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INTEGRATED CONTROL IN GLASSHOUSES

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INTERNATIONAL ORGANIZATION FOR BIOLOGICAL
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WORKING GROUP INTEGRATED CONTROL IN GLASSHOUSES

REPORT OF THE MEETING HELD FROM 18 TO 20 SEPTEMBER 1973

AT THE GLASSHOUSE CROPS RESEARCH STATION, LITTLEHAMPTON, ENGLAND

GROUPE DE TRAVAIL LUTTE INTEGREE EN CULTURES SOUS VERRE

RAPPORT DE LA REUNION TENUE DU 18 AU 20 SEPTEMBRE 1973

A LA GLASSHOUSE CROPS RESEARCH STATION, LITTLEHAMPTON, ANGLETERRE

BULLETIN SROP
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INTRODUCTION

Since the first meeting of our working group in Naaldwijk in 1970 much progress has been made in the integrated control in glasshouses. In the Naaldwijk meeting many of lectures dealt with laboratory work or small scale experiments. In this years' meeting the practical application of integrated control was much more emphasized.
The objectives of our work are still of present interest and probably even more so than they were three years ago. Pollution of the environment is at the moment a very much used (and misused) word. Pesticides are often mentioned as important polluting agents.
As a consequence many people (whether they are familiar with agriculture or not) speak of or cry for biological control. In my opinion, however, we should not be mislead by emotional, political or other nonscientific arguments. Our ultimate aim must be to help the grower to supply the consumer with enough food of good quality and if possible free from residues of pesticides. Biological control can be of great help in this respect, especially for vegetables grown under protected cultivation, as practically all these products are eaten fresh.
The choice to hold this meeting in Littlehampton was very appropriate as the Glasshouse Crops Research Institute belongs to the leading institutes in the world with regard to research on biological control in glasshouses.

L. Bravenboer

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Belgium, G. VANWETSWINKEL; Denmark, O. BERENDT; Finland, M. MARKKULA, Mrs. M. JOKINEN; France, Mrs. M. PRALAVORIO, J.P. LYON; Great Britain, N.W. HUSSEY, W.J. PARR, N.E.A. SCOPES, I.J. WYATT, H.D. BURGES, H.J. GOULD; Holland, L. BRAVENBOER, J. WOETS, W. OVERMEER, L. BRADER; Norway, C. STENSETH; Poland, S. PRUSZYNSKI, J.J. LIPA; Roumania, N. IACOB; Sweden, G. SVENSON, B. WIBRANT.

REPORT ABOUT INTEGRATED CONTROL OF PESTS UNDER GLASS IN NORWAY

by

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INTRODUCTION

Biological control is in practical use in Norwegian glasshouses. Many growers show a general interest in these control methods. The effort has so far been concentrated in cucumbers and tomatoes.
The production of cucumbers and tomatoes is scattered all over the country, but the major part is grown in Rogaland and Vestfold - Buskerud. Rogaland is a district with Atlantic climate while Vestfold - Buskerud has more of an inland climate. Biological and integrated control have so far been used mostly in the districts mentioned above.
The main pest on cucumber is the two-spotted spider mite (*Tetranychus urticae*). Onion thrips (*Thrips tabaci*) is also a common, but less troublesome pest. In recent years greenhouse white fly (*Trialeurodes vaporariorum*) has become a more serious problem on cucumber. The most serious pests on tomato are the greenhouse whitefly and the two-spotted spider mite. Aphids and noctuid larvae occasionally attack tomato, but these pests are of little importance.
The biological agents used are *Phytoseiulus persimilis* for control of the two-spotted spider mite and *Encarsia formosa* for control of the greenhouse white fly.

PHYTOSEIULUS PERSIMILIS

The commercial use of *P. persimilis* started in 1971 and many growers with spider mite problems now use this predator. The leaf damage assessment worked out by Hussey and Parr (1963) has been used to estimate the time for introduction of *P. persimilis* on cucumber. Two to four predators per plant have been set out at a leaf damage index of 0,4-0,5. In spite of the leaf damage guide many first time users of *P. persimilis* introduce the predator too late. When the growers have acquired the necessary experience they apply the predator properly, and in these cases the control has been satisfactory.
The introduction of the predator in cucumber houses has been conducted in two ways:

1. Natural infestation. Weekly examinations of the plants and introduction of the predator on natural infestation of the two-spotted spider mite, and, further, weekly examinations of the plants till the predator is evenly distributed in the houses.

2. Artificial infestation. Introduction of the two-spotted spider mite on every third plant followed by predator introduction on the same plants.

Although the best experimental results are obtained with method 2, many growers prefer method 1. Especially the first time users of *P. persimilis* prefer method 1, but when they have developed some reliance on the biological control method they often switch over to method 2.
It is easier to use *P. persimilis* for control of the two-spotted spider mite on tomato than on cucumber. On tomato plants in contact with each other it has been sufficient to introduce 3-4 predators on every 3rd plant at the first sign of attack.

ENCARSIA FORMOSA

The use of *E. formosa* is more or less in the experimental stage and the experience so far shows that good control might be expected in some cases.
In two large scale experiments five parasites per tomato plant were liberated in three successive introductions at fortnightly intervals. The parasite introduction started in March at a level of 0-6 whiteflies per plant (counted on four top leaves). Complete control was achieved in 24 weeks (Table 1). The whitefly population was kept at the same low level all the time in experiment 1. In experiment 2 there was a sudden increase in the population in June. This was most probably due to immigrants originations from a neighbouring house (Table 2).
In a third experiment five whiteflies per tomato plant were introduced in two successive introductions at a 7 days' interval. The experiment started in June at a level of 2-182 whiteflies per plant and the control was satisfactory in 12 weeks (Table 3). The whitefly population was fluctuating and sooty mould damage was noted periodically on some plants.

INTEGRATED CONTROL

In cases where *P. persimilis* was used against the two-spotted spider mite, thrips has been controlled by drenching with diazinon. When necessary, tetradifon has been used as selective acaricide.
Light traps have been used for control of tortricid moths on roses with very good results and this control method might also be of value for control of noctuid moths on tomato and cucumber.
Of the two crops above, tomato seems to be the one where biological or integrated control can be used with greatest success. At the moment the control of cucumber mildew is the most limiting factor for the use of *P. persimilis* in cucumber.

Table 1. Experiment 1. Tomato, 2100 plants. Temperature: 18-19°C night and 23-24°C day.
Three introductions of 5 parasites per plant; 8. March, 22. March and 5. April.

date	Number of whitefly (counted on 4 top leaves) per plant min	– max	total on 50 plants
8/3	0	3	20
26/3	0	6	31
8/5	0	2	10
21/5	0	1	9
29/5	0	2	16
28/6	0	14	27
10/7	0	2	11
23/7	0	2	10
8/8	0	3	11
21/8	0	3	9
5/9	0	3	16

Table 2. Experiment 2. Tomato, 1600 plants.
Temperature: 18-19°C night and 23-24°C day.
Three introductions of 3 parasites per plant;
8. March, 22. March and 5. April.

date	Number of whitefly (counted on 4 top leaves) per plant min	– max	total on 50 plants
8/3	0	2	19
26/3	0	1	20
8/5	0	2	17
21/5	0	1	3
28/5	0	1	6
25/6	1	147	863
10/7	0	444	722
23/7	0	367	1179
10/8	1	289	1144
21/8	0	300	620
5/9	0	180	270

Table 3. Experiment 3. Tomato, 3000 plants.
Temperature: 18-19°C night and 23-24°C day.
Two introductions of 5 parasites per plant;
15. June and 21. June.

date	Number of whitefly (counted on 4 top leaves) per plant min	– max	total on 50 plants
28/6	2	182	1393
10/7	2	72	1161
23/7	9	237	3269
8/8	9	360	4864
21/8	0	250	1236
5/9	0	80	300

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BIOLOGICAL CONTROL OF PESTS IN GLASSHOUSES IN FINLAND

by

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In Finland 2250 market gardeners have glasshouses, with a total area of 310 ha. The area has increased slowly but steadily, together with production. In contrast to many other countries, most of these market gardens are run by families, and these small firms cover 60 percent of the area under glass. The monetary value of the production is 170 million Fmk.
Vegetable crops occupy 190 ha, tomato and cucumber being the most important. Cut-flower crops are grown on 120 ha, roses, carnations and chrysanthemums being the main species. The choice of plants has also become wider, paprica being one of the latest additions. At present lettuce, radish, dill and parsley are grown in glasshouses more often than before.
The most injurious pests in glasshouses are the two-spotted spider mite (*Tetranychus urticae*) and aphids (*Aphididae*). The most harmful of the aphids are the green peach aphid (*Myzus persicae*), the potato aphid (*Macrosiphum euphorbiae*) and the rose aphid (*M. rosae*). Other significant pests are the glasshouse white fly (*Trialeurodes vaporariorum*) on tomato, the onion thrips (*Thrips tabaci*) in cucumber and carnation, and woodlice and slugs on many other plants. A clear picture of the abundance and degree of damage by pests on different plants was obtained as a result of an inquiry to growers (Markkula, 1969).

PRESENT SITUATION IN PRACTICE AND IN RESEARCH

In glasshouses chemical control is by far the most widely used method. Only *Tetranychus urticae* on cucumbers is controlled biologically. Since 1970 Kemira Ltd, a company producing fertilizers and pesticides, has sold Phytoseiid mites (*Phytoseiulus persimilis*) to growers, and their use has steadily increased. This year about half the cucumber growers have controlled the two-spotted spider mite by this biological method alone.
At the Institute of Pest Investigation of the Agricultural Research Centre, and at Kemira Ltd the primary aim is to improve the use of the Phytoseiid mites on cucumbers in the light of the growers' experiences, and to develop methods for their use on roses and chrysanthemums as well. During the last few years broad-based studies have been performed on Coccinellids at the Institute of Pest Investigation, the goal being to develop methods for their use in the control of aphids in glasshouses. This year investigations have been started to determine whether *Aphidoletes aphidimyza* can also be used for the control of aphids.

Lasr year at the Institute of Agricultural and Forest Zoology of the University of Helsinki studies were begun on the suitability of the green lacewing *Chrysopa carnea*, for the control of *Myzus persicae*. This year the method has been used on commercial crops.

BIOLOGICAL CONTROL OF *TETRANYCHUS URTICAE*

The first Phytoseiid mites (*Phytoseiulus persimilis*) were obtained from Switzerland in 1965 (Dr. R. Maag AG, Dielsdorf) and studies were started during the same year. As data had already been published on the biology of this species in other countries (e.g. Dosse, 1958, Bravenboer and Dosse, 1962), fundamental studies were considered unnecessary, and the development of control methods was started immediately. From the beginning the experiments were conducted in commercial cucumber crops.

Following the promising results obtained in 1968 and 1969 Kemira Ltd took over the production and the sale of *Phytoseiulus persimilis* to growers in 1970. By that time four cucumber growers had controlled the two-spotted spider mites exclusively with Phytoseiid mites, partly based on instructions given by the Institute of Pest Investigation and partly on their own initiative.

The procedure recommended is that, after planting, the grower examines the cucumber crop daily during different routine tasks and starts control immediately on noticing the first signs of damage on the leaves. The grower should then place 1 Phytoseiid mite per 5 - 10 spider mites on each damaged leaf. If the grower takes his step immediately, one package of 100 Phytoseiid mites is enough for control of the whole cucumber nursery, regardless ot its size. An additional condition is that the grower continues to follow the instructions. A package of Phytoseiid mites costs 28 Fmk, which is equivalent to three pound sterling.

After control has been started, the grower has to examine the crop at least once a week. If he notices new signs of damage on the leaves he has to transfer Phytoseiid mites there. These predators should explicitly be taken from parts of the crop where they have become dominant and short of prey. Correspondingly, spider mites have to be used to feed the predators.

Transfer of *Phytoseiulus persimilis* and *Tetranychus urticae*, i.e. maintaining the predator-prey balance, might appear difficult. However, a roughly maintained balance is sufficient, as cucumbers tolerate quite a number of *Tetranychus urticae* without any reduction of yield (Hussey and Parr, 1963). In practice leaves are removed from the plants and are placed on other parts of the crop. Leaves with Phytoseiid mites are placed where spider mites are becoming dominant, and leaves with spider mites are transferred to spots where the Phytoseiid mites are starving for lack of food. Growers have found this method quite straightforward and soon became very handy at applying it.

The method developed in Finland is largely based on co-operation with growers. It differs from the method used in England (Gould, 1971) as the cucumber crop is not deliberately infested with the two-spotted spider mite; control is not started until natural infestation with spider mite is observed.

In 1970 Phytoseiid mites were bought by 120 market gardeners, that is by a quarter of the 500 cucumber growers in Finland. Each buyer was asked to report his experiences and results at the end of the season. Most growers reported favourable experiences with the predatory mites (Markkula et al., 1972). Slightly over half of them had needed no pesticides, the result of the control was estimated to be somewhat better and costs were lower than for chemical control and 95% of the growers decided to continue with biological control. Because of these positive results the method is gaining popularity. In 1971 an equal number of growers used Phytoseiid mites (124), and in 1972 the number rose to about 200. This year about 250 growers used the mites, that is, half our cucumber growers. Use of the predator requires care and interest. For this reason better results were usually obtained by small family growers than by large firms run by paid staff.

As biological control on cucumbers has spread, the use of acaricides and insecticides has correspondingly decreased. This has caused an increase in the numbers of *Thrips tabaci*, *T. nigropilosus* and *Trialeurodes vaporariorum*. However, it has been possible to integrate the chemical control of these pests with the biological control of the two-spotted spider mite. This has been done by controlling thrips and greenhouse whiteflies from one glasshouse at a period when the numbers of spider mites and Phytoseiid mites have been low. If necessary, new predators have been introduced from other glasshouses. Kemira Ltd has conducted some experiments on the use of the chalcid wasp *Encarsia formosa* to control the glasshouse whitefly on commercial crops, but the method is not yet ready for extensive use.
The possibility of using the predatory mites for the control of two-spotted spider mites on roses and chrysanthemums is also being studied at the Institute of Pest Investigation. However, the method has not yet been applied in practice. Spider mites appear on these plants in March-April. However, at that time the temperature is too low for adequate reproduction of the control agent. In summertime the temperature would be more suitable for the Phytoseiid mite, but at that stage pesticides have to be used to control the regularly appearing aphids. If the aphids could be controlled efficiently and inexpensively in glasshouses by biological methods, the use of *Phytoseiulus persimilis* to control *Tetranychus urticae* could be extended from cucumbers to other plants.

BIOLOGICAL CONTROL OF APHIDS

Our studies on the biological control of aphids were started in 1970. So far research has been concerned with the basic data needed for biological control, but experiments have also been conducted in nurseries. Biological methods of control are not yet available to growers.

Coccinellids (Coccinellidae)

As a first step towards finding the most suitable coccinellids for biological control, the distribution of the various species on the most important field crops was studied. *Coccinella septempunctata* was found to be the dominant species, and *C. quinquepunctata*, *Adalia bipunctata* and *Propylaea quattuordecimpunctata* were fairly common (Clayhills and Markkula, 1973).
Simultaneously, we found that in an 18-hour photoperiod *C. septempunctata* develops without diapause, which is quite important for the production of the species (Hämäläinen and Markkula, 1972a). In later experiments it was found that under these long-day conditions *Adalia bipunctata* also develops without diapause.
It was found that storage of eggs at 10°C for 1, 2 or 3 weeks considerably reduced hatching of *C. septempunctata*, *C. quinquepunctata* and *A. bipunctata*. The effects of lower temperatures are now being studied in view of finding the optimal conditions for storing the eggs.
Larvae of *C. septempunctata* developed to adults even when fed on pea aphids (*Acyrthosiphon pisum*) stored in a deep-freeze. However, mortality was somewhat higher and development slower than in controls fed on live aphids. The females fed on frozen aphids were less fecund than those fed on live aphids, they laid only half the number of eggs (Hämäläinen and Markkula, 1972b). No eggs were laid by females fed on the artificial diet developed by Smirnoff (1958).
A simple method for producing ample food is one of the main problems in rearing Coccinellids. Rearing aphids and their food-plants is quite laborious and requires a great deal of space. Therefore studies are in progress at the Institute of Pest Investigation to develop an artificial diet for the Coccinellids. We expect to achieve this goal, although so far only a few larvae have been reared to adult on an artificial diet.
The behaviour of the Coccinellid larvae, especially their ability to stay on the crop, is important for the success of the method. During the experiments

70 - 100% of the larvae of *A. bipunctata* and *P. quattuordecimpunctata* remained on paprica and chrysanthemum; on roses the percentage was lower. Young larvae of *A. bipunctata* did not stay at all on roses, while 70% of the fourth-instar larvae stayed; 50 - 70% of the larvae of *P. quattuordecimpunctata* stayed on roses. The poorest results in this respect were obtained with *C. septempunctata* and *C. quinquepunctata*.
During preliminary experiments on commercial crops it was found that by placing eggs of *C. septempunctata* on chrysanthemums and roses, and second-instar larvae on chrysanthemums it was possible to postpone the use of pesticides considerably (Markkula et al., 1972). Adult Coccinellids were not used, as we already knew that they do not stay on the crop (see also Gurney and Hussey, 1970). However, differences may exist between species.
Our studies so far suggest that the most promising species for biological control are *C. septempunctata* and *A. bipunctata*. *C. septempunctata* reproduces rapidly and feeds actively, but shows a strong tendency to leave the crop. *A. bipunctata* may be slightly better. It reproduces rapidly, feeds fairly actively and stays on the crop.
Between coccinellids and aphids it is not possible to create a balance similar to that existing between *Phytoseiulus persimilis* and *Tetranychus urticae* on cucumber crops. This is mainly because adults do not lay their eggs on the plants but tend to fly out of the glasshouses

Predatory Itonidiid, *Aphidoletes aphidimyza*

Recently aphid-eating Itonidiid larvae have appeared in the aphid rearings at the Institute of Pest Investigation. They appeared for the first time in the glasshouses in 1970. From time to time in 1971 and 1972 they were so abundant that they interfered with the production of aphids for feeding coccinellids. The Itonidiid larvae were so efficient in destroying aphids that studies on their commercial usefulness were started.
Nijveldt, Institute for Phytopathological Research, Netherlands, identified this species as *Aphidoletes aphidimyza* Koch. Research aimed at the development of a control method was started immediately in the glasshouses of the Institute of Pest Investigation, in this advantage was taken from earlier work (Azab, Tawik and Ismail, 1965; Nijveldt, 1966; Uygun, 1970 and El-Titi, 1972). The biology of *A. aphidimyza* has been described very fully, especially the effect of the amount of food on reproduction, and the distribution of eggs on the crop and its significance in biological control. El-Titi (1972) states that either *A. aphidimyza* has to be taken into the glasshouse at the pupal stage or an open population has to be maintained in the glasshouse.
Studies on the adaptability of *A. aphidimyza* for biological control were started on a commercial glasshouse culture last spring. The experimental plant was rose and the target the potato aphid (*Macrosiphum euphorbiae*). The glasshouses are 1000 m^2 in size. In one house the aphids are being controlled by *A. aphidimyza*, in three others with insecticides.
A. aphidimyza was reared in cages in the laboratory of the Institute of Pest Investigation, on green peach aphid living on paprica and eggplant.
In the rearing units the Itonidiids were allowed to lay eggs on the plant for three days, after which the adults are removed. The larvae pupate in the soil, which is then taken to the glasshouse and spread near the aphid-infested plants. The roses are inspected daily. The numbers of Itonidiid larvae and aphids per shoot are recorded and when necessary more soil containing pupae is brought in. The first aphids appeared on the roses in the middle of May and the first pupae were then transferred to the crop. New pupae were introduced several times but their numbers were evidently not adequate, as the aphids increased rapidly. After a month, at mid-June, the roses had to be treated with dichlorvos.
These first experiences have encouraged us to continue the experiments. *A. aphidimyza* is able to reproduce in the glasshouses like *Phytoseiulus*

persimilis, although maintenance of the balance between the Itonidiid predator and the aphids is more difficult than between spider mites and phytoseiid mites. The short interval between generations and the tendency to stay on the crop are great advantages of Itonidiids.
The main problems are that *A. aphidimyza* does not lay eggs if the aphid infestation is low, and the difficulties encountered to produce an adequate stock to meet commercial demands.

The green lacewing (*Chrysopa carnea*)

In 1972 studies on the biological control of green peach aphid with green lacewing were started at the Institute of Agricultural and Forest Zoology of the University of Helsinki.
Adult Chrysopids are fed on an artificial diet (Hagen and Tassan, 1965), and the larvae are given living green peach aphids. The Chrysopids are transferred to the glashouses as eggs. This year experiments have been performed on three commercial crops and, according to Unto Tulisalo, the results on all three have been very promising.

CONCLUSIONS

The possibilities for biological control and integrated control are better in glasshouses than in the open. The first studies were performed less than 50 years ago (Speyer, 1927) and especially the experiments of Dosse (1958) and Bravenboer and Dosse (1962) proving the ability of Phytoseiid mites to control the spider mite have incited research workers to develop methods of biological control in glasshouses.
Although biological control in glasshouses has already proved its feasibility, the results could still be greatly improved if research workers would adopt new attitudes. It is no longer essential to conduct fundamental studies on the life-histories of the hosts, predators and the parasites. In most cases existing information is already adequate. New and even well-known agents for biological control can be tested immediately on commercial crops. Co-operation with experienced growers produces the best results.

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BIOLOGICAL CONTROL OF SPIDER MITES IN GLASSHOUSES IN SWEDEN

by

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The total area of glasshouses in Sweden amounts to about 415 ha, of which 191 ha are used for vegetables (cucumbers = 39 ha, tomatoes = 87 ha, lettuce = 39 ha, other vegetables = 26 ha).

During the two last years some demonstrations with biological control of the greenhouse spider mite *Tetranychus urticae*, using the predatory mite, *Phytoseiulus persimilis*, have been done in cucumber holdings in South Sweden, where about 68% of the glasshouse area in Sweden is located.

Cucumbers are in Sweden mainly planted out from January until March and the crop is kept until September - October. Greenhouse spider mite, mildew, *Sphaerotheca fuliginea*, and also in the two last summers, greenhouse white fly, *Trialeurodes vaporariorum*, are the main problems.

In recent years some growers were forced to apply higher rates of acaricides to protect their cucumber crop and an alternative control method was urgently required. Experiments by Bravenboer and Dosse and the success of large scale use of *P. persimilis* in other countries had shown that this predatory mite was a promising means of biological control.

A commission organized by the Swedish growers in 1971 took the initiative to start demonstrations in the south of Sweden on the use of the predatory mite in cucumber glasshouses. This commission received money from the Government and appointed a specialist for a two year period, to manage the breeding and the distribution of the predatory mite.

Although biological control has numerous advantages it is understandably difficult to persuade growers to introduce pests to their crop as a preliminary treatment. Also visuable effects are often delayed for several weeks, which may prove disheartening to the grower who wishes to produce a clean crop. Therefore all demonstrations in 1972 and 1973 were made in holdings where spider mites occurred spontaneously. The intention was to utilize biological control only, but in some cases resort to chemicals proved necessary. During the first year the number of holdings, where predatory mites were used was limited to ten. The available data from the demonstrations of 1972 are shown in Table 1.

Table 1. Demonstrations with *Phytoseiulus persimilis* in Sweden 1972

Holding number	Total area of cucumber in each holding m^2	Area of demon-stration with *P. persimilis* m^2	Days from planting of cucumber until first intro-duction of P.P.	Number of inspections of the holding	Number of intro-ductions of P.P.	Number of new intro-ductions of P.P.	Total number of P.P. used, approx.
1	4100	980	135	21	3	-	400
2	2200	750	90	19	7	1	5600
3	4000	1000	127	20	8	1	5000
4	2200	1100	79	16	7	1	11600
5	4250	350	135	12	4	-	300
6	5000	1200	28	27	17	2	6600
7	8500	600	10	29	18	2	37900
8	6420	1650	103	21	8	-	8200
9	3800	1200	82	23	13	1	4200
10	2500	720	72	20	4	-	4500

As each holding as a rule was visited every week and the whole area under control was carefully checked on the presence of spider mites, the number of newly discovered infections was relatively high and thus the distributions of predatory mites. The total number of distributed predatory mites has been estimated fairly roughly. In three holdings acaricides had to be used to prevent too vigorous attacks from the spider mites. These attacks came with warm and dry weather and always affected the upper parts of the cucumber plants. Furthermore white flies appeared on some holdings. These attacks were controlled with pyrethrum preparations. In most cases the predatory mites survived these treatments, but in some they had to be reintroduced.

All the growers from 1972 were satisfied with the biological control of spider mites and were therefore among those who tried the method in 1973. One grower had changed his production, tomatoes instead of cucumbers. As the demonstrations were paid with special funds and as a consequence did not cost the growers anything, it was considered necessary to try to transfer as much work as possible to the growers. Thus the growers who in 1972 had become familiar with the system, were made responsible to a large extent for the inspections of the spider mite attacks, and introduced themselves the predators on the affected plants.

In 1973 the predatory mite has been used on 19 holdings. The total area has been enlarged from an ample 9500 m^2 in 1972 to 47100 m^2 in 1973 (Table 2).

Due to the gained experience the demand for predatory mites has been only slightly increased whereas the area treated had been increased five times. A more effective use of the predatory mite was at the basis of this result. As in the previous year it has been necessary at certain times to spray the upper parts of the cucumber plants with acaricide and to treat some glasshouses with insecticides as a consequence of attacks by various insects.

Table 2. Demonstrations with *Phytoseiulus persimilis* in Sweden 1973

Holding number	Total area of cucumber in each holding m^2	Area of demon- stration with *P. persimilis* m^2	Days from planting of cucumber until first intro- duction of P.P.	Number of inspections of the holding	Number of intro- ductions of P.P.	Number of new intro- ductions of P.P.	Total number of P.P. used, approx.
1	4100	4100	74	6	3	-	2000
2	4200	4200	134	6	2	-	2500
3	4000	4000	66	9	5	-	6000
4	2200	2200	87	9	6	1	5000
5	4250	4250	113	9	2	-	1500
6	4400	2400	59	16	3	1	3000
7	8500	600	58	14	6	2	7000
8	6750	1550	126	14	5	-	6500
9	2800	1200	103	11	3	-	4000
10	3750	3750	45	17	6	1	5000
11	7500	1200	78	19	4	1	4500
12	1600	1600	95	13	3	1	4500
13	1600	1600	93	5	3	-	5500
14	600	600	130	16	2	-	2500
15	11500	2100	50	15	6	-	2500
16	4200	1500	67	16	7	1	8000
17	10000	2500	98	15	9	1	13500
18	1500	750	41	14	6	-	3600
19	7000	7000	37	13	4	1	5000

The successes obtained in 1972 and 1973 may result in still further popularity of the method. A limiting factor at the moment, however, is the lack of an organisation responsible for the production of *P. persimilis*. There has also been some discussions on the need for *Encarsia formosa* to control the greenhouse white fly in glasshouses where biological control of spider mites is applied. Demonstrations with this parasite will probably be made in some of the glasshouses, where the predatory mite will be used during 1974.

EFFICACITE DES LACHERS DU PREDATEUR *PHYTOSEIULUS PERSIMILIS* EN CONDITIONS CONTROLEES ET DANS DES SERRES DU TYPE COMMERCIAL

par

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Les conditions climatiques et techniques existantes dans les serres ont déterminé l'adoption de mésures spéciales de protection des plantes, nécessaires pour assurer des productions optimales de légumes et de plantes ornamentales.
En Roumanie des traitements chimiques sont surtout appliqués en serres pour lutter contre les acariens *Tetranychus urticae* et *T. cinnabarinus*. Les défauts de ces traitements sont maintenant bien connus, ils concernent surtout la présence de résidus sur les fruits récoltés et le développement des races d'acariens résistantes aux acaricides employés. L'application de la méthode de lutte biologique à base d'introductions de *Phytoseiulus persimilis* pourrait remédier à cette situation.

L'efficacité des lâchers

L'efficacité des lâchers de *P. persimilis* a été déterminée en cultures d'haricots et de Callas, attaquées par *T. urticae*, en suivant le développement des populations des deux espèces antogonistes.
Sous les meilleures conditions de température (26 à 30°C) et d'hygrométrie d'air (humidité relative 70 à 90%) et par de lâchers à une densité de 1/20, un prédateur sur 20 ravageurs, on obtient une stabilisation des populations après 6 à 8 jours.
Lorsque les lâchers sont effectués à des températures plus basses (14 à 16°C) et en utilisant des prédateurs maintenus au préalable aux conditions d'alimentation réduite l'activité devient insatisfaisante. Il se trouve que le taux de mortalité des prédateurs est assez élevé dans ces conditions, et que les prédateurs ne sont pas assez mobiles. Au début de l'essai le rapport prédateurs/ravageurs était de 1/22,5, après 17 jours il est devenu 1/205. Sous conditions de température modérée (20°C), l'efficacité des prédateurs devient légèrement meilleure. En partant d'un rapport prédateurs/ravageurs de 1/2, les populations se stabilisent après environ un mois.

Intégration des traitements dans la lutte contre l'ensemble des ravageurs en serre

Simultanément à la multiplication et à l'évolution de l'attaque des acariens phytophages, en serre les principales cultures (concombres, tomates, aubergines, rosiers, oeillets, Calla, etc) sont attaquées par d'autres ravageurs, tel que

Trialeurodes vaporiarorum et *Myzus persicae*, insectes polyphages très redoutés. Contre ces insectes, on utilise à présent encore des produits pesticides qui, en plus de leurs effets insecticides, exercent aussi une influence sur l'évolution des acarophages lâchés dans la lutte biologique contre les acariens. Cependant les recherches effectuées au cours des dernières années par Herne et Putman (1966) au Canada, Oatman (1965) et Hoyt (1969) aux Etats Unis, Dabrowski (1968) en Pologne, Wyatt (1970) en Grande Bretagne, Swiasky, Amitai et Dorzia (1967) en Israel, ont mis en évidence une gamme de produits pesticides selectifs qui ne sont pas très nocifs vis-à-vis de *P.persimilis*. La plupart de ces produits sont utilisés dans la lutte contre les acariens phytophages (Tetradifon, Kelthane, Phenkapton, Fenson, Tetrasul Genite, Pentak, BAY-80530, BAY-93388), mais seulement quelques uns peuvent être utilisés pour les traitements executés en serre contre les autres insectes ravageurs (Isolan, Metasystox). L'activité sélective des acaricides Kelthane, Tedion, Milbex, Omite et Karathane à l'égard de *P. persimilis* a été mise en évidence dans des essais effectués en Roumanie. Le produit Solvirex appliqué dans le sol a une très bonne efficacité contre les pucerons en serre, et est toleré par les acarophages.
Par contre on remarque que les produits à base d'esters phosphorés, administrés directement dans le sol, présentent une forte action nocive vis-à-vis des prédateurs.

Introduction dans la pratique

La mise en valeur en serre, des résultats expérimentals sur la technologie de la méthode de lutte biologique contre les acariens ravageurs à l'aide du prédateur *P. persimilis*, a été testée à plusieurs endroits (tableau 1). Dans tous les cas on a assisté à une élimination des populations du ravageur.
Il sort des résultats donnés que la plante-hôte ne joue pas ou guère un rôle dans la réussite d'une introduction de *P. persimilis*. Par contre la température et l'humidité relative sont d'une importance majeure.

Tableau 1. Introduction en pratique de la méthode de lutte biologique contre *T. urticae* à l'aide de *P. persimilis* en 1972

Département	Exploitation productive	Cultures infestées	Surface de la culture en ha	Moyens supplémentaires de lutte
Braşov	Codlea	roses	3,00	aphides avec Solvirex
		oeillets	0,30	aphides avec DDVP
		callas	0,10	-
	Cristian	oeillets	0,15	-
		callas	0,10	-
		Datura	-	-
		Gerbera	0,05	-
		Cyclamen	-	-
	Vulcan	oeillets	0,20	aphides avec Solvirex
		callas	0,10	-
	Halchiu	callas	0,10	-
	Braşov	oeillets	0,10	-
Prahova	Brazi	callas	0,10	-
	Ploieşti	roses	0,05	aphides avec Solvirex
		callas	0,10	-
	Voila	concombres	0,02	-
		oeillets	0,05	-
Bucureşti	Popeşti	concombres	0,10	-

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ESSAI D'UTILISATION DE *PHYTOSEIULUS PERSIMILIS* DANS DIFFERENTES CULTURES SOUS SERRES DE LA REGION MEDITERRANEENNE

par

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Les cultures sous abri se présentent en France sous des aspects extrêmement divers de par la dispersion des zones de productions maraîchères et florales, la diversité des climats, des types d'abris utilisés et des variétés végétales cultivées. Si dans le Nord de la France, les productions de serre en culture maraîchère sont essentiellement laitue, concombre et tomate comme en Europe septentrionale, dans le Sud, tomate, melon et piment occupent la première place mais on cultive également fraisier et céleri et plus secondairement haricot et aubergine.
Notre étude ayant pour cadre l'extrême Sud-Est de la France, région traditionnelle de culture florale, nos premiers essais d'introduction de *Phytoseiulus persimilis* ont eu lieu en serre de rosiers ou les tetranyques posent à longueur d'année un problème. Par la suite, nous avons fait des essais sur fraisier, culture de serre et de plein champ également très répandue dans les Alpes-Maritimes et sur aubergine, production en extension dans le Midi de la France. Enfin, nous avons effectué des observations et des essais de lutte biologique en serre de concombres.

Essai en serre de rosier

En serre de rosier, on a noté à plusieurs reprises un développement accéléré de la résistance des tétranyques aux divers acaricides dû le plus souvent, à une multiplication erronée des traitements. L'utilisation de *P.persimilis* permettrait de pallier à ce problème en diminuant la fréquence des applications.
L'essai a eu lieu dans une demi-serre de 350 m^2 comprenant huit doubles rangs de rosiers de la variété Lara. Les populations ont été évaluées par comptage des folioles attaquées, réparties en deux classes (a : 1 à 5 tétranyques adultes; a' : 6 à 25 tétranyques adultes). Notre approvisionnement en prédateurs étant encore insuffisant lors de ce premier essai en dans le but d'obtenir quelque soit la quantité de prédateurs lâchés une protection suffisante de la culture avant et pendant le récolte nous avons opté pour de lâchers continus consistant à apporter des *Phytoseiulus* chaque semaine sur les foyers ne contenant pas ou ne contenant plus de Phytoseiides (Figure 1A).
Les résultats ont été décevants, les populations de tétranyques ayant continué à croître durant toute l'expérience, ce qui a même nécessité à plusieurs reprises des traitements chimiques partiels. Corrélativement, la population du prédateur, loin de se multiplier, ne se maintenait même pas au niveau de la population lâchée dans la serre.

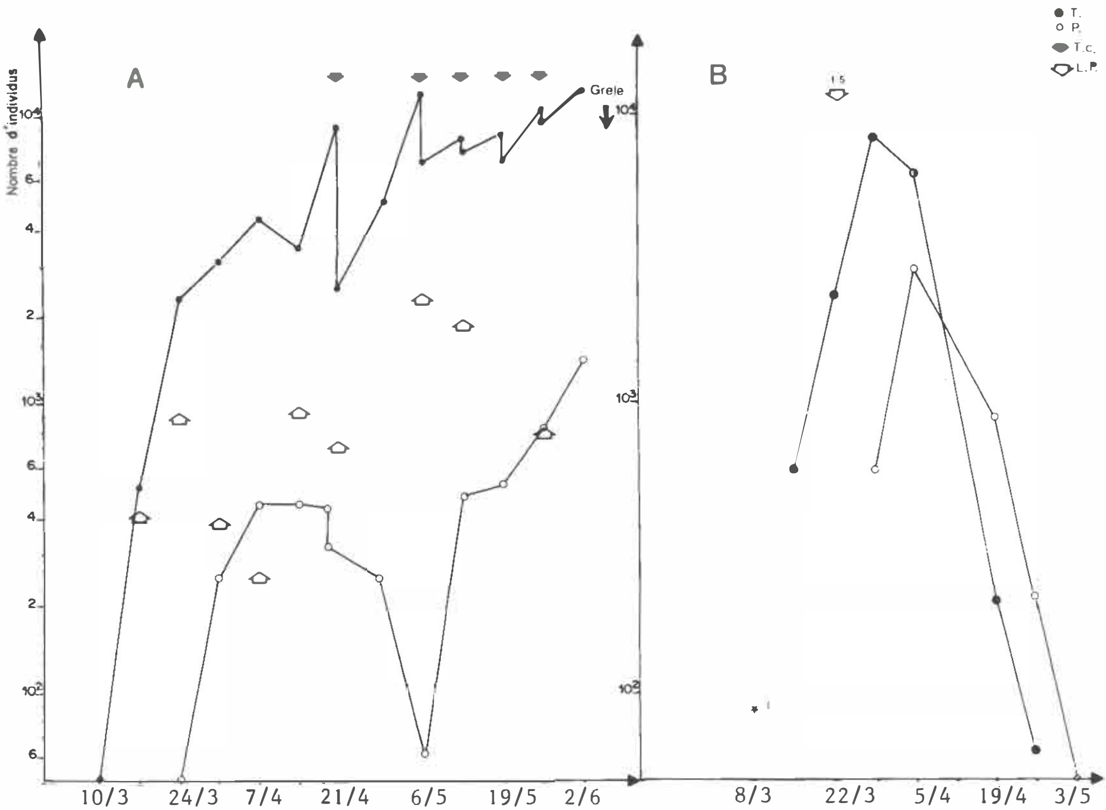

figure 1. Rosiers; évolution des populations adultes de Tetranyques (T.) et de Phytoseiulus (P.) en serre de Lara (A) et en compartiment de serre de Baccara (B).
(T.c. = Traitement chimique partiel, L.P. = Lacher de Phytoseiulus, I. = Infestation de Tetranyques)

Par contre, un deuxième essai de dimension plus réduite effectué dans un compartiment de serre a donné des résultats satisfaisants (Figure 1B), mais à l'inverse de la première expérimentation, cet essai a été mené en l'absence de vapeurs de soufre utilisées habituellement contre l'oïdium. Ceci nous a amené à tester la toxicité de ce produit sur *P.persimilis* selon la méthodes mise au point par Coulon (communication personelle) pour tester la nocivité des différents pesticides sur ce prédateur. Nous avons pu constater que notre premier échec était très probablement dû à la présence de vapeurs de soufre dans la serre.
Nous retiendrons, cependant, que sur rosiers, en dehors bien entendu de tout facteur toxique diminuant l'efficacité des Phytoseiides, le seuil de tolérance aux tétraniques est très bas puisque ceux-ci ont tendance à infester naturellement les parties jeunes du végétal qui seront commercialisées. Les *Phytoseiulus* doivent donc être lâchés à un niveau d'infestation très faible. Néanmoins, il ne semble pas hypothétique d'envisager une utilisation de ces prédateurs pour réduire dans un premier temps dès leur apparition les tétraniques réfugiés dans les structures de la serre ou dans le paillage et qui sont à l'origine des nouveaux foyers, ce qui permettrait dans un second temps, d'exercer une lutte biologique plus efficace et d'éviter les pullulations. Cette perspective nous amènera à effectuer de nouveaux essais sur cette culture.

Essai en serre de fraisiers

En serre de fraisiers, le problème se pose de manière fort différente. Dans les Alpes-Maritimes cette culture se fait le plus souvent en serre froide, sous tunnel plastique avec seulement un appoint de chauffage pour éviter le gel. On trouve également des surfaces beaucoup moins importantes en serre chauffée.
La récolte est donc ainsi échelonnée toute l'année, dès janvier-février en serre chauffée, puis à partir de mars-avril en serre froide. Le relais est ensuite pris par les productions de plein air jusqu'en décembre.
Les attaques de tétranyques sont, suivant les années, plus ou moins précoces et importantes, mais en serre froide, elles coïncident toujours avec la récolte. D'une part, ceci oblige l'agriculteur à n'utiliser que des produits de faible rémanence souvent moins actifs, d'autre part, le traitement d'une plante basse telle que le fraisier ne va pas sans difficulté car il faut atteindre la face inférieure des feuilles. Pour ces deux raisons, la lutte biologique est bien évidemment préférable.
Un essai préliminaire a tout d'abord été effectué en mars 1972 dans un compartiment de serre. Nous avons ensuite traité une demi-serre soit environ 220 m^2 divisés en quatre parcelles A, B, C, D avec *Phytoseiulus* (Figure 2).
Les populations du ravageur et du prédateur ont été estimées par un comptage des feuilles attaquées suivi d'un prélèvement de folioles dont la population était comptée au laboratoire puis rapportée à une moyenne. Un simple rapport permettait d'avoir une estimation des deux populations.
Les résultats ont été très positifs et l'on a obtenue une éradication totale des tétraniques sur certaines parcelles. Dans tous les cas on n'a pas enregistré de dégât notable sur la culture. Il faut noter que dans ces essais la proportion des prédateurs lâchés était très élevée soit 1 pour 5 ou 1 pour 10 tétraniques.

En 1973, nous avons repris ces essais dans le cadre d'une serre de 450 m^2, nous voulions tester l'efficacité des lâchers de *Phytoseiulus* dans une proportion beaucoup plus faible, 1 pour 100 tétraniques. Notre méthode d'estimation avait, elle aussi, fondamentalement changée car nous avons essayé d'adopter des procédés valables sur une grande échelle en serre ou en plein air : une récolte de feuilles à raison de une par mètre linéaire environ est effectuée sur l'ensemble de la surface à traiter puis les feuilles sont passées par quatre ou multiple de quatre dans une machine brosseuse où les acariens sont récoltés sur une plaque préalablement encollée dont on ne compte qu'une partie de la surface.
On peut ainsi faire une estimation rapide des populations en rapportant ces résultats à la densité de feuilles par pied ou par m^2, ce qui permet d'évaluer le niveau de l'attaque ainsi que le bon développement du prédateur après lâcher.
Malheureusement, aucun résultat valable n'a pu être obtenu dans cette serre par suite d'un traitement effectué par erreur peu de temps après le lâcher qui a entraîné un décalage dans le temps par rapport à la récolte. De ce fait, les résultats, d'ailleurs concordants, avec les résultats précédemments obtenus, présentent beaucoup moins d'intérêt.
Nous pensons que la lutte intégrée en serre de fraisier comprenant la lutte biologique contre les tétraniques est une solution intéressante sur cette culture. Mais pour la réussite et l'application de cette méthode, il nous semble nécessaire là aussi de définir clairement à quel niveau de population se situe le seuil de tolérance économique et à quel niveau doit être effectué le lâcher. Ces deux buts que nous avons poursuivi cette année n'ont pu être mis en évidence faute de possibilité pratique, mais ils seront de nouveau envisagés dans les années à venir.

Essais en serre d'aubergine

En serre d'aubergine, nous n'avons effectué qu'un seul essai dans une serre de 200 m^2 dans laquelle deux variétés ont été plantés en quantité égale. Une infestation artificielle rendue nécessaire par l'éloignement de toute culture maraîchère susceptible de renfermer des tétranyques a été effectuée par deux

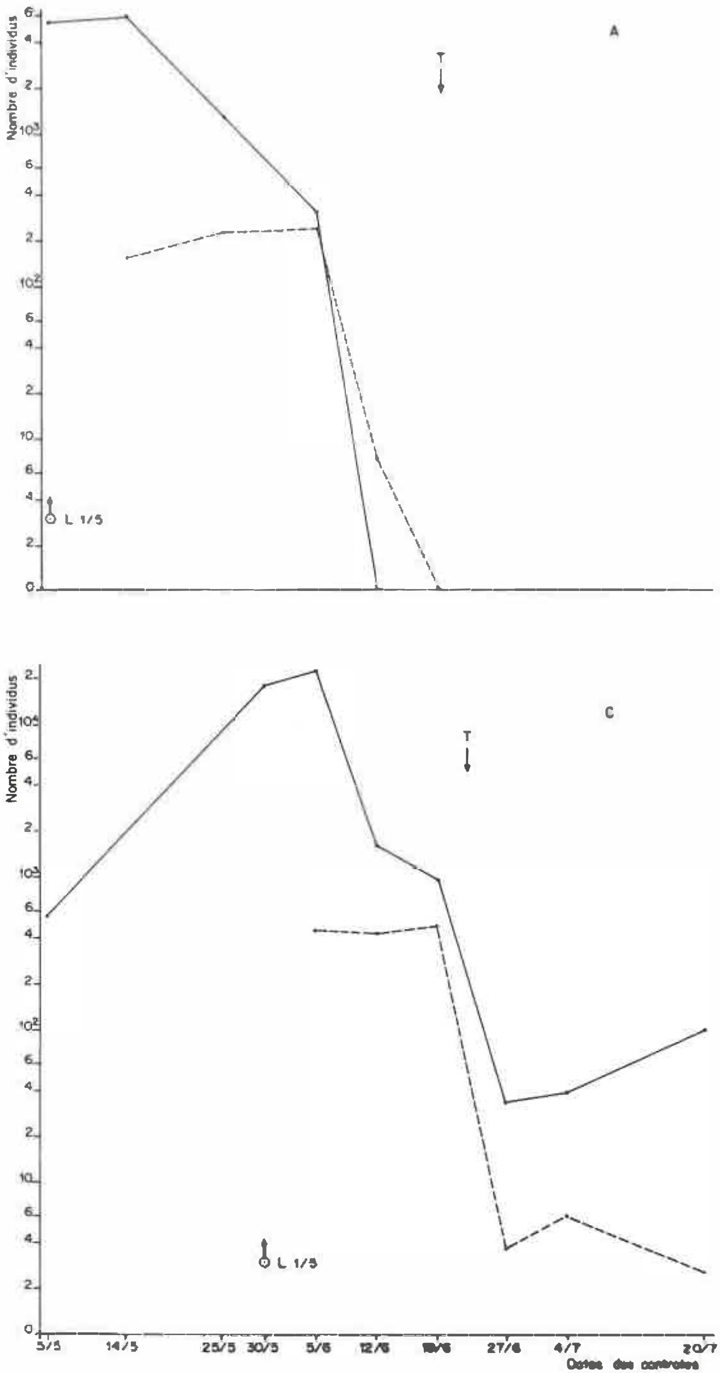

figure 2 a et c. Fraisiers; Evolution des populations de Tetranyques (T) et de Phytoseiulus (P) (tous stades compris) rapportés au m^2 de serre dans 2 parcelles ayant bénéficié d'un lâcher au 1/5e.
(L = lâcher de Phytoseiulus)

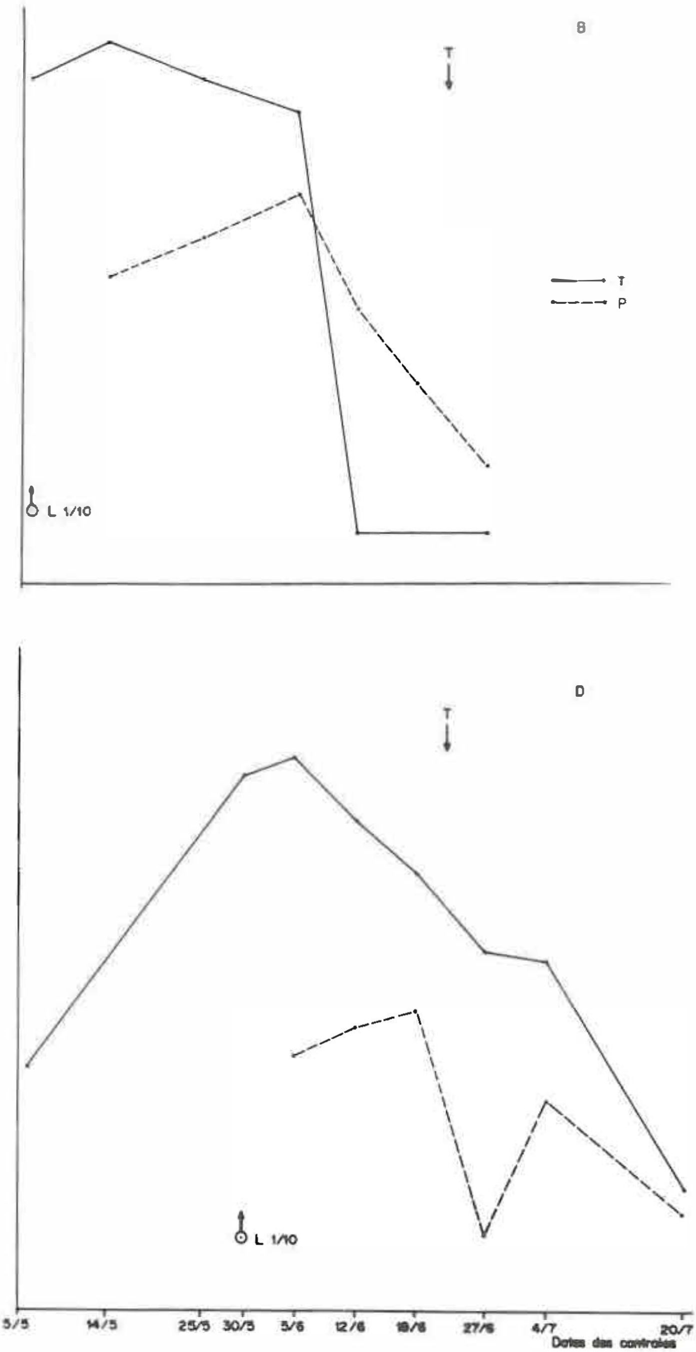

figure 2 b et d. Fraisiers; Evolution des populations de Tetranyques (T) et de Phytoseiulus (P) (tous stades compris) rapportés au m^2 de serre dans 2 parcelles ayant bénéficié d'un lâcher au 1/10e
(L = lâcher de Phytoseiulus)

fois de manière homogène dans la serre. Un lâcher correspondant au 1/10e des ravageurs a été mis en place sur l'ensemble des pieds.
Afin d'éviter la prise d'échantillons répétée sur cette petite surface, nous avons procédé à l'estimation des populations parcomptage hebdomadaire sur 15 pieds de chaque variété, des femelles des deux espèces.
Les résultats ont été particulièrement concluants (Figure 3) puisqu'après une croissance accélérée des tétranyques dont le nombre a triplé voire quadruplé en quelques jours, on a observé une chute totale des populations et corrélativement un bon développement de *Phytoseiulus*.
Cette méthode semble donc pouvoir être adoptée dans l'avenir sur cette culture.
Notons par ailleurs, que des observations suivies de lâchers de prédateurs effectués chez un agriculteur ont confirmé ces premiers résultats. Néanmoins, de nouveaux essais sont nécessaires pour la mise au point de techniques appropriées.

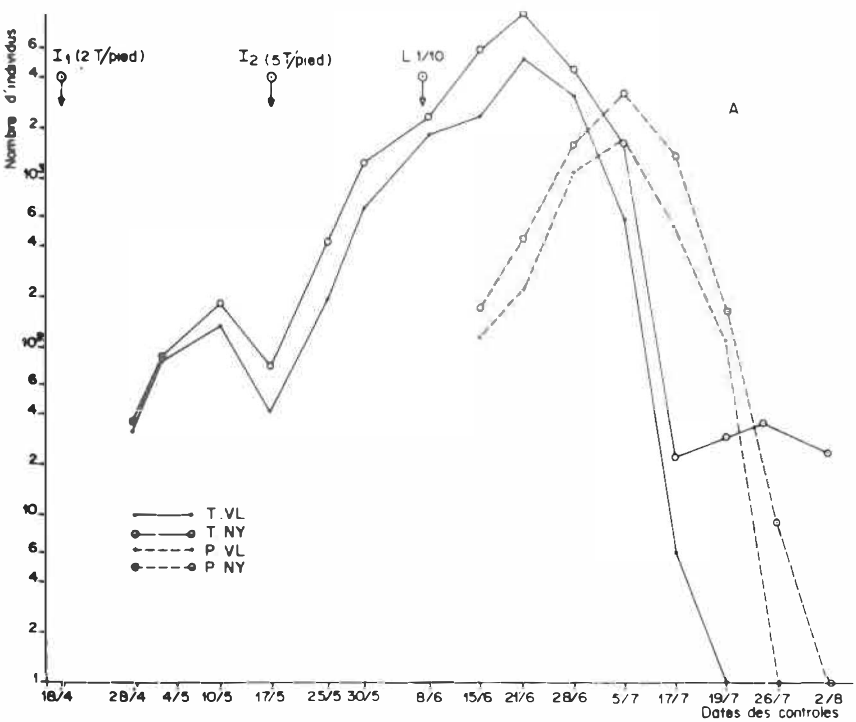

figure 3. Aubergine; Courbe cumulative des populations de Tetraniques (T) et de Phytoseiulus (P) sur 14 pieds des variétés "Violette longue" (V.L) et "Monstrueuse de New York" (N.Y).
(I = infestation de Tetranyques, L = lâcher de Phytoseiulus)

En serre de concombre, un essai portant sur une surface de 6.000 m^2 a été effectué cette année dans les environs de Lyon. Les résultats obtenus ont été satisfaisants et meilleurs, semble-t-il que dans les serres traitées uniquement par voie chimique. Un extension de ces essais est prévisible dans les années à venir.

CONCLUSION

Exception faite du rosier dans lequel les conditions d'expérimentation étaient défavorables, nous avons obtenu une bonne efficacité de *Phytoseiulus* sur toutes les cultures sous verre envisagées.

Plusieurs observations peuvent en être tirées:
1. Il est préférable que les lâchers de prédateurs soient effectués sur des populations peu importantes mais réparties de manière à peu près uniforme, soit spontanément, soit par dispersion volontaires des foyers.
2. Un certain temps de latence inhérent à l'effet différé de toute méthode de lutte biologique est nécessaire avant d'obtenir l'éradication des tétraniques.
Il nous semble donc indispensable de définir pour chaque type de culture envisagée, un seuil d'intervention au-delà duquel si on n'effectue pas un lâcher, le développement ultérieur des tétranyques risque de dépasser le seuil de tolérance économique avant l'arrêt de croissance du ravageur. Ces notions dépendent étroitement de la culture envisagée. Elles peuvent correspondre à des populations très basses sur rosiers, très élevées sur concombres et dépendent aussi en partie des conditions climatiques régionales et saisonnières.

Dès maintenant, des méthodes de lutte intégrée comprenant une lutte biologique contre les tétraniques, pourront être mises au point en France sur certaines cultures maraîchères et permettront d'améliorer ces productions tant par l'inocuité de cette technique que par son efficacité.

INTEGRATED CONTROL IN VEGETABLES UNDER GLASS IN THE NETHERLANDS

by

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INTRODUCTION

As Bravenboer (1970) stated 1970 was the first year *Phytoseiulus persimilis* controlled the red spider mite, *Tetranychus urticae*, on a large scale. It concerned 200 ha (500 acres) glasshouse cucumbers, i.e. nearly 25% of the Dutch acreage of cucumbers. More details about the production and introduction of the predator are given by Bravenboer (1970) and Hussey and Bravenboer (1970).
In 1971 a severe outbreak of the greenhouse white fly, *Trialeurodes vaporariorum* Westwood, occurred. All chemicals approved for the control of white fly are desastrous to the predator. Thus the producer of *P.persimilis*, Mr. Koppert, stopped his production. It happened that he had at his disposal a glasshouse of tomatoes with *Encarsia formosa*. He utilized this parasite for introduction in eight commercial holdings (both tomatoes and cucumbers).
In October 1971 he started the first planned production of *E.formosa* on tomatoes for introductions from December 1971 till April 1972. He provided the parasitic wasp for over 200 holdings (100 with cucumbers, 100 with tomatoes). Effective control of white fly was obtained on only 30 holdings (5 with cucumbers, 25 with tomatoes; i.e. resp. 4 ha and 20 ha).
For the introduction season December 1972 - May 1973 the production of *Encarsia formosa* was started on tomatoes and later on he switched to cucumbers, primarily for phytosanitary reasons. Introduction was restricted to tomato holdings according to a scheme, developed at our station in the preceding years. Nearly all growers (over 150) obtained good results by *Encarsia* introduction which was accompanied by *Phytoseiulus* for the control of red spider. It covered an acreage of about 120 ha (300 acres), i.e. 5% of the tomato-acreage in the Netherlands. Besides this, red spider control with *P.persimilis* was done on 150 ha (375 acres) of cucumbers (i.e. 15% of the total cucumber acreage in the Netherlands) and in 10 holdings with sweet peppers. Roughly said the producer bred 30 millions of predators and 15 millions of parasites.
This season *Phytoseiulus*-production was the first year round one. The predator was also applied on a limited scale in autumn crops.

THE INTRODUCTION SCHEME IN TOMATOES

In 1971 and 1972 *Encarsia formosa* was available on a more or less limited scale. There were limitations both on the quantities and on the moment of delivery. In these two years production and introduction schemes have been developed by Mr. Koppert and our station.
On developing the introduction schedule the next considerations are of paramount importance:

1. The grower does not like an arranged introduction of a pest
2. It is doubtful whether population developments in practice are predictable
3. *Encarsia formosa* needs young larvae for host feeding and older stages for parasitizing
4. Burnett (1960) states that in an interaction system of greenhouse white fly and *Encarsia formosa*
   a. The numbers of host and parasite fluctuate with increasing amplitude
   b. The higher initial densities the higher the resulting amplitudes
   c. The fluctuations are smallest if the infestation period of both host and parasite is long.

In practice the period of infestation starts when the first white fly adults are established. A long infestation period results from the length of the life time of the females. Besides some spread in the period of hatching from the pupae on the cotyledones or first leaves will occur.
According to Burnett more parasite introductions are needed within the first generation of white fly. The best moment for the first introduction of *Encarsia* as puparium in the scales of white fly is the moment when larvae (first and second stage) of white fly are present. When the wasps hatch from the introduced scales, there are plenty of larvae available for host feeding (second stage). Repeated introductions are needed in the next generations (= months) of the white fly to prevent the increasing population fluctuations and to diminish the risk of damage to the crop. In our trials it appeared that four introductions during two generations of the white fly are sufficient for adequate control on tomatoes. We needed four till six wasps per plant, varying somewhat from year to year.
Table 1 shows the data of populations in a glasshouse in our station (size 670 m^2, nearly 0.17 acres) in 1973.

Table 1 Developments of the population of *Trialeurodes vaporariorum* and its introduced parasite *Encarsia formosa* in tomatoes at Naaldwijk on 14.XII.'72-20.VII.'73

Days after planting	Average number of *T.v.* per plant					Introduced *E.f.* per plant	Black/ white ratio
	Eggs	Larvae	Pupae	Adults	Black pupae		
5	0.5	1.3	0.8	0.3		0.6	
19	1.0	9.7	0.3	0.6		0.9	
40	0	6.8	0.2	0.8		1.7	
49	1.0	11.2	2.1	0.6	3.7		1.8
53	13.7	7.1	0.5	0.5	0	1.6	
63	6.4	19.4	15.7	0.5	9.9		0.6
77	0	3.2	18.9	0.1	24.9		1.4
105				0.2			2.1
117							3.1

From this table it is clear that younger and older larvae were present on the plants when they were planted. So we decided to introduce immediately. The second introduction followed in a fortnight. The next (3rd and 4th) introductions were about one month later (day 40 and 49). In the beginning the introduced numbers were rather low, according to the tendency of the producer of the parasite to start with low numbers. In the second generation the numbers of

larvae of white fly were increasing, so we had to introduce more black scales with *Encarsia* than in the first generation.
The ratio of black and white pupae on the leaves gives a good indication for the degree of control. The grower can check this himself on the leaves on which most white flies have hatched and the first wasps are hatching. When the ratio is 1 or more in the second generation and the white fly numbers are rather low (translated by the grower as no honeydew on the leaves), controll will be good. Summarizing the trials 1971 - 1973 it can be said that the first introduction of 1.5 or 2 scales per plant is realized when the first white fly larvae are present. This is repeated within a fortnight. New introductions follow after one month with lower numbers of scales (1 per plant) when parasitization is good, i.e. continuing increase of the portion of black scales. Parasitizing can be checked by the black/white ratio which should be at least 1.

CONTROL IN TOMATOES IN PRACTICE

Planting the young tomatoes (December - February), tying them up and twisting them in, are excellent occasions for the grower to detect the first white flies (adults). In most cases the first adults hatch from pupae on the cotyledones and lower leaves of the young plant. When the first spot with white fly is found the grower has to go through the whole glasshouse more thoroughly.
After this he invites the producer of the parasite to check his tomato crop. Thus the producer fixes the day for the first introduction and the amount of *Encarsia* to be used. When it is evident that there are only one or a few foci and no white flies are spread through the glasshouse, it can be decided to use a higher dose in the white fly patches and low doses in the rest of the glass-house. This last point is important to avoid the development of unexpected spots. In this way the producer of natural enemies sells both enemies and guidance. It is included in the price of 16 cents per m^2 glasshouse area (£ 95,- per acre). There are three tomato plants on a square meter. Thus the 4-6 black scales per plant do cost 5 cents, included all guidance.
The grower has to cut the cucumber leaves with scales he receives from the producer into pieces and distribute them through the glasshouse by putting the pieces on the leaves of the tomato plants. Thus he obtains a good spread of the parasites through the whole glasshouse. The producer will visit the grower regularly and fix the next introductions. In this way the results have been very good this year.
Red spider control with *P.persimilis* also costs 16 cents/m^2. There are three plants on 1 m^2 and a bean leaflet with ± 8 predators is put on every second tomato plant when there are 6 - 8 patches of red spider per 1000 m^2. Thus there is an average of 4 predators per plant, which costs 5 cents. Concluding it can roughly be said that the price per predator is 1.2 cents.
Biological control of white fly requires a change in cultural practice. Taking off the older leaves of the tomato plant is common. It is important that the grower does not remove the puparia of *Encarsia* in this way. So he has to check whether the wasps have already hatched from the black scales on the leaves the grower wants to take off. Generally speaking it is sufficient when the leaf picking is retarded a few days.
Biological control of the white fly has consequences for other pests. It is evident that *Phytoseiulus* can control red spider and so the two major pests of tomatoes can be controlled biologically. Tomato leafminer can be a limiting factor, because all chemicals used against this insect are harmfull to the natural enemies. Thus the crop must be free from leaf miners before the intro-duction of natural enemies can be started. When this pest is attacking the crop later on in the season (June), the population development is rather slow and can be retarded by consequent picking of mined leaves. Chemical control of leaf miners in summer has not been necessary with some growers and in the three years of trials at our station.

In July 1973 there was an outbreak of the tomato rust mite, *Vesates lycopersici* Massee, which caused severe damage in 30 holdings where biological control was practiced. The consequence of this new pest can not yet be predicted.

CONTROL IN CUCUMBERS

In comparison to tomatoes a cucumber crop is grown at higher temperatures allowing a quicker development of the parasite. So better results were expected with this crop. Nevertheless the results in tomato were much better, in 1971/1972 25 out of 100 tomato growers had good control compared to only 5 out of 100 cucumber growers. Although there were problems concerning the date of introduction and the numbers to be used, there was no reason to ascribe the differences to the external factors in cucumber growing. Differences in host plants were therefore considered more closely.

In the past it has been suggested by several authors that a high grade of pubescence and insufficient control are correlated, but others deny this. However, the leaf of tomato is more pubescent than that of cucumber. Criteria such as number of eggs laid on the host plant, the mortality of eggs, larvae and pupae, the length of development do have influence, and should be analysed. But some experiments carried out did not support the idea that the different results originated from this type of interactions between host plant and insect species. From observations on the behaviour of a single female wasp on a tomato leaf, it is clear that it walks rather quickly over the surface. After leaving a white fly scale it has no special trouble in finding another one. A wasp searching for scales on a cucumber leaf, however, looks like a mountaineer passing the high nerves as mountainchains. The stiff hairs are obstacles that cause a lot of trouble in going forward. The insect needs much more time to cover a certain distance on a cucumber leaf than on a leaf of a tomato plant. Owing to the rough surface there is more dust on a cucumber leaf and a wasp needs extra time for cleaning itself on cucumber. We hope it will be possible to express differences like these into a figure to obtain a better estimate of the numbers to be used on different crops.

We do not advise biological control of white fly in cucumbers, but biological control of the red spider is certainly possible, as hydrocyanic acid is approved against white fly since 1972 and *Phytoseiulus* is relatively unsusceptible to it. Thus it is possible to combine *Phytoseiulus* with hydrocyanic acid if the chemical is applied only once in a fortnight.

The price for *Phytoseiulus* is 16 cents/m^2 glasshouse area, inclusive all the guidance the grower needs especially in the first year of biological control of red spider. The dosage is one bean leaflet with about 8 predators per plant. There are 1.5 plant per m^2. Thus the price per predator is 2.5 cents for a cucumber crop.

Two mildew fungicides ara available that do not harm the predator (curamil and "Imugan").

CONTROL IN SWEET PEPPERS

This crop has two main pests: aphids and red spider. Since the approval of pirimicarb in 1972 it is possible to integrate this aphicide and *Phytoseiulus* which is introduced in the same way as in cucumbers (Bravenboer, 1970).

This year about 20 growers carried out the integrated scheme.

Since 1968 the broad mite *Hemitarsonemus latus* is a new pest in sweet pepper in glasshouses. Although it can disturb integrated control of the main pests, it needs not be a problem as it can be controlled by local application of dicofol (Kelthane).

The use of specific chemicals (dicofol as an acaricide, pirimicarb as an aphicide) and *Phytoseiulus* as a predator have given a chance to *Thrips tabaci* as a pest in summer and autumn. The consequences of this new attack cannot yet be forecasted.

CONTROL IN EGG PLANTS

In 1972 a provisional trial was carried out on integrated control in egg plants. Although the available quantities of *Encarsia* were limited the results were encouraging. At the planting date (5.IV.1972) 2 to 3 white flies and several larvae per plant were present. Three and five black scales per plant were introduced on respectively 6 and 15.IV.'72. The percentage parasitism reached 80 and more percent during the season. Despite of these results the white fly numbers increased and resulted in sticky fruits in July.
In 1973 the crop was planted earlier and there was a sufficient supply of *Encarsia*. We used this crop to check the general idea of the introduction schedule:

1. More introductions per generation and
2. introductions during more generations.

As can be seen in table 2, the first introduction was rather high (4 scales per plant). Afterwards in the lesser infested glasshouse no.2 relatively low numbers of the parasite were introduced till the beginning of the third generation (day 47).
In the more infested glasshouse no.1 we introduced the parasite four times in relatively high dosages and three times at low dosages as in glasshouse no.2. As can be seen there were no problems at all as to the control despite of the large numbers of larvae 45 - 60 days after planting.

Table 2 Population developments of *Trialeurodes vaporariorum* and its introduced parasite *Encarsia formosa*, in egg plants at Naaldwijk. Comparison of two glasshouses, 160 m^2 each, 250 plants per glasshouse. Period: 1.II.'73 - 20.IX.'73

Days after planting	Average number of *T.v.* per plant: Larvae	Pupae	Adults	Black pupae	Introduced numbers of *Encarsia formosa*	Black/ white ratio
Glasshouse 1						
1	7.7	2.5	1.5		4	
13	9.5	1.4	0.5		3	
20	12.7	1.0	1.6		3	
27	17.7	1.6	1.5		3	
34	20.5	22.5	1.7	9.0	1.3	0.4
41	28.0	4.2	1.7	14.4	1.3	3.4
47	300	4.6	1.9	15.3	2	3.6
54	300	11.4	2.4	20.9		1.8
61	800	28.8	3.5	57.0		2.0
95		5.3		38.2		7.2
174		4.1		37.1		9.0
Glasshouse 2						
1	3.0	0	0.2		4	
13	2.9	2.8	0.3		1	
20	5.1	0.5	0.5		2	
27	10.0	2.4	0.5		2	
34	4.4	2.5	0.7	1.4	1.3	0.5
41	32.7	11.4	1.0	9.9	1.3	0.9
47	70	16.2	0.5	14.7	2	0.8
54	60	17.0	1.7	18.2		1.0
61	60	38.0	1.7	28.0		0.7
95		2.3		16.2		7.0
174		6.2		57		9.2

Phytoseiulus gave a good control of the red spider mite, although higher dosages were needed than in cucumbers (about two times higher). Pirimicarb was applied for the control of aphids. *Thrips tabaci* appeared in July but control measures were not necessary.

TRENDS IN RESEARCH

The chances are increasing that thrips will become a serious pest, as is known from cucumbers in England and from sweet peppers and egg plants in our country. The chemical control by drenching or spraying the soil has its limitations. Our research will be directed towards biological control, because we found a thrips feeding mite (*Amblyseius cucumeri* Oudemans) in a sweet pepper crop last year. But we have not yet been able to breed this predator.
The second problem is the chemical control of white fly in cucumbers which limits the application of the predator *Phytoseiulus*. Apart from new introduction trials, we started to look for new parasites. More parasites are known from Western Europe but experiments to compare the efficiency of several species for the control of the greenhouse white fly have never been carried out. It would be of interest to have a parasite that is more efficient on cucumbers and at lower temperatures than *Encarsia formosa*.
In literature some data about *Encarsia*-species as parasite of *T.vaporariorum* are available (Butler, 1936; Ferrière, 1956; Speyer, 1927; Stüben, 1949; Trehan, 1940; Weber, 1930).
Aleurodes proletella and *A.lonicerae* were found in natural habitats near our station. From both species, three parasites were bred:
Encarsia formosa Gahan,
E.tricolor Förster and an
Euderomphale species.
Now we are trying to breed these parasites.

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THE USE OF INTEGRATED CONTROL IN GLASSHOUSES IN GREAT BRITTAIN

by

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The principle of biological control of some of the major glasshouse pests has now become an established fact and, with the ever increasing resistance to pesticides displayed by many insect and other pests, growerdemand for the use of these methods has increased considerably in recent years. In Britain at the present time, it is estimated that at least 300 acres (120 hectares), equivalent to one-fifth of the total heated glasshouse acreage, are being treated with *Phytoseiulus* predators, *Encarsia* parasites or both. In the Lea Valley, the main centre of our glasshouse industry, about 50% of nurseries are using integrated control methods.

Cucumbers: The use of *Phytoseiulus persimilis* to control red spider mites (*Tetranychus urticae*) on cucumbers has now become an accepted practice on many nurseries and a precise programme for its use, based on the "pest-in-first" technique, has been devised (Anon, 1972). Many growers, however, either through their reluctance to infest their plants with the pest, or, in an attempt to short cut the method to save time and labour, have devised their own treatments based mainly on delaying treatment until natural infestations occur. These sort of methods have an inherent danger in that most natural infestations, particularly those arising from ex-diapause populations, occur in patches, and predators introduced into these centres of high prey density will not readily disperse until all the prey have been consumed. Thus, an uneven distribution is created where some plants have a high predator density while others have none and are quite unprotected against possible spider mite invasion. Experience has shown that the introduction of small numbers of predators onto a low, evenly distributed red spider mite infestation is the best guarantee for a successful and predictable control with the minimum of damage.

Often, in mid-summer, swarms of spider mites migrate to the top 3-4 leaves, causing severe damage, following what appears to have been successful biological control. The reason for this phenomenum is not yet understood. It could be related to some physiological reaction of the mites to the longest day, or, merely a response to senescing foliage. However, the predator does not respond in the same way and appears to prefer lower regions of the plant. Thus an imbalance is created which is usually corrected by a single spray of petroleum white oil emulsion or tetradifon along the tops of the plants.

The biological control of whitefly (*Trialeurodes vaporariorum* Westw.) by the parasite (*Encarsia formosa* Gahan) still presents some problems mainly in synchronising parasite introductions with the presence of suitable whitefly scales on the plants. Also, a succession of mild winters with a correspondingly high survival of whiteflies out-of-doors has brought earlier and increased populations into glasshouses.

The G.C.R.I. method of control (Anon, 1972) whereby *Encarsia* parasites are introduced at 20 per plant following an artificially established whitefly population of two adults per plant, is giving good control provided care is taken to ensure that the parasite introduction coincides with the presence of suitable whitefly scales on the plants. The whiteflies are normally introduced as pupae and the parasites as black, parasitised scales from leaf material hung from sites, each covering five plants. However, at the present time, the commercial producers are able to supply only parasitised material so that an alternative method which does not require the introduction of whiteflies has been devised. This consists of introducing parasites into the glasshouse at fortnightly intervals, starting soon after planting, at the rate of 8 per plant as a safeguard against subsequent whitefly attack. The parasites, which are supplied as scales on leaf material are hung above the plants at sites each covering about 40 plants. The introductions are continued until whiteflies have appeared and black, parasitised scales established on the plants.

Aphis gossypii is the major aphid pest of cucumbers in Britain, and research is continuing into the potentialities of various predators (Coccinellids) and parasites (*Aphelinus flavipes*:*Trioxys sinensis*) for the biological control of this pest. Meanwhile, this aphid is being effectively controlled in commercial glasshouses by soil drenches of Pirimicarb (Pirimor) used at 6 ozs dispersible powder (50% a.i.) per 100 gals and applying 20 fl.ozs per large plant. Similarly, thrips (*Thrips tabaci*) are controlled by soil drenches of 0.02% gamma BHC using 1 gal per yard run of bed and cucumber mildew (*Sphaerotheca fuliginea*) by soil drenches of dimethirimol (Milcurb) or benomyl (Benlate). Benomyl has strong ovicidal effects on *Phytoseiulus* and is not recommended for use as a high volume spray where this predator is being used to control red spider mites. Strains of cucumber mildew resistant to one or other of these fungicides have been recorded from some nurseries in Britain and new materials are being screened for their effects on *Phytoseiulus* and *Encarsia*.

This complete integrated programme for the control of cucumber pests and diseases is now widely used on cucumber nurseries with considerable success.

Tomatoes: A precise method for the use of *Phytoseiulus persimilis* to control red spider mites on tomatoes has not yet been finalised. The large number of plants involved - 14,000 per acre - precludes the use of the "pest-in-first" technique on account of the time and labour needed to infest every plant. Treatment is therefore aimed at patches of natural infestation as they occur. Introductions of up to ten predators per plant within infested patches has given good results commercially though it demands repeated introductions as more and more patches of infestation arise. This type of treatment is greatly facilitated where a grower has his own predator rearing unit.

An alternative method, of particular use on early planted crops, is to set up the pest/predator interaction on young plants while still in the propagating stage. Experiments over the last 2 years in which one-fifth of the plants were each infested at the 6-leaf stage with 30 red spider mites followed, after 10 days, by the liberation of four predators onto each treated plant gave good control when planted out with the main batch of plants in the ratio 1:5. The mites, followed by predators, quickly colonised the neighbouring plants and control of the infestation was achieved in 3 weeks. Normally, the interaction would be sustained by ex-diapause mites emerging onto the plants from over-wintering sites in the glasshouse structure. When this emergence takes place soon after planting, the mites are quickly controlled by the increasing predator population without serious feeding damage to the plant. If, however, it is delayed until some time after the initial infestation has been eliminated, then the decline in predator numbers, which takes place through lack of food, will allow the ex-diapause mites to re-colonise the plants in large numbers with correspondingly severe leaf-damage unless the plants are "re-seeded" with spider mites to maintain the predator population.

Control of whiteflies on tomatoes is being achieved either by a single introduction of up to four *Encarsia* parasites per plant when the pest is first seen on the plants, or by repeated introductions of parasites every fortnight at the rate of 1 per plant until black scales appear on the crop plants. The latter method appears to offer greater success and recently we have attempted to rationalize the parasite introductions to coincide more closely with peaks of 3rd instar whitefly scales over the 1st and 2nd generations. At temperatures of 18^{o}-20^{o}C used for early tomato production, parasites are introduced at the following intervals and rates following an introduction of ten whitefly pupae on one plant in 100 throughout the crop:

1st	introduction	1 week	before	planting	at 5000 per acre
2nd	"	3 "	after	"	" 20,000 per acre
3rd	"	5 "	"	"	" 20,000 per acre
4th	"	9 "	"	"	" 10,000 per acre

These recommendations have been successful on a number of commercial nurseries this year. The pre-planting introduction is intended as a safeguard against the small numbers of whiteflies which often persist in propagating houses, and could be omitted where these do not exist.

A recent problem which has arisen with biological control of whitefly on tomatoes is the introduction of the "layering" system of growing where frequent and heavy de-leafing of the plant is practised. Often, two-thirds of the lower leaves are removed and it is known that many parasitised scales are also removed on these leaves before the adult parasites have energed from them. This may cause a serious depletion in the parasite population.

Benomyl drenches or dichlofluanid sprays, for the control of *Botrytis* and leaf-mould (*Cladosporium fulvum*), can be safely integrated with *Phytoseiulus* and *Encarsia*.

Other Crops: A comprehensive integrated programme for use on chrysanthemums has been developed at G.C.R.I., but its use has been deferred because soil-applied aldicarb (Temik) is giving good control of most chrysanthemum pests. However, resistance to this material by *T.urticae* has already been reported from Scandinavia and should this resistance become widespread, as seems likely, alternative control methods must be available.

The use of *Phytoseiulus* to control *T.urticae* on roses and strawberries is being investigated.

Production of natural enemies: At the present time, there are two mai[illegible]cers mass-rearing *Phytoseiulus* predators and *Encarsia formosa* parasites, for use in commercial glasshouses. In 1973, they estimate that between them they have produced and distributed over 1 million predators and the same number of *Encarsia* parasites to commercial growers. Normally, *Phytoseiulus* is mass-reared on French beans and *Encarsia* on *Nicotiana* plants (var. 'White Burley'). *Phytoseiulus* is sold at £12.00 per 1000 and *Encarsia* at £1.30 per 1000: so that the cost of materials to treat one acre of cucumbers for combined red spider and whitefly control is approximately £130 and rather more for tomatoes. These costs compare very favourably with that of high-volume spraying which on many nurseries is estimated to cost at least £250 per acre per year. In addition, there is the added bonus of increased crop once chemical treatments are withdrawn. Many growers estimate that the crop is increased by up to 20% where biological control has been used.

A few larger growers have, or contemplate having, their own rearing units and this is an ideal arrangement, for the grower always has supplies of natural enemies on hand.

There is a widespread demand in Britain for integrated control and most growers who have used it have expressed their satisfaction with it even though the quality of control in some cases falls short of what we would consider acceptable.

One of the most pressing problems is the provision of some sort of "after-sales service" by which the growers can obtain expert guidance on the various aspects of integrated control and the problems which might arise during its use. For example, an interaction between a pest and natural enemy which gets out of balance resulting in unnecessary pest damage could often have been forestalled had expert advice been available earlier to make the necessary correction. At the present time, this sort of supervision relies on the interest and enthusiasm of a few ADAS entomologists and advisers. If integrated control is to play its full part in modern pest management such advice must be more readily available and there must be greater liaison between the adviser, the producer and the grower.

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INFLUENCE OF PREY DENSITY ON ACARICIDAL EFFECT ON THE PREDACIOUS MITE, *PHYTOSEIULUS PERSIMILIS*

by

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In a simplified ecological universe, where only a bean leaf, the spider mite, *Tetranychus urticae*, and its predator, *Phytoseiulus persimilis*, interact, the predator population will annihilate the prey population under certain climatic conditions. On a commercial glasshouse crop, however, various factors interfere with the simple predator/prey relation. The so far most frequent interference is from pesticides, which use is regarded indispensable, when climatic conditions are in favour of the prey. That is high temperature (above 30°C), and low humidity. Under these conditions will the net rate of increase in the prey population exceed that of the predator population, and it will be necessary to reduce the density of the prey to a certain level. In situations where other pests as well as diseases have to be controlled, the control measures are likely to interfere with the predator/prey relation.

When combining biological and chemical methods of crop protection, it is essential to be able to predict, whether a certain chemical treatment will interfere insignificantly with the simple predator/prey relation, or if it will favour either the prey or the predator.

In the case of acaricidal interference with the predator/prey system consisting of *P. persimilis* and *T. urticae* the predator population can be reduced in various ways. Directly by poisoning of the predators. Indirectly by the acaricide passing through the food chain, and eventually accumulating in the predator. Incidently, the accumulation of a sufficiently stable acaricide will be enhanced under conditions of low prey density due to the fact that *P. persimilis* will turn to intraspecific predation. Another indirect reduction of the predator population occurs simply by starvation, when the acaricide causes a high mortality rate in the prey population.

The present experiment was carried out in order to evaluate the gross effect of an acaricide on a population of the predator, *P. persimilis* under conditions of respectively high and low prey density.

MATERIALS AND METHODS

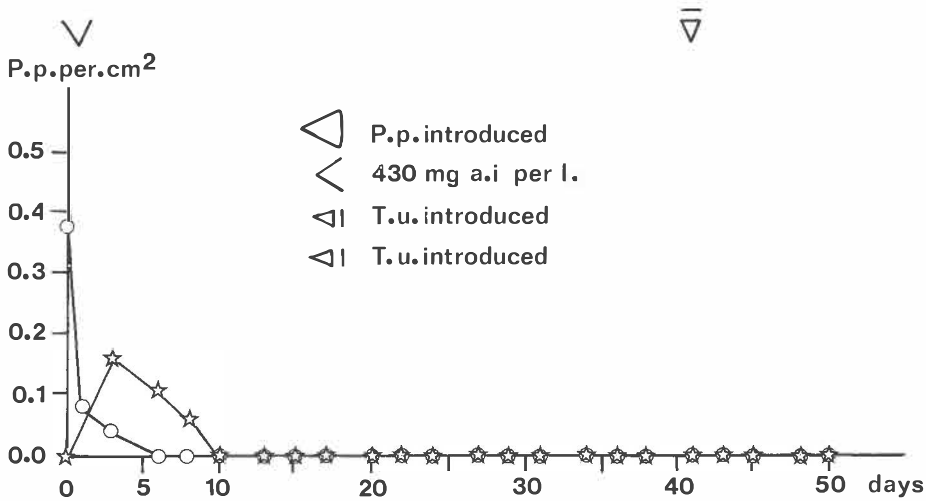
The two mite species were confined to bean plants, *Phaseolus vulgaris*, in cages of polythene covered cylindrical steel wire frames (hight 40 cm, diameter 25 cm). The cages, each representing one universe, had their tops covered with cloth. The individual cage was placed on clean sand in a tray. All the cages were kept during the experiment in a glasshouse at an average temperature of 19°C during

nights, and 23^{o}C during day time. The natural photoperiod was extended to 16 h per day by means of Hg-lamps,
The spider mite population was composed of strains having different history of chemical pressure. The predator population, however, had never been subjected to acaricides.
The acaricide chosen was dinobuton as the commercial product, Acrex 50, which contains 43% 2-(1-methyl-n-propyl)-4,6-dinitrophenyl isopropylcarbonate. The universes were sprayed with 4,5 g of dinobution dilution per treatment, using a chromatography-sprayer. Concentration of dinobuton, and time of application are given at the top of the figures.
The experiment was divided in two series. Each consisting of four cages. All cages in the one serie had high prey density, and all in the other had low prey density. Each serie consisted of two cages with no acaricidal treatment, and two treated with different concentrations of dinobuton.
Untreated spider mites were introduced into the universes with high initial prey density while dinobuton residues were still active, thus simulating prey emerging from refuges.
Individual mites were counted on the lower surface of intact leaves. The density on the upper surfaces was negligible. All stages, except eggs of spider mites, were counted. The density of eggs appeared to be proportional to the densities of other stages of the spider mite.

RESULTS AND DISCUSSION

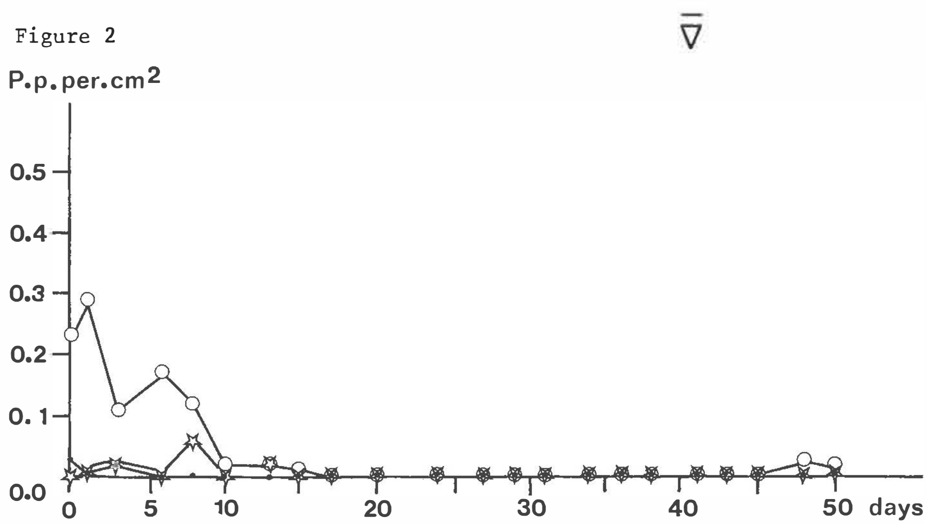
The results from cages treated with respectively 430 mg and 215 mg a.i. per litre are showing the same trends. Therefore, only results of the treatment with the highest concentration are given in this context. The experimental results will be published in detail elsewhere Berendt (1973). The population densities are given as average of individuals per cm^2 leaf.
The results from universes with low initial prey density are shown in figures 1 and 2. The increase of quiescent *P.persimilis* in the dinobuton treated universes was probably due to poisoning. The main cause to the decrease of predator density was, however, intraspecific predation indicated by a large number of carcasses. After reintroduction of the prey only a slight tendency to a second wave of predator population was observed in the acaricide free universe. The experiment had, however, to be discontinued due to the condition of the host plants.
The results from universes with high initial prey density are shown in figures 3 and 4. The acaricide does affect the predator population. Lack of prey seems, however, to be the factor that reduces the predator population most, as no principal difference of population dynamics appeared in treated compared to untreated universes.
McClanahan (1970) has evaluated the effect of dinobuton on *T. urticae* and *P. persimilis*. The experiments revealed that the prey was considerably more sensitive to dinobuton, than was the predator. The present experiment was carried out in more complex universes, and the direct effect of the acaricide on the predator was less significant than the indirect effects, such as food chain effect, and starvation.
The present results indicate that egg production of the predator was drastically reduced, when prey was scarce. The biomass of the population is thus concentrated in stages having great searchingcapacity. Incidently, the age distribution of the predator population will not become stabilized, unless prey density is stable.
Nackman (1973) has investigated the egg production of *P. persimilis* as a function of its consumption of eggs of *T. urticae*. Predators in individual cells were offered different numbers of prey eggs under controlled laboratory conditions, 25 ± 2^{o}c and 70 ± 5% r.h. If a predator consumed less than 5 eggs per day its egg production stopped. A predator could eat up to 30 prey eggs per day at which consumption its egg production stabilized around 5 per day.

Figure 1



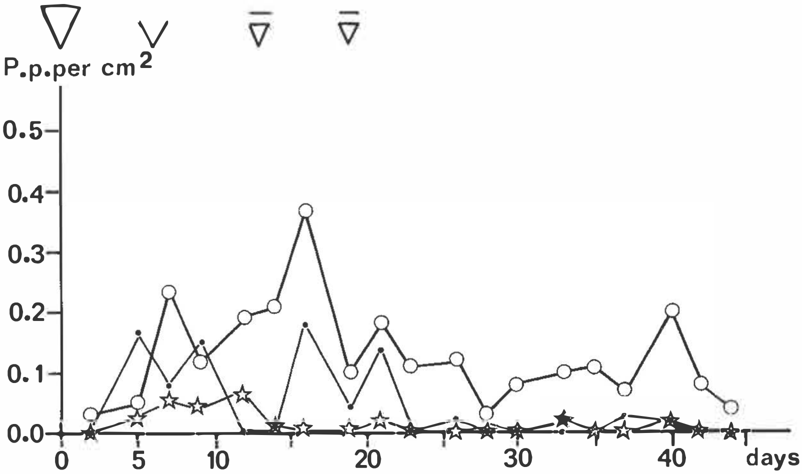
Density of dinobuton treated population of *Phytoseiulus persimilis*, with low initial prey density. Less than one post oval *Tetranychus urticae* per cm^2. Symbols at top indicates respectively time of application, concentration in mg active ingredient per litre, and time of introduction of acaricide free T.u. Movable P.p. per cm^2 (circles), quiescent P.p. per cm^2 (triangles), and P.p. eggs per cm^2 (dots).

Figure 2



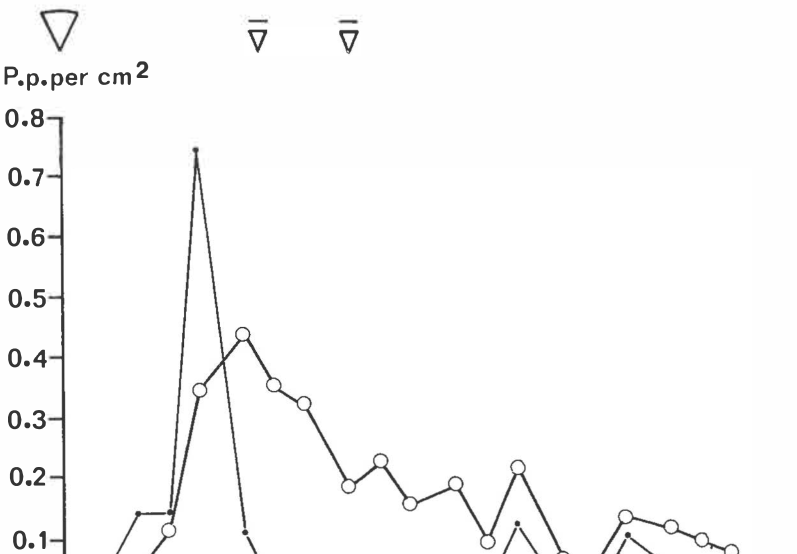
Density of *Phytoseiulus persimilis* population without acaricidal interference and with low initial prey density. Less than one post oval *Tetranychus urticae* per cm^2. Symbols as in fig. 1.

Figure 3



Density of dinobuton treated population of *Phytoseiulus persimilis*, with high initial prey density. More than 10 post oval *Tetranychus urticae* per cm^2. Symbols as in fig. 1.

Figure 4



Density of *Phytoseiulus persimilis* population without acaricidal interference, and with high initial prey density. More than 10 post oval *Tetranychus* per cm^2. Symbols as in fig. 1.

Experience from dinobuton treated cucumber crops under glass also suggests that the predator population will survive the direct effect of the acaricide, and that it will recover, if sufficient live prey is present.

CONCLUSION

The composed effect of an acaricide on a population of the predator *P.persimilis* depends on the initial prey density. Low prey density enhances the food chain effect as the predation becomes intraspecific, and the predator population is likely to crash because egg production is practically stopped.
The specific acaricide dinobuton can be used under conditions of high prey density without eradicating the population of *P.persimilis*.

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THE INFLUENCE OF PREY DENSITY ON PREY CONSUMPTION AND OVIPOSITION OF *PHYTOSEIULUS PERSIMILIS* ATHIAS-HENRIOT (ACARINA: PHYTOSEIIDAE)

by

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The functional response to prey density among predatory Phytoseiidae has already been subject of many publications (Chant, 1961; Mori and Chant, 1961; Mori, 1969; Sandness and McMurtry, 1970) and the results obtained by several authors indicate that it is characteristic for a particular species. At the same time explanation of the problem allows to determine possibilities and methods of utilization of the predator.
Chant (1961) in research on *Typhlodromus occidentalis* Nesbitt obtained a curve which has been interpreted as a linear increase to a plateau (Holling, 1961,1965). Mori and Chant (1966) demonstrated a domed curve using *Phytoseiulus persimilis* feeding on *Tetranychus urticae* Koch. Identical response was obtained by Mori (1969) with *Amblyseius longispinosus*(Evans).Sandness and McMurty (1970) obtained an unusual form of functional response to prey density in research on three other species showing a double rise of curve at low and then high prey density. The purpose of this paper is to give a detailed explanation of the functional response of *P.persimilis* to prey density with a great number of combinations and high numbers of prey applied.

MATERIAL AND METHOD

The experiments were done under laboratory conditions using young gravid females of *P.persimilis* and active female deutonymphs of two-spotted spider mite, *Tetranychus urticae*. Deutonymphs were taken from a mass culture of *T.urticae* reared on French bean and then placed on leaf-discs cut out of French bean leaves of 2, 3 and 4 cm in diameter corresponding to 3.13; 7.06 and 12.56 sq. cm of area. The discs were placed on a sponge in Petri dishes filled partly with water, forming a barrier against migrating deutonymphs and the predator.
P.persimilis females were individually transferred onto the discs, directly from a mass culture carried out on bean plants. The following prey densities were used: 2, 3, 5, 10, 15, 20, 30 and 40 deutonymphs per disc. Additionally, 80 deutonymphs were used on discs of 3 cm diameter and 80 and 120 deutonymphs on discs of 4 cm in diameter (27 different combinations in total). All combinations were done in 40 replications. In each combination 8 predator females were introduced and they stayed in the experiment for 5 days.
Every 24 hours the number of prey consumed and eggs laid was recorded. Then the females were moved to new discs with the same amount of prey.

The experiments were conducted at 21°C ± temperature and relative humidity 60 - 80 per cent.

RESULTS AND DISCUSSION

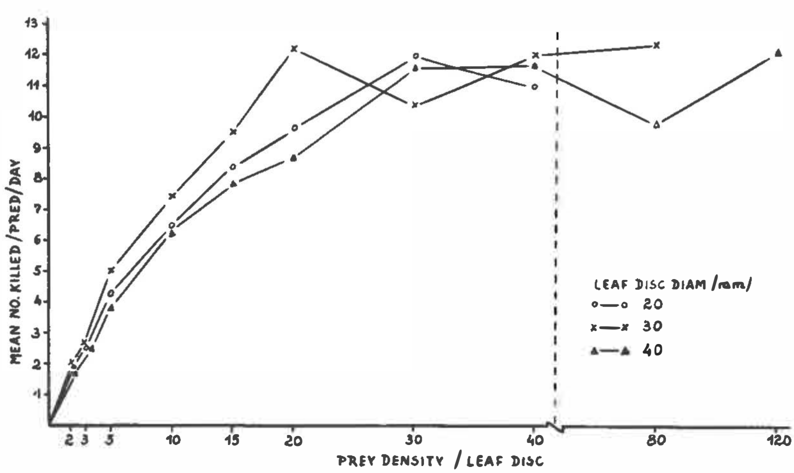
The results obtained are shown in tables 1 and 2 and in figures 1 - 4.

Table 1 Mean number prey killed and oviposition rates/female/day of *P.persimilis* on bean leaf-discs

Prey density	Leaf disc diam/mm 20		30		40	
	Prey killed	Eggs	Prey killed	Eggs	Prey killed	Eggs
2	1.94	0.56	2.00	0.62	1.76	0.47
3	2.51	1.03	2.67	0.86	2.50	1.00
5	4.34	2.12	5.00	1.72	3.90	1.21
10	6.50	2.50	7.46	2.03	6.40	1.45
15	8.45	2.85	9.55	2.44	7.90	2.23
20	9.59	2.82	12.20	2.95	8.70	2.26
30	12.00	2.69	10.40	2.75	11.60	2.71
40	11.05	2.74	12.10	2.85	11.80	2.90
80	-	-	12.40	3.27	9.90	2.95
120	-	-	-	-	12.20	3.00

The prey consumption by *P.persimilis* females (figure 1, table 1) was independant of disc size. The females fed a little better on 3 cm discs and the greatest amount of consumed prey, that is 12.2, was obtained at the density of 20 deutonymphs per disc. On the discs of other diameters maximum was obtained at density of 30 deutonymphs and amounted 12.0 on 2 cm diam. discs and 11.6 deutonymphs per female on 4 cm diam. discs.

Figure 1. The average number of prey consumed by the predator on three leaf-disc diameters.



At higher prey densities the majority of results remained on the same level and no decrease in prey consumption by females described by Mori and Chant (1961) was found in our observations.
The difference in results obtained by us in comparison with those of Mori and Chant (1961) can be explained by the different prey used in the experiments. Mori and Chant used grown up females of *T.urticae* that laid eggs in the course of the experiment. According to our observations (table 2) predator females after 24 hours of starvation were more likely to feed on eggs than active stages of *T.urticae*.

Table 2 Analysis of the activities of *P.persimilis* for 2 hours period on bean leaf-disc 3 cm diam. at a prey density of 40 deutonymphs or all stages of *T.urticae*

Prey offered	Starvation	Accidental contacts (Ac) and average prey consumption (P)				Mean time eating
		Eggs		Active stages		
		Ac	P	Ac	P	
40 deutonymphs	No starvation	-	-	3.5	1.75	13.26
40 deutonymphs	24 hours starvation	-	-	7	2.1	45.59
all stages +	24 hours starvation	15	6.1	2.5	-	25.05

+ mean: 125 eggs, 23 active stages

When predator females were released on 3 cm diam. discs with all stages of *T.urticae* it was found within 2 hours that they fed only on spider mite eggs and during this time predator females destroyed on an average 6.1 eggs. At the same time in the other combinations the females without starvation period consumed on an average 1.75 and after 24 hours starvation consumed 2.1 deutonymph
The feeding on spider mite eggs was probably the reason for reduced feeding of the predator on females of spider mites observed by Mori and Chant (1961).
Figure 2 shows that the number of eggs laid by the predator females increased with increased prey density. In that case we can see distinct effect of disc size on number of laid eggs visible first of all at the prey densities from 5 to 30 deutonymphs per disc. The largest number of eggs laid by females on the smallest discs was 2.85 eggs per female at a prey density of 15 deutonymphs per disc. A little less eggs were laid by females on discs of 3 cm in diameter attaining the greatest number, 2.95,at 20 deutonymphs. The poorest results were obtained on 4 cm discs, at 30 deutonymphs per disc females produced an average of 2.71 eggs. From 30 deutonymphs per disc the fertility of the females on all discs was similar and remained at the same level.
However, if we take as a base for interpretation the number of deutonymphs per sq.cm of disc area, the results look quite differently (figure 3). It appears then, that the females fed most intensively on deutonymphs on the largest discs of 3 and 4 cm in diameter. In both cases the end of prey consumption increase took place at the number of 2.3 - 3 deutonymphs per sq. cm.

Figure 2. The average number of eggs laid by the predator on three leaf-disc diameters.

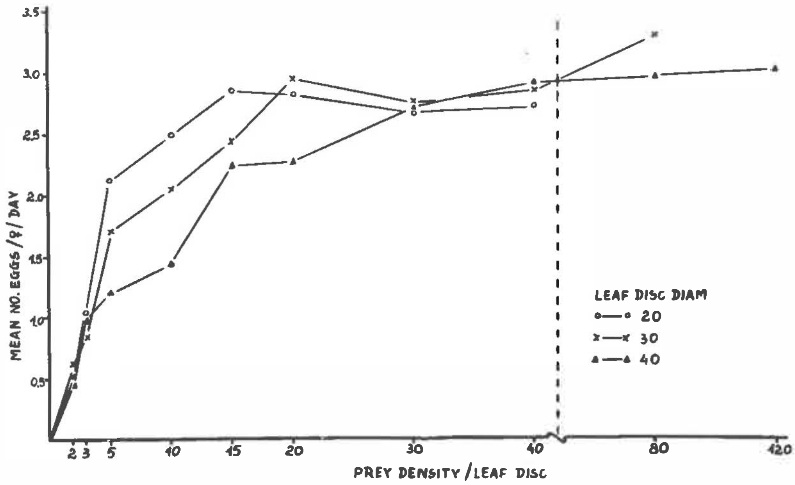
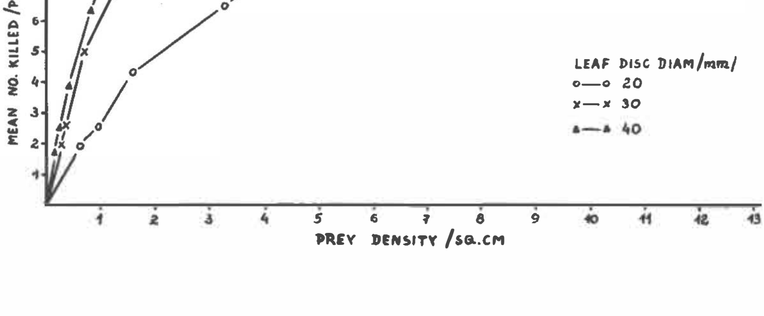
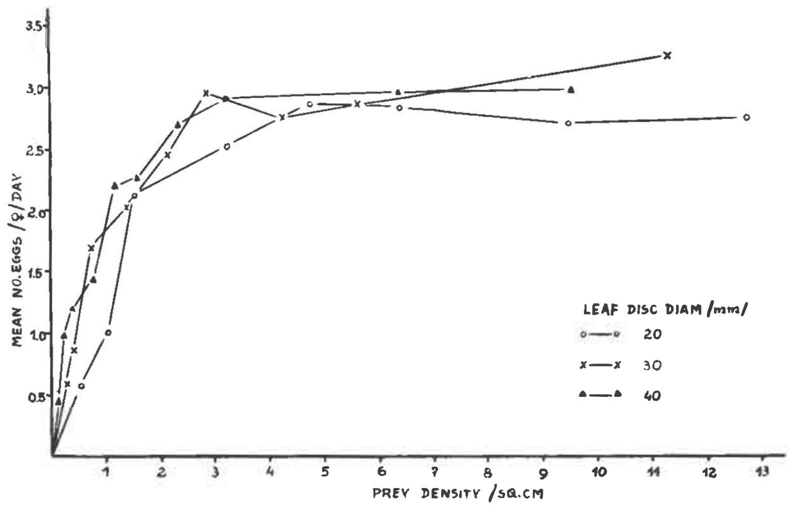


Figure 3. The average number of prey consumed on three leaf-disc diameters when prey density is counted per sq. cm.



Analysis of the eggs-production of the females on the same basis (figure 4) shows a great similarity in the results obtained on the different discs.

Figure 4. The average number of eggs laid the predator on three leaf-disc diameters when prey density is counted per sq. cm.



Increase in number of eggs laid by predator ended at the number of 2.7 - 3.3 deutonymphs per sq. cm for discs of 3 and 4 cm in diam. and 4.7 deutonymphs for the smallest discs. If we compare the results from the last 2 figures we see that in the experiments described the optimum conditions for predator females were reached at the number of about 3 deutonymphs per sq. cm, when prey consumption as well as egg laying were at a maximum. Different results were obtained on discs of 2 cm diam. and this might be explained by a too small disc area and frequent attempts of the females searching for prey to leave the substrate.

CONCLUSION

The purpose of this investigation was to find how prey density affects the prey consumption and oviposition of *P.persimilis*. The results obtained in our research indicate that *P.persimilis* has specific requirements in relation to prey density. Great similarity of figures refering to prey consumption and number of eggs laid at different prey densities indicate that it is possible to determine accurately the optimum prey density at which this predator will be most effective.
The need for such research seems to be very urgent because it might explain the migratory behaviour of *P.persimilis* searching for food at low prey density. Besides it might explain the changes in the predator populations when the optimum prey density has been passed.

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UTILISATION DES ENTOMOPHAGES POUR LA LIMITATION DES POPULATIONS APHIDIENNES EN SERRE

par

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Dans nos régions, les pucerons sont les principaux ravageurs en serre du fait de la rapidité de leur multiplication et de la gravité de leur dégâts directs et indirects. Ils sont en grande partie responsables de l'utilisation intense et répétée d'insecticides, dont les inconvénients sont exacerbés dans ce milieu: apparition de lignées résistantes, pullulations secondaires d'acariens, phytotoxicité, pollution des sols et des eaux de drainage. Ceci nous amène à rechercher d'autres solutions susceptibles de remplacer ou de limiter les interventions chimiques. Or, en serre, on ne peut compter sur l'introduction spontanée des auxiliaires souvent trop tardive ou insuffisante. En revanche, on peut agir sur les échanges avec le milieu extérieur en freinant l'invasion des pucerons et surtout en introduisant artificiellement des auxiliaires.
C'est tout d'abors un parasite de *Myzus persicae* Sulz, *Diaretiella rapae* M'Int (*Aphidiidae*), qui a été choisi pour les premiers essais de lutte biologique en serre. Il semblait en effet que ce puceron constituait le principal danger pour de nombreuses cultures maraichères ou ornementales et nous avions pu obtenir une souche de *D.rapae* bien adaptée au milieu serre. Nous avons pu effectivement montrer que ce parasite pouvait être élevé massivement, stocké et utilisé de façon pratique pour lutter contre *M.persicae* (Lyon, 1968). Il s'est avéré par la suite qu'en l'absence de traitement chimique, d'autres espèces, moins résistantes aux insecticides que *M.persicae* étaient susceptibles de causer d'importants dégâts alors que leur importance était souvent considérée comme secondaire en culture traditionnelle. C'est pourquoi nous avons fait par ailleurs en liaison avec l'institut Pasteur un premier examen des possibilités d'utilisation d'*Aphelinus asychis* Walk et comparé son action parasitaire à celle de *D.rapae*. Nous avons pu démontrer que l'utilisation simultanée des deux hyménoptères était parfaitement possible et fructueuse dans la mesure où leurs exigences éthologiques et écologiques complémentaires permettent une adaptation remarquable à de brusques variations des conditions de milieu et à un large éventail d'hôtes. Ceci a été confirmé par un essai sur poivrons où nous avons pu obtenir l'élimination de populations aphidiennes importantes avec une répartition spatiale très différente pour chacun des deux parasites en fonction des différences de microclimat au sein d'une même serre.
Une méthode d'utilisation des auxiliaires a été mise au point et décrite (Lyon, 1973). Indépendamment de l'association de 2 entomophages elle comporte deux aspects originaux:
1) L'alternance de la production intensive et de l'élevage en milieu serre où la souche, sélectionnée en fonction des conditions d'utilisation est régulièrement recyclée afin d'assurer la conservation de ses caractères d'adaptation aux cultures protégées.

2) L'introduction des auxiliaires en serre par deux techniques complémentaires: lâchers massifs et introduction en serre "d'unités mobiles de production permanente" de parasites. Ces dernières permettent la sortie des parasites mais non celle des pucerons. Elles assurent le maintien en serre d'une souche de parasites après la disparition des pucerons du fait de changement de culture ou de traitements chimiques et permettent une lutte préventive.
Actuellement nous adaptons notre méthode pour la production et l'utilisation de souche de Chrysopes et d'Hémérobes fournies par M. Canard (Faculté des Sciences de Toulouse). Bien que l'alimentation artificielle doive progressivement remplacer les pucerons, la méthode reste foncièrement la même.
Les essais de lutte biologique ont porté sur deux types de culture (ornementales et maraichères). Dans un premier temps, les productions ornementales régionales (roses et chrysanthèmes) ont été retenues au niveau de la Station.
L'obtention d'une souche d'*A.asychis* adaptée au puceron du rosier est un résultat intéressant: son utilisation peut en effet contribuer à réduire la fréquence des traitements. Mais la généralisation de la pratique de l'échelonnement des récoltes, dont l'état sanitaire doit être parfait, et la rapidité de la multiplication de *Macrosiphum rosae* incite à rechercher un agent de lutte plus radical (prédateur ou éventuellement entomophtorales, en liaison avec l'Institut Pasteur).
Sur chrysanthème, les résultats sont plus encourageants; malgré une infestation précoce, une récolte saine a pu être obtenue en évitant tout traitement (au printemps) ou avec un seul traitement localisé aux boutons floraux (à l'automne).
En outre, l'étude méthodique de la dynamique des populations à permis de montrer l'importance de l'influence variétale sur la multiplication et la répartition spatiale des pucerons et d'apporter des éléments en vue de définir une stratégie de lutte. La culture ne durant que 100 jours en échappe ainsi aux dégâts par viroses, qui ne se manifestèrent qu'au delà d'une durée généralement supérieure.
Actuellement, les cultures maraichères sont devenues l'orientation prioritaire du fait de l'importance des problèmes liés aux résidus d'insecticides. Une étude comparative de la dynamique des populations dans les conditions propres au Sud-Est a été menée sur tomates, poivrons et aubergines. C'est sur la tomate que les populations sont les moins fortes, bien qu'elles atteignent couramment plusieurs milliers de pucerons par pied en serre non traitée. Chez le poivron et l'aubergine, la rapidité des pullulations est foudroyante, la culture de poivrons étant la plus sensible. Là encore, l'influence variétale joue un rôle considérable. Cette étude a permis de définir les meilleures conditions d'utilisation des auxiliaires sur solanées maraichères. Durant deux années consécutives des cultures de tomates en lutte biologique ont été conduites, sans aucune utilisation de produits chimiques. L'influence des lâchers de parasites (*D.rapae* et *A.asychis*) a été clairement démontrée tant sur *M.persicae* que sur *M.euphorbiae*, de même que la possibilité d'utiliser simultanément deux parasites en mélange sans manipulation supplémentaire. La technique de suppression des feuilles basses infestées (Della Guistina, 1970) peut être utilisée, non seulement pour diminuer le niveau des populations aphidiennes, mais encore pour alimenter en pucerons nos "unités mobiles de production permanente" et restituer à la serre les parasites qui se trouvent sur ces feuilles.
Sur poivron, nous avons obtenus une éradication pratiquement totale des pucerons en pépinière, où les conditions se sont révélées très favorables à l'utilisation des parasites. En culture, nous avons comparé l'action des Chrysopes à celle des parasites et obtenu des résultats intéressants dans les deux cas, tant en cultures expérimentales - trois serres de 120 m^2 - que chez des particuliers (serres de 300 à 3000 m^2) malgré de fortes infestations initiales. Il faut signaler en outre le fait qu'un foyer d'acariens a pu être spontanément réduit par ses prédateurs naturels (*Phytoseiulus persimilis* notamment), grâce à l'absence d'intervention aphicide.

En conclusion notre méthode de lutte biologique a permis:

- sur le plan expérimental de tester les possibilités d'utilisation pratique en serre de divers auxiliaires sur différentes cultures ornementales et maraichères,
- sur le plan pratique, d'introduire la lutte biologique contre les pucerons en cultures protégées à l'échelle de serres d'exploitations maraichères et d'obtenir des récoltes de tomates et de poivrons normales sur le plan qualitatif et quantitatif, sans traitement insecticide.

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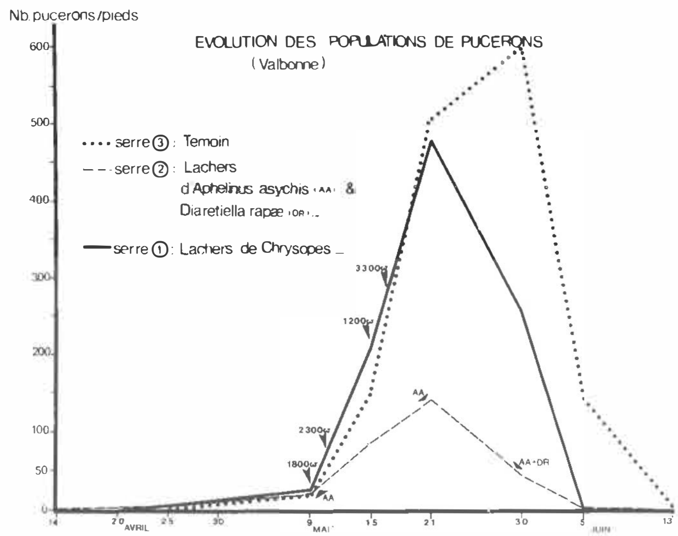

Introductions d'ennemis naturels dans une population de pucerons.

THE EFFECT OF SOME FUNGICIDES ON *TETRANYCHUS URTICAE* IN GLASSHOUSES

by

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The two-spotted spider mite, *Tetranychus urticae*, is a very polyphagous pest causing damage to a great number of plants as for instance vegetables, ornamentals, fruit trees, hops, cotton and strawberries.
All these host-plants are in practice sprayed with a great number of different fungicides against several diseases. Some of these fungicides have showed very peculiar side effects on the red spider mite: sometimes a stimulating, sometimes an inhibiting influence on the population of *T.urticae*. This influence seems also to differ according to the composition of the mite population at the time of treatment. It is not always easy to define whether this positive or n[illegible]e influence is a result of:

- a direct effecc of the compound on the mite itself (for instance adu[illegible]l, larvicidal or ovicidal action, reduced or prolonged viability, highe[illegible] lower fertility);
- or an indirect influence on the interrelations between host-plant and pest through a modification of the physiological status of the leaves of the host-plant (for instance higher nitrogen content of the leaves);
- or an elimination of some natural ennemies of the spider mite.

It seems that sometimes several causes may be involved at the same time.
The experiments of many authors e.g. Chaboussou, Post, Locher, Van de Vrie, Gunthart and Vogel and others have already furnished some information on this subject. The stimulating influence on the red spider mite has for instance clearly been proved for DDT, parathion and sevin.
In our own experiments we investigated the influence of some commonly used fungicides on the evolution of the population of the two-spotted spider mite *T.urticae* when applied in a regular programme to control various plant diseases.
The experiment was continued with one promising fungicide, inhibiting the mite population, in order to determine its mode of action.

MATERIAL AND METHOD

The investigations were realised on a normal population of the two-spotted spider mite, reared since years in a greenhouse on young *Phaseolus* bean plants which were never sprayed neither with acaricides, nor with fungicides.
For the trials we used small bean plants grown in pots with only two fully d[illegible]oped leaves; the new grow[illegible]-points always being suppressed.

At a given time, the plants were inoculated with 20 females per plant, every treatment in 4 replications. As these females were taken out of a mixed population their age was varying.
After 24 hours the inoculated plants were sprayed a first time with the fungicides. Eight days later a first series of plants was examined in the laboratory and the number of mites and eggs counted. The other series of plants were sprayed a second, a third and a fourth time, always at 7 days interval and new countings were also made 7 days after each spray.
Spraying took place with a little hand-spray under constant pressure. The upper- and underside of the leaves were sprayed until drip, the check plants were sprayed with water.
The plants were kept in a greenhouse at a temperature of about 22^{o}C and relative humidity of about 80%.

Compounds used and concentration (commercial formulation)

Dichlofluanid	Euparen	0,2 %
Orthocide	Captan 80	0,15%
TMTD	Pomasol	0,2 %
Wettable sulphur	Kumulus	0,4 %
Benomyl	Benlate	0,04%
Check	-	-

The results of the different countings after 1, 2, 3, and 4 sprays are given in table 1, and include the total number of eggs and mites for the 4 replications.

Table 1

Fungicide	number of mites + eggs after ..... treatments 1	2	3	4
Dichlofluanide	1,424	1,373	932	2,219
Orthocide	1,223	2,561	3,475	14,448
TMTD	835	406	315	366
Wettable sulphur	1,553	2,057	3,899	12,356
Benomyl	590	246	48	15
Check	802	1,873	2,994	7,540

The following conclusions can be drawn:
1. the mite population on the plants sprayed with Benomyl and TMTD and to a lesser extent with Dichlofluanide has been reduced in comparison to the population on the check plants
2. the mite population on the plants sprayed with Orthocide and with wettable sulphur is much higher than on the check plants.

Benlate, TMTD and dichlofluanide have severely inhibited the development of the spider mite while Orthocide and wettable sulphur have clearly stimulated it.
The importance of the inhibiting or stimulating effect during the 4 weeks of the trials whereby 4 sprays were applicated, is summarized in table 2.

Table 2

Check	Population increased	998,2	times
Dichlofluanide	increased	27,7	times
Orthocide	increased	180,6	times
TMTD	increased	4,6	times
Wettable sulphur	increased	154,4	times
Benomyl	decreased	5,4	times

Ovicidal action of TMTD

In order to define more accurately the depressing effect of Thiuram on the red spider mite, trials were realized in order to determine the share of the ovicidal action; five Thiuram preparations were used at 0,2%.
Twenty adult females were transferred on leaf discs of strawberries and allowed to oviposit during two days. After two days the females were discarded and the

leaf discs immersed during 2 seconds in the Thiuram solutions. Egg hatch was recorded daily and the young larvae removed immediately until no hatching occurred anymore on the check. Finally the non-hatched eggs were counted; the results are given in table 3.

Table 3 Ovicidal action of some Thiuram preparations, all used at 0,2%

Compound	Number of eggs present		% of non hatched eggs	
	A	B	A	B
Check	296	335	26,4	18,6
TMDT Ultra	291	237	91,2	95
Fungitex	294	277	76,5	88,8
Tripomol	304	281	84,9	73,3
Pomasol	248	316	90,8	77,5
TMDT Luxan	372	272	83,4	81,3

DISCUSSION

The results of these counts reveal that thiuram has a strong ovicidal action. This explains why the mite population when sprayed with thiuram remained low as compared to the development of the mite population in the check. The difference of the ovicidal action between the used thiuram preparations is not significant.

THE EFFECT OF ENVIRONMENT ON THE DEVELOPMENT OF AND BALANCE BETWEEN PESTS AND THEIR NATURAL ENEMIES

by

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Integration of pesticide spray programmes with biological pest management systems may be achieved in one of three ways, selective chemicals, discriminating doses, or careful timing of application. The use of temperature integrators, using the integral of time and temperature, are being developed to predict the stage of development of parasites on crops. This knowledge would enable sprays to be applied at the best time, i.e. when a parasite is in the pupal stage.
The developmental period of a parasite from egg to adult depends on temperature. A knowledge of the preoviposition period is a prerequisite for obtaining an accurate forecast of the developmental state of a parasite population.
Two parasites, *Encarsia formosa* attacking *Trialeurodes vaporariorum* and *Diglyphus isaea* attacking *Phytomyza syngenesiae* have failed to establish in glasshouses under low light intensity and/or short days. Laboratory studies at the University of Bath determined the effect of these factors on the oviposition of *E.formosa* and *Aphidius matricariae* during 24-hour periods of exposure to their host insects.

The effect of light intensity during a 16-hour daylength on the oviposition of *E.formosa* is shown in the Table from which it is clear that higher intensities favour parasite activity.

Effect of light intensity on oviposition of *E.formosa* - (16-hour photoperiod)

Light intensity (Lux)	Numbers of *Encarsia* tested	Numbers of *Encarsia* ovipositing	% oviposition
0	30	0	0
1050	30	0	0
2100	20	0	0
3150	30	0	0
4200	30	5	16.7
5250	35	12	34.3
6300	26	14	53.8
7300	30	30	100.0

Mortality of adult parasites was high (greater than 83%) at light intensities less than 4200 lux while at 5200 lux and 7300 lux mortalities during the 24-hour exposure period were 37 and 16% respectively. Further tests have shown that these figures give only a guide to trends because *Encarsia* maintained throughout their life on the experimental plants or leaves lay eggs at light

intensities below 250 lux, though less than when continuously kept in bright conditions.
Studies with the aphis parasite *Aphidius matricariae* have shown similar trends in that oviposition is greatly reduced by light intensities below 1500 lux maintained for a sixteen hour daylength. Oviposition increased with daylength, from 2% up to 66% at 12 hours. It was concluded that the oviposition of *A.matricariae* reached a maximum at a daylength of 13 hours and 20 minutes. Further tests with these parasites are being made to study oviposition throughout the adult lifespan. However, these tests are only of value if the reproductive potential of the respective host insects is also studied under identical conditions. Studies at G.C.R.I. have shown that both daylength and light intensity drastically affect the period over which aphids produce their young. The reproductive potential may therefore be affected, although the numbers of progeny produced may be the same.

EFFICACITE DE QUELQUES PESTICIDES DANS LA LUTTE CONTRE *TETRANYCHUS URTICAE* KOCH DANS LES CULTURES EN SERRE

by

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En Roumanie, les cultures maraîchères et de plantes ornamentales sont considerées parmi les plus susceptibles aux attaques des acariens, et surtout de l'espèce *Tetranychus urticae* Koch (Iacob, 1971a,b).
Dans les conditions éco-climatiques optimales offertes par le milieu des serres (temperatures au-dessus de 22-24 °C et humidité de 60 à 90%), les acariens phytophages représentent un danger permanent à partir du début du développement des plantes et jusqu'à la période qui suit la récolte.
Simultanément à l'introduction et à l'application des méthodes de lutte biologique il est nécessaire d'utiliser aussi parallèlement ou de façon intégrée, des produits chimiques à effet acaricide ayant une faible toxicité vis-à-vis de l'homme, des propriétés sélectives vis-à-vis des déprédateurs et une faible activité résiduelle sur les fruits ou sur les plantes comestibles.
Au cours des deux dernières années (1971 et 1972), plusieurs produits à action acaricide ont été essayés contre l'araignée rouge (*Tetranychus urticae*) infestant les cultures de piment, de concombres et de Callas en serre. Les essais ont été effectués dans les serres de la CAP de Dudeşti-Ciplea (Bucarest) sur plantes maraîchères et dans celles de l'I.O Sere de Boldeşti-Ploieşt sur plantes ornamentales.
Les produits essayés sont cités dans les tableaux 1 à 3. Leur efficacité a été déterminée en calculant le coeficient d'efficacité exprimé selon le critère de la mortalité des individues dans les variantes traitées, à la suite d'observations effectuées après 24 et 48 heures et ensuite à 7 jours d'intervalle.
Les expériences ètant exécutées avec une seule espèce d'acariens ravageurs sur plusieurs cultures, nous avons essayé de déterminer l'influence de la plante-hôte sur la capacité de résistance de l'espèce, sur le nombre des traitements et sur l'action des produits. Cette interprétation a été effectuée en utilisant la méthode de la covariance rapportée aux testages de produits (Iacob, 1973; tableaux 4 et 5).

RÉSULTATS

L'influence de l'action des produits acaricides testés, sur le niveau des populations d'araignées rouges, est présentée dans les tableaux 1 à 3.
L'analyse de ces données montre que la plupart des produits experimentés a eu une bonne efficacité après 24 heures, et généralement même après 7 à 14 jours, ce qui prouve la bonne persistence de ces produits. Omite E, Falon, Sintox, Carbicron, Owadophos, Neoron, Galecron,Pentac ont eu un effet remarquable dans les cultures de piment de même que les produits Lovozal, Acrex et Anilix dans

Tableau 1 Influence de l'action de certains acaricides dans la lutte contre *Tetranychus urticae* dans les cultures de piment

Produit	Efficacité, % après (jours)				
	1	2	7	14	21
Omite E	89	97	99	99	91
Falon	88	79	97	95	88
Sintox	97	92	91	84	62
Carbicron	73	99	100	95	86
Owadofos	91	96	96	88	48
Sumithion	97	84	98	74	44
Tetradifon	66	99	97	94	72
Neoron	95	94	100	100	100
Galecron	83	95	98	100	83
Pentac	90	74	94	99	83
Animert	66	53	88	84	74
Lovozal	92	69	88	98	89
Methyl parathion 158	88	75	75	75	75
Methyl parathion 157	73	80	80	-	-
Carbetox 155	43	70	70	-	-
Carbetox 156	39	77	77	-	-
Citrazon	71	69	69	-	-

Tableau 2 Influence de l'action de certains acaricides dans la lutte contre *Tetranychus urticae* dans les cultures de Callas (Ploieşti - Boldeşti, 1971)

Produit	Efficacité, % après (jours)			
	1	2	3	4
Lovozal	97	94	81	99
Animert	74	84	93	95
Acrex	93	92	100	100
Omite E	67	62	81	100
Owadofos	91	74	100	96
Neoron	71	75	84	-
Sintox	95	98	90	97
Pentac	89	77	90	98
Citrazon	80	79	90	93

Tableau 3 Influence de l'action de certains acaricides dans la lutte contre *Tetranychus urticae* dans les cultures de concombres (Dudesti - Cioplea, 1972)

Produit	Efficacité, % après (jours)			
	1	2	7	14
Lovozal	72	77	98	86
Anilix	88	91	100	100
Omite E	91	93	83	100
Galecron	85	99	92	98
Acrex	83	100	96	83

les cultures de concombres et de Callas infestés.
Les traitements dans les cultures de piments et de concombres ont été appliqués au début de la période de végétation (1 à 3 semaines après leur répiquage) évitant le risque de résidus sur le produit récolté.
Un autre group est celui des produits pour lesquels le coefficient d'efficacité présente des valeurs moindres. Parmi ceux-ci il faut citer Animert, Methyl-parathion, Carbetox et Citrazon employés dans les cultures de piments et Neoron dans les cultures de Callas.
En décomposant l'effet polyfactoriel représenté par l'ampleur de la covariance on a déterminé pour chaque essai, l'importance de chaque catégorie de facteurs afférents à l'essai.
La conclusion principale qu'on peut tirer de l'analyse des données présentées dans le tableau 4 est que les facteurs, représentés par la capacité de résistance du ravageur vis-à-vis des produits et par l'action directe et totale des produits, ont dans la plupart des essais des valeurs comparatives.
La seule exception à cette conclusion est l'essai sur concombres où, de l'effet polyfactoriel, l'importance des produits est le facteur déterminant (tableau 4).
Dans les essais sur piment, le facteur déterminant est représenté par le nombre de traitements, qui dépasse de 4 à 5 fois la variance des facteurs produits acaricides ou capacité de résistance. Dans ce cas la nécessité de l'application de deux traitements a déterminé une variabilité particulière. Certainement, ceci est aussi en corrélation avec la grande densité initiale des acariens et avec les conditions techniques de la culture qui ont favorisé de nouvelles infestations d'acariens pendant l'essai.
L'influence comparative de l'action acaricide et de la capacité de résistance du ravageur, exprimée toujours par l'ampleur de la covariance, est présentée pour chaque produit dans le tableau 5.
Ainsi que l'on peut remarquer de l'analyse des donnés présentées, à l'exception de 2 (Galecron et Owadophos) des 11 produits acaricides essayés comparativement sur plusieurs cultures attaquées par la même espèce de ravageur (*Tetranychus urticae*), chez tous les autres acaricides la variance déterminée par l'action du produit est nettement supérieure à la variance causée par la capacité de résistance du ravageur vis-à-vis des produits respectifs.
L'importance particulière de l'action directe du produit sur le ravageur, dans les conditions de l'essai sur plusieurs plantes-hôte, est attribuée à la faible capacité de résistance du ravageur. En ce cas, la plante-hôte n'a pas offert au ravageur une possibilité de résistance.
Cette méthode statistique d'essai des produits acaricides offre, en plus de données directes sur l'efficacité des produits vis-à-vis de l'espèce d'acarien, aussi la possibilité d'une interprétation corrélée à la capacité de résistance du ravageur par rapport à sa plante-hôte.

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Tableau 4

Influence des acaricides, de la capacité de résistance des ravageurs et du nombre des applications, exprimée par l'ampleur de la covariance, dans les essais de lutte contre *Tetranychus urticae* dans différentes cultures maraîchères et de plantes ornamentales

Plante hôte	Année	Localité	Capacité de résistance du ravageur		No. d'appli-cations		Produits acaricides		Facteurs accidentels
			Variance	F	Variance	F	Variance	F	Variance
Piment	1971	Dud.Cioplea	3720	7	11303	22	2359	4	510
Piment poivré	1971	Dud.Cioplea	673	4	-	-	648	4	154
Concombre	1972	Dud.Cioplea	63	1	-	-	7844	131	59
Callas	1971	Boldeşti	334	3	-	-	121	1	109

Tableau 5

Influence comparative de l'action acaricide et de la capacité de résistance du ravageur, exprimée par l'ampleur de la covariance, en fonction de la nature du produit acaricide sur différentes cultures maraîchères et plantes ornamentales, dans les essais de lutte chimique contre *Tetranychus urticae*

Acaricide	Cultures comparatives contenant des plantes attaquées	Capacité de résistance du ravageur		Action acaricide		Facteurs accidentels
		Variance	F	Variance	F	Variance
Galecron	Piment poivré/concombre	73	2	15	0,4	33
Neoron	Piment poivré/Callas	54	0,7	2054	26	76
Owadofos	Piment poivré/Callas	214	0,6	95	0,3	348
Sintox	Piment poivré/Callas	85	0,7	254	2	114
Animert	Piment poivré/concombre	181	0,4	13572	31	429
Acrex	Piment/concombre	196	0,9	3126	14	221
Citrazon	Callas/piment poivré/ piment	44	0,4	6854	58	117
Lovozal	Callas/piment poivré/ piment/concombre	192	0,9	4310	20	209
Omite WP	Callas/piment poivré/ piment	628	2	3708	14	261
Omite E	Callas/piment poivré/ piment/concombre	156	1	3176	20	158
Pentac	Callas/piment poivré/ piment	263	0,6	12221	29	417

STUDIES ON GENETIC CONTROL OF SPIDER MITES IN GLASSHOUSES

by

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Since the successful application of a genetic control method against the screw worm fly, *Cochliomyia hominivorax* (Baumhover et al., 1955) a considerable number of studies were started to investigate whether this approach of pest control could also be applied against other species.
Helle (1969) suggested that genetic control might be of use to eradicate spider mite populations in glasshouses. Successive application of various pesticides eventually will lead to multiresistance. From time to time there will be a need for new compounds and it is doubtful whether these will be always available. Therefore, in order to stop the process of the build up of multiresistance it is necessary to eradicate populations which are resistant to a good many pesticides. Thereafter when new immigrants will enter the area there is a fair chance that several pesticides can be used again for successful control. With respect to genetic control of spider mites, the idea was put forward that use should be made of the fact that in many instances there exists a certain degree of reproductive imcompatibility between populations of spider mites from different origin. The reproductive incompatibility is characterized by the fact that the hybrids obtained from crosses between such strains produce eggs of which a certain proportion is not viable. The degree of reproductive incompatibility may be up to 100%. By releasing overwhelming numbers of spider mite males in a glasshouse which are reproductively incompatible with the resident glasshouse population, the reproductive rate of the glasshouse population will drop soon due to the sterile hybrids that will appear. Repeated releases eventually would lead to eradication of the glasshouse population. This approach of control is only suitable for glasshouses, as glasshouses are more or less isolated areas. Although spider mite males can readily be reared in large quantities in the laboratory, it is not believed that a genetic control method can be applied on its own. Reduction of the glasshouse population beforehand is necessary to warrant any success. It is therefore suggested to use a pesticide against the glasshouse population at regular intervals and to release males which are resistant to the pesticide concerned. Releases of males should be made quite frequently, for instance every day. In order to prevent that resistance genes will be passed on to the resident population and to make complete eradication possible, a 100% reproductive incompatibility is necessary. Another point is that the males to be released should be sufficiently competitive with the resident males for successful matings with the females of the

glasshouse population. The studies made with respect to genetic control of spider mites mainly deal with these points, viz reproductive incompatibility between spider mite populations and mating competitiveness between different types of males

Reproductive incompatibility

Reproductive barriers between spider mite populations of different origin are commonly found (Boudreaux, 1963).
Helle and Pieterse (1965) studied the genetic affinities occurring between various populations of spider mites collected in different glasshouses in the area of Aalsmeer, the Netherlands. Mass crossing experiments were set up whereby 9 different strains were involved. Apart from a few exceptions, in most cases the percentages of nonviable eggs in the F_1 was fairly low. When the haploid eggs produced by the various types of hybrids were examined it appeared that the percentage mortality in the F_2 was considerably higher. Various degrees of reproductive incompatibility between the populations concerned were found. The degree of reproductive incompatibility was expressed by the percentage nonviability of the haploid F_2 eggs. These eggs were obtained from unmated hybrids. The highest degree of reproductive incompatibility was over 80%. Reciprocal differences were found in some instances.
Crosses between various laboratory strains kept in the Laboratory of experimental Entomology in Amsterdam revealed similar phenomena and in a few instances 100% reproductive incompatibility was found (Dieleman & Overmeer, 1972).
Screening for populations which are reproductively incompatible with a particular glasshouse population is one way to obtain suitable material for release. Another one could be: producing multiple translocation homozygote strains. Van Zon and Overmeer (1972) proved that translocation strains were easily established. Structural chromosome mutations were induced by X-irradiation and although there is no cytological evidence it is assumed that it concerns reciprocal translocations. By bringing such a translocation in the homozygous condition a single translocation homozygote strain is obtained. A number of different strains were made. High degrees of partial reproductive incompatibility with the original strain were found, from well over 50% up to 92%. Overmeer and van Zon (1973a) thereafter established a number of double translocation homozygote strains starting from a single translocation homozygote strain and the values of partial reproductive incompatibility between the original normal population and the double translocation homozygote strains ranged between 87 and 94%. By repeating these manipulations it must be possible to produce multiple translocation homozygote strains. It appeared that the triple translocation heterozygotes which were obtained from different crosses between double translocation homozygotes (♀♀) and single translocation homozygotes (♂♂) produced over 96% nonviable eggs up to 99.7%. For determining these values large egg samples, consisting of 700 to 3000, were examined. Recently 100% sterility was found in samples of three different quadruple translocation heterozygotes. These facts seem rather optimistic for genetic control of mites. However, it was found also that the translocation strains are not very stable. After two years of experience with rearing translocation strains it seems that in most of these strains the fitness decreases after a while which may be due to damage at the points of exchange in the chromosomes. Most of the stocks show increasing degrees of intrasterility and quite a few stocks have been lost already. Reduced fitness seems the rule rather than the exception although the reduction in fitness comes little by little.

Mating competitiveness

The establishment of translocation strains was also considered to be important with respect to a phenomenon discovered on other occasions which is called assortative mating. Smith et al. (1969) mentioned instances of mating preference of *Tetranychus urticae* females for males of their own strain when males of other *T.urticae* strains were also immediately available. The males belonging to the same strain from where the females were taken had relatively more offspring than males of other strains had. Similar results were found by Dieleman and Overmeer (1972) when these authors tried to demonstrate the possibility of genetic control of spider mites. It seemed that the females under study preferred to mate with males of their own kind rather than with males of another strain that was also used in the experiment. Although the males of the alien type attempted to mate quite frequently, the males of the females' own strain were more successful in inseminating the females. Such a phenomenon hampers successful genetic control.

It was hoped that assortative mating would not occur when normal males and translocation males derived from the normal population would compete. Both normal and translocation males would have the same genome and different behaviour during the mating act is then not expected. Whether this is true or not has not been established so far. However, in mating competition experiments with normal and translocation males there were still differences in successful matings. It seems, that these differences are mainly due to differences in activity and fitness of the males concerned. Though assortative mating is usually in favour of males belonging to the same strain as that of the females, we found one case of negative genotypic assortative mating (not published). Females of the so-called Nairobi-strain, collected in Africa, were more successfully inseminated by males of a dicofol resistant-white eye strain, originating from Moscow than by males of the Nairobi strain. When the two types of males mentioned were added in equal proportion to a large number of Nairobi females then the frequency of hybrid females was 3x that of the Nairobi females in the next generation. The explanation seems that when Nairobi females are present the dicofol resistanet-white eye males were readily accepted by the females and moreover they were far more active than the Nairobi males. This was not the case when dicofol resistant-white eye females were used in the experiment. Then the two types of males had female offspring in equal proportions. This phenomenon is still under investigation.

The small scale experiment of genetic control

So far we succeeded in controlling a Nairobi population by releasing dicofol resistant-white eye males under simultaneous spraying with dicofol at low pressure. The experiments was done in a small glasshouse of about 1000 sq feet. This glasshouse was divided into two halves each containing 200 rose plants. In one part of this glasshouse the genetic control method was applied integrated with chemical control. In the other part only chemical control was applied. The Nairobi population was brought into the glasshouse by putting 10 mated females on an average per plant. Then dicofol resistant-white eye males were released, about 500 per plant, every day. This is at least 10 times the expected number of resident males then present. Dicofol was sprayed at regular intervals from then on at a concentration of 15 ppm. Laboratory experiments revealed that such a dosage killed about 90% of the adult males and more than 50% of the adult females. The hybrids of Nairobi x dicofol resistant-white eye were hardly affected. The adult hybrids are characterized by the fact that their colour changes to red a few days after they emerge and they hardly produce eggs. After a few weeks no normal Nairobi females or Nairobi males were found any more in the part of the glasshouse where genetic control had been applied, whereas they were still found in the other part of the glasshouse. In this respect the integrated control had been a success. However, it appeared that the large hybrid mass present in the one half of the glasshouse caused serious damage to the plants. This damage could have been prevented in the present case by spraying with higher dosages of dicofol, since resistance to dicofol is due to the operation of a single nearly recessive gene (Overmeer & van Zon, 1973b) and, therefore the hybrids must be rather sensitive to dicofol. However, if in an integrated control programme the males released are resistant to a chemical to which resistance is based on a dominant gene then the hybrid mass cannot be controlled by this pesticide. Killing the hybrids, if possible, with another pesticide means in that case also killing the males that were released. All in all the successful results of genetic control studies obtained so far are more of academic interest than that they have any practical value as yet.

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POSSIBILITES D' UTILISATION D' UN NEMATODE ENTOMOPARASITE CONTRE LES NOCTUELLES EN SERRE

par

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INTRODUCTION

Une des méthodes de la lutte biologique consiste à enricher artificiellement le milieu que l'on désire protéger: cultures, vergers, forêts, par des micro-organismes utiles. Parmi ces derniers, les nématodes entomoparasites et plus particulièrement les Neoaplectanidae, représentent un secteur nouveau dont seules quelques potentialités ont été exploitées à ce jour.
La famille des Neoaplectanidae appartient à l'ordre des Rhabditida dont les représentants, qui ne sont pas phytophages mais saprophages ou bactériophages, forment la plus grande partie de la faune nématologique libre du sol. Le premier représentant de cette famille: *Neoaplectana glaseri* a été découvert sur le hanneton japonais *Popillia japonica* en 1929 aux U.S.A. Cette espèce fut élevée avec succès sur milieu artificiel mais les tentatives d'utilisation pratique, effectuées principalement contre son hôte d'origine, furent assez décevantes.
Ce n'est cependant qu'avec la découverte de *N.carpocapsae* en 1953 sur *Carpocapsa pomonella*, que les possibilités réelles de cette famille de nématodes furent mises en évidence. *N.carpocapsae* fut utilisé avec des résultats variables contre divers ravageurs: doryphore, pyrale du mais, mouche du chou, etc.
Bien qu'aux U.S.A. notamment, diverses recherches aient été entreprises pour tenter de l'élever sur milieu artificiel, la multiplication de *N.carpocapsae* pour l'utilisation en lutte biologique, s'effectue sur un insecte hôte, le plus souvent *Galleria mellonella*, élevé en laboratoire.
N.carpocapsae présente la particularité d'être associé à une bactérie: *Achromobacter nematophilus*. Cette association semble être, en fait, une symbiose entre le nématode qui sert de refuge et de vecteur et la bactérie qui crée, dans l'insecte mort, un milieu favorable pour le développement et la multiplication du nématode. Les bactéries sont localisées dans la partie antérieure de l'intestin du nématode. Les larves de troisième stade de *Neoaplectana* qui représentent le stade de résistance et le stade infestant dans le sol, pénètrent dans l'insecte en général par voie orale. Elles passent ensuite dans l'intestin dont elles traversent la paroi pour envahir la cavité générale. Les bactéries sont alors libérées et se multiplient très rapidement, provoquant une septicémie mortelle pour l'insecte. Les *Neoaplectana* muent alors deux fois, deviennent

adultes et plusieurs générations se succèdent alors dans le cadavre de l'hôte jusqu'à ce que toutes les ressources nutritives soient épuisées. Durant cette multiplication, les troisièmes stades néoformés migrent à l'extérieur de l'insecte et peuvent rester pendant plusieurs mois dans le sol sans s'alimenter, en attendant de rencontrer un nouvel hôte.

A la Station de Recherches sur les Nématodes d'Antibes, *N. carpocapsae* est multiplié sur *G. mellonella*. Deux souches sont produites en parallèle: la souche DD 136 provenant des U.S.A. et la souche Agriotos trouvée sur taupin *Agriotes linaetus* en U.R.S.S. Actuellement, la plupart des tests sont effectués avec la souche Agriotos qui semble la plus efficace.

Nous avons testé depuis trois ans *N. carpocapsae* contre divers ravageurs, en particulier les insectes du colza: *Psylliodes*, *Meligethes*, *Ceuthorrhynchus*, la teigne du poireau: *Acrolepia assectella* et diverses noctuelles polyphages: *Agrotis*, *Peridroma* sur artichaut. Tous ces essais sont réalisés dans les conditions normales de culture, c'est-à-dire en plein champ. Cependant, les exigences écologiques des nématodes en général sont relativement strictes et les Neoaplectanidae ont besoin en particulier d'une température assez élevée, supérieure à 13°, pour être efficace, ainsi que d'une hygrométrie importante pour survivre.

Ces deux conditions sont réalisées dans les cultures de serre et c'est pour cette raison que nous avons tenté une expérimentation avec la souche Agriotos contre les noctuelles polyphages sur salades. Ces essais ont été effectués en serre vitrée, dans les conditions normales de la culture de salades sous abri à l'automne, telle qu'elle se pratique couramment dans le Sud Est de la France.

MATÉRIEL ET MÉTHODES

Pour la commodité et la rigueur de l'expérimentation, nous avons réalisé une infestation expérimentale de noctuelles. L'espèce utilisée était *Agrotis ipsilon* qui avait été élevée au laboratoire jusqu'au troisième stade. Les *Neoaplectana* ont été appliqués sous deux formes différentes: en pulvérisation et en appats au son. Un insecticide réputé efficace, l'Endosulfan, a également été inclu dans le protocole pour comparaison.

La serre utilisée avait une surface de 100 m^2 environ. Elle avait été divisée en 25 parcelles élémentaires comprenant chacune, 3 rangées de 10 salades d'une surface approximative de 2 m^2 chacune. Chaque essai: nématodes en pulvérisation, nématodes en appats au son, insecticide et témoin, était composé de cinq parcelles élémentaires, soit 150 salades. Au début de l'expérimentation, les salades (variété Ostinata) avaient 15 feuilles en moyenne.

La température moyenne dans la serre a été de 16,3° et l'hygrométrie relative de 72,5%.

Les nématodes en pulvérisation ont été appliqués à l'aide d'un appareil de traitement standard. Ils étaient en solution dans l'eau additionnée de quelques gouttes d'un mouillant (Tween 20 de GUUR) non toxique pour les nématodes. Le feuillage était abondamment aspersé ainsi que le sol pour permettre aux nématodes d'être en contact avec les noctuelles aussi bien quand celles-ci se nourrissent dans le plant de salade que quand elles se déplacent sur le sol. La dose utilisée a été de 1 000 000 N dans 1 litre d'eau/m^2.

Les appats au son ont été obtenus en mélangeant les nématodes avec de l'eau et du son. Cette méthode est très intéressante car le son garde l'humidité pendant plusieurs jours, permettant ainsi aux nématodes de rester vivants nettement plus longtemps que dans le cas de l'aspersion et donc d'être efficaces pendant un laps de temps plus important. Le son n'était pas déposé sur les salades, mais uniquement sur le sol. La dose a également été de 1 000 000 N dans 12 g de son et 12 ml d'eau/m^2.

L'Endosulfan a été appliqué également sous forme d'appats au son et à la dose normalement préconisée : 2 g de matière active et 500 ml d'eau par kg. de son à raison de 60 kg de son/ha, soit 6 g/m^2. Là également, le son a été déposé uniquement sur le sol, ce procédé ayant l'avantage d'éviter tout contact direct

entre la plante et le produit.
Les traitements nématodes insecticides ont été effectués à 8 jours d'intervalle à partir de la date d'infestation avec les noctuelles.
En ce qui concerne les contrôles, une échelle de dégâts très simple a été choisie, en tenant compte essentiellement du niveau des attaques et du préjudice causé à la récolte:

+ attaques faibles ou D1 sans préjudice pour la plante,
+ attaques fortes ou D2, occasionnant des dégâts à la plante avec dépréciation à la récolte,
+ attaques très fortes ou D3 pouvant aller jusqu'à la mort de la plante et la rendant dans tous les cas invendable.

Ces contrôles ont été effectués tous les 8 jours à compter du premier traitement et sur la totalité des salades.

RÉSULTATS

Date des contrôles	Endosulfan			Nématodes + son			Nématodes pulvérisation			Témoin		
	D 1	D 2	D 3	D 1	D 2	D 3	D 1	D 2	D 3	D 1	D 2	D 3
18/10	11	10	0	29	8	0	29	11	0	13	45	2
23/10	19	13	0	17	16	3	13	14	1	5	44	21
3/11	17	19	4	15	23	9	9	27	11	0	31	38

% de dégâts d'*Agrotis ipsilon* en fonction des différents traitements

Les pourcentages de dégâts relevés au cours des trois contrôles, montrent que les meilleurs résultats ont été obtenus dans les parcelles traitées avec l'insecticide. On remarque en particulier la quasi-inexistance de dégâts D3, c'est-à-dire de dégâts entraînant la mort de la salade.

Il ne semble pas exister de différences sensibles entre les deux modes d'application des nématodes. Les résultats sont légèrement moins favorable qu'avec l'Endosulfan mais l'efficacité reste bonne, surtout si l'on considère les très forts pourcentages de dégâts D3 enregistrés chez le témoin. Le nombre élevé de chenilles distribuées sur le terrain a certainement contribué à l'homogénéité des attaques at à l'importance des dégâts. Ces conditions, rarement rencontrées dans la pratique à partir d'infestations naturelles, peuvent expliquer de ce fait le pourcentage élevé de salades fortement attaquées sur le terrain.
L'examen des pourcentages de dégâts dans le premier contrôle semble d'autre part montrer, si l'on considère les dégâts D1, que les nématodes n'agissent qu'avec un certain retard (29% de dégâts avec les nématodes en pulvérisation ou en appats contre 11% seulement avec l'insecticide). Cette constatation confirme les expériences complémentaires effectuées au laboratoire qui ont montré que, dans les conditions de la pratique, seules quelques larves infestantes de *Neoaplectana* pénètrent dans les chenilles. La mort ne survient qu'au bout de quelques jours et la multiplication des nématodes reste faible. Les chenilles contaminées peuvent donc, malgré leur vigueur diminuée, causer encore quelques dégâts aux salades
Si l'on fait abstraction des dégâts D1 qui sont économiquement négligeables, et si l'on tient compte globalement des dégâts D2 et D3, on peut noter que, dans le cas de l'insecticide, les résultats les moins favorables montrent quand même une réduction de dégâts de 66% par rapport au témoin. Dans les mêmes conditions, les nématodes appliqués en appats au son provoquent une réduction de dégâts de 54% et 45% en pulvérisation.

On constate, de plus, que le pourcentage de dégâts est en constante augmentation dans tous les lots, y compris l'insecticide, entre le premier et le dernier contrôle. Ceci peut s'expliquer, pour les lots traités, par la combinaison de trois facteurs:

- la sensibilité moins grande des chenilles de 4ème et 5ème stade aussi bien à l'insecticide qu'aux nématodes, ce qui est le cas à partir du deuxième traitement,
- la difficulté d'épandage des appats à partir du deuxième traitement, les plants de salades couvrant la quasi-totalité du sol des essais,
- la mobilité moins grande des chenilles de noctuelles qui trouvent dans les plants de salade déjà gros, à la fois une nourriture abondante et un refuge de choix.

CONCLUSION

Les résultats obtenus dans cette expérimentation montrent que la souche Agriotos de *N. carpocapsae* possède une bonne efficacité contre *Agrotis ipsilon* sur salade en serre. Bien que les deux méthodes d'épandage se soient avérées comparables, il semble que l'appat au son présente certains avantages, en particulier une plus grande durée de vie des nématodes due à la conservation de l'humidité dans le son en atmosphère humide, comme c'est le cas en serre. Une application préventive toutes les semaines, quand les salades sont encore jeunes, devrait procurer une bonne protection de la culture, surtout si l'on considère que, dans la pratique, les attaques de noctuelles sont très localisées et beaucoup moins fortes. *N. carpocapsae* s'est avéré également efficace contre les autres espèces de noctuelles polyphages des cultures maraîchères et il semble possible d'appliquer l'une ou l'autre des deux méthodes d'épandage dans d'autres cas de cultures sous serre. Il est également à noter que les nématodes peuvent se conserver dans le sol pendant assez lomgtemps, ce qui pourrait être un élément favorable pour diminuer le nombre de traitements dans l'hypothèse d'une rotation de la même culture dans la serre.

Les recherches doivent cependant être approfondies et il faudrait tendre, en particulier, vers une diminution de la dose employée (1 000 000 N/m^2), car la technique actuelle de multiplication de *N. carpocapsae* est onéreuse et ne permet pas, dans l'optique d'une utilisation pratique, de produire de très grosses quantités de nématodes à un coût peu élevé. La mise au point d'une méthode de multiplication sur milieu artificiel est donc primordiale.

Le fait d'utiliser des organismes vivants comme moyen d'intervention contre les insectes ravageurs est certainement contraignant car les impératifs biologiques et écologiques sont stricts. Les conditions favorables à leur emploi sont cependant quelquefois réalisées, c'est le cas dans le milieu serre. Les résultats favorables déjà enregistrés doivent encourager les recherches fondamentales sur les Neoaplectanidae tandis que les essais doivent être diversifiés et étendus pour apprécier encore plus exactement leurs possibilités en lutte biologique.

POTENTIAL OF INSECT PATHOGENS FOR CONTROLLING INSECTS UNDER GLASS

by

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Tactics of microbial control

Insect pathogens may be used to control pathogens in two ways - as introductions or as "microbial insecticides". An introduced pathogen, applied in modest amount, must spread and restrain the pest level below economic proportions. A sawly virus, for instance, succeeded in this manner in the huge coniferous forests of Canada. Usually, however, pathogens spread effectively only at high pest densities. When a pathogen will not spread adequately, it must be applied copiously as a microbial insecticide to cause disease in all or most of the pests present. Applied in this way, a pathogen is equally effective against sparse and dense pest populations.

Pests either maintain permanent resident populations in individual glasshouses or immigrate seasonally into glasshouses from the surrounding countryside. There is more hope of an introduced pathogen spreading and persisting in a resident pest population than in an immigrant population, although pathogens could curb immigration if introduced into populations in the surrounding countryside. At present, the use of microbial insecticides seems more promising than introductions.

The potential of the available groups of pathogens is summarised in a very general manner in Table 1. All these groups are under study at the G.C.R.I.

Table 1 Potential use of pathogens to control glasshouse pests

Pathogen	Speed of action	Modes of use
Viruses	Fairly slow to slow	Introductions in and around glasshouses. Some have potential as microbial insecticides
Protozoa	Usually slow	Introductions or microbial insecticides
Nematodes	Usually slow	Introductions or application of large numbers
Bacillus thuringiensis	Rapid	Microbial insecticide only
Fungi	Often rapid	Mainly microbial insecticide. Some by periodic introductions

Viruses, Protozoa and Nematodes can be grouped together as slow to fairly slow acting pathogens more suitable as introductions, although some at high concentrations cause acute disease capable of reducing a pest population rapidly. Any pests not acquiring a high dose usually succumb to chronic disease later. Some bacteria and fungi act rapidly and may be used as microbial insecticides. Work on two examples, *Bacillus thuringiensis* and *Verticillium* (= *Cephalosporium*) *lecanii*, is described in detail.

Bacillus thuringiensis

This bacterium is produced by commercial fermentation. Commercial products contain roughly equal numbers of spores of the bacterium and bipyramidal crystals of a proteinous toxin. The bacterium and its crystal toxin are specific to caterpillars of susceptible Lepidoptera, in some of which the crystal toxin is among the most potent known poisons. After being eaten, the crystal paralyses the caterpillar's mouth-parts, which prevents further damage to the plant crop. The lining of the caterpillar's gut is then destroyed and death may follow high dosages in as little as 2 hours. At lower dosages death is protracted over many days: the crystal upsets the gut enough to allow the spores to germinate and the bacteria to increase and overwhelm the insect. The bacterium does not spread naturally at pest infestation densities likely to be found in glasshouses.
An assay system, using bacteria-treated sprigs of chrysanthemum leaves, has been devised in the laboratory under constant physical conditions to simulate conditions deep in chrysanthemum beds in glasshouses. Dosage levels indicated by this assay were applied to potted chrysanthemums under glass and gave very good control of one of the commonest caterpillars, *Autographa* (= *Plusia*) *gamma*, the Silver Y moth. Subsequent tests on beds of chrysanthemums gave a good control of *A.gamma* and 4 other caterpillar species with a drenching aqueous spray containing 0.2 or 0.5% of the commercial product Dipel, when adequate leaf coverage was obtained, including the undersides of leaves. Labour requirements for spraying and material costs are high and *B.thuringiensis* at present is likely to be economic only when valuable natural enemies used in integrated pest control must not be harmed.
The laboratory assay is being used to compare accurately the effectiveness of different bacterial products. Products, such as Dipel, that contain bacterial serotype 3b are best. The assay is also being used to compare accurately the susceptibilities of different pest species of caterpillar. All six species so far bred, develop well on chrysanthemum leaf and so the same food plant can be used in the assays. The five species tested to-date fall in the moderately susceptible bracket.

Verticillium (= *Cephalosporium*) *lecanii*

Over the years since the Institute moved its present site, this fungus has appeared periodically under glass, mainly on aphids. It grows readily on agar media, producing heads of conidiaspores in mucilage. Three common chrysanthemum pest aphids, *Myzus persicae* (peach-potato aphid), *Macrosiphoniella sanborni* (chrysanthemum aphid) and *Brachycaudus helichrysi* (leaf-curling plum aphid) are susceptible. Work has been concentrated on *Macrosiphoniella* on the reasoning that, since it is least susceptible, the fungus used to control it should also control the other two species.
On all-year-round chrysanthemum beds with a normal commercial blackout regime under black polythene covers, naturally occurring fungus controlled aphid infestations rapidly only after the infestations had reached extremely high levels. The same fungus controlled sparse populations rapidly only when the plants were covered continuously with clear plastic. Thus artificial application of fungus is necessary to control sparse populations not continuously covered. An aqueous suspension of 10^8 spores/ml reduced a *Macrosiphoniella* population after 14 days with eventual control in 1 month, with clear covers shrouding the beds continuously. *Brachycaudus*, however, was completely controlled in 14 days. A spray of 10^7 spores was much less effective, eventual control being delayed.

Methods of laboratory study in accurately controlled environmental conditions have been developed to analyse the factors that control the interaction of fungus and aphid in the glasshouse.
In the laboratory, fungus was often visible under the microscope on the aphids two days after application of spores. At high spore concentrations, dead aphids appeared on the third day, 95% were dead in 3.7 days at 20^{o}C, virtually 100% R.H. and 16 hours daylength. Heavily diseased aphids continue to produce healthy offspring even on the eventual day of death. Because of the mucilaginous sheath spores are not readily released into the air, hence spread of the fungus occurs only when a healthy aphid touches a diseased one or its footsteps and spread is thus dependent on population density. Several consecutive sprays, timed to infect healthy aphid progeny before they mature and begin to reproduce, are therefore necessary to control sparse populations. Experiments with relative humidity alternating 12-hourly between 100% and 44% showed that the greatest kill was obtained when the humidity for the first 12 hours after applying spores was 100%. Thus sprays at sundown would be most effective.
A reproducible method of counting viable spores by germination on Sabouraud agar films on slides has been developed. Using this technique, it was shown that spores could be stored in water at 2^{o}C and at -19^{o}C, the half-lives being 180 and 80 days respectively. Spores died rapidly when exposed on glass slides to 60% R.H., the half-life being 1.2 hours and 85% dying in 8 hours. Possibly the mucilage from the spore heads which is washed away when harvesting the spores, is important for survival. Although survival on leaf may be better, work on formulation will be needed to improve spore survival.
A sensitive, reproducible laboratory bioassay has been developed, which will be used to study, among other things, the activity of different fungal strains and the susceptibility of different aphid species.
By combining the results of experiments in glasshouse and laboratory in an analytical ecological study, we intend to delineate the conditions under which *V. lecanii* will control aphid populations of various sorts and to understand the factors involved.

POSSIBILITIES OF BIOLOGICAL CONTROL OF PLANT DISEASES IN GLASSHOUSES

by

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INTRODUCTION

Biological control of diseases of glasshouse crops is a neglected area of research. It seems obvious that after having so many successes in biological control of glasshouse pests we should take a closer look at possibilities of biological control of plant diseases. I would like to give you some information about some developments in this area mainly in the Soviet Union and Eastern Europe.

Biological control of plant diseases in glasshouses can be conducted in three following ways:

1. by improving the phytosanitary conditions of the soil; this can be achieved by creating favorable conditions for the development of soil microorganisms producing antibiotics;
2. by increasing the number of antibiotic producing microorganisms in the soil by application of microbial fungicides to the soil or by applying them on seeds and bulbs;
3. curing the plants during their growth by spraying or dusting them with microbial fungicides.

The first two methods are especially useful in controlling pathogens attacking the root system of plants; the third method is mostly applicable in controlling diseases of plant parts above the ground.

CONTROL OF SOIL PATHOGENS

Such pathogens like *Fusarium*, *Rhizoctonia*, *Pythium* and *Verticillium* are responsible for a number of diseases of stem and root system of plants cultivated under glass. The method most frequently used to control these pathogens is sterilization or disinfection of soil and seed dressing. The two first methods are costly, laborious and destroy the useful soil microflora. The solution of this problem can be achieved by increasing the number of antagonistic soil microorganisms in order to destroy or eliminate the pathogenic microorganisms in the soil.

The soil microflora antagonistic to pathogens is very numerous. The number of such microorganisms can be increased by simple cultural methods such as: improving the soil structure, use of proper fertilizers and proper crop rotation. Among a number of antagonistic microorganisms the most important are fungi belonging to the genus *Trichoderma*. They are members of Fungi Imperfecti and produce different antibiotics; the best known is glyotoxin. The proper structure and humidity of the soil provides aeration of various layers of the soil and favors the development of *Trichoderma* spp. Some crops also favour development of such microorganisms. Gvozdjak (1966) has shown that the antagonistic microorganisms are most numerous in cucumber and cabbage crops and least numerous in tomato crops.

Proper fertilizing increases the number of antagonistic microorganisms e.g. *Trichoderma* spp. Morquer et al. (1967) showed that antifungal avtivity of *Trichoderma* increased when the contents of nitrogen in the soil increased to the level of 40-80 mg/100 ml. However, further increase of nitrogen content decreased the activity of *Trichoderma.*

The effect of *Trichoderma* developing in the soil is multilateral. It breaks down the cellulose, increases the concentration of easily assimilated phosphorus, potassium and nitrogen compounds, and accelerates the fermentative processes in the soil.

There is a quick and simple method of increasing the number of antagonistic microorganisms in the soil in order to eliminate the pathogens in the soil; this refers especially to *Trichoderma lignorum.* In fact in the Soviet Union there are some products containing spores and mycelium of *T. lignorum* which are used to control plant diseases (Fedorincik, 1965). These products contain also a great amount of nutritional substances which alow the fungus to establish and to multiply in the soil soon after application of the product.

These products are produced in three formulations under one trade name Trichodermin:

Trichodermin-1, is produced on grain and contains several milliards of spores of *T. lignorum* per gram of the product.

Trichodermin-2, is produced on chopped straw and other post-harvest materials and contains 3-4 milliards of spores per gram.

Trichodermin-3, is prepared on sterilized turf and contains 2,5 milliards of spores per gram.

There is different use of these formulations. The most concentrated Trichodermin-1 is used for seed dressing. Two other formulations that is Trichodermin-2 and Trichodermin-3 are applied to soil.

The Trichodermins are effective against diseases of many crops. For example Trichodermin-2 at the dose 30-35 grams per square meter lowered the infection of cucumbers with *Sclerotinia sclerotiorum* nine times and increased the yield (Kustova, 1972). The cost of such treatment is 8 kopeeks per square meter that is about 10 cents.

Different formulations of Trichodermin can be used to control various diseases of tomatoes, carrots, cabbage, ornamental crops and others.

The Trichodermins can also be used together with chemical fungicides for seed dressing or treatment of seedlings (Kustova, 1972).

Another method of preventing or controlling diseases of root system or stem basis of plants is seed dressing with antibiotics or phytocides.

Kolobkova (1969) showed that seeds of cucumbers treated with Trichotecin 0.01% were well protected against antracnosis and infection level dropped from 90% to 23%.

Beltjukova (1968) treated tomato seeds with Arenarin and found that significant decrease in number of plants infected with *Corynebacterium michiganense*, *Phytophthora infestans* and some virus diseases.

CONTROL OF PATHOGENS OF LEAVES AND STEMS

The control of pathogens attacking leaves and stems can be achieved by spraying and dusting of total plants or by seed dressing. Therefore, this method resembles the general procedure used at chemical control.

Several antibiotica and phytocides can be used for this purpose. Antibiotics are microorganism products mostly of fungus origin. On the other hand, phytocides are obtained from plant tissues by extraction.

At the very beginning medical and veterinary antibiotics were used for plant protection purpose. However, it was promptly stopped as it was felt that it can create some danger of causing resistance among microorganisms pathogenic to man and animals. At present, only such antibiotics are used in plant protection which are not related to antibiotics used in medicine.

To a group of antibiotics and phytocides proved to be very useful in plant protection belong: Trichotecin, Fitobakteriomycin, Arenarin and Imanin all

produced in the Soviet Union. Polyoxin and Blasticidin are well known Japanese antibiotics.
Trichotecin is obtained from a fungus *Trichotecium roseum* and is applied against phytopathogenic fungi and bacteria. In many a research it was proved to be very effective against cucumber mildew, cucumber antracnosis, fusarioses and bacterioses of cucumbers and tomatoes.
Fitobakteriomycin is obtained from *Actinomycetes lavendula* and is effective against *Phytophthora infestans* on tomatoes and against various bacterial and fusarial diseases of vegetables and ornamental crops.
Blasticidin is a Japanese product, a highly selective antibiotic effective against bacterial diseases of cucumber.
Polyoxin AL is also a Japanese antibiotic for agricultural use only. It is obtained from *Streptomyces cacaoi* var. *ascensis* and marketed as wettable powder. This antibiotic can be used on a number of plants: tomatoes, cucumber, carrot and other. Among many pathogenic fungi controlled by this antibiotic are: *Botrytis cinerea, Sclerotinia sclerotiorum, Sphaerotheca fuliginea, Colletotrichum lagenarium* and others.
Aremarin is a phytocide that is obtained by alcoholic extraction from flowers of *Helichrysum arenarium.* This product is very effective against virus diseases of tomatoes, *Corynebacterium michiganese* on tomatoes, *Cladosporium* and other diseases of vegetables.
Imanin is a phytocide obtained from leaves and flowers of *Hypericum perforatum.* It is a wettable dust containing two active substances. Imanin is effective against virus diseases of tomatoes, egg plant and others.

CONCLUSIONS

A survey of the literature especially of this in the Soviet Union indicates that biological control of plant diseases offers great perspectives. Therefore I would suggest that we should ask our colleagues plant pathologists to undertake intensive studies on the use of antibiotics and phytocides against various diseases of plants grown under glass. On the other hand entomologists should study the effect of these substances on pest species and beneficial arthropods used for biological control. One of the most important problems nowadays is to have such fungicides that are harmless to *Phytoseiulus persimilis, Encarsia formosa* and to other predatory and parasitic insects. So far no data are available on the effect of the above-mentioned antibiotics and phytocides on beneficial arthropods. Perhaps, incorporating these products into an integrated control programme of *Tetranychus urticae* and *Trialeurodes vaporariorum* will be easier than with several chemical fungicides.

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