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 glasshouse. 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 $\pm$ 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 introduction 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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