall mean		Shaded	1165	159	12.0
		Unshaded	510	98	16.1

Experiment 3: To achieve different scale densities, four batches of 10 plants each 12 in. high) were exposed in the whitefly rearing house for periods of 15 mins., 2 hrs., 8 hrs., and 24 hrs. On removal, the plants were fumigated with DDVP strips to kill-off all adult whiteflies and then transferred to a clean glasshouse to await development of scales.

On 10 March, when scales had developed to 2nd instar, 5 plants from each batch were transferred to the shaded and unshaded glasshouses used in the previous experiment and arranged at random in an oval fashion around the house. On 12 March, 200 adult parasites were released from the centre of each house. The presence of adult parasites on the plants was recorded daily for 12 days after which the parasites were killed-off with DDVP strips. On 10 April, a complete assessment was made of the scale densities and the degree of parasitism on the plants in both houses. Temperatures ranged from night min. 62°F to day maxima of 75-85°F.

Results: There was a remarkable similarity in the number of eggs laid on the plants for each period of exposure to whiteflies which gave a good differential of scale densities. However, owing to the small numbers of adult parasites which colonised the plants following

their release on 12 March, the results were inconclusive. The maximum number of parasites recorded in either house on any one day was 49 - only 25 percent of the total introduced. Nevertheless, there was some indication that, regardless of light intensity, parasites were more attracted to those plants with the larger scale populations (Table 4). In this experiment, unlike the previous one, more parasites were recorded on the plants in the unshaded house than in the shaded one.

At all scale densities parasitism was extremely low (Table 5) and bore no relation ship to the number of adult parasites recorded on the plants.

TABLE 4. Effect or scale density on dispersal of Encarsia formosa

Time of exposure	Scale density mean/leaf		Total no. adults on 5 plants						
		Date	12/3	13/3	14/3	17/3	18/3	19/3	24/3
15 mins	12	Shaded	2	0	0	0	3	1	1
		Unshaded	5	0	3	2	1	1	1
2 hr.	100-150	Shaded	4	0	1	5	9	6	4
		Unshaded	9	4	8	6	3	3	1
8 hr.	250-300	Shaded	3	8	6	9	7	10	7
		Unshaded	10	4	21	12	11	11	2
24 hr.	570-600	Shaded	7	6	4	5	12	7	5
		Unshaded	11	16	17	15	22	20	9
Total in house		Shaded	16	14	14	19	31	24	17
		Unshaded	35	24	49	35	37	35	13

TABLE 5. Degree of parasitism on different scale densities

Scale density mean/leaf		% parasitism
12	Shaded	12.8
	Unshaded	3.0
100-150	Shaded	7.6
	Unshaded	23.3
250-300	Shaded	3.7
	Unshaded	13.4
570-600	Shaded	2.3
	Unshaded	9.2

CB. 6232

DISPERSAL OF THE PARASITE ENCARSIA FORMOSA AS INFLUENCED BY IT'S HOST, TRIALEURODES VAPORARIORUM

by

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Relatively little is known about the factors which influence the dispersal and searching capacity of the parasite Encarsia formosa as it seeks it's host, Trialeurodes vaporariorum within a glasshouse crop. A better understanding of such factors might enable researchers to devise more effective means of using this parasite in biological and integrated control programmes.

Work at the Glasshouse Crops Research Institute during the summer of 1975 (Parr, W.J. unpublished) showed that Encarsia formosa adults were apparently able to identify, and so congregate on, a few plants bearing the host insect within a crop otherwise free of the host. Within the three days between release of the parasites and the first sample, the parasites had dispersed over a distance of 4 m and had reached the most distant infested plant 17 m away within 6 days.

EXPERIMENT 1

In the autumn of 1975 a further test was made to measure parasite's dispersal and it's ability to differentiate between plants bearing the host and those not.

Forty young tomato plants, about 15–20 cm tall, were distributed evenly in a glasshouse (area of about 650 m^2). Alternate plants had been lightly infested with Trialeurodes vaporariorum adults about two weeks earlier and so bore 3rd – 4th instar whitefly scales. About 1,000 adult parasites were released from the centre of the glasshouse at mid-day, during sunny weather.

The number of parasites on each plant was recorded 2, 4 and 24 h after their release (Table 1) and showed that E. formosa was able to differentiate between infested and clean plants despite the low density of whitefly scales. The fact that this was evident only two hours after the release of parasites suggested that something other than random search was involved.

TABLE 1

No parasites	Time elapsed after release		
	2 h.	4 h.	24 h.
On 20 infested plants	51	122	89
On 20 clean plants	7	10	23
% on infested plants	88	92	79

The data also showed that Encarsia formosa was able to disperse over considerable distances in a short period, individuals being found up to 15 m. from the release point at the first sample.

EXPERIMENT 2

Three days later a second experiment using Nicotiana seedlings about 15 cm. tall was conducted in the same glasshouse. Twenty four plants were evenly distributed in the glasshouse; alternate plants, having been exposed for the preceding 48 h under large Nicotiana plants bearing dense cultures of whitefly scales, were covered with fresh honeydew. None of the experimental seedlings had come into contact with whiteflies.

Parasite adults were released from the centre of the house in early afternoon sunshine and the numbers on each plant recorded 1, 2, 3 and 19 h later.

Encarsia formosa was again able to differentiate between clean plants and those bearing whitefly honeydew (table 2). Thus, the stimulus which guides the parasite to whitefly infested plants is apparently also present in the honeydew.

TABLE 2

No parasites	Time elapsed after release (hours)			
	1	2	3	19
On 12 honeydew plants	9	18	23	29
On 12 clean plants	2	6	10	8
% on honeydew plants	82	75	70	78

EXPERIMENT 3

Forty eight Nicotiana plants were evenly spaced in a glasshouse 7 x 5 m. The experiment was divided into two sectors, each of twenty one plants, by a line of uninfested guard plants running more or less diagonally across the house. One sector contained twelve infested plants bearing 3rd - 5th instar whitefly larvae, alternating with nine clean plants; the other sector had only four infested plants evenly distributed amongst the remaining seventeen clean plants. Thus a high and a low density whitefly sector was created, the high density sector having three times as many infested plants as the low.

About 2,000 parasites were released from the centre of the house in bright sunshine.

RESULTS:

Parasites flew immediately and within a few minutes were present on many of the plants. The number on each plant was therefore assessed within an hour of release (Table 3).

TABLE 4

	Guard plants	Low density		High density	
		Infested	Clean	Infested	Clean
No plants	6	4	17	12	9
Parasites/plant	7.5	20.8	2.1	30.9	0.7
No parasites	45	83	35	371	6
Total parasites	-	118		377	

A second assessment was made 24 h after release (Table 4).

TABLE 4

	Guard plants	Low density		High density	
		Infested	Clean	Infested	Clean
No plants	6	4	17	12	9
Parasites/plant	3.0	70.5	3.5	75.3	1.2
No parasites	18	282	59	903	11
Total parasites	-	341		914	

Not only was response of the parasite to the host confirmed, but it also appeared to be density dependant. 3.1 times more parasites were found in the high density sector compared to the low in the first sample, and 2.7 times in the later sample. This corresponds very closely to the ratio of infested plants in the respective sectors, namely, 3 : 1.

EXPERIMENT 4

In a similar trial to that of Experiment 3, all the uninfested plants were treated with a micronised fluorescent dust while the infested plants being kept clean.

24 h after release, parasites were collected from plants, both near the centre of the glasshouse and from its edge.

Microscopic examination under ultra-violet illumination revealed wheter individual parasites had become contaminated by fluorescent dust.

Most individuals collected from uninfested plants had picked up the dust but few of these from infested plants did so (Table 5).

TABLE 5

	Uninfested plants		Infested plants	
	Central	Edge	Central	Edge
No. marked parasites	16	9	1	2
Total no. sampled	19	10	31	10
% marked	84	90	3	20

It appears that Encarsia is able to detect infested plants at a distance and that it rarely lands to search uninfested plants. This suggests that the aggregation of parasites on infested plants is due to an "attractant" rather than an "arrestant" effect of a volatile compound in whitefly honeydew.

CB. 6233

THE PARASITE-HOST RELATIONSHIP BETWEEN ENCARSIA FORMOSA (HYMENOPTERA : APHELINIDAE) AND TRIALEURODES VAPORARIORUM (HOMOPTERA : ALEYRODIDAE).

V. Population dynamics of Trialeurodes vaporariorum and Encarsia formosa in a glasshouse.

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Introduction

During the last four years the greenhouse white fly is successfully controlled by the chalcid wasp Encarsia formosa Gahan in tomato crops in The Netherlands (Woets, 1976). This was possible only with the following introduction schedule, developed by Woets (1973): A few weeks after the first white fly adults have been seen, four successive introductions, each with a fortnight interval, must be carried out. The number of wasps that have to be introduced per plant are 1.5, 1.5, 1.0 and 1.0 respectively. The schedule is built on the arguments that (a) the wasps should be introduced when young larvae are present for host feeding as well as older larvae for parasitization (see Van Lenteren et al., 1976, and Nell et al., 1976), (b) more than one introduction is necessary to prevent strong fluctuations of host and parasite, (c) introductions are started after white flies have been observed because the grower dislikes an arranged introduction of the pest.

Although in most cases control turned out to be successful, sometimes bad results were obtained (see also Woets and Van Lenteren, 1976). To get an idea about the possible causes of the differences in control success we thought it would be necessary to know the distribution of the white flies over the plants (regular, random or clustered) and the changes in this distribution during the growing season. We considered this to be important since it might determine the right places to introduce E. formosa (at patches with important

white fly infestations, or evenly over the glasshouse). Studying the population development of both white fly and parasite would give indications about the necessary frequency of E. formosa introductions (more or fewer times than the four we used up till now). Finally we hoped to answer the question at which white fly densities biological control is possible.

These problems led us to the decision to start a research into the change in numbers and distribution of both species in several glasshouses. This paper presents the results of an investigation in a glasshouse in which control was successful, which is the common situation.

Material and methods

We worked in a glasshouse of about 6500 m^2, containing c. 18.000 tomato plants. The glasshouse was subdivided into 648 plots, each containing 28 plants. The tomatoes were planted from 2-5 January, 1974.

culture methods

After the second week:

- the side shoots were pruned weekly
- the plants were vibrated once or twice a week to achieve fertilization of the flowers

In week 9, 12 and 14 the oldest (lowest) leaves were removed.
The night temperatures were c. 11°C (January) and c. 16°C (June), the day temperatures were c. 18-20°C (January) and c. 25-27°C (June).

parasite introduction

In week 4, 6, 8 and 10 parasites were introduced (0.7, 2.1, 4.5 and 2.5 wasps per plant respectively). Hence, except for the first introduction, this is more than advised, but the producer sells roughly estimated minimum numbers, so often the actual dose is higher than the adviced minimum. They were evenly spread over the glasshouse. The introduced parasites were counted. The introduction moment was determined by the fact that adult flies were found already

in the first week, so the first larval generation could be expected 2-3 weeks later.

sampling methods

A. During 16 weeks absolute countings were carried out, which consisted out of:

1. Countings on all plants (18.000) in the 1st, 6th and 10th week by a group of volunteers, acquainted with searching of white flies and wasps, but not knowing the local distribution of the animals.
2. Countings on each plant on which an infestation was once found. When the white flies or wasps disappeared this sampling was still continued until at least 6 weeks after their disappearance. The neighbouring plants were also examined for animals, till an animal-free zone of at least 2 m was found.

   Till week 8 all infested plants were checked each week. Afterwards countings were made with a fortnight interval. This change in sampling caused no problem because the developmental rate of T. vaporariorum is 24-32 days and of E. formosa 15-31 days at the temperatures measured in the glasshouse.

B. Besides this absolute counting programme, a random sampling programme was performed to find out whether it is possible to obtain a reliable picture of host and parasite distribution and abundance by a much less time-consuming sampling method. Preliminary observations gave us the impression that T. vaporariorum and, hence, also E. formosa, are not distributed at random over the glasshouse. We therefore used a stratified random sampling method (Southwood, 1966). The glasshouse was subdivided into 108 plots (each containing 148 plants). Each week another randomly chosen plant per plot was searched for hosts and parasites. In this way 0.6% of the total plant population was checked by this sampling method weekly.

At both sampling methods we counted pupae because they are easy to find. Further, it is easy to determine which pupae are parasitized (the unparasitized

pupae are white, parasitized pupae are black), and as pupal mortality is very low, the number of pupae gives a proper estimation of the number of white flies and parasites. When time permitted adult white flies and larvae were counted.

Change in T. vaporariorum numbers

The first adult white flies (121 adults) were found at the very first day we started with our observations, so apparently some white flies were transferred with the tomato plants from the nursery.

The first white pupae were found in week 4. Afterwards the number of pupae increased till week 6 and fluctuated later on (range: from a minimum of 0.008 white pupae per plant (week 4) to a maximum of 0.033 white pupae per plant (week 6)). The total number of pupae during the 16 weeks of this study is presented in Fig. 1.

Change in E. formosa numbers

The first introduction of E. formosa (parasitized black pupae of the host on cucumber leaves) took place in week 4. The wasps which emerged from these pupae had parasitized their first hosts in week 4 and 5, since the first black pupae on tomato plants were found in week 6. The number of black pupae increased rather fast afterwards and fluctuated later on (range: from a minimum of 0.002 black pupae per plant (week 6) to a maximum of 0.112 black pupae per plant (week 10-11)). See for the total number of black pupae Fig. 1. The percentage parasitism was rather high (about 50%, Fig. 2), the parasite caused a decrease in white fly numbers and prevented a serious increase of T. vaporariorum after the 6th week.

Distribution pattern of T. vaporariorum

Immediately after planting adult white flies were found at several plots in the glasshouse. The highest number of adults was present in the south-east

corner of the glasshouse, being the place where all young plants had been cultured for some weeks. From this place they were distributed over the whole glasshouse and planted on their definite place. When the grower removed the plants, we saw the white flies fly up and land rather frequently on an adjacent plant. The first white fly concentration is probably caused in this way.

In the second week fewer adult white flies were found. The highest number was found again in the south-east corner. The same holds for the 3rd and 4th week.

The first white pupae were found in week 4, once more in the south-east corner. One week afterwards we found white pupae in some other plots. In the south-east corner the first foci develop. A focus is defined as a spot with a consistent and isolated white fly infestation.

From then onwards we see the development and temporary disappearance of foci (Fig. 3); other foci do not disappear but increase slowly (Fig. 4). In focus 8 (see also Fig. 6) pupae were not found during five weeks, which means that the pupae found in week 12 originated from eggs laid by a female white fly migrated from another focus. The number of white pupae per plant first increases and then decreases strongly. The total number of infested plants increases when the decrease of pupae per plant sets in (Fig. 5).

From the distribution pattern of T. vaporariorum we may conclude the following:

1. The distribution of the white flies over the glasshouse is clustered (Fig. 6).
2. The white fly foci are mostly permanent - only some of them temporarily disappear (Fig. 3).
3. First, an increase of white pupae per infested plant is found (till the 6th week), afterwards the number per plant decreases. However, the total number of white pupae does not decrease since the total number of infested plants increases (Fig. 7). This occurs without exception in all foci and we

called it "oil-stain effect". Due to this oil-stain effect some foci fuse. The cause of this phenomenon is unknown. It may be brought about by vibrating the plants which occurs some times a week by the grower and causes migration of the flies.

4. Sometimes never larvae were found on a place where for some weeks adult white flies were found (Fig. 6, focus No. 2). We are very certain about this because spots where a fly was once seen were controlled intensively for six succeeding weeks. This may be explained by the fact that tomato is a rather bad host plant for T. vaporariorum. (For a comparison how several host plants differ in quality to T. vaporariorum see Woets and Van Lenteren, 1976.)

Distribution pattern of E. formosa

E. formosa pupae were uniformly introduced over the glasshouse. The first black pupae parasitized by the introduced wasps were found at a spot with a high white fly density in the 6th week. In the succeeding week black pupae were found in all foci, and a rather high percentage parasitism was measured. This could only be caused by the wasps that were introduced in the 6th week. The percentage parasitism remained high afterwards, and most of the new foci that developed were found by the wasps rather quickly.

From these data we may conclude the following:

1. The number of wasps introduced was sufficient to control the white fly population; the economic threshold was never crossed during the growing period.
2. The introduction of wasps in a regular pattern is sufficient, since all white fly infested spots were found by the wasps.
3. Multiple introductions are required to stabilize population fluctuations. One introduction is certainly insufficient.
4. E. formosa has a very good host searching ability because even at very low white fly densities (areas with 1 pupa per 28 plants or even fewer) a high percentage parasitism was reached.

5. E. formosa has a very good dispersal ability because after the last introduction, newly infested plots with flies were discovered. In these cases the wasps had to cover at least distances of 10-20 meters (Fig. 8).
6. Locally, E. formosa may parasitize all T. vaporariorum larvae present and so cause extinction of parts of a focus (Fig. 9).
7. The fluctuations in host and parasite numbers and the occurrence and disappearance of foci with and without E. formosa confirms the description given by Huffaker (1958) about appearance and extinction of foci of prey and predator mites living on oranges.
8. At the borders of a large focus the percentage parasitism was often lower than in the centre of that focus, especially in expanding foci. We made cross-sections through a focus, counted white fly and parasite numbers per plot, calculated percentage parasitism and found that at the borders of expanding foci a significant lower percentage parasitism was reached. Two simplified examples are given in Fig. 10. This may be caused by the fact that, after wasp introductions had finished, E. formosa only could survive at places where hosts are present. (They may survive for only a few days if no hosts are available.) When there are sufficient numbers of hosts they will not migrate, but stay at the spot where they emerged. However, as soon as all hosts have been parasitized and, hence, become unsuitable, the parasite's tendency to migrate increases. (E. formosa is perfectly able to discriminate between parasitized and unparasitized hosts, see Van Lenteren et al., 1976).) T. vaporariorum has the possibility to escape from the parasite at the borders of a focus as long as the focus centre contains sufficient unparasitized hosts. This again agrees with Huffaker's findings.

Results of the random sampling

Compared with the absolute countings, which asked 5 days of two observers per weekly check, the random sampling was less time-consuming and lasted only 6 hours by 1 observer.

The picture of the number and distribution of both species studied was, however, much worse than that of the absolute countings.

- the fluctuations are not synchronous with those found in the countings and they show much greater amplitudes (Fig. 11)
- the percentage parasitism is not in agreement with that of the countings (Fig. 12)
- the distribution maps constructed on the random sampling programme differ strongly from those found with the countings

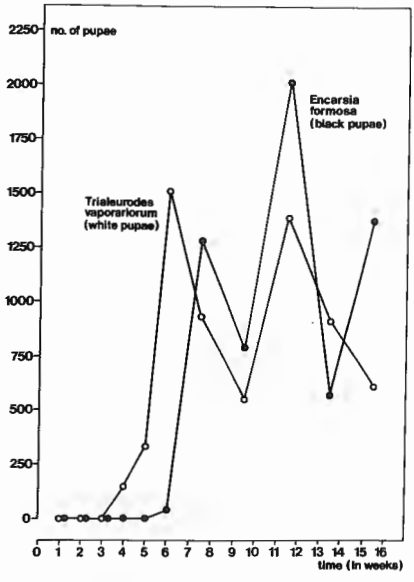
This was, of course, to be expected, but the results were so bad that this sampling method was useless. It appeared that at the end of the season more agreement between the data obtained by both methods is found, due to the fact that parasites and hosts are more evenly spread over the glasshouse. There remain, however, large differences.

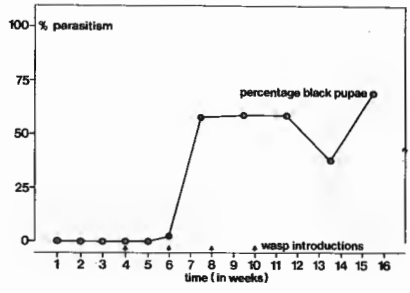
Conclusion: to obtain an impression about degree and sites of infestation a random sampling programme of this size is not sufficient. The grower will get more precise data if he is alert on finding white flies patches when he is planting the young tomatoes, tying them up and twisting them in, and especially at vibrating the plants.

Acknowledgements

Prof. dr. K. Bakker and Mr. J. Woets are acknowledged for carefully reading the manuscript and the improvements which resulted from this. Special thanks are due to Mr. G. van Bohemen for his hospitality. He allowed us to work in his glasshouse and to damage his plants, and he changed his culture programme to simplify our sampling work. Mr. G.P.G. Hock drew all figures, Mr. J. Simons and Mr. J. Lens made the photographs and Miss Marjolein van Wijngaarden typed the manuscript.

Messrs. G.J.F. Boskamp, H.W. Nell, and Mrs. Lydia Sevenster-van der Lelie acted as volunteers at the absolute countings.





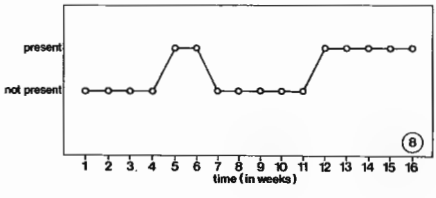


Fig. 1. Change in numbers of Trialeurodes vaporariorum (white pupae) and Encarsia formosa (black pupae).

Fig. 2. The percentage parasitism of Trialeurodes vaporariorum by Encarsia formosa.

Fig. 3. Temporary disappearance of focus 8.

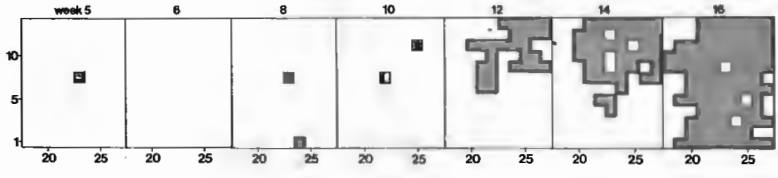


Fig. 4. Development of focus 4 and 5 shown by the number of infested spots (dotted). The numbers on the ordinate and abcissa stand for the plot number in the glasshouse (see Fig. 6).

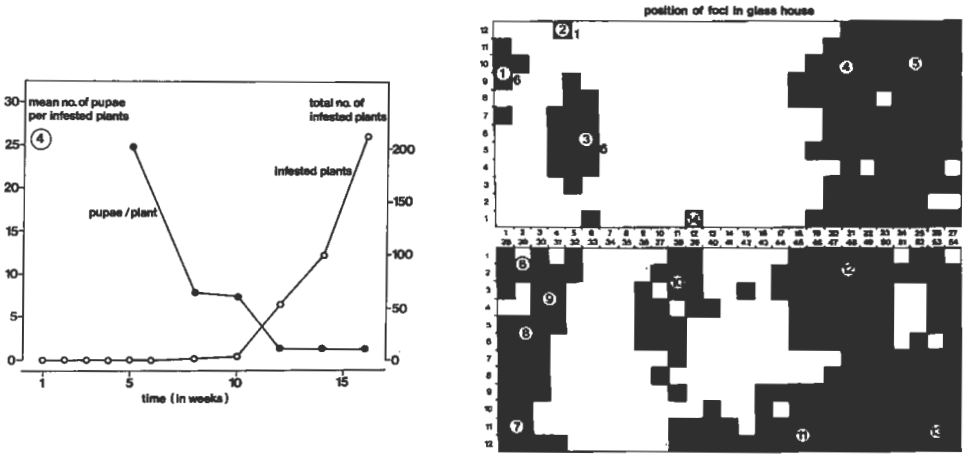


Fig. 5. Relation between the number of infested plants and the mean number of pupae per infested plant in focus 4 and 5.

Fig. 6. Position of the foci in the glasshouse at the 16th week of sampling. The numbers in the white circles stand for the focus numbers, the numbers beside the circles give the week numbers in which the first white flies were found. On the ordinate and abcissa plot numbers are given.

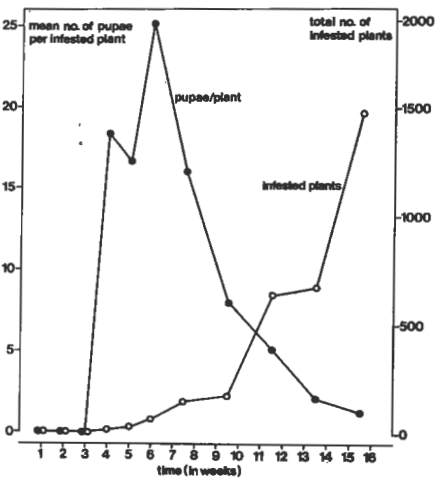


Fig. 7. Relation between the total number of infested plants and the mean number of pupae per infested plants.

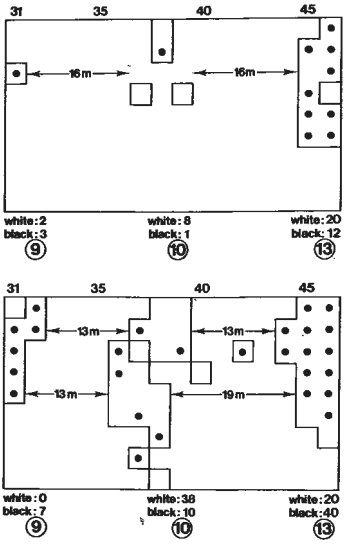


Fig. 8. Plots with unparasitized pupae (white) and plots with unparasitized (white squares) and/or parasitized pupae (white squares with shaded areas) in week 13 and 15 from foci 9, 10 and 13. At the upper abcissa plot numbers are given, at the abcissa below, the foci number and the number of black and white pupae.

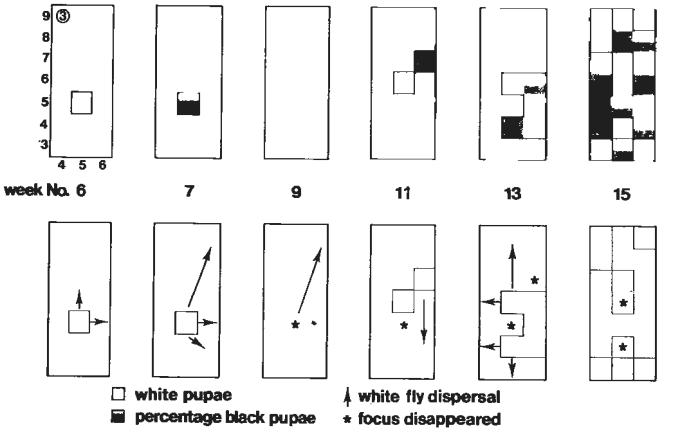


Fig. 9. Development of focus 3. White squares show plots with unparasitized pupae, dotted squares plots with unparasitized and parasitized pupae. The size of the shaded areas gives the percentage parasitism per plot. Example: week 6: only one plot with unparasitized pupae. Week 7: one plot with about 75% parasitized pupae. At the ordinate and abcissa plot numbers are given.

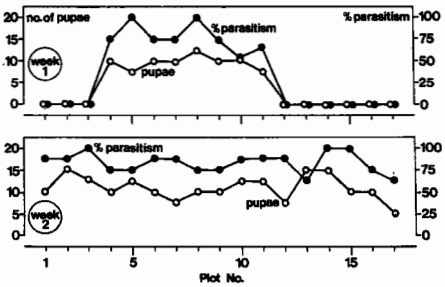


Figure 10a

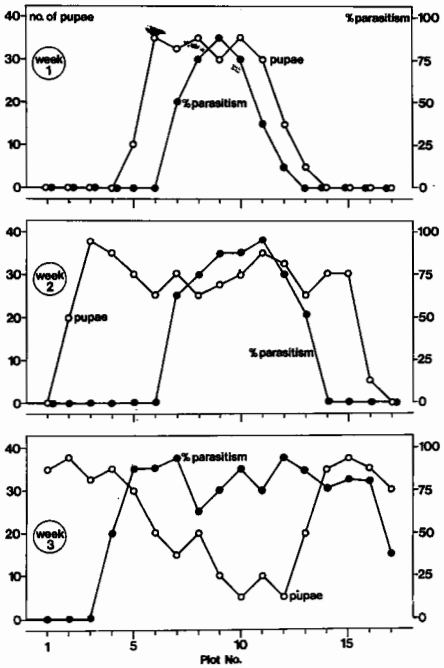


Figure 10b

Fig. 10. Total number of pupae and percentage parasitism during two or three successive weeks in a focus with low total numbers (A) and one with high total numbers of animals (B). (Simplified examples).

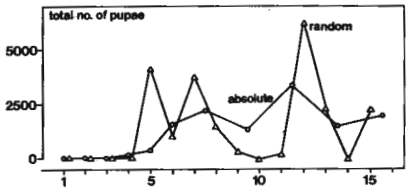


Fig. 11. Total no. of pupae estimated with the aid of the random sampling data (triangles) and total no. of pupae from the absolute countings (circles).

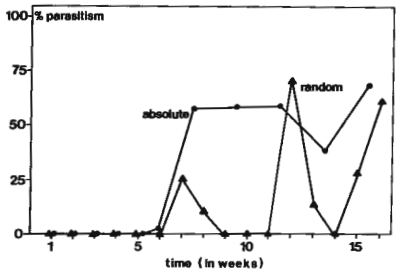


Fig. 12. Percentage parasitism estimated with the aid of the random sampling data (triangles) and percentage parasitism calculated from the absolute countings (circles).

CB. 6234

RESULTATS PRELIMINAIRES DU CONTROLE BIOLOGIQUE DE L'ALEURODE DES SERRES, T. VAPORARIORUM WEST. (HOMOPT., ALEURODIDAE) PAR E. FORMOSA G. (HYMENOPT., APHELINIDAE) EN SERRES D'AUBERGINE.

par

ONILLON J.C., ONILLON J. et DI PIETRO J.P.

Station de Zoologie et de Lutte Biologique

C.R.A. de Provence - 06602 ANTIBES.-

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Mots-clés : aubergine, surface foliaire, T. vaporariorum, E. formosa, contrôle biologique.

Lorsque l'on examine la littérature concernant l'utilisation d'Encarsia formosa pour le contrôle de l'aleurode des serres, Trialeurodes vaporariorum, l'on est assez étonné de lire que dans la partie relative aux données pratiques d'emploi de l'entomophage, l'inoculum, ou la quantité d'auxiliaires à libérer, n'est reliée qu'aux paramètres "plant" ou "unité de surface de plantation" sans que le végétal support biologique normal du ravageur, soit pris en considération. C'est ainsi que dès 1938 MAC LEOD proposait un lâcher de 10 parasites/m2. Plus récemment HUSSEY et al. (1969) estiment que 20 parasites/m2 suffisent à maintenir les populations d'aleurodes en dessous d'un seuil commercialement acceptable.

Or sans conteste la plante hôte, tant par les altérations possibles du potentiel biotique du ravageur (augmentation de la fécondité, mortalité différentielle, réduction de la durée de développement, ...) que par les modifications offertes en ressources disponibles, joue un rôle fondamental dans l'évolution du couple aleurode-parasite. Si les perturbations apportées par le végétal sur la physiologie du ravageur restent encore à préciser, l'on peut penser que la plante hôte, et par l'évolution de la surface foliaire globale et par le nombre de feuilles présentes à la plantation, de 2-3 pour la tomate à 6-8 pour l'aubergine, et ultérieurement durant toute la période d'évolution de la culture, est responsable d'une grande variabilité dans les densités observées à partir d'une même population de l'hôte.

Deux observations majeures peuvent d'ailleurs être faites concernant les dispositifs associés à l'utilisation d'E. formosa dans les serres de cultures maraîchères. En premier lieu il semble délicat pour ne pas dire impossible de faire admettre, au niveau du praticien, la notion de "pest in first", difficulté déjà signalée par WOETS (1973) sur le plan de l'adaptation psychologique d'une telle méthode dans le domaine de l'application et de la vulgarisation, l'amplitude des températures observées dans nos régions méridionales étant d'ailleurs par trop favorables au développement de ce ravageur.

Enfin l'on peut se demander la signification et la portée d'introductions suivies pendant plusieurs générations du ravageur. S'il est somme toute logique de procéder à une cascade d'introductions d'E. formosa à l'intérieur d'une même génération de T. vaporariorum de façon à maintenir la présence de l'entomophage en face des différents stades sensibles du phytophage, l'on peut se demander quel sera l'impact des introductions d'Encarsia lors des générations ultérieures de l'aleurode alors que le parasite est déjà largement présent et efficace dans la culture. Le fait d'apporter de nouveau le parasite dans un rapport de 1/50 ou 1/100 vis-à-vis de la population parasitaire présente, représente-t-il un acquit si important ?

Ces divers points précédemment soulevés nous ont amené à tenter une approche différente du problème posé par le contrôle de Trialeurodes vaporariorum au moyen d'Encarsia formosa en tenant compte de l'état phénologique, de la réceptivité et de la croissance de la plante hôte d'une part et du rapport des forces des deux antagonistes en présence d'autre part.

C'est ainsi qu'est esquissée la définition du nombre optimum de parasites à libérer en fonction d'une population imaginale (stade reconnaissable par le praticien) connue, les larves sensibles au parasite étant par ailleurs corrélées aux adultes présents trois semaines plus tôt sur la culture.

I - METHODES UTILISEES

Elles dépendent tout à la fois du choix de la plante et de son type de culture et des caractéristiques du développement du couple phytophage - entomophage.

1. Choix de la plante-hôte

Des essais préliminaires, réalisés en 1974 dans les serres de la Station d'Antibes, joints à des observations effectuées chez des serristes, avaient montré que dans la liste des plantes maraîchères cultivées en serre (concombre, tomate, poivron, aubergine, ...) et susceptibles de subir des dommages imputables à T. vaporariorum, l'on pouvait retenir dans un premier classement, et sans que soient connues les raisons profondes dépendant de l'impact de la physiologie et de la biochimie du végétal sur l'expression du potentiel biotique de l'aleurode :

Aubergine : très sensible.
Concombre : sensible.
Tomate : sensible à tolérante selon la variété
Poivron : peu sensible à résistant.

L'aubergine (Solanum melongena) a donc été choisie en tant que plante test susceptible de présenter une exacerbation des dégâts imputables à l'aleurode. La variété "Bonica", hybride F1 d'obtention I.N.R.A. est une plante demi-haute, à port légèrement retombant .

2. Type de culture et mode de conduite

Hormis le poivron qui en serre est maintenu par la taille avec la forme grossière d'un gobelet, tomate et concombre sont palissés et conduits sur un bras. Il était donc intéressant de tester sur aubergine un type de conduite mis au point par l'I.N.V.U.F.L.E.C. * (ODET, 1973) et qui permettait de relier l'évolution phénologique classique des plantes les plus couramment attaquées par l'aleurode (tomate, concombre) à la contamination de ce dernier qui se réalise par niveaux regroupant de 4 à 6 feuilles.

Le principe de la conduite à 1 bras est schématisé dans le graphique n° 1, chaque rameau secondaire étant pincé après la première feuille suivant le second bouquet floral. Le bras principal est écimé à 1,80 m.

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* I.N.V.U.F.L.E.C. : Institut National de Vulgarisation pour les Fruits, Légumes et Champignons 30. BALANDRAN.

Les 200 plants d'aubergine ont été plantés le 18/3/1975 dans une serre vitrée de 120 m2 sur 4 lignes espacées de 1,10 m et à 0,37 m sur la ligne donnant une densité de 2,5 plant au m2, soit la densité commerciale usuelle.

3. Mode de contamination par le ravageur

Le plus souvent les jeunes plants sont contaminés par l'aleurode en pépinière. Afin de pouvoir disposer d'une population imaginale connue et définie du ravageur, la contamination a été réalisée artificiellement le 8 avril à raison de 16 adultes par plant soit 8 femelles (le sex-ratio étant présumé être de 1: 1) Cette densité, d'adultes de T. vaporariorum, élevée, est supérieure à ce que l'on peut observer couramment en avril-mai dans les serres d'aubergine et de concombre dans le Sud-Est de la France.

4. Mode d'utilisation d'Encarsia formosa

Le rapport hôte-parasite défini pour cette étude étant de 1 adulte du parasite pour 1 adulte de l'aleurode, 3.500 Encarsia ont été libérés en 3 fois les 2,6 et 13 mai, la population de l'aleurode étant représentée essentiellement par les larves du troisième et quatrième stades.

5. Estimation des populations de T. vaporariorum et d'E. formosa

Nous avons défini comme niveau foliaire d'infestation à une date donnée, l'ensemble des feuilles présentant à cette date les mêmes caractéristiques physiologiques qui déterminent préférentiellement la présence d'un stade de développement du ravageur (fig. 2).

En effet les adultes de l'aleurode s'installent préférentiellement sur les jeunes feuilles. On peut donc considérer l'ensemble de ces feuilles comme un niveau spatial d'infestation parfaitement défini et portant par la suite et à une date donnée, sensiblement le même stade du ravageur.

Les comptages hebdomadaires sur les 8 plants d'échantillonnage ont permis de regrouper les feuilles où l'apparition des larves du quatrième stade a été constatée pour une semaine donnée, en niveau foliaire défini pour cette semaine. Sur les feuilles constitutives du niveau foliaire ont été notés les adultes, les larves du quatrième stade non parasitées et celles présentant visuellement une trace du parasitisme (larves noires et trous de sortie).

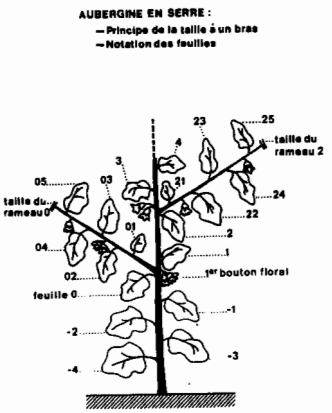

Figure 1 : Schéma du principe de taille à un bras.

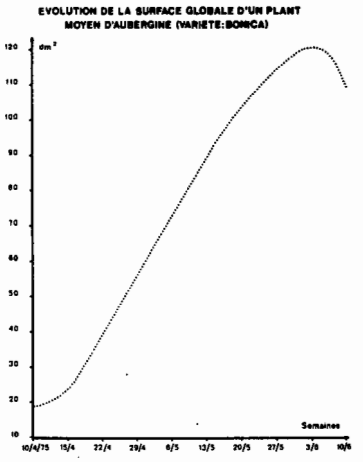

Figure 3 : Evolution de la surface foliaire d'un plant moyen de Bonica.

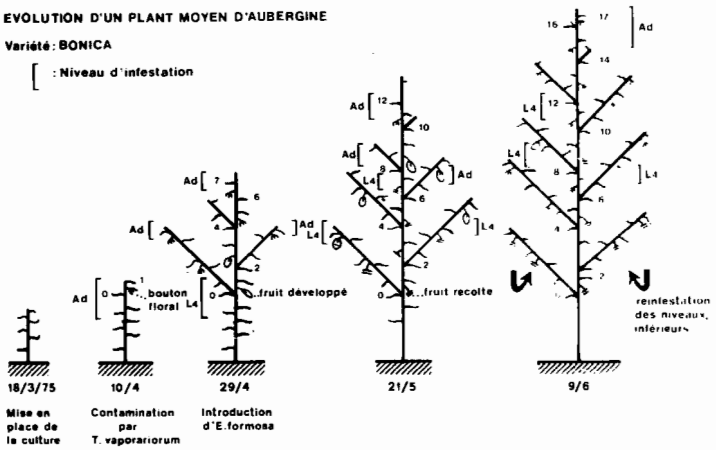

Figure 2 : Evolution d'un plant moyen de Bonica et détermination des niveaux d'implantation.

II - RESULTATS

1. Estimation de la croissance du végétal

Afin de pouvoir étudier simultanément l'évolution des populations de l'aleurode et de son parasite, soit par feuille, soit par densité sur les niveaux foliaires déterminés, la formule de la surface foliaire de l'aubergine, variété "Bonica" a été établie suivant une méthode précédemment définie (ONILLON et al, 1971) pour des feuilles de Citrus. Les données relatives aux mesures de 200 feuilles d'aubergine prises au hasard, ont été soumises à une analyse de régression logarithmique et ont donné les résultats suivants :

$$S = 0{,}64379 \; a^{1{,}2246} \; b^{0{,}7739}$$

où S est la surface calculée en cm2, a et b respectivement les plus grandes longueur et largeur du limbe exprimées en cm (écart type résiduel σr = 0,207 coefficient de corrélation multiple R = 0,981).

Pour chacun des 8 plants d'aubergine réservés à l'étude complète de la dynamique de la croissance de la plante-hôte, toutes les feuilles ont été mesurées chaque semaine, permettant outre l'estimation de la loi de croissance de la surface contaminable en relation avec la température qui fera l'objet d'une publication ultérieure, la détermination de la surface foliaire de chaque niveau et l'évolution de la surface moyenne d'un plant moyen d'aubergine.

Le tableau I permet de suivre l'évolution de la surface foliaire de chaque niveau considéré et la surface moyenne d'une feuille :

Dates	29/4	6/5	13/5	21/5	27/5	2/6	9/6
Surface foliaire du niveau (cm2)	2400	1270	1634	2189	1829	1295	786
Nbre de feuilles/ niveau	4	4	5	6	6	5	3
Surface moyenne d'une feuille (cm2)	600	317,5	326,8	364,8	304,8	259	262

Tableau I : Evolution des surfaces moyennes d'un niveau foliaire et d'une feuille.

L'on peut remarquer qu'à la fin avril, les feuilles constitutives du premier niveau foliaire sont grandes (600 cm2 en moyenne) et sont localisées sur le rameau principal de part et d'autre de la première fleur (feuille -2, -1, 0 et 1 du graphique n° 1).

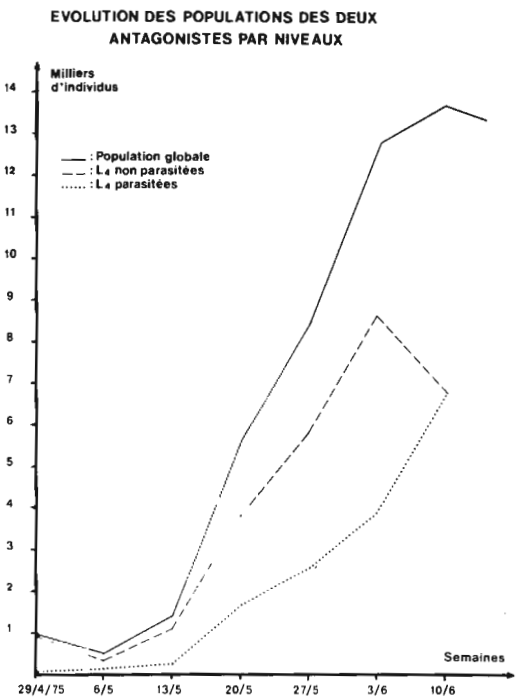

Figure 4 : Evolution des populations des deux antagonistes par niveaux.

Pendant toute la durée du mois de mai, la surface moyenne des feuilles constitutives des niveaux successifs reste constante et comprend sur les 4,5 ou 6 feuilles présentes, deux feuilles portées par le rameau principal, les autres étant portées par les rameaux secondaires. En fin début juin et pendant le reste de la culture, la surface des feuilles demeure plus faible et se stabilise aux environs de 240 à 260 cm2.

Le graphique n° 3 représentant l'évolution de la surface foliaire globale d'un plant moyen de "Bonica" montre un schéma de croissance classique ayant l'allure d'une sigmoïde jusqu'au début juin. A cette date une décroissance rapide est observée imputable au fait que les plants sont éclaircis et que les feuilles de la base du plant sont éliminées. Parallèlement à nombre égal de feuilles formées, la surface moyenne des jeunes feuilles diminue ayant pour conséquence, non plus une conservation du stock foliaire mais une diminution de la surface totale. Nous verrons plus loin l'importance de cette diminution de la surface contaminable, donc des ressources disponibles, sur l'extériorisation des dégâts de T. vaporariorum.

2. Evolution des populations de T. vaporariorum

Nous ne mentionnerons ici que les résultats relatifs aux larves du dernier stade du ravageur susceptibles de présenter, à l'observation visuelle, l'activité du parasite. La distribution spatio-temporelle des adultes de T. vaporariorum en relation avec leur localisation préférentielle et l'évolution des plants d'aubergine fera l'objet d'une note ultérieure (ONILLON et al., 1976).

Cependant il est bon de noter pour la détermination ultérieure du niveau des feuilles susceptibles d'abriter des larves réceptives pour Encarsia, que 2 jours après la contamination homogène par les 3.200 adultes de T. vaporariorum, 86 % des adultes étaient présents sur les feuilles de rang -1, 0 et 1. Le 15 avril 83,3 % de la population imaginale était retrouvée sur les feuilles 0, 1 et 2 du rameau principal et sur les feuilles 01 et 02 du premier rameau secondaire. Enfin le 22 avril, soit quinze jours après le lâcher initial du ravageur, 76,1 % de la population adulte de l'aleurode étaient présents sur les feuilles 3,4,5 et 6 du rameau principal et 03, 04 du même premier rameau secondaire.

Ainsi donc pendant la durée du premier vol d'adultes qui a duré deux semaines, le ravageur en colonisant les jeunes feuilles constituant les sites préférentiels de ponte, s'est adapté à la dynamique de la plante-hôte créant ainsi ses niveaux d'infestation. Aux adultes observés le 10 avril sur les feuilles - 1,0 et 1 du premier niveau foliaire correspondent les larves du quatrième stade (L4) de l'aleurode notées le 29 avril. Les totaux des L4/plant moyen, pour une semaine donnée, tels qu'ils sont figurés dans le tableau 2 ont été calculés en effectuant la somme du maximum des L4 comptées sur les feuilles appartenant au niveau foliaire déterminé pour cette semaine sur 8 plants du 29/4 au 13/5 et sur 4 plants ultérieurement. L'augmentation du temps de comptage sur place en relation avec la croissance des populations présentes a conduit à une réduction du nombre de pieds d'échantillonnage.

L'examen des données incluses dans le tableau 2 et le graphique 4 montre une certaine stabilité du nombre de larves sur les deux premiers niveaux avant l'augmentation spectaculaire qui débute le 13 mai.

Dates	29/4	6/5	13/5	20/5	27/5	3/6	9/6
Nombre de L4/niveau sur un plant moyen	926	464	1073	5619	8402	12.569	13.690
Densités de L4/dm2	38,05	23,8	67	270,8	457,7	970,3	1.754

Tableau II : Evolution du nombre total de L4 (parasitées et non parasitées) par niveau.

Cette croissance exponentielle des populations de l'aleurode qui s'amorçait se ralentit à la mi-juin du fait de la réduction de la surface foliaire disponible conduisant à une surpopulation et une mortalité préférentielle des jeunes stades de l'aleurode pour la possession de l'espace vital.

Parallèlement si l'on se refère aux conséquences logiques que de telles infestations sont susceptibles d'amener sur l'aspect sanitaire de la culture et sur une altération qualitative de la récolte, l'on s'aperçoit que l'apparition de miellat sur les feuilles le 20 mai correspond à des densités de l'ordre de 250 L4/dm2 et que l'apparition de miellat et de fumagine sur fruits est notée le 3 juin avec 950 L4/dm2 lorsque l'arrêt de la croissance de la surface foliaire ne permet plus de compenser la croissance exponentielle des populations du ravageur.

3. Evolution des populations d'Encarsia et du contrôle exercé sur l'aleurode.

Nous avons vu précédemment que le parasite Encarsia formosa avait été libéré sur les larves réceptives dans un rapport très voisin de 1 : 1 vis-à-vis de la population imaginale du ravageur observé trois semaines plus tôt.

Les premières pupes noires apparaissent fin avril avec un taux de parasitisme très faible de l'ordre de 4 %. Puis sur les niveaux successifs, il se stabilise aux alentours de 20 % pendant deux semaines. Par la suite jusqu'au début juin, les taux de parasitisme observés oscillent (tableau III) aux environs de 30 %. Il est bon de remarquer que pendant toute la durée du maintien du parasitisme à un taux constant, soit deux semaines à 20 % et trois semaines à 30 %, le nombre de pupes noires a été multiplié par 2,5 attestant d'une présence et d'une multiplication notables de l'entomophage sur chacun des niveaux successifs.

Dates	29/4	6/5	13/5	20/5	27/5	3/6	9/6
Nombre de L4 parasitées par niveau/plant moyen	36	100	254	1778	2540	3910	6775
% de parasitisme	3,90	21,55	22,86	31,64	30,23	31,12	49,5

Tableau III : Evolution du taux de parasitisme et du nombre de L4 parasitées sur un plant moyen.

Jusqu'au niveau foliaire défini pour la semaine du 27/5, le parasitisme maximal a été observé environ 2 à 3 semaines après l'apparition des larves du quatrième stade de l'aleurode.

Par contre au 9 juin, le taux de parasitisme atteint 50 % alors que le nombre de L4 par niveau sur un plant moyen ne semble plus évoluer (tableau II) L'évolution des populations (telle qu'elle est présentée sur le graphique 4) est symptomatique à cet égard. La population d'Encarsia formosa présente dans la culture est importante mais elle ne suffit pas à contrôler les populations de l'aleurode dont le principal facteur de régulation est représenté en l'occurence par la limitation de la surface contaminable.

A partir de l'instant où le stock foliaire tend à rester constant, voire à diminuer, la population d'Encarsia formosa est susceptible de contrôler le ravageur comme le témoigne la chute du nombre de L4 amorcée dès le début juin.

III - DISCUSSIONS ET CONCLUSIONS

Dans l'optique où nous nous étions placés d'essayer de définir un rapport optimal entre une population d'adultes de T. vaporariorum présente sur aubergine et la population d'E. formosa à libérer deux à trois semaines plus tard, un certain nombre de faits peuvent être avancés :

- le rapport des forces en présence des deux antagonistes (1 : 1) compte tenu de la dose de l'inoculum du ravageur, n'a pas permis d'obtenir un contrôle complet des populations de l'aleurode, 4 récoltes sur 13 ayant présenté sur fruits des dépôts plus ou moins importants de fumagine. En face d'une population élevée du ravageur, le rapport 1 : 1 n'est pas suffisant pour une culture d'aubergine,

- compte tenu de l'évolution et de l'importance de la population parasitaire présente dès la fin de la première génération de l'entomophage, des lâchers ultérieurs d'E. formosa ne semblent pas se justifier.

- la plante-hôte joue un rôle essentiel dans l'évolution du couple aleurode-parasite. Des densités relativement élevées de larves du ravageur peuvent être supportées par le végétal sans impact immédiat sur l'évolution phénologique de l'aubergine et sur la récolte. D'autre part l'extériorisation des dégâts, dépôt de miellat et développement de la fumagine, ne se réalise que lorsqu'il y a un ralentissement ou une diminution de la surface foliaire contaminable par le ravageur.

Si les techniques utilisées, tant dans la conduite de la culture que dans la définition des niveaux d'infestation, ont donné toute satisfaction et sont susceptibles d'être étendues à d'autres cultures maraîchères, il semble que le taux de parasitisme tel qu'il a été calculé et observé dans les différents niveaux ne soit pas un reflet exact de l'activité d'E. formosa. En effet, il s'agit du taux de parasitisme apparent, c'est-à-dire de la prise en considération des pupes noires parasitées. Du fait de l'hétérogénéité de la population en stades sensibles à Encarsia, il n'a pas été tenu compte des larves des divers stades de l'aleurode susceptibles d'abriter des oeufs ou des larves de l'auxiliaire. Le taux de parasitisme observé l'est donc par défaut.

Du fait de ces remarques et des résultats acquis dans l'étude de la dynamique des trois éléments de l'écosystème, aubergine - aleurode - parasite, il semble que des résultats intéressants soient susceptibles d'être obtenus dans le contrôle de T. vaporariorum par E. formosa en définissant un rapport du nombre de parasites à libérer en fonction d'une population connue du ravageur. Ce rapport, dans notre esprit, devrait être fonction de la densité initiale du ravageur et de la nature de la culture à protéger et c'est dans cette voie que s'orientent à l'heure actuelle nos recherches.

RESUME

Pour contrôler les populations de T. vaporariorum sur aubergine l'utilisation d'E. formosa est envisagée en libérant l'auxiliaire sur les stades sensibles du ravageur dans un rapport défini, fonction de la population imaginale du ravageur. Le rapport d'un adulte du parasite pour un adulte de l'aleurode est insuffisant pour assurer un contrôle biologique complet sur aubergine compte tenu de l'infestation initiale.

Les seuils de nuisibilité de l'aleurode, avec apparition des dégâts miellat et fumagine, sont esquissés.

La formule de la surface foliaire de l'aubergine, variété "Bonica" est donnée ainsi que l'évolution de la surface contaminable par le ravageur.

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CB 6235

THE PARASITE-HOST RELATIONSHIP BETWEEN ENCARSIA FORMOSA (HYMENOPTERA : APHELINIDAE) AND TRIALEURODES VAPORARIORUM (HOMOPTERA : ALEYRODIDAE).

VI. The influence of the host plant on the greenhouse white fly and its parasite Encarsia formosa.

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Introductions of Encarsia formosa Gahan to control the greenhouse white fly (Trialeurodes vaporariorum (Westwood)) in crops in Dutch glasshouses gave highly different results. Observations in practice as well as experimental data generated the assumption that differences in host plant quality influencing developmental rate of the white fly, and differences in the structure of the leaf surface of the plants influencing parasitization efficiency of the wasp, are the main factors affecting the outcome of the control measures. The differences in the degree of success are summarized below:

		T. vaporariorum (developmental rate)	E. formosa (parasitization efficiency)	control success
eggplant (aubergine)	(E)	+ +	+	$\pm$
cucumber	(C)	+	-	-
tomato	(T)	$\pm$	+	+
paprika (sweet pepper)	(P)	-	+	not necessary

+ = fast (developmental rate), or high (parasitization efficiency), or good (control success).

1. Relation T. vaporariorum - different host-plant species

host-plant selection*

Flight experiments were done in a vertical flight chamber in which white flies can be kept flying towards an overhead light with the aid of an opposing down current of air (see Kennedy & Fosbrooke, 1972).

Firstly, the two most extreme host plants as regards suitability for white fly development and mortality, i.e. eggplant and paprika, were offered to the flies. Results are shown in Fig. 1. There is no significant difference in number of landings on the two host plants. The same result was obtained at similar experiments done in a perspex cylinder (Ø 11 cm, height c. 20 cm), see Fig. 2.

In the flight chamber we also tested the reaction of the white flies to a paprika leaf and an artificial leaf of the same surface area and shape. Again no preference was measured (Fig. 3).

Finally, the four different host plants were offered simultaneously to the flies. Although there seems to be a trend from eggplant to paprika in numbers of white flies landed, there is no significant difference (Fig. 4). Of course, more tests need to be done but up till now we cannot say that the host plant species accepted for oviposition or feeding is chosen before landing.

A second series of experiments in which we offered isolated leaves of the different host plants to one T. vaporariorum female revealed that (Fig. 5) on a "bad" host plant (e.g. paprika):

- the number of take-offs is higher
- the percentage time of the total observation period spent on the leaf is lower
- and the number of position changes by the white flies on the leaf is higher

than on a "good" host plant (e.g. eggplant). (About 20 females were tested per host plant during c. 7 hours.)

* All experiments were done with white fly adults, reared as larvae on tomato, and maximally half a day after hatching.

On the basis of these results we may state that it is only after landing on a plant that T. vaporariorum detects whether it is a suitable host plant or not.

A third series of experiments where white flies were released to the four host-plants species in an insect cage showed that after an hour most white flies were present on eggplant, the next highest number of cucumber, followed by tomato and finally paprika. This distribution pattern is caused by the fact that after a presumed initial random distribution over the four host plants the white flies take-off from some host plants (tomato and paprika) and stay feeding and ovipositing on others (eggplant and cucumber).

life span

At 22°C the following mean life span data have been obtained (number of flies tested on each host-plant species: 20-40) (see Fig. 6):

	E	C	T	P
♀♀ (reared on tomato)	28.0	21.1	20.4	4.8

fecundity (see also Fig. 7)

Average number of eggs per female per day (22°C) (number of flies tested on each host-plant species: 20-40):

	E	C	T	P
♀♀ (reared on tomato)	10.1	8.3	4.7	0.7

average egg production per female during whole life span (22°C) (number of flies tested on each host-plant species: 20-40):

	E	C	T	P
♀♀ (reared on tomato)	285.8	175.0	94.4	3.1

developmental period

Average life span of the different developmental stages (22-23°C) in days (no. of eggs at the start on each host-plant species: c. 400):

plant	egg	I1	I2	I3	I4	P	total
E	8	4	1.5	2.5	4	5	25
C	8	4	2.5	2.5	4	5	26
T	8	6	2	3	4	5	28
P	8	6.5	3.5	4	4	4	30

mortality (as percentage from the initial number of eggs)

Average mortality of the different developmental stages calculated as the ratio of the initial no. of animals of a certain stage and the no. that died during that stage (c. 25°C):

plant	egg	(n)	I1	I2	I3	I4	P	total mortality as % of the initial number of eggs
E	4.2	(192)	2.2				2.8	8.9
C	5.4	(167)	3.2	1.3	1.3			10.8
T	6.3	(161)	9.9	2.2	1.5	0.8	2.3	21.1
P	12.0	(145)	72.7	45.7	15.8	18.8	15.4	92.4

conclusion

The higher the number of white flies counted on a host plant after some time (in decreasing rate: eggplant, cucumber, tomato, paprika), the higher the total number of eggs laid per female, the higher the oviposition frequency, the longer the life span of the females, the shorter the complete developmental period, and the lower the mortality.

Thus host-plant selection in the white fly must have a biological significance: the more often a host plant is chosen, the better is its quality to the white fly.

2. Relation Encarsia formosa - Trialeurodes vaporariorum - different host-plant species (eggplant- cucumber - tomato - paprika)

host-habitat searching

E. formosa does not show a clear preference to plant species offered to it. Fig. 8 shows the choice of 293 wasps for cucumber, tomato, paprika and bean.

However, the wasp does clearly prefer plants infested with white flies above non-infested plants. In an experiment in which 100 wasps were tested individually, 90 went immediately to infested and 10 to uninfested leaves.

host searching

As soon as a parasite arrives at the underside of a leaf with hosts it starts to drum with its antennae on the leaf surface. Searching is not directed towards larvae of certain stages especially suitable for oviposition: the wasp walks in a random way. The probability of encountering a host is equal to the proportion of outline of that particular host to the summed outlines of all hosts present on the leaf part (Fig. 9, for details see Van Lenteren et al., 1976a).

host selection

After the wasp has found a host, she will examine it with her antennae. The antennal test may result either in rejection (in which case the wasps walk away from the host) or in provisional acceptance. Then the ovipositor is stung through the cuticle of the host. The parasite apparently again tests the suitability of the host, because in a number of cases the ovipositor is withdrawn before an oviposition takes place. Oviposition postures lasting longer than 100 seconds resulted predominantly in actual egg deposition. Fig. 10 shows that first and second instar larvae and the pupae are rejected very frequently for oviposition. Instar 3 and 4 and prepupae are stages selected for oviposition.

The biological meaning of this host selection might be that the most preferred stages produce the highest percentage offspring for a certain number of eggs laid in them. When first and second instar larvae are parasitized, host and parasites

die prematurely. Oviposition in pupae does not result in parasites either (for details see Nell et al., 1976).

host discrimination

Analysis of the oviposition behaviour of the wasp towards unparasitized and parasitized host larvae showed that she is able to discriminate between these two groups (for details see Van Lenteren, 1976b). She avoids to oviposit in the parasitized hosts. Rejection of a parasitized host takes place after the wasp examines the host with her antennae and sometimes after examination with her ovipositor. The percentage rejection of unparasitized and parasitized hosts is shown in Fig. 11. Almost all hosts are rejected for oviposition after a first egg has been laid in them. After all hosts on a certain leaf part are parasitized, the wasps leave the site. This relation between host discrimination and tendency to migrate is very important for the population development of both host and parasite, see Van Lenteren et al. (1976c). When the wasp does not have the opportunity to leave, she will eventually superparasitize some hosts.

life span, fertility and oviposition frequency of E. formosa

The life span of the wasp was not studied by us up till now, literature data say it to be about 20 days.

A wasp is able to oviposit at least 73 times (the highest number of ovipositions we observed during direct observations). Extensive quantitative data are not available.

Oviposition frequency of E. formosa depends strongly on leaf structure. Under identical abiotic conditions and when density of host and parasite is the same, the oviposition frequency on tomato leaves is about 1.2 to 2 times as high as on cucumber leaves. The differences causing this will be dealt with below.

rate of development of E. formosa

The rate of development is equal for wasps developing in hosts on the four

plant species and amounts about 15 days at 25°C. At temperatures below 18°C the development of the wasps takes more time than that of its hosts; above 18°C the wasp develops faster than the white fly.

mortality of E. formosa

The mortality of E. formosa has not yet been analysed quantitatively; pupal mortality is found to be very low.

influence of host quality on the development of E. formosa

Because differences in size were observed between white fly pupae cultured on different host plants, we thought that this might result in differences in wasp quality too. We did not study this up till now.

3. Differences in success of control (see also Woets, 1973)

During the research just described we found that a combination of factors is responsible for the differences in control success on the various host plants:

a. causes for the good control on tomatoes

Tomato is a rather bad host plant for the white fly compared with egg-plant and cucumber. Life span is relatively short, total number of oviposi-tions, oviposition frequency and rate of development is low, larval mortality is rather high.

To the wasps, on the other hand, this plant presents a rather good "working surface". Neither the small hairs nor the type of venation hamper the wasps seriously when searching for hosts. Furthermore, E. formosa shows a strong functional response: to white fly in tomato cultures the percentage parasi-tization increases with increasing white fly density. The parasite is able to control the white fly satisfactorily.

b. causes for the bad control on cucumber

Although the English workers on this problem mention good control possibi-lities of white fly in cucumbers, our efforts to this end failed (see Hussey

and Bravenboer, 1971; Gould et al., 1975).

As compared with the situation on tomato as host plant all the measured properties of the white flies are more positive on cucumber (long life span, high total number of ovipositions, oviposition frequency and rate of development, and low larval mortality). Hence, on cucumber population growth of white fly is very fast.

This alone already causes an important difference in control possibilities. Moreover, some other factors which are unfavourable to the parasite, play a role.

The parasitization efficiency of E. formosa on cucumber leaves is much lower than on tomato leaves because:

- the wasp is strongly hampered by the retiform venation and by the relative large hairs (walking speed on cucumber is about half of that on tomato: 3.3 mm/sec versus 5.9 mm/sec), so much so that the probability to meet hosts is much lower on cucumber;
- the wasp spends more time in preening her body, which becomes dirty from honeydew present up on the long hairs. Wasps on cucumber spent 20% of their time in preening, those on tomato only 10%.

The wasps do not show a strong functional response: the percentage parasitization decreases slightly with increasing white fly density. This is certainly partly caused by the increasing amount of honeydew present on the leaves, as a result of which the percentage time spent in preening increases.

c. causes for the moderate control on eggplant

The fact that control on eggplant is better than on cucumber seems to be unexpected at first sight because the conditions for the white fly are even better than on cucumber. However, on eggplant the wasp is less hampered in its locomotion (walking speed is higher and percentage time spent in preening is lower).

Still, for a sufficient control, many more parasites have to be introduced on eggplant (14 wasps per plant, instead of 5 on tomato), and it is not always possible to control the white flies biologically during the whole

growing season.

d. causes for the sufficient control on paprika

Incidentally white fly has to be controlled on paprika. A good success is easily obtained because:

- paprika is a very bad host plant for the white fly
- conditions for the parasite are rather good, the leaves are smooth, so the wasp is hardly hampered by obstacles. So parasitization efficiency is, therefore, high.

Acknowledgements

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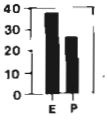


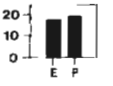


Fig. 1. No. of first landings by white flies on leaves of eggplant (E) and paprika (P) in a vertical wind tunnel.

Fig. 2. No. of first landings by white flies on leaves of eggplant (E) and paprika (P) in a perspex cylinder.

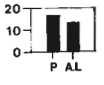


Fig. 3. No. of first landings by white flies on leaves of paprika (P) and an artifical leaf (A.L.) in a vertical wind tunnel.

Fig. 4. No. of first landings by white flies on leaves of eggplant (E), cucumber (C), tomato (T) and paprika (P) in a vertical wind tunnel.

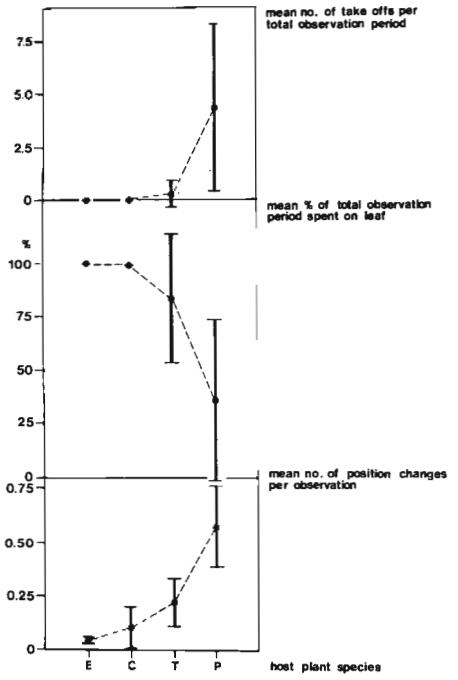


Fig. 5. a. Mean no. of take offs per total observation period of c. 7 to 8 hours.
b. Mean % of the total observation period spent on the leaf after the first landing.
c. Mean no. of position changes per observation period.
All means with standard deviations.

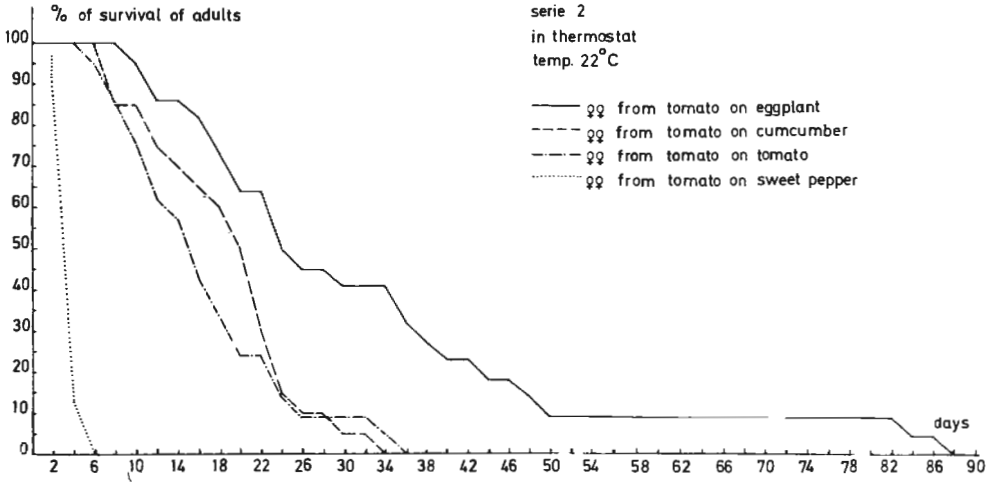


Fig. 6. Percentage survival of adults (♀♀) on different host plant species.

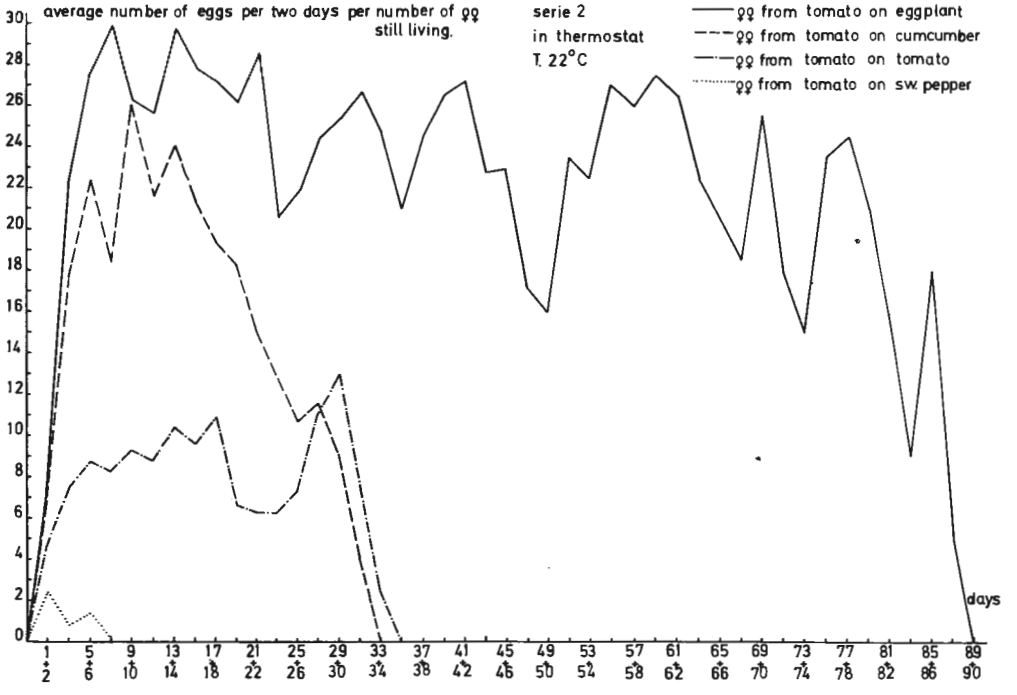
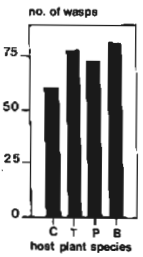


Fig. 7. Average number of eggs per living female per two days on different host plant species.



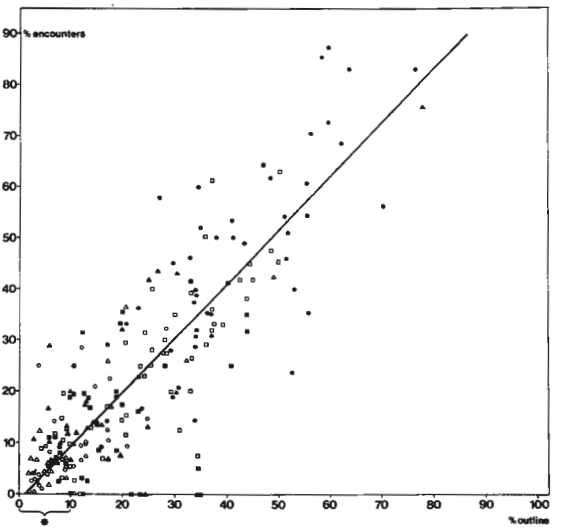
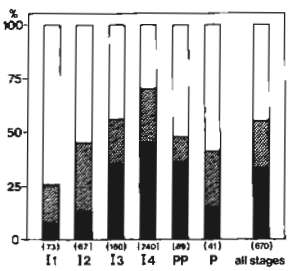


Fig. 8. The no. of first landings of wasps on cucumber (C), tomato (T), paprika (P) and bean (B) leaves.

Fig. 9. Relation between percentage outline of a particular host stage of T. vaporariorum and the percentage encounters with it by E. formosa ($y = 1.05 x - 0.99$, $r = 0.89$, $n = 214$, $P < 0.005$).
* = not drawn were 48 symbols with a percentage outline less than 10 and with which no contact was made.



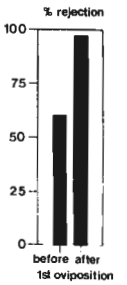


Fig. 10. Percentage rejection after antennal test (open column), percentage rejection after ovipositorial test (hatched column) and percentage acceptation (solid column) of Trialeurodes vaporariorum by Encarsia formosa.

Fig. 11. Percentage rejection of hosts before and after the first oviposition (no. of contacts with unparasitized host c. 700, with parasitized hosts c. 300).

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THE PARASITE-HOST RELATIONSHIP BETWEEN ENCARSIA FORMOSA GAHAN (HYMENOPTERA: APHELINIDAE) AND TRIALEURODES VAPORARIORUM WESTWOOD (HOMOPTERA:ALEYRODIDAE)

THE IMPORTANCE OF HOSTFEEDING AS A MORTALITY FACTOR IN GREENHOUSE WHITEFLY NYMPHS

by

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Ingesting the bodyfluids of a host, through a hole which is made with the ovipositor, is a common habit in many hymenopterous parasites. It occurs also in the Chalcids, the Braconids as in the Ichneumonids (De Bach, 1974).

Hostfeeding in an Encarsia species was first mentioned by Stüben (1949), when she described the behaviour of Encarsia tricolor Förster feeding on its host, Aleyrodes proletella L.

Although research on Encarsia formosa is carried out since 1927, it was not until 1966 that hostfeeding was observed.

Gerling (1966) describes the hostfeeding behaviour of protein starved females of Encarsia formosa on pupae of Trialeurodes vaporariorum, but does not give evidence that hostfeeding is a frequently occurring habit under more natural conditions.

Burnett (1962) stressed the occurrence of an important mortality of host larvae caused by Encarsia formosa, additionally to the mortality caused by parasitism. By then he did not know that hostfeeding was one of the causes of this mortality and stated "Hostfeeding by adult parasites of Encarsia formosa has never been observed". Two years later, he writes (Burnett, 1964): "In the present experiments, only about one dozen adults of Encarsia formosa were observed feeding on host larvae and these may have been feeding on honeydew. In spite of considerable effort, the mechanism whereby adult parasites either kill or parasitize larvae of T. vaporariorum has not been determined". Ironically he had already observed hostfeeding in 1943, but had misinterpreted the behaviour as a possible mechanism for host discrimination: "A female parasite was observed feeding on a scale at a point were it had just laid an egg and it is possible that the hostfluid on the surface of the whitefly may be of some assistance to the adult parasite in determining the suitability of the host" (Burnett, 1943).

The question arose if hostfeeding was an important cause of the nymphal mortality. Nymphal mortality in the greehouse whitefly, caused by E. formosa, may have different causes:

a. The hostlarvae die from injury caused by the ovipositor. This may happen with small larvae after normal oviposition behaviour of the parasite, or may be the result of repeated stinging by "inexperienced" parasites.

b. The nymph is killed by the larval parasite, which has also died before maturation.

c. The nymph has died as a consequence of hostfeeding.

To determine the importance of hostfeeding as a cause of the nymphal mortality, direct observations of the adult wasps are necessary.

Materials and methods

The hostplants. The tomato (strain Moneydor) and cucumberplants (strain Sporu) were grown in rooms with direct sunlight at about 20°C.

The hosts. One room was used to multiply T. vaporariorum. Before an experiment was started a leaf with the required host stages was selected and removed from the plant.

The parasites. In another room T. vaporariorum and E. formosa were multiplied on host plants on which all host stages were continuously available. When it was necessary to know the age of the parasites exactly, the leaves with the black (parasitized) pupae were gathered and isolated in glass vials. The vials were placed at 25°C and inspected a few times a day. If parasites had emerged, they were put in a vial in which a leaf with some unparasitized host larvae was present, so they could feed and parasitize. At least 12 hours before an experiment, about three unparasitized host larvae were offered to E. formosa. This procedure was developed to ensure that the wasp starts to parasitize at once if a fresh leaf with hosts is presented in the experiment. The age of the females at the start of an experiment varied between one and ten days. The data used in this paper originated from 163 hours of observation with 25 different females.

The set up of the experiments. If we want to study the behaviour of E. formosa under natural condition we have to place and observe it at the underside of a leaf. The parasite is only 0.6 mm long, so we need a microscope to look at it. To execute the experiments rather efficiently this method is too time consuming method, as the parasite may walk or fly away and leave the field of the stereo microscope many times. Therefore, we constructed a special set up. The upperside of a part of a leaf with hosts was fixed with plasticine against the inside of a petridish bottom. The petridish was closed and mounted on a burette holder in such a way that the underside of the leaf is directed downward as in the natural situation. All experiments were executed in a room of 25°C ± 1.

The behavioural components analysed in this paper are:

a. hostfeeding
b. oviposition
c. feeding on honeydew

Results and discussion

During our observations hostfeeding was a frequently occurring. Some parts of the hostfeeding behaviour are rather similar to the oviposition behaviour and a detailed description of this behaviour is, therefore, given.

When a wasp has found a host, it first examines it by drumming with the antennae on the surface of the host. Then it turns her body and stings with the ovipositor through the cuticle of the host, making up and downward movements with the abdomen and the ovipositor. The ovipositor pierces thus the tissues of the host in several directions. When the ovipositor is withdrawn, the wasp turns again and examines the wound with her antennae. The wasp may, then, bring her mouthparts to the wound and start to feed or she may turn for a third time and use her ovipositor to enlarge the hole in the host before feeding. She, sometimes, uses her mandibles to enlarge the wound. The feeding may last from some seconds up to fifty minutes. Sometimes feeding is interrupted to reopen the wound with the ovipositor. The host is often sucked out completely. The stinging behaviour that occurs before hostfeeding is different from the egg-laying behaviour. When laying an egg, E. formosa does not move the abdomen and the ovipositor as soon as the host cuticle is pierced.

E. formosa feeds on all the sessile host stages, the mobile first instar larva walks away when a parasite hits it with its antennae.

Not all the host stages are used in an equal proportion. The second instar and the pupa are more used for hostfeeding than the other instars. As the third instar and the prepupa are the best stages for oviposition, the biological significance of this phenomenon will be clear. Although E. formosa uses a larger proportion of the third instar and the prepupae for oviposition, we did not find a significant negative correlation between the ratio of hosts used for hostfeeding and the hosts accepted for oviposition in the different developmental stages ($r=0.65$, $n=6$, $P > 0.05$). This is probably due to the low numbers of larvae attacked in the different instars. Fig. 1 shows the percentage of hostfeeding compared to the percentage of oviposition in the different larval instars.

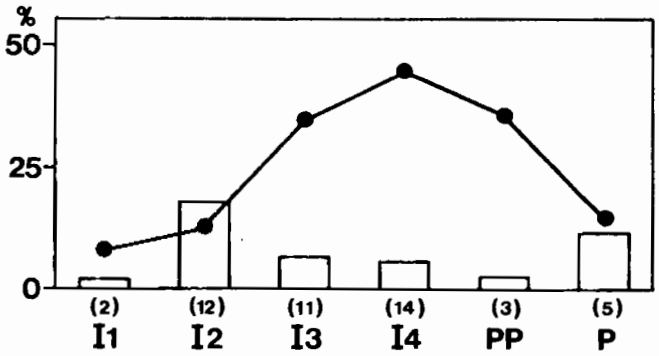

Fig. 1
Percentage used for hostfeeding (columns) and percentage used for oviposition (line) in each nymphal stage.

Flanders (1953) found that the hosts destroyed by the parasite Metaphycus helvolus were generally smaller than those suitable for receiving parasite eggs. Burnett (1962) found an obvious negative correlation between the numbers killed and the numbers parasitised in the different host stages. Small larvae were more likely to be killed than the older larval stages.

E. formosa used seven percent of all the hosts met to feed upon, compared to 35 percent of all hosts met used for parasitisation. We may conclude from this that host-feeding can be an important mortality factor.

Burnett (1964) found the nymphal mortality in greenhouse whitefly larvae dependent on the density of the parasite and on the host density. As we used in each experiment, only one parasite which was only observed during a small part of its life time, our experiments do not give any information on how hostfeeding operates as a mortality factor in the field.

Besides feeding on the bodyfluids of its host, E. formosa feeds also on the honeydew produced by T. vaporariorum. In our observations, 3.2 percent of the total observation time was spent feeding on honeydew, compared to 5.1 percent spent with feeding on hosts. We have a slight indication of an inverse relationship between feeding on honeydew and host-feeding.

According to Weber (1931) the honeydew of T. vaporariorum contains nitrogen. Auclair listed the number of amino acids occurring in the honeydew of aphids (Auclair, 1963). If the honeydew of white flies contains amino acids, the feeding on honeydew might replace the feeding on hosts. As whiteflies produce different quantities of honeydew on the different species of hostplants, this may affect the number of hosts attacked on different species of hostplants. This will be subject of further research.

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CB . 6237

ESSAI DE MISE AU POINT D'UNE METHODE DE LUTTE INTEGREE EN SERRE DE ROSIERS

Par

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Parmi les problèmes posés par les ravageurs en serre de rosiers, les Tétranyques (Tetranychus urticae KOCH. et T. cinnabarinus BOIS DUVAL) tiennent la première place. Les attaques bien que limitées généralement aux périodes printanières et estivales, peuvent intervenir également en cours d'automne et d'hiver sous notre climat dans des serres chauffées et obligent les horticulteurs à intervenir fréquemment contre ces ravageurs ; cependant, le nombre d'acaricides utilisables est très limité d'une part, par la phytotoxicité de certains produits, d'autre part, par une généralisation de phénomènes de résistance des Acariens aux matières actives les plus utilisées.

Il nous est donc apparu qu'une méthode utilisant le prédateur Phytoseiulus persimilis ATHIAS-HENRIOT pourrait diminuer la pression de sélection qui s'exerce sur les Tétranyques par une utilisation beaucoup plus restreinte des acaricides et faire également décroître les populations réfugiées dans les parois et le paillage de la serre qui sont à l'origine de nouvelles attaques dans ce peuplement végétal permanent que réprésente une serre de rosiers.

Matériel et méthode

L'essai a eu lieu au cours du printemps et de l'été 1975 dans une serre de rosiers de la variété "Lara", d'une superficie de 700 m2 située au service de Vulgarisation florale de la Chambre d'Agriculture des Alpes-Maritimes. Quatre compartiments comprenant chacun quatre double rangées de longueur égale ont été délimitées ; deux d'entre eux ont été menés suivant une lutte chimique classique et les deux autres en lutte intégrée.

Les conditions climatiques de la serre ont été contrôlées à l'aide de deux thermo-hygromètres enregistreurs dont les résultats sont indiqués sur le graphique N° 1. L'humidité relative était généralement élevée durant la nuit et une partie de la journée du fait de bassinages quotidiens.

Le développement des populations de Tétranyques et du prédateur ont été suivis par des prélèvements de feuilles effectués tous les 15 jours sur les rangées des quatre parcelles, la population portée par ces feuilles étant ensuite dénombrée au laboratoire.

Résultats

Ceux-ci sont exposés sur les graphiques 2 et 3. On note tout d'abord trois gradations successives des populations de Tétranyques dans l'ensemble de la serre au cours de la fin du printemps, de l'été et du début de l'automne. Les populations maxima étant généralement plus élevées dans les parcelles menées en lutte chimique. Dans les deux autres, on notera qu'un seul lâcher de P. persimilis (effectué sur foyers dans un premier temps puis généralisé 8 jours plus tard) a permis de protéger efficacement la culture de Juin à septembre alors que dans le même temps, cinq applications d'acaricides étaient nécessaires dans les lots voisins. On constatera également que les températures maxima les plus élevées de l'été (36° de moyenne fin Juillet) ont coïncidé avec la réapparition spontanée et le développement des prédateurs dans la serre lors de la deuxième gradation. Il semble que des températures assez élevées puissent être bien supportées par P. persimilis sous réserve qu'elles s'inscrivent dans une thermopériode comprenant des températures inférieures à 20°, l'humidité relative étant alors très élevée.

A partir du mois de Septembre, les traitements dirigés contre le Thrips (Sulfotep, Endosulfan) anéantissent pratiquement les populations du prédateur. Un nouveau lâcher effectué vers la mi-Octobre, n'empêche pas les populations de Tétranyques de se développer. A cette époque, à la suite de l'application de fongicides tels que le Ditalimphos et l'Ethirimol, pourtant couramment utilisés sans problème au cours de l'été, on constate une forte mortalité dans la population de prédateurs (1/5e à 1/6e environ). Des études poursuivies au laboratoire permettent de penser qu'un changement d'état physiologique intervient chez P. persimilis qui serait lié en grande partie

aux modifications du métabolisme des Tétranyques en automne et qui se manifesterait par une baisse de fécondité et de longévité et probablement aussi par une plus grande sensibilité aux pesticides.

Trois récoltes de fleurs ont eu lieu au cours de cette expérimentation car contrairement à ce qui se passe habituellement sous nos climats où l'été est la saison de repos de végétation, la rose "Lara" est récoltée de préférence en saison chaude étant donné ses exigences thermiques. La comparaison des récoltes sur les rangées des quatre parcelles traitées par une méthode non paramétrique pour des raisons d'hétérogénéité entre les rangées (Test de MANN-WHITNEY, WILCOXON - WHITE) n'a montré aucune différence significative entre les parcelles menées en lutte chimique ou en lutte intégrée.

CONCLUSIONS

Dans la perspective du développement de cette méthode de lutte intégrée, plusieurs problèmes doivent être évoqués.

En ce qui concerne les autres ravageurs animaux tel que le puceron du rosier Macrosiphum rosae L. son élimination est relativement facile et certains aphicides peu toxiques pour P. persimilis peuvent être utilisés. Par contre, les traitements dirigés contre les Thrips à l'automne empêchent tout prolongement de l'action du prédateur.

En ce qui concerne les maladies, leur apparition est inhibée par la modification du climat de la serre (suppression d'un excès d'humidité pour le Mildiou (Peronospora sparsa BERK.) par exemple) seul l'Oïdium (Sphaerotheca pannosa var. rosea WORON) nécessite des traitements répétés ainsi qu'on peut le constater sur les graphiques 2-3 (12 à 13 traitements pour la période envisagée). En 1976, de nouveaux produits dont la toxicité semble faible vis-à-vis de P. persimilis doivent être essayés. Simultanément, pendant la période chaude, une élimination de l'oïdium sera tentée sur une moitié de la serre par l'utilisation d'un "mist-system", celui-ci en maintenant une humidité très élevée pendant un temps donné doit faire éclater prématurément les spores d'oïdium. Ces essais sont poursuivis avec la Station de Pathologie Végétale d'Antibes (I.N.R.A.).

Malgré les obstacles constitués par les problèmes du Thrips et de l'Oïdium, il semble possible de mettre en place, dans les années à venir, un véritable système de lutte intégrée susceptible notamment d'apporter une solution aux difficultés rencontrées actuellement par les horticulteurs dans la lutte contre les Tétranyques.

LISTE DES PESTICIDES UTILISES (ANNEXE AUX LEGENDES DES FIGURES 2 et 3)

FONGICIDES : La = Laptran et Pl = Plondrel (Ditalimphos)
M = Milgo E (Ethirimol), T = Turbofal (Folpel + cuivre)
B = Mehltaumittel BASF (Dodemorphe acetate)

INSECTICIDES : Pi = Pirimor (Pirimicarbe), D = Nogos (Dichlorvos)
Bl = Bladafum (Sulfotep), I = Insectophène fort (Endosulfan)
U = Ultracide (Méthidathion)

ACARICIDES : F = Fundal forte (Chlorphenamidine + Formetanate)
K = Kelthion (Dicofol + Tetradifon)
P = Pentac (Dienochlor), O = Ovicide Seppic (Fenizon)

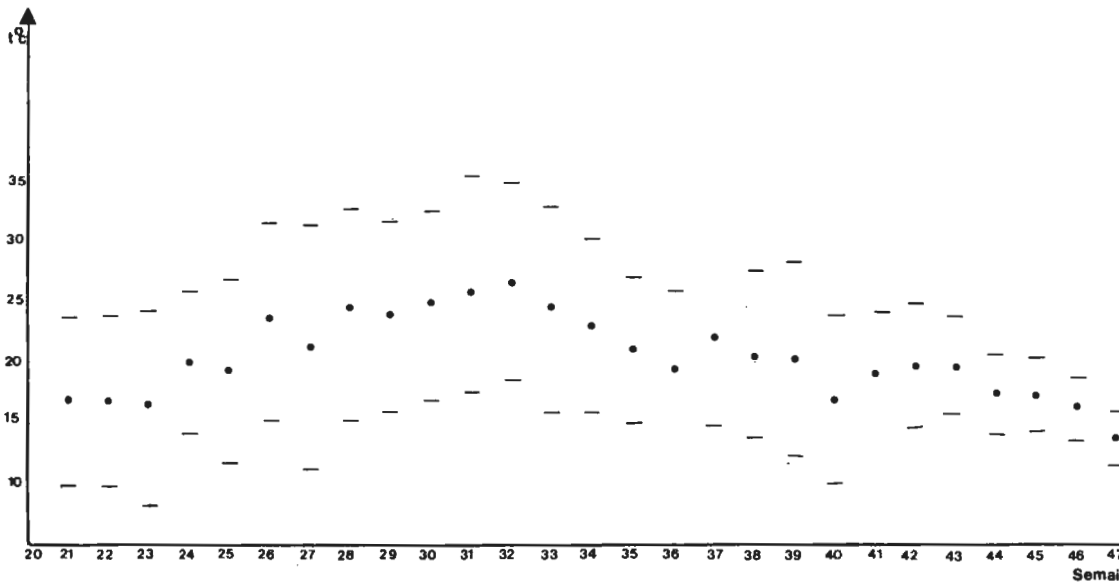

Fig. N° 1 : Moyenne des températures maxima et minima hebdomadaires au cours de l'été 1975.

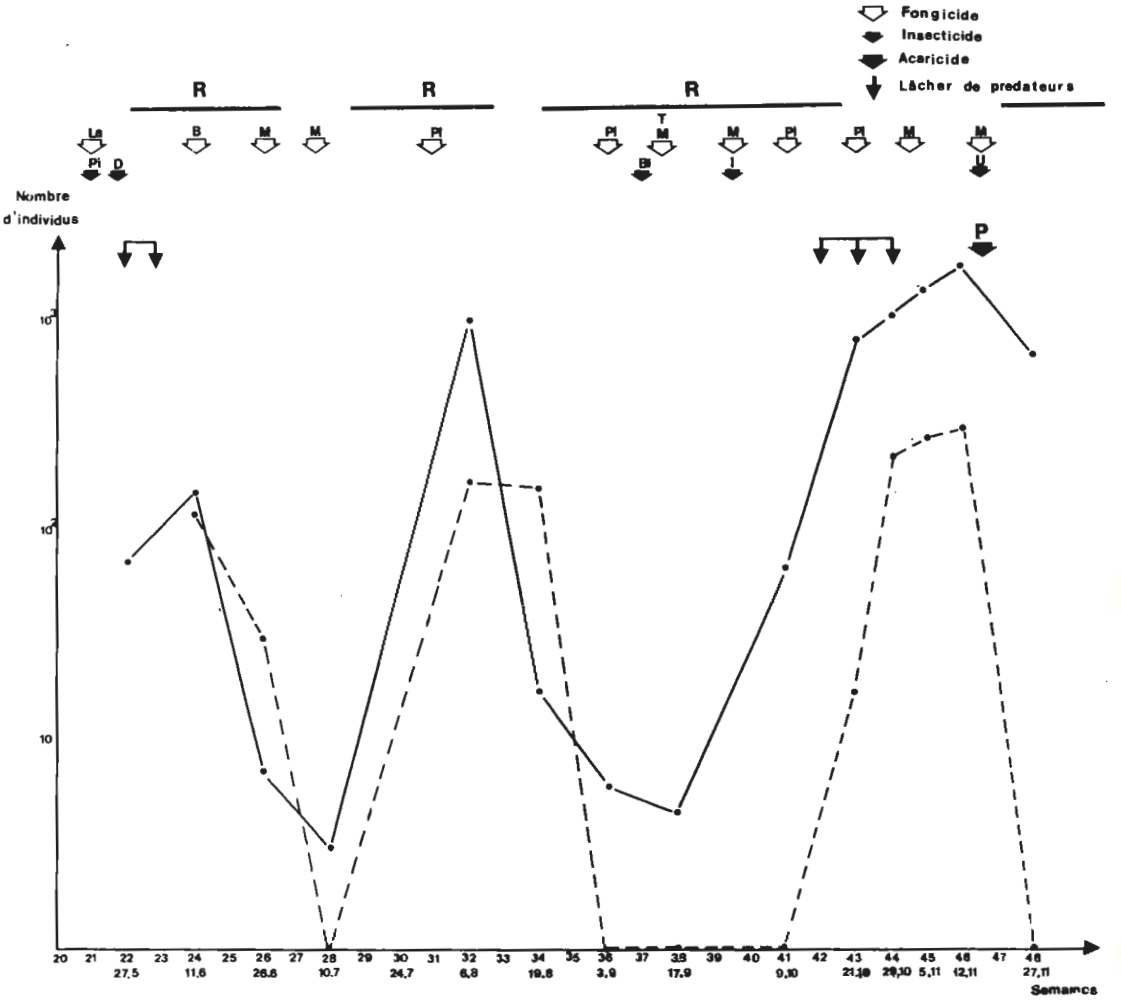

Fig. N° 2 : Développement des populations de Tétranyques (trait continu) et du prédateur P. persimilis (trait discontinu) dans les parcelles menées en lutte intégrée (population moyenne pour 100 feuilles) au cours de l'été 75 (R = récolte).

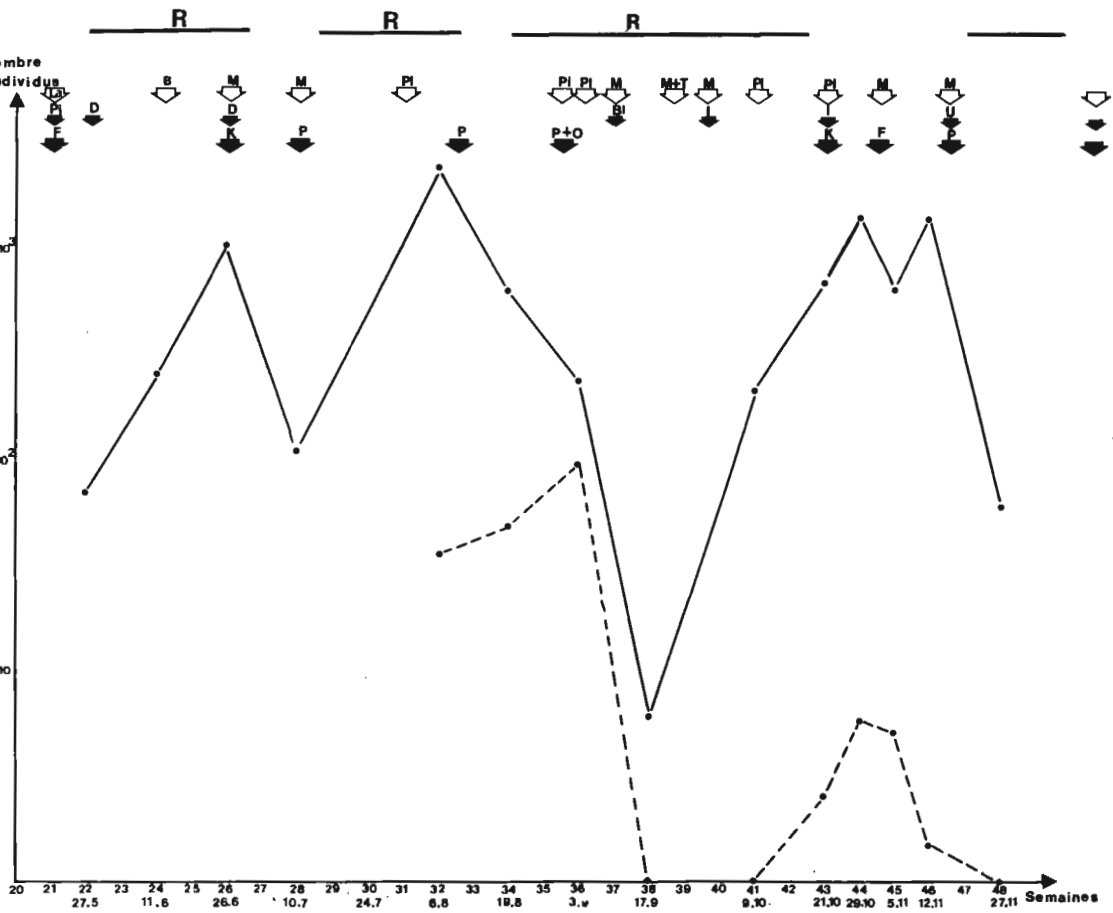

Fig. N° 3 : Développement des populations de Tétranyques (trait continu) et du prédateur P. persimilis (trait discontinu) dans les parcelles menées en lutte chimique (population moyenne pour 100 feuilles au cours de l'été 75) (R = récolte).

CB 6238

AUTOMATED SPRINKLER SPRAYING AS A TOOL TO CONTROL THE TWO-SPOTTED SPIDER MITE TETRANYCHUS URTICAE KOCH ON GLASSHOUSE CUCUMBER

by

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Before the effective pesticides came on the market, it was quite customary to sprinkle or water the foliage of cucumbers daily in glasshouses in order to control the two-spotted spider mite. Now it looks like this same method would provide new opportunities in its automated form.

At present, the sprinkling and spraying with automated equipment is an essential part of modern cucumber growing, which aims at large and first-class yields without any marked increase of expenses.

It was observed some years ago that the shortage of water during sunny days is the most important growth limiting factor of glasshouse cucumbers. Although there is enough water in the soil, roots are incapable to supply it sufficiently for the foliage. As a consequence, plants close their stomata and assimilation ceases. This deficit in evaporation may be compensated by spraying. A thin layer of water cools the leaves and glasshouse air, thus decreasing the need for evaporation, this again facilitates the opining of stomata. In the ideal situation a thin water layer should always cover the leaves.

Also the reducing effect of this kind of spraying on the growth of spider mite populations has already been documented earlier (KINN et al., 1972, TAHVONEN & TULISALO, 1973).

Equipment

The essential element of the sprinkling system is a detector, which follows changes in temperature, relative humidity and total radiation, and produces impulses for spraying. The detector consists of two metal discs placed on top of each other. A green coloured upper disc absorbs the solar radiation, and lower one follows the ambient temperature.

The temperature difference between the two discs will be preset into a central system, which triggers magnetic valves. Primarily three factors cause temperature differences, namely solar radiation, ambient temperature and relative humidity. During the spraying, the upper disc is wettened and cools consequently. A new spraying takes place after the water has evaporated from the top disc, and the temperature has risen to the trigger value.

The water atomizers must produce as fine a spray as possible. In the experiments, the duration of one single spraying has been three seconds. A counter registers the number of sprayings per one day, and this enables the checking of the number of sprayings in relation to various weather types. The number of sprayings, during the main weather types, is given in Table 1. The water pressure required is about 10 atm. and the central unit regulates also the pressure pump if needed.

TABLE 1. Frequency of spraying in various weather conditions

Weather	Frequency of spraying	
	a.m.	p.m.
sunny	2.7	38.6
partly cloudy	0.8	21.9
cloudy	-	3.8

Results and discussion

The overhead spraying has been used since 1971 in a glasshouse of 400 m^2. This overhead spraying alone decreased considerably the demand of control measures against the spider mites. Similar results were obtained in all commercial glasshouses where this spraying system was used.

Fully finished automatics applying both overhead and downside sprayings were tested during two months in summer 1975.

Table 2 gives the increase of a mite population on cucumbers. The control result was good. Only in some places, where atomizers failed during use, could the mites increase in number. In the present year a similar experiment was started a few weeks ago. The greatest problem is how the plants will stand the watering of both leaf sides. The worst threat is naturally an outbreak of various root and stem diseases. In practice, however, both sprayings can be controlled by separate sense organs, and if required, the downside spraying can be limited to a minimum.

TABLE 2. Number of mites per leaf during inspections
(one sample consisted of 12 leaves)

	30.6			16.7			31.7			14.8		
part of plant	1	2	3	1	2	3	1	2	3	1	2	3
no. of mites	0.08	0.58	-	-	-	-	1.0	11.7	39.8	175.8	289.0	543.3

1 = lower part of plant, 2 = middle part of plant and 3 = upper part of plant.

The real expenses of control consist of the downside atomizers and magnetic valves. The central automatics and overhead spraying are already commonly used and quite necessary in many glasshouses. Spider mite control on cucumbers will become easy, and also quite economical in a long term. If this automated sprinkling proves practical and safe as far as growth disturbances are concerned. There will also be no problems with pesticide residues anymore.

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CB .623

PRELIMINARY OBSERVATIONS ON AN ENTOMOPHTHORA SP. ON THRIPS TABACI LIND. IN DUTCH GLASSHOUSES

by

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In vegetable as well as ornamental glasshouse crops in the Netherlands growers are increasingly confronted with damage caused by several Terebrantian thrips species. Probably these insects can develop as a result of the fact that pesticides of the persistent type are abandoned more and more, which increases chances of survival of pupal stages in the soil and/or of eggs in the leaf tissue.

On vegetable crops, injury is done by Thrips tabaci Lind., in particular on cucumber, sweet pepper, eggplant and melon. In the last years, Thrips tabaci can be classified in many occasions as (whitefly, red spider and aphids) as an all year pest. Difficulties arise from the necessity to integrate thrips control with the biological control of the main pests. Currently at least three insecticidal treatments shortly after each other are required to cover the entire thrips population, and in summer continuous fortnightly applications are usual. The problem is most critical on sweet pepper. In spite of good results, biological control of red spider on sweet pepper is not widely applied, as an early infestation of thrips often occurs. Moreover; only small numbers of thrips can be tolerated on this crop because of fruit damage that may occur.

Consequently, a study of T. tabaci has been undertaken with special attention to a possible presence of natural enemies in glasshouses. In September 1975, an entomophagous fungus was found attacking a population of T. tabaci on eggplant at the Naaldwijk Research Station. In October of that year, thrips were collected from two commercial eggplant holdings. Within a few days they showed fungal sporulation too, which indicates that the fungus can occur under environmental circumstances not exceptional for normal glasshouse growing. In November, the fungus was found in a cucumber glasshouse close to the eggplant holding where it was first observed. The thrips population was much smaller here, and the relative fungal infection was higher. Since pesticide treatments during this observations were continued normally, it was impossible to obtain reliable information about the quantitative influence of the fungus on the thrips population. In the same autumn thrips adults were collected from yellow aphid traps placed outdoors in the neighbourhood of the Research Station; in September, in some of the insects hyphal bodies, typical for Entomophthorales, were observed.

The glasshouse fungus could easily be transmitted to healthy adults and larvae feeding on floating discs cut from eggplant leaves. It was thus possible to study parts of the life cycle of the fungus. Thrips maior Uzel, which often occurs simultaneously with T. tabaci in glasshouses in summer, could be infected too, but efforts to infect Parthenothrips dracaenae (Heeger) failed.

In the spontaneously infested glasshouse populations fungal sporulation could most easily be found in the morning. On the dorsal side of a diseased thrips adult three or four collars of fungal material were visible then, consisting of conidiophores protruding from the intersegmental membranes. Every conodiophore produced only one spore of a typical shape, comparable with the conidia of Entomophthora muscae (Cohn) Fres., E. planchoniana Cornu and E. culicis (Braun) Fres. (cfr. GUSTAFSSON, 1965). It is remarkable that the thrips were still alive during sporulation, obviously even sucking the leaf, although locomotion was greatly reduced. Sporulation lasted only a few hours; after that the thrips died and a quick covering of the dead body by saprophytic fungi followed during the afternoon of the same day. By then the entomophagous fungus had spread its spores by means of a shooting mechanism connected to the spore-bearing structure. (This mechanism facilitates isolation of the fungus for culturing on artificial media). The spores are contained in a plasma envelope, by which it sticks to any hit object, for example a leaf. Soon, after landing the spore starts to germ, forming an upright pedicel at the end of which a secondary spore is formed. A secondary spore might be picked up by an occasionally passing thrips; it penetrates the thrips body by means of a germ tube and within a few days the abdomen is entirely filled with fungal material. At room temperature, the life cycle of the fungus is only 4 or 5 days.

In literature, an entomophagous fungi is not often mentioned in relation to thrips. In several review papers dealing with entomogenous fungi Thysanoptera are missing in the lists of known hosts (e.g. LEATHERDALE, 1970). Two previous records have been found so far dealing with fungal attack of T. tabaci.

1. In Connecticut Valley, Massachusetts, observations were made on an entomophagous fungus of T. tabaci on onions, causing a breakdown of the population (BOURNE & SHAW, 1934; BOURNE, 1935). The fungus was identified by Fitzpatrick and Thompson as Empusa, probably Empusa sphaerosperma Thaxter., which is now called Entomophthora sphaerosperma Fres.; it is rather polyphagous and can be grown on artificial media (GUSTAFSSON, 1965).

2. In Switzerland, the incidence of an entomophagous fungus on T. tabaci on onions and leeks was studied and some laboratory experiments were carried out to test the suitability of the fungus for application in glasshouses (CARL, 1975). The fungus was identified by Müller-Kögler as an undescribed Entomophthora sp. Trials made to grow the fungus in the laboratory failed.

3. The fungus found in the Naaldwijk glasshouses is probably another undescribed Entomophthora sp. Its conidia show resemblance with those of E. culicis (Braun) Fres., but they are not identical (GAMS, personal communication), conidia did not germinate on artificial media.

T. tabaci may thus be attacked by at least two, perhaps three Entomophthora spp. Attempts will be made to obtain them in culture, preferably on an artificial medium. In further experiments it will be tried to answer the following questions:

a. Why does Entomophthora only occur late in the season?

b. What is the effect when the fungus is introduced artificially?

c. Is the normal or a slightly modified glasshouse climate suitable for an epizootic?

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CB

6240

A METHOD FOR MASS REARING OF APHIDOLETES APHIDIMYZA (ROND.)

by

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As soon as the predatory midge (Aphidoletes aphidimyza) had proved efficient to control aphids in glasshouse cultures of roses and green pepper, development of a method for its mass rearing was studied.

For research purposes and the first practical applications, the midges were reared in cages on green pepper and aubergine infested with peach aphids. The midges were allowed to lay eggs on the plants for three days before they were removed. Subsequently, at the end of the pupal stage the soil in the pots was transferred with the pupae into glasshouses (Markkula, 1973). This was a modification of the method used by Uygun (1970) and El-Titi (1972) in their studies to rear predatory midges. In this way, midges were obtained in sufficient numbers for the experiments, however, it was no mass production. When the development of mass production method was started, we were not aware yet of the method that Bondarenco and Asyakin (1975) had developed to rear quite large numbers of predatory midge pupae for their research work.

The aim of mass production was to obtain with as little labour as possible a certain number of midge pupae of about the same age. After many tests, it was concluded that the peach aphid is the most suitable prey for the midge larvae and green pepper and aubergine the most suitable host plants for the aphid. These two plants were considered especially suitable because of the high rate of reproduction of the peach aphid while on the hosts and because they tolerate damage caused by the aphids.

A method for mass production was finalized in the beginning of the growing season 1975 and is based on the following: green pepper and aubergine are sown continuously at two week intervals to provide the aphids all the time with host plants of suitable age.

The plants are grown in pots in glasshouses. When the plants are 20–30 cm high, three of them are put into a cage of 32 x 32 x 60 cm in size. Each plant is then infested with about 50 peach aphids. When the aphids have reproduced about 2000 on each plant, the cages are taken into the laboratory at room temperature and 70 female and 30 male predatory midges are introduced into each cage. The midges are allowed to lay eggs during two days which yields about 3000 eggs. Then the plants are removed from the cages and the midges killed.

When the larvae are in their last developmental stage, the leaves with the larvae are detached from the plants and placed into a container to pupate. A plastic container 9 cm high and with a diameter of 16 cm has been used for the purpose. In the bottom of the container is a 4 cm thick layer of fine sand to maintain even humidity. The sand layer is covered by nylon gauze and on top of this is another layer of sand for the larvae to pupate. The container is covered with nylon gauze fixed with a plastic sheet. The top layer of sand with the pupae is transferred into glasshouses infested with aphids just before the adult midges emerge. Usually there have been 200 larvae in one container but there is room for more. The whole rearing from egg to adult takes less than three weeks.

The method is so simple that it could be easily used for "industrial" production of the predatory midge.

Predatory midges can be reared in 16 hours day length throughout the year. They can be kept also in diapause to start the rearing when required.

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