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WORLD SITUATION OF BIOLOGICAL CONTROL IN GREENHOUSES, WITH SPECIAL ATTENTION TO FACTORS LIMITING APPLICATION

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Summary

A survey is given of the activities of the working group on Integrated Control of Pests in Greenhouses of the International Organization for Biological Control of Noxious Animals and Plants (I.O.B.C.), which met four times since it was formed in 1970. Several integrated control projects have been put into practice with good success. On a steadily increasing area Encarsia formosa and Phytoseiulus persimilis are applied against the greenhouse whitefly (Trialeurodes vaporariorum) and the spider mite Tetranychus urticae respectively. Eleven countries apply those natural enemies, which are produced by five commercial rearing units. Two or three new natural enemies will be used in the near future to control aphids, leafminers and thrips.

A list of causes preventing or limiting application of biological control in greenhouses is given, the most important causes being: a) factors that make biocontrol unnecessary or impossible (pest does not occur, biocontrol in ornamental crops still difficult because of low insect tolerance on marketed products, climatological conditions may limit application, b) factors that hamper application of biocontrol which are related to insufficient guidance of the grower (bad condition of natural enemies and mistakes made at the introduction or check of development of natural enemies, use of wrong insecticides), c) all other factors that hamper application (total system of application too complicated, availability of new pesticides that cannot be integrated in existing biocontrol programs, limited research for new methods, insufficient training and education of extension officers).

The world greenhouse area is estimated to be 80.000 to 90.000 ha, on 20.000 ha biocontrol can potentially be applied, in 1979 biocontrol was applied on about 2000 ha, which is roughly 10 percent of the total potential area.

Biological control of pests in glasshouses has not been applied as long as biocontrol of pests in field crops. The purposeful use of natural enemies is said to have started around 1200 by the Chinese, who transferred ant nests to their citrus orchards to control insect pests. The real start of application of biological control was at the middle and the end of the 19th century with some striking successes, from which the vedalia beetle success is best known. A handful of those beetles was sufficient to save the Californian citrus industry. Later many other successes were obtained (DeBach, 1964, 1974; Huffaker, 1971; Huffaker & Messenger, 1976).

The history of biological pest control in glasshouses starts around 1930. Speyer (1927) observed that some of the greenhouse whitefly (*Trialeurodes vaporariorum*) pupae turned black instead of staying white. From these pupae small wasps of the genus *Encarsia* emerged. A few years later (1930) a research station in England was annually supplying 1½ million of these parasites to about 800 nurseries in Britain (Hussey & Bravenboer, 1971). At about the same time *E. formosa* was shipped to Canada, Australia, New Zealand and some European countries, among which the Netherlands.

After the Second World War distribution of *E. formosa* was discontinued in most countries because the newly introduced insecticides provided convenient and efficient control on most glasshouse crops. After a few years the first signs were observed of resistance of spider mites (*Tetranychus urticae*) to a number of pesticides. Research by Dosse (1959) and Bravenboer (1963) revealed a predator of spider mites that was able to efficiently reduce spider-mite numbers. A research group at the Glasshouse Crops Research Station in England put the method into practice and the revival of biocontrol in greenhouses was a fact. For a review of biocontrol in glasshouses in Europe before this period, see Greathead (1976).

After successful application of the predator of spider mites, the interest in whitefly parasites increased, because at the start of the 1970ties enormous outbreaks of whitefly populations took place and whiteflies frequently developed to pest status. The knowledge about the availability of an efficient parasite eased the development of a control programme and after some trials mass-rearing and introduction methods were available (Woets, 1973, 1978).

Since this revival biological control in glasshouses obtained a firm basis. The number of researchers on biocontrol and the number of countries with application of biocontrol increased steadily during the last decade. We will use data of the meetings of the I.O.B.C. (International Organization for Biological Control of Noxious Animals and Plants) and data from a newsletter on biological control in glasshouses (Sting) to illustrate the developments during the last 10 years. In the second part of this paper factors will be discussed that limit the application of biocontrol.

Every three years the members of the working group on integrated control in greenhouses discuss the progress and problems of the preceding period. Although the working group started as a section of the European branch of the I.O.B.C., workers from the USA and Canada have usually joined the meetings and at the following conference we hope that Russian and Japanese workers will also be present.

The first meeting was organized in 1970 at Naaldwijk (the Netherlands). Application of biocontrol in greenhouses was still limited. The predatory mite *P. persimilis* was used in three countries (the Netherlands, United Kingdom and Austria) but only on a small area. Application of *E. formosa* occurred in the United Kingdom and Canada. At that moment one private company produced natural enemies (Koppert, the Netherlands). An important subject of discussion at this first meeting was the necessity to determine the effect of pesticides on natural enemies, and the availability of selective insecticides for the development of integrated control programmes. To obtain such integrated solutions, three ways of application of pesticides were studied:

1. spraying of chemicals at a time when natural enemies were not seriously harmed (separation of application in time; selective timing),
2. spot treatment so that only the most seriously attacked spots were sprayed (separation of application in space; selective spacing),
3. simultaneous treatment with selective chemicals (separation in action;

selective action).
The number of pests for which biocontrol possibilities were studied was three: *T. vaporariorum*, *T. urticae* and aphids. Several authors pressed for the selection of pesticide-resistant natural enemies and pest-resistant plants (see Table 1).

At the second meeting held in 1973 in Littlehampton (U.K.), it became clear that application had increased: in five countries *P. persimilis* was used and in two countries also *E. formosa* was applied (see Table 1). Four companies produced natural enemies, one in Finland, one in the Netherlands and two in England. The main topics discussed were the results obtained in practice with different introduction schemes. Many papers dealt with basic research for development of good mass-rearing and introduction schemes. The number of pest species increased to four: control of Lepidoptera with nematodes was added to the list. Much time was devoted to the topic of biocontrol of aphids, being a group of species the chemical control of which frequently interferes with biocontrol of other pests. Results about control of the green peach aphid (*Myzus persicae*) with predators, parasites and pathogens were presented; a sufficiently cheap solution was not yet available. Further, the possibility to use pathogens for several glasshouse pests was discussed.

At the third meeting, in 1976 in Antibes (France), a further increase in application was established. The number of countries using biocontrol increased rather fast, and the area on which *E. formosa* and *P. persimilis* were applied increased substantially. In eleven countries *E. formosa* was used and nine of these also applied *P. persimilis*. Five commercial organizations produced natural enemies. Basic research for development of biocontrol of new pests or for perfecting the already applied methods was the main theme of this conference (see Table 1). Biological control of aphids was again considered as the third important step in the progress of the working group. In Finland a sufficiently cheap method to control aphids with predators was almost ready. In the Netherlands an organo-phosphorous resistant strain of *P. persimilis* was available. Further, *Thrips tabaci* was added to the list of species for which biocontrol possibilities were studied.

Last year's meeting at Vantaa (Finland) provided the following data. Eleven countries applied both *E. formosa* and *P. persimilis*. In one country the predator *Aphidoletes aphidimyza* was used in commercial crops to control aphids, in another country the first application of parasites against tomato leafminers was tested in commercial holdings. Most papers were about the basic research and application of *P. persimilis*, *E. formosa* and aphid parasites and predators. A new pest obtained attention from workers from several countries: the leafminers *Liriomyza sativae* in Canada and *L. bryoniae* in the Netherlands. In Scotland a strong development was observed of the tomato moth *Lacanobia oleracea*: it has been the main pest there for a few years now. Biocontrol methods for two pests, thrips and tomato leafminer, will apparently be put into practice before the following meeting of the working group. We hope that more countries (especially Japan, which has a tremendous greenhouse area) will try to put already existing methods of biocontrol into practice instead of doing a lot of basic research.
It is a rather negative sign that at the meetings more and more time is spent on discussing basic research only, because we cannot perceive a proportional increase in application.

After this optimistic part of the paper we will continue with a survey of the greenhouse area treated with biological control (Figure 1). For some countries only rough estimates were available, though more detailed

Table 1 Survey of activities of the working group on Integrated Control of Pests in Greenhouses I.O.B.C.-W.P.R.S.

year	1970		1973		1976		1979	
participants	9		22		25		36	
countries	8		10		8		12	
papers, main topic								
practical application	2		5		4		8	
experimental application	2		2		2		2	
basic research	2		7		14		19	
effect of pesticides on natural enemies	4				3		1	
limiting factors							4	
others	1		3		2		2	
total papers	11		17		25		36	
number of natural enemy producers	1							
pest species studied	research	application	res.	appl.	res.	appl.	res.	appl.
whitefly	6	1	3	2	9	4	8	10
spider mite	7	3	7	4	6	5	5	9
aphids	2		4				12	2
thrips					1		2	
moths			1				1	1
leafminers							4	
number of countries with application of								
Encarsia	3		5		9		11	
Phytoseiulus	2		3		11		11	
Aphidoletes							1	
Dacnusa							1	

data will not change the general picture drastically. Reliable data for several East-European countries, the U.S.S.R. and China are lacking. The area on which biological control is applied increases steadily. More than fifty percent of all biological control application occurs in the Netherlands, although their greenhouse area is not the largest: it ranks third after Japan and Italy (see Table 2). In the U.K. another 20 to 30 percent of the total application takes place. So two of the eleven countries where biocontrol is used account for 75 to 80 percent of the total application.

If we compare the data on the area of biocontrol practice with the total greenhouse area (estimate for 1978: 80.000 to 90.000 ha) we see that still much remains to be done. In the second part of this paper we will discuss the question: 'Why is biological control in greenhouses not applied on a larger scale?'. Most of the causes we will discuss here were mentioned by a number of practical workers in this field of pest control at the latest meeting of our working group in Finland.

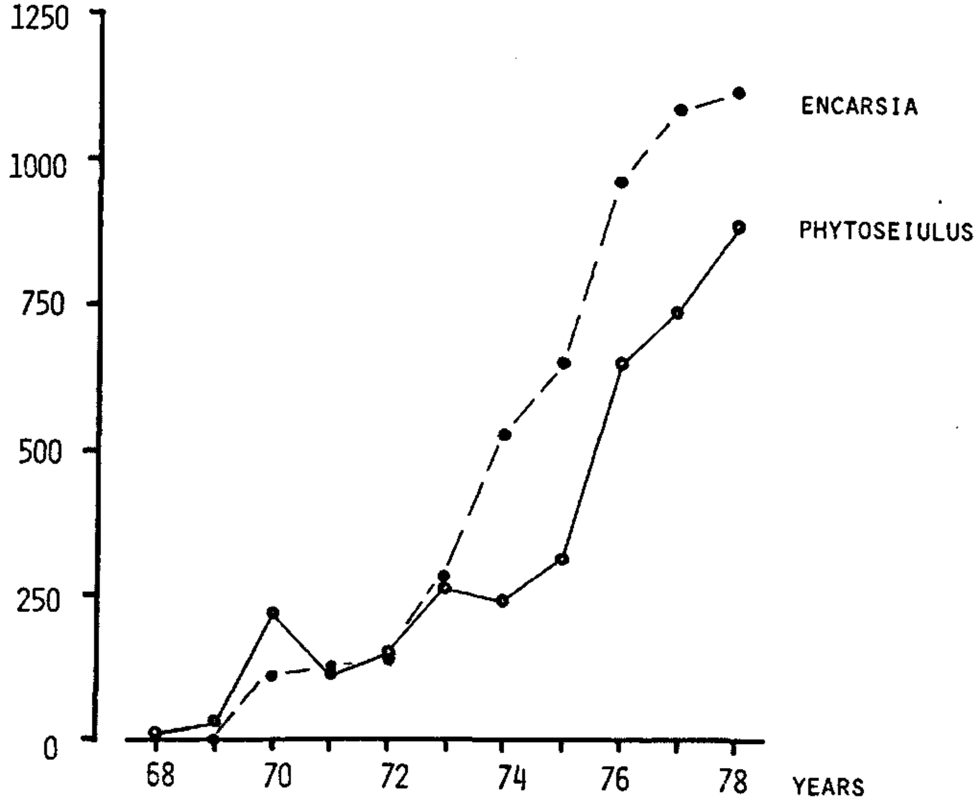

Figure 1 Total greenhouse area of the world on which biological control is applied

Table 2 Area with application of *E. formosa* and *P. persimilis* in greenhouses in the Netherlands and the United Kingdom as a percentage of the entire greenhouse area on which either *E. formosa* or *P. persimilis* is applied

		1976	1979
the Netherlands	*E. formosa*	50	55
	P. persimilis	65	55
United Kingdom	*E. formosa*	30	30
	P. persimilis	12,5	20

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1. Causes that make application of biological control unnecessary or impossible

1a. In greenhouses with a certain crop the typical pest for that crop does not always occur, or occurs so late in the season that control measures are not necessary. In the Netherlands about 95% of the tomato growers will have whitefly, whereas in some countries (e.g. Sweden, USA) the probability of whitefly attack is much lower because the greenhouses arenot as concentrated in large areas as in the Netherlands. Another example: the probability of attack of a tomato crop by spider mites is 90% in the Netherlands and only 60% in Scotland (Foster, pers. comm.).

1b. The data on areas with biocontrol are based on information given by the research and extension workers, which only have data about the growers who were officially supplied with natural enemies. It is well known that in several countries the growers obtain parasites and predators from their neighbours of have a small culture themselves. Official data are therefore certainly underestimated by about 5 to 10%. In fall crops we also observe sufficient parasitization by parasites that migrate into the glasshouse.

1c. In ornamental crops, which are grown in a large part of the total greenhouse area (50%), biocontrol cannot easily be applied, because even the minimum amount of pest individuals that will remain in a crop when biological pest control is applied cannot be tolerated and pesticides legislated for this kind of crop are often not compatible with biological control. We have to be careful before completely dismissing biocontrol for such crops, because checking of heavily sprayed ornamental crops sometimes also reveals still living pest insects, the number of pest insects being as high as or higher than crops treated with biocontrol.

1d. For some vegetable crops in which low pest populations can be allowed, biocontrol is impossible because the quality of the plants for the pest insect is such that the development of the pest population is too fast for the natural enemy that may be used with success in other crops. In other cases, the physical properties of the plants may hamper the natural enemy in its activities. Because of a combination of these two causes biocontrol by *E. formosa* more often fails in cucumber and eggplant than in tomato (van Lenteren & Woets, 1977).

1e. Climatological conditions may make biological control impossible. Too low temperatures during the long nights in a large part of the growing season makes application of *E. formosa* impossible in northern countries, whereas in the Mediterranean area it is frequently too hot and dry for application of *P. persimilis*.

1f. A number of pests may occur in the glasshouse that cannot (yet) be controlled by natural enemies or selective insecticides. If there is a large probability that such pests will occur, the grower is of course not interested in applying biocontrol for other pests. Examples of pests that cannot (yet) be controlled with natural enemies are *T. tabaci*, *M. persicae* and *Liriomyza* species.

However, these six causes still do not account for the large discrepancy between the total greenhouse area and the area treated with biocontrol. Considering these factors, about 20.000 ha remains for potential application.

2. A number of other causes hamper application of natural enemies in crops where biocontrol seems feasible. Several of these causes depend on the quantity and quality of natural enemies that are available and the service that growers may obtain from the producer and/or extension service. These problems usually do not occur in countries with large, concentrated greenhouse areas. In the Netherlands, for example, the large greenhouse areas attract a number of supporting industries and organizations (auctions, growers study groups, extension service, glasshouse factories, fertilizer and pesticide companies, producer of natural enemies, research station, etc.). An intensive network of interrelations exists in which information and use of biological control is also integrated. Most of these organizations supply guidance together with selling their products. This guidance can be given for a low price because the distances between growers and producers are so small. It is

common that salesmen of the natural enemy producer visit the grower frequently to check pest and natural enemy developments, and to inform the grower about integration with pesticides. If such large greenhouse areas do not exist, the growers are insufficiently guided by the natural enemy producer or by extension people. Natural enemies are sent by postal service and this may result in:

2a. a bad condition of the natural enemies on arrival,

2b. a too low number of the natural enemies on arrival,

2c. introduction of natural enemies at the wrong moment,

2d. because of lack of information and guidance the growers do not know how to check and evaluate pest and natural enemy symptoms and therefore corrections of mistakes due to wrong timing are not made or made too late,

2e. further, the grower may use pesticides that are not suitable for integrated control and exterminate his natural enemies by applying one of these pesticides, and

2f. bad guidance may also result in too much trimming of leaves with the result that a large part of the natural enemy population is destroyed before becoming effective if the leaves on which they develop are removed from the greenhouse.

Our experience is that good guidance is a first condition for application of biocontrol to be successful. Failures due to causes mentioned in this paragraph are not necessary and usually influence application of biocontrol very negatively.

3. Causes that hamper application that are not related to the way of production of natural enemies are the following:

3a. The total system of application may become too complicated for a grower. If more than three different species of natural enemies have to be applied and checked in one crop, the method may lose the attraction it now has for growers of greenhouse crops.

3b. The fast changing situation on the pesticide market regularly creates difficulties for application of biocontrol. Usually negative effects of new pesticides on natural enemies are not being studied before such a pesticide replaces an old one, but we hope that this will change in the near future as a result of the activities of the I.O.B.C. working group on 'Pesticides and Beneficial Arhtropods'.

3c. Many growers already using biocontrol methods ask for similar procedures to control other pests. Limiting is the amount of research for development of new methods. The biological control industry is still too small to invest in basic research. Research possibilities have to be provided by (semi)governmental institutions. Other ways in which the government could increase the application of biocontrol are education and training of extension officers and incorporation of data as meant under 3b in the legislation policy (Woets et al., 1980).

Finally some positive remarks after mentioning so many negative factors. The aim of a steadily increasing group of research workers is to develop as many biocontrol methods as possible against greenhouse pests. This research was started mainly to prevent and overcome problems due to resistance to insecticides. The international cooperation that was developed during the last 10 to 15 years stimulates research workers to reach this goal. The most important factor for our continuation, though, is the positive attitude of growers towards the use of methods for biological control of pests. They have this positive attitude because 1. chemical control of the main pests is difficult because of resistance problems, 2. more time is required to apply chemicals than to distribute natural enemies, 3. young plants are susceptible to application of

chemicals, 4. when biocontrol is used no safety period is required after application, 5. biocontrol is cheaper than chemical control (in 1979 tomato growers paid 9 dollarcent per m^2 for biocontrol and 25 dollarcent per m^2 f r chemical whitefly control). For further advantages of biocontrol in greenhouses see Van Lenteren et al., 1980.
In the Netherlands growers already ask for new parasites and predators before we ean provide them the necessary knowledge and a reliable method of application. This enthusiasm may, however, create its own problems, since it would be a serious blow to biocontrol if natural enemies were produced and released before their effectivity would be adequately checked.

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