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Working Group

"Integratred Control in Field Vegetable Crops"

OILB / SROP

Groupe de Travail

"Lutte Intégrée en Culture de Légumes"

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COMPTE RENDU de la REUNION

at / à

Einsiedeln (Switzerland)
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Edited by S. Finch & E. Brunel

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INTRODUCTION

Although pest control in most countries is currently based almost entirely on the application of commercially-produced insecticides, only three papers dealt specifically with this subject. Members now appear to have generally accepted that the main emphasis of this Group should be to develop methods that help to reduce the amounts of insecticide applied currently for pest control in field vegetable crops.

This emphasis was reflected in the contributions, as about 40% of them (11 papers) were concerned with developing systems for monitoring pest activity, for using such information in the production of pest forecasts and in using a combination of the two to develop systems of supervised control to indicate whether there are sufficient insects within a crop to merit the application of insecticide. The culmination of such work is the development of Integrated Production systems. Although Ernst Boller and Christian Gysi gave lucid accounts of the way such systems are being introduced in Switzerland, many participants had doubts about whether such systems could ever be implemented satisfactorily in the major vegetable producing countries.

The other three major topics discussed formally in Einsiedeln were host plant resistance (3 papers), insect predators and parasitoids of the cabbage root fly (7 papers), and intercropping/undersowing (5 papers). The latter shows considerable promise in cabbage and leek production but there are still some problems in scheduling the undersown crop to be at the correct growth stage to have the desired effect on pest control.

The meeting in Switzerland was appreciated greatly by all participants. I therefore thank Professor Ernst Boller from Wädenswil for his hospitality and Dr Erich Städler and colleagues for all they did with the local arrangements to make our meeting in Einsiedeln so enjoyable.

Finally, I thank Mrs S K Proctor, secretary of the Wellesbourne Entomology Department, for her invaluable help during the production of this Bulletin, and in particular for the marvellous job she did in re-typing the manuscripts into a standard format.

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Monitoring the flight periods of aphid pests of vegetable crops to forecast the timing of virus spread by aphids and when to apply control measures

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Summary

The flights of the main aphids pests of vegetable crops and related aphidophagous insects were monitored in an agricultural area, at Silves, in the Algarve, during 1989-91. The annual activity of *Acyrthosiphon pisum* (Harris), *Aphis craccivora* Koch., *A. fabae* Scopoli, *A. gossypii* Glover, *A. nasturtii* Kalt., *Brevicoryne brassicae* L. and *Myzus persicae* (Sulzer) were recorded from daily samples collected in a suction trap, operating 1.5 m above ground level.

Flights of the migrating aphids were analysed with respect to the variation in daily maximum temperatures, wind speed, atmospheric humidity, rain and the abundance of the natural enemies.

Catches of *M. persicae* or *A. craccivora* were correlated with the temperature sums accumulated from the first day of the year, in attempts to forecast the timing of alate outbreaks and the risk of virus spreading from crop to crop.

Besides indicating the appropriate dates for aphid control, this paper also suggests those periods of the year when insecticides that have the least harmful effects on beneficial aphidophagous insects should be employed.

Introduction

In an earlier paper (Cruz De Boelpaepe *et al.*, 1992) flight activity of the main aphid pests of vegetables and related aphidophagous insects were reported for an agricultural area in Southern Portugal.

Data from suction trap catches, started in 1989, were used to forecast the periods when vegetable crops, growing in the monitored area, were at risk of colonization and infection by aphid species known to be transmitters of virus. This kind of information is considered of crucial importance, particularly in cereal crops, to avoid economic yield losses from virus diseases (Rabbinge & Mantel, 1982).

The danger of virus outbreaks depends not only on aphid flights by also on the information given by virologists concerning the availability of source of inoculum from within the area.

The establishment of accurate forecasting systems required the study of the relationships between pest populations and local weather data (Collier *et al.*, 1992). Temperature and wind speed are the two main meteorological variables that influence the behaviour of migrating aphids (Dewar, 1982). Forecasts of aphid outbreaks can be derived from a series of equations which describe the relationships between the rate of increase in alate numbers and physiological time.

Besides suggesting appropriate dates for aphid control, this work indicates how certain insecticides should be selected to preserve the useful action of aphidophagous insects.

Materials and Methods

Monitoring of aphid flights was carried out at Silves, in the Algarve, from 1989 to 1991, using a suction trap that operated continuously at a height of 1.5 m. The insects caught were collected twice daily and counted in the laboratory.

The importance of vegetable crops in the area has been described previously (Cruz de Boelpaepe *et al.*, 1992). Each year, early crops are sown towards the beginning of February and late crops towards the beginning of September. Weather data, such as temperature, humidity and rainfall were recorded daily from a local meteorological station. The wind speed was available for periods of 10-days.

Results

Flight activity of the aphid pests of vegetable crops

Acyrthosiphon pisum (Harris), *Aphis craccivora* Koch., *Aphis fabae* Scopoli, *Aphis gossypii* Glover, *Aphis nasturtii* Kalt., *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulzer) were the most abundant aphid pests of vegetables caught during the sampling periods.

Flight activity of *M. periscae* and *A. craccivora* were computed from the numbers of aphids recorded in daily samples. The mean annual flight curve for 1989-91 and respective standard errors (upper limit) are shown in Figs. 1 and 2.

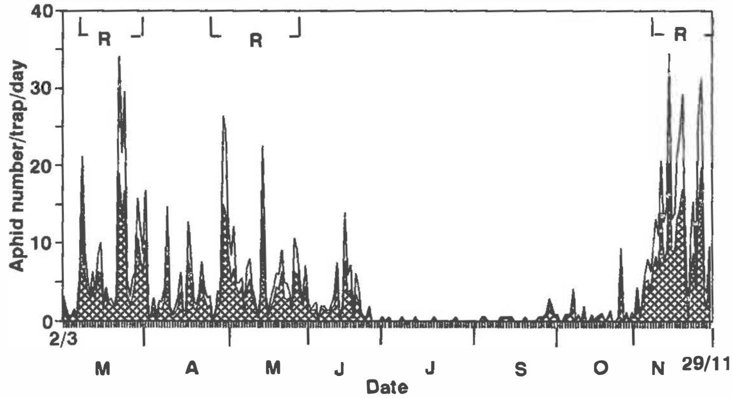

Fig. 1: The mean daily aerial abundance ▒ and standard error (upper limit) ☐ of *Myzus persicae* caught at a height of 1.5 m in a suction trap operating at Silves, in the Algarve, Portugal during 1989-91.

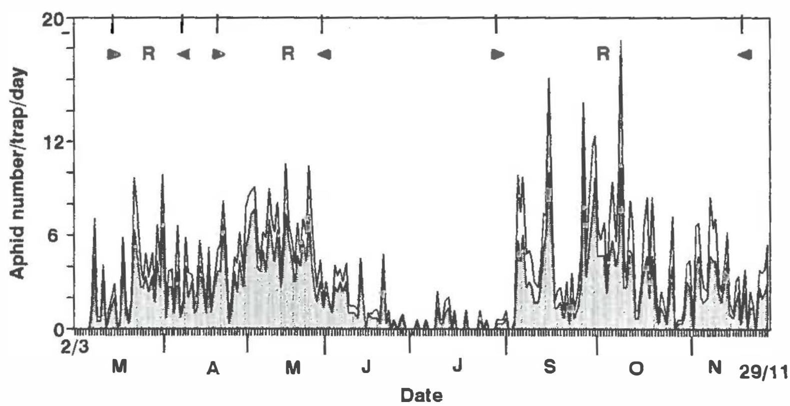

Fig. 2: The mean daily aerial abundance ▒ and standard error (upper limit) ☐ of *Aphis craccivora* caught at a height of 1.5 m in a suction trap operating at Silves, in the Algarve, Portugal during 1989-91

The high standard errors during the three years of sampling, indicate that aphid numbers varied greatly from year to year. Large numbers of aphids were caught in 1989, whereas very low and medium numbers were caught in 1990 and 1991, respectively. However, the periods when outbreaks occurred were similar for all three years.

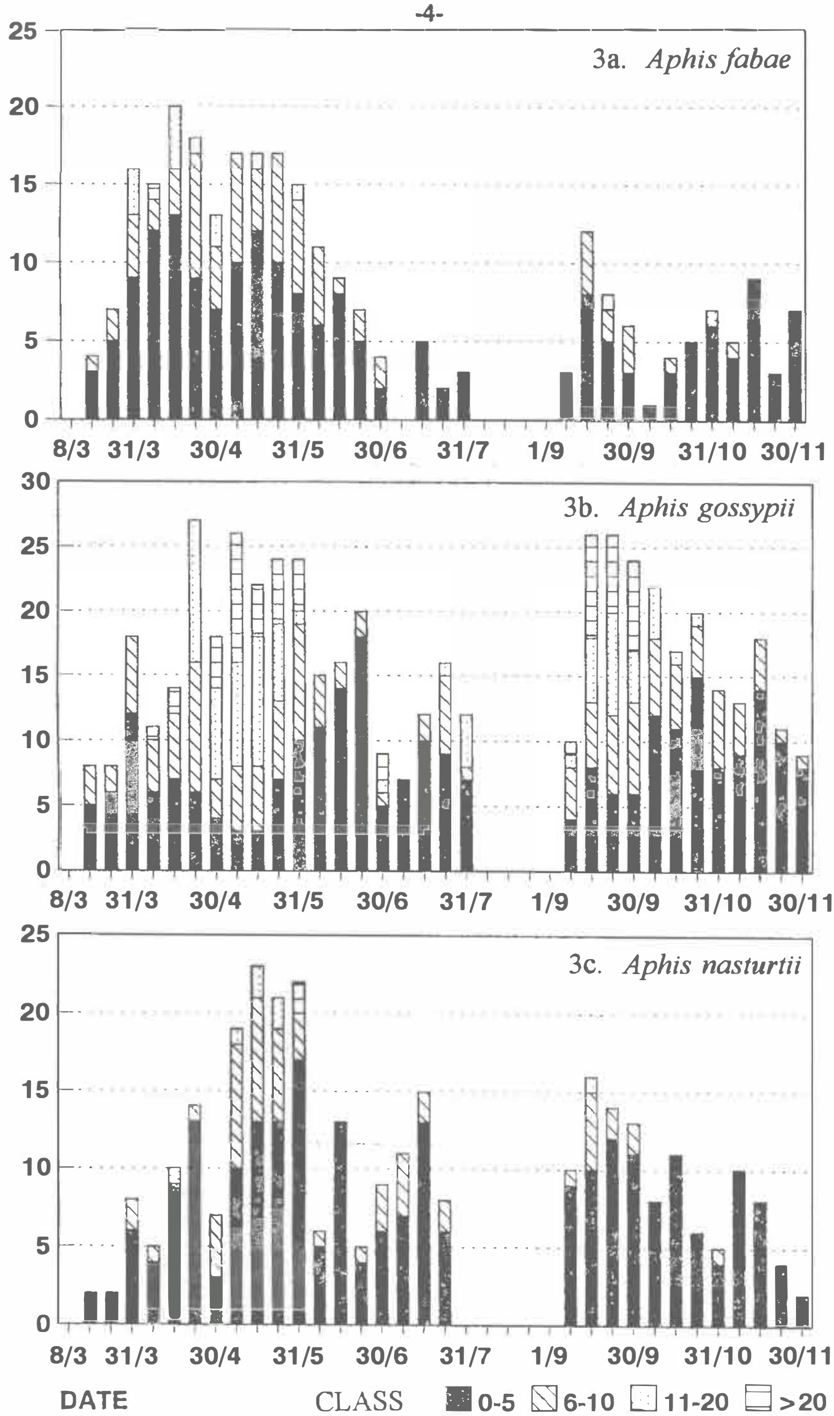

Fig. 3: Weekly frequencies, accumulated from 1989 to 1991, of four density classes of the alatae of *Aphis fabae* (3a), *Aphis gossypii* (3b) and *Aphis nasturtii* (3c) caught at a height of 1.5 m in a suction trap operating at Silves, in the Algarve, Portugal.

Outbreaks of alates of *M. persicae* occurred in March, May and November. In March, the spring flight of *M. persicae* could result in viral contamination and aphid build up within the early vegetable crops. In May, increases in the alate exules could spread the infection from crop to crop.

In autumn, alate populations of *M. persicae* consisted mainly of males and alate exules. Male aphids, which averaged about 14% of the total catch, appeared throughout November and migrated to the woody host *Prunus persica* L. Only the alate exules migrated to late vegetable crops to overwinter. Survival of aphid populations on vegetable crops during mild winters, created reservoirs of both infestation and infection for vegetable crops in the following spring.

Compared to *M. persicae*, the flight activity of *A. craccivora* was higher during September-October than during November (Fig. 2). The absence of the late peak might be because sexual migrants are not present in autumn populations of *Aphis craccivora*.

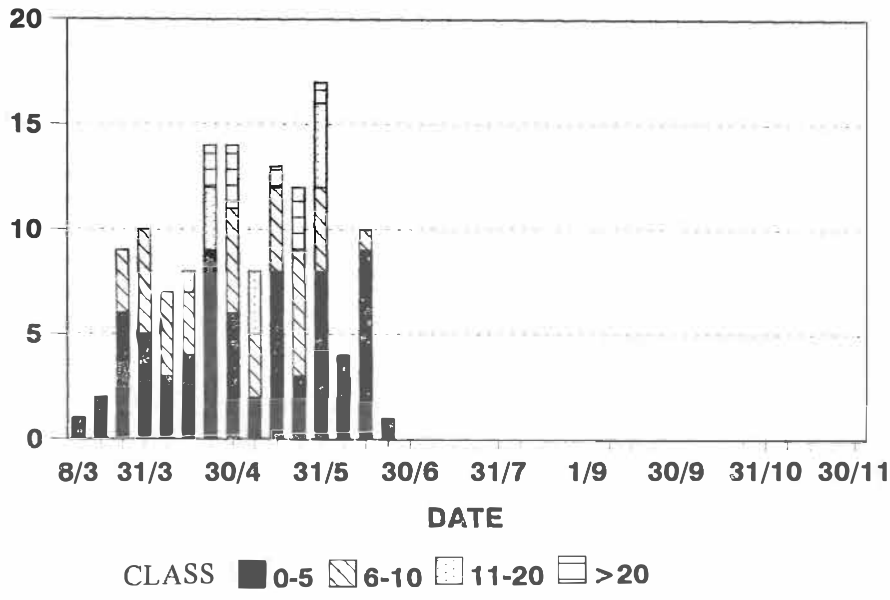

Fig. 4: Weekly frequencies, accumulated from 1989 to 1991, of four density classes of the alatae of *Acyrthosiphon pisum* caught at a height of 1.5 m in a suction trap operating at Silves, in the Algarve, Portugal

Aerial abundance of the remaining aphid pests of vegetables, such as *A. fabae*, *A. gossypii*, *A. naturtii*, *Acyrthosiphon pisum* and *B. brassicae* were exhibited weekly, by the yearly cumulative frequencies, from 1989-91, of four density classes (Figs. 3 a, b, c; 4 and 5). As the general flight patterns of the *Aphis* species were similar, the *A.* craccivora data were used, as the standard, to indicate the risk of virus spreading by *Aphis* species.

The danger of damage by species of the genus *Aphis*, became imminent from late March through May and from early September through November (Fig. 2). According to the flight peaks the risk of crop damage by *A. pisum* could occur during late April and late May (Fig. 4) and by *B. brassicae* during late April, early May and early September (Fig. 5).

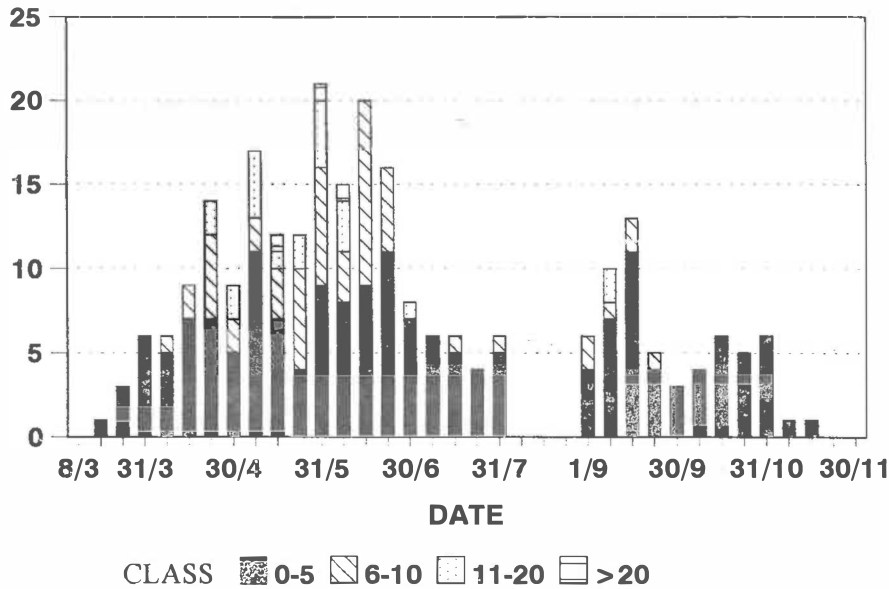

Fig. 5: Weekly frequencies, accumulated from 1989 to 1991, of four density classes of the alatae of *Brevicoryne brassicae* caught at a height of 1.5 m in a suction trap operating at Silves, in the Algarve, Portugal

Influence of weather on aphid flights

Several authors have demonstrated that flight activity of aphids is influenced by temperature, especially the maximum temperature (Dixon, 1978), wind speed (Davies, 1939; Dixon, 1978) and humidity (Davies, 1939). The effect of rainfall was also considered in the present analyses.

From March to late May, variations between 16°C and 25°C in the maximum daily temperatures (Fig. 6) were associated with general increases in the levels of alate activity. This range of temperatures was considered suitable to the progressive increase of aphid flights. Between early June and late September, maximum temperatures, frequently in excess of 28°C, were related to a sharp fall in aphid numbers, particularly of aphids like *M. persicae*. Members of the genus *Aphis* and *B. brassicae* seemed less sensitive to high summer temperatures. From October, the lowering of the maximum temperature gave conditions favourable for aphid flight.

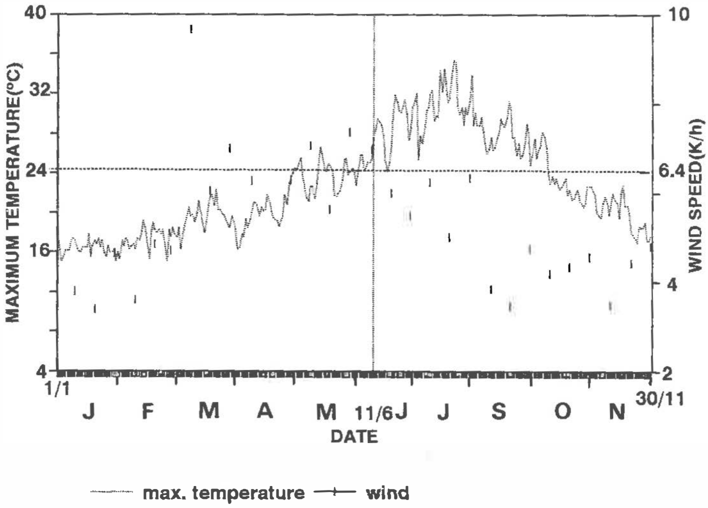

Fig. 6: The mean daily maximum temperature and the average wind speed, by decades, during 1989-91, at Silves in the Algarve, Portugal

Wind speeds above 6,4 km/h (4 miles/h), recorded in early and late March, early and late May and early June (Fig. 6) coincided with marked decreases, in catch, particularly of *M. persicae*. It is generally agreed that voluntary aphid flight ceased when wind speeds, at a height of 2 m, are in excess of 4 m.p.h. (Broadbent, 1946).

High humidities, above the limits for aphid flight (80%), could also have contributed to the low aphid catches at the beginning of March and at the end of May (Fig. 7).

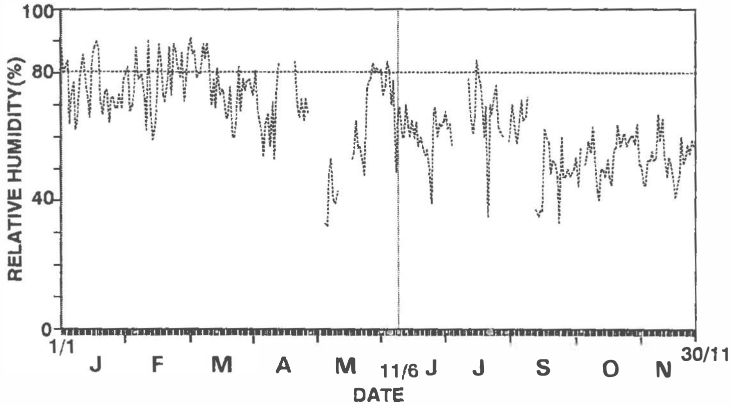

Fig. 7: The mean daily relative humidity, during 1989-91, at Silves in the Algarve, Portugal

High rainfall during April and mid-October (Fig. 8) coincided with decreases in the numbers of alate aphids caught.

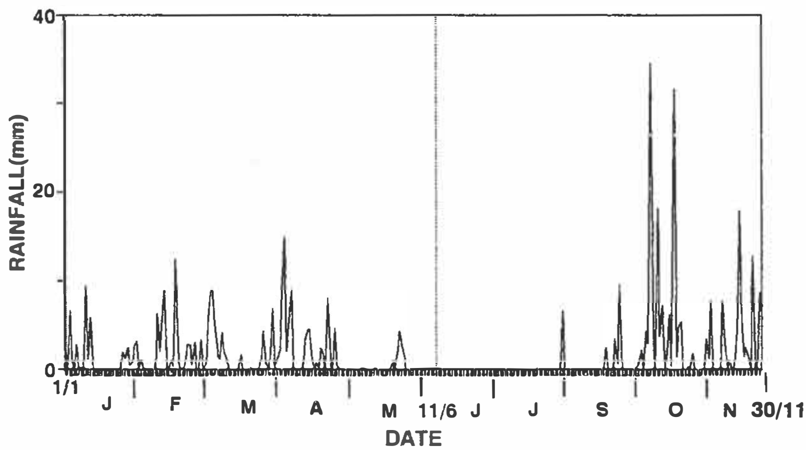

Fig. 8: The mean daily rainfall, during 1989-91, at Silves in the Algarve, Portugal

Aphid catches and related changes in the numbers of aphidophagous insects

Comparison between catches of aphids and their main parasitoids/predators, helps the farmers to choose the most appropriate insecticides to use.

The flight patterns of *M. persicae* was related to that of its parasitoid *Aphidius* Nees and that of the predator *Chrysoperla carnea* Steph. (Fig. 9). The numbers of the parasitoid peaked in late April and mid-May and were associated with decreases in the catches of *M. persicae*. The large increase in numbers of *C. carnea*, during June-July was correlated with a decline in aphid numbers.

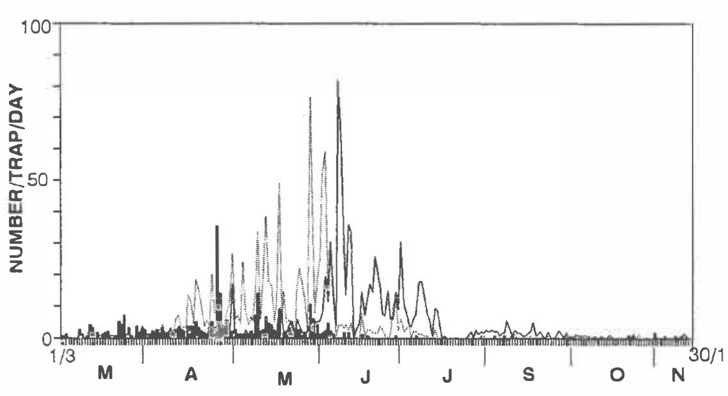

Fig. 9: The mean daily aerial abundance of the alatae aphidophagous insects of the genus *Aphidius* ▒ , *C. carnea* (——) and the genus *Lysiphlebus* (-----).

Comparisons between catches of *A. craccivora* or *A. gossypii* and their parasitoid *Lysiphlebus* spp. and the predator *C. carnea* (Fig. 9), indicated that parasitoids had a great potential for controlling such aphids during April to early June, whereas the predator became most effective when *Aphis* spp. were declining naturally.

Numbers of other *Aphis* spp., such as *A. fabae* and *A. nasturii*, were compared with the numbers of their parasitoids, namely *Lipoplexis* Forst. and *Lysiphlebus* Forst. The most effective control by both parasitoids could be accomplished during April-May (Fig. 10).

The considerable increase in catch of the parasitoid *Diaeretiella* Stary, during April (Fig. 10), was related to the activity of its main aphid hosts, *Brevicoryne brassicae* and *Myzus persicae*.

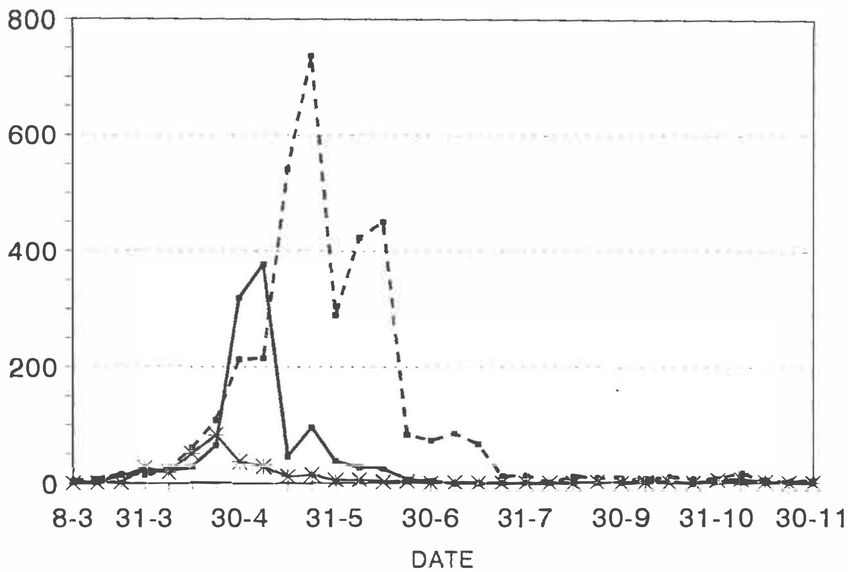

Fig. 10: Total weekly aerial abundance of aphidophagous insects, from 1989-91, of the genus *Diaeretiella* (——), *Lysiphlebus* (----) and *Lipoplexis* (*—*) caught at a height of 1.5 m in a suction trap operating at Silves in the Algarve, Portugal

Forecasts of the risk of damage to vegetable crops from alate aphids

Correlations between the cumulative catches of *M. persicae* or *A. craccivora* and accumulated day-degrees above 5°C (base temperature) from the first January, were computed from when the suction traps were started in (early March)) until the summer decline. Regression equations and determination coefficients (R^2) are shown below for both aphids for three years.

M. persicae	*A. craccivora*
In 1989: Y = -242.32+0.64 x; R^2=0.956	In 1989: Y = -198.52+0.41 x; R^2=0.985
In 1990: Y = -28.42+0.06 x; R^2=0.947	In 1990: Y = -107.76+0.18 x; R^2=0.976
In 1991: Y = -88.07+0.34 x; R^2=0.934	In 1991: Y = -155.18+0.34 x; R^2=0.972

From the above equations, it is possible to forecast the timing of aphid outbreaks and the risk of crop damage.

The periods of the risk of damage by *M. persicae* on vegetable crops, are indicated in Fig. 1. The first period, corresponding to aphid migration in the spring, and the second period, corresponding to virus spread between surrounding crops, were predicted to occur from 372 (± 61) to 750 (± 36) and from 956 (± 10) to 1406 (± 61) day-degrees, accumulated from 1 January.

The last period linked to autumn migration, was forecasted for the period between 949 (± 15) and 1206 (± 30) D°, accumulated from 1 September.

The forecasts for *A. craccivora* (Fig. 2) activity and other species of *Aphis* were calculated in a similar manner from their respective regression equations.

Conclusions

The numbers of *M. persicae* and *A. craccivora* caught during the three years of sampling varied considerably. Hence it is not possible to forecast on the basis of aphid numbers, but simply to establish the periods of the year when vegetable crops are at risk from invasion by alate aphids.

Analysis of the effects of abiotic factors on the behaviour of aphid migrants showed that maximum temperature was the variable related most consistently to changes in number of alate aphids. The temperatures favourable for aphid flight were between 15°C and 25°C.

Relative humidity was not generally a limiting factor, as the humidity level which inhibits aphid take-off was rarely exceeded.

Parasitiods and predators could control aphids most effectively during late spring and early summer.

The existing information on aphid flight periods, sources of virus infection and the potential of natural enemies to regulate aphid numbers indicate clearly that insecticides should be used in the periods when there is risk of crop damage. During such periods, selective insecticides should be alternated with less-selective insecticides. The choice of chemical should be determined by the abundance of aphidophagous insects at the time of spraying.

Acknowledgement

We thank Dr Stan Finch, of Horticulture Research International, Wellesbourne (UK) for his comments and help in revising this manuscript.

Résumé

Détermination des périodes de vol des puçerons ravageurs des cultures légumières afin de prévoir les dates de contamination des virus transmis par les puçerons et les dates des applications phytosanitaires

Les vols des principaux puçerons ravageurs des cultures légumières et des insectes aphidiphages ont été suivis dans une région agricole, à Silves en Algarve durant la période 1989-1991. L'activité annuelle de *Acyrtosiphon pisum* (Harris), *Aphis craccivora* Koch., *A. fabae* Scopoli, *A. gossipii* Glover, *A. nasturtii* Kalt., *Breviocryne brassicae* L. et *Myzus persicae* (Sulzer) a été enregistrée à partir des captures quotidiennes obtenues d'un piège à succion placé à 1,5 m au dessus du sol.

Les vols des puçerons migrants sont analysés en fonction des variations des températures maximum quotidiennes, de la vitesse du vent, de l'humidité atmosphérique, de la pluie et de l'abondance des ennemis naturels. Les captures de *M. persicae* et de *A. craccivora* sont corrélées avec les sommes de température cumulées à partir du premier jour de l'année, afin de prévoir la date des attaques des ailés et le risque de contamination des virus dans les cultures. Outre l'indication des dates qui peuvent justifier les traitements contre les puçerons, cet article suggère également les périodes de l'année ou les insecticides pourraient être utilisés en ayant le moins d'effets néfastes sur les aphidiphages auxiliaires.

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The flight activity of *Thrips Tabaci* (Lind.) in relation to cabbage and cereal crops

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Summary

Flight activity of *Thrips tabaci* (Lind.) was monitored in a cabbage crop using white water-traps that were emptied each day. Peak flight occurred on 4 July 1992 and on 12 June 1993. The numbers of *T. tabaci* found in plant samples taken weekly from cereal crops paralleled those recorded for the flight-curve. Most individuals were found on rye and wheat. Contrary to the theory that the mass-invasion of *T. tabaci* is from cereals into cabbage, no individuals of *T. tabaci* could be found in cereal crops before the onset of the mass-flight.

Introduction

Oedema on the leaves of cabbage, caused by *Thrips tabaci* is a considerable problem in cabbage production in the eastern part of Austria. If measures are to be taken to improve crop protection against *Thrips*, it is important to know more about the population dynamics of *T. tabaci*. In the USA, Thrips are reported to invade cabbage fields when cereals are harvested in adjacent fields (Wolfenbarger, 1958, Shelton, 1986). Our own results (Kahrer, 1991), also showed that there was a mass-flight of *T. tabaci* to cabbage fields, during which more than 300 Thrips could be caught/trap/day. Questions arose about the origin of these individuals and whether the swarming was a mass invasion from the ripening cereals as reported by Shelton (1986). The answer to these questions is also of importance for the establishment of a warning service, as it would be extremely easy for farmers to base their decision to spray by monitoring the ripening of cereals.

Materials and Methods

The experimental work was carried out in a 2 ha field at Seibersdorf, located about 50 km south-east of Vienna. This area has a pannonian climate, which is characterized by dry, hot summers. The main field crops are cereals, cabbage and to a lesser extent rape. A local variety of late-cabbage was planted in the middle of April. In the middle of May the experimental field was treated twice with a mixture of Pirimicarb and Deltamethrin. It was treated again with Deltamethrin in mid-August. The flight periods of *T. tabaci* were monitored using two white water-traps (dimensions 20 cm x 30 cm) placed on the ground (Czenz, 1985). A few drops of detergent were added to the water to lower the surface tension and hence help considerably in trapping *T. tabaci*. The traps, put out at the beginning of June, were emptied each day until the end of July. The insects trapped were preserved in alcohol, and identified using a dissecting microscope. Samples that did not contain any Thysanoptera that looked like *T. tabaci* were discarded. The remaining samples were prepared for inspection by heating the insects in lactic acid for 15 minutes and then embedding them in a mixture of chloralhydrate, glycerol and gum arabic (André's medium). This was done initially with insects caught on 12 separate days spaced at regular intervals across the sampling period. As only occasional thrips were found that were not *T. tabaci*, the insects caught on the remaining days were identified, without first being embedded, using a dissecting microscope .

At the same time as the flight of *T. tabaci* was being monitored with traps, *Thrips* numbers were also monitored in cereal crops. To do this, it was essential to develop first develop a method of extracting the *Thrips*. In a trial that started on 30 June 1992, 300 plants of wheat were divided into two sub-samples, one containing only the ears of the corn, and the other containing the rest of the plant. The sub-samples were placed into long plastic bags that were exposed to daylight at one end. The other end was in the dark and was left open to let the moisture escape. The bags were changed daily and their contents were preserved in alcohol. After 3 days, a total number of 106 *Thrips* had been extracted by this method. The results showed that 88% of the *Thrips* recovered were from the ears of the corn. After this preliminary test, the numbers of *T. tabaci* in samples from 2 fields, each of wheat, barley, rye and durum, were determined each week in 1993. The sample from each field contained 200 cereal ears collected at random. Sampling started at the beginning of June and ended when the cereal was harvested.

Results and Discussion

The timing of the mass-flight and several other peaks of activity of *T. tabaci* are shown for both 1992 (Fig. 1) and 1993 (Fig. 2). The numbers of individuals caught during the peak of flight activity, were similar to those in previous years, and reached up to 350/trap/day. The period when high numbers of *Thrips* were trapped lasted for more than three weeks. As in 1990 and 1991 (Kahrer, 1992), the mass-flight in 1992 occurred about 3 weeks before the wheat was harvested. In 1993, however, the mass-flight occurred 48 days before the wheat was harvested. From 1990 to 1992 the time of mass-flight coincided with the time when no more milky sap could be squeezed out of the grain of the corn. This temporal correlation did not hold in 1993, as the first peak of flight occurred 14 days before the milky-sap cereal stage. The distribution of *T. tabaci* in the different cereal samples is shown in Fig. 3: for the 530 individuals of *T. tabaci* that were trapped. Most individuals were caught in rye, followed by wheat and durum. Only small numbers were caught in barley. Fig. 4 shows the yield of the field crops in 1993 and indicates the area drilled with the various crops. It appears that, in that area, wheat crops have the potential for being the source of *T. tabaci*. The temporal distribution of the *Thrips* sampled from the cereals is shown in Fig. 5.

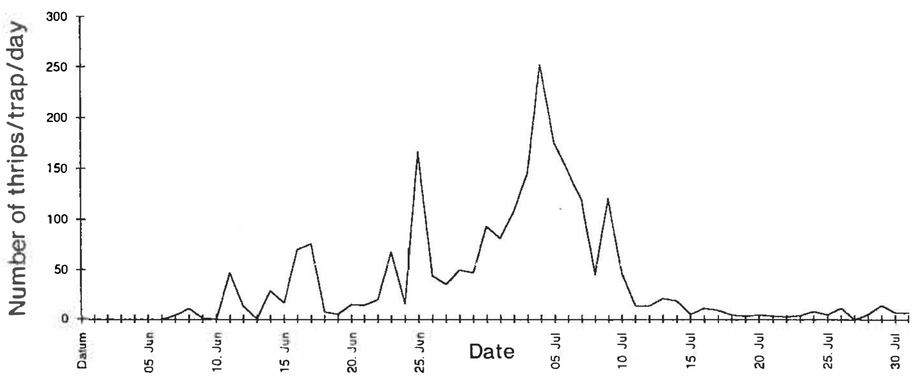

Fig. 1: Numbers of *T. tabaci* collected from traps situated in a cabbage field in Seibersdorf in 1992

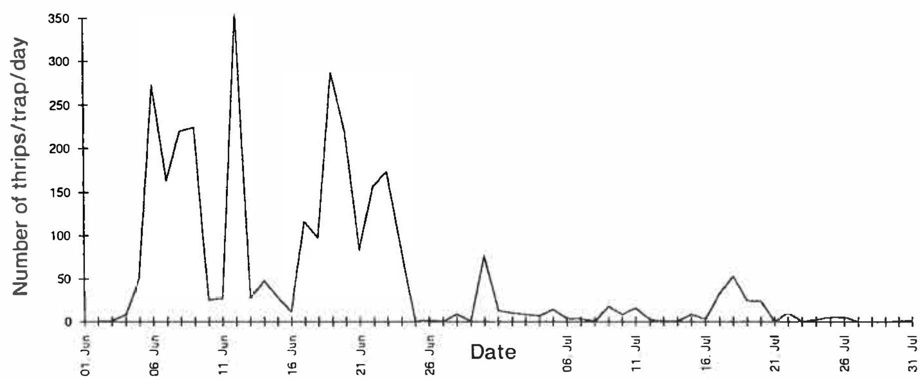

Fig. 2: Numbers of *T. tabaci* collected from traps situated in a cabbage field in Seibersdorf in 1993

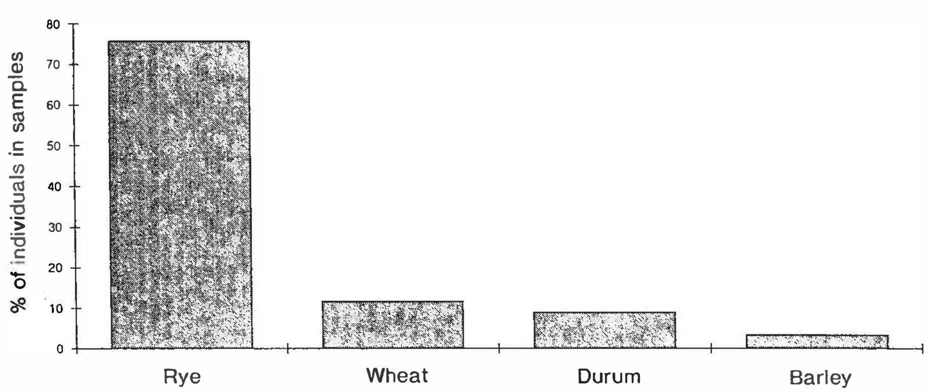

Fig. 3: Distribution of *T. tabaci* in samples taken from cereal crops in Seibersdorf in 1993

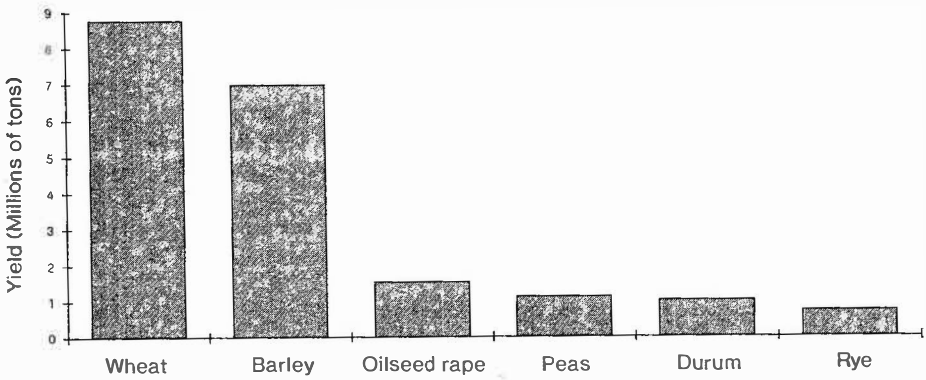

Fig. 4: Amounts of field crops delivered to the agricultural storehouse in Seibersdorf in 1993

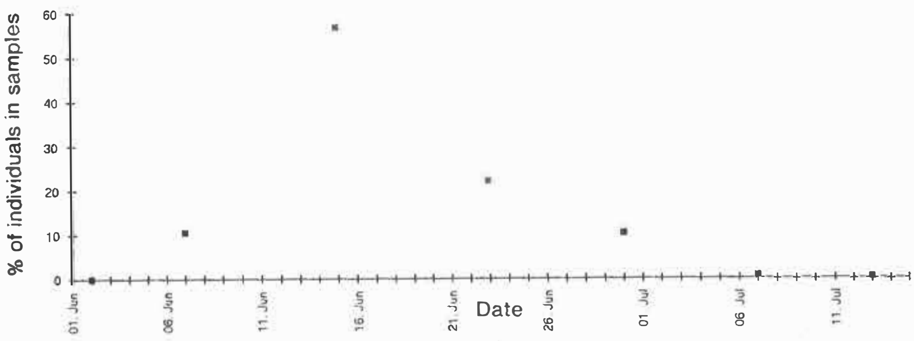

Fig. 5: Temporal distribution of *T. tabaci* in samples taken from cereal crops in Seibersdorf in 1993

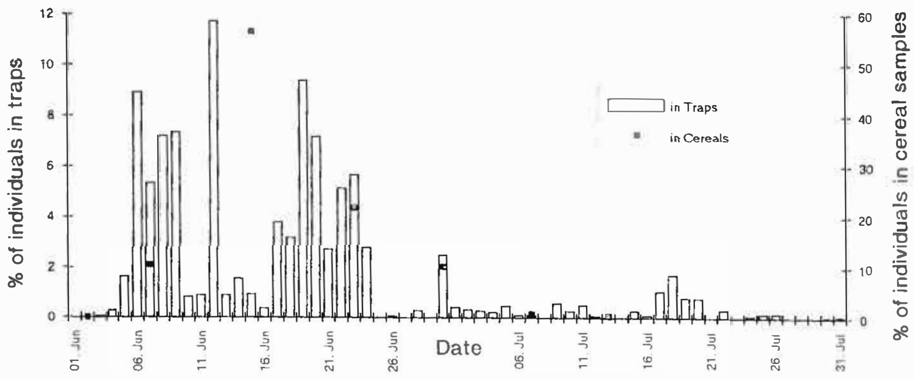

Fig. 6: Relation between the numbers of *T. tabaci* caught in a cabbage field and recorded from samples of cereals collected in Seibersdorf in 1993

Surprisingly, the "curve" is more or less parallel to that of the numbers of *T. tabaci* caught in the traps (Fig. 6). It has to be noted that samples were also collected on 2 June. If *T. tabaci* developed on wheat or rye prior to the mass swarming, then large numbers of *Thrips* would be expected on such crops prior to swarming.

There was no evidence to support this hypothesis in the current results. Therefore it seems that *T. tabaci* does not develop on cereals prior to the mass-flight, but that it develops instead on a wide range of field crops and wild plants.

Résumé

L'activité de vol de *Thrips tabaci* (Lind.) en relation avec les cultures de chou et de céréale

L'activité de vol de *Thrips tabaci* (Lind.) a été suivie dans une culture de chou en utilisant des piéges à eau de couleur blanche qui étaient relevés chaque jour. Un pic de vol a lieu le 4 juillet 1992 et le 12 juin 1993 les nombres de *T. tabaci* trouvés sur les échantillons de plantes prélevées chaque semaines dans une parcelle de céréale sont parallèles à ceux notés sur la courbe de vol. De nombreux individus ont été trouvés sur seigle et sur blé. Contrairement à la théorie qui affirme que l'invasion massive de *T. tabaci* sur chou est issue des céréales, aucun individu de *T. tabaci* ne peut être trouvé dans les cultures céréalières avant le déclenchement du vol principal.

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Phenology of aphids attacking processing tomato

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Summary

In 1992, the phenology of the aphid species found infesting processing tomatoes, cv. H.30, was studied in Central Greece. Only two species of aphid, namely *Myzus persicae* and *Macrosiphum euphorbiae* were found on the processing tomato plants. *M. persicae* was found in low numbers and had two peaks of activity, a small one early in the season, and a larger one during July. *M. euphorbiae* was found in much higher numbers but had only one peak during August. Both species produced larger infestations on young than on old leaves. The results from this continuing study, should help to provide a better understanding of the role of aphids as pests of processing tomatoes and eventually help towards integrated pest management in this crop.

Introduction

Several different genera and species of aphids attack tomatoes (Blackman & Eastop, 1985). They include *Macrosiphum euphorbiae* (Thomas) (Potato aphid), *Aulacorthum solani* (Kaltenbach) (Glasshouse - Potato Aphid), *Myzus persicae* (Sulzer) (Green Peach Aphid) and some species of *Aphis*. Large infestations of *M. euphorbiae* have been recorded on processing tomatoes in Ohio, USA (Walker *et al.*, 1984). However, aphids are no longer considered to be the key pests in greenhouse crops, as *Trialeurodes vaporariorum* (Westwood) and *Tetranychus urticae* Koch now tend to be the dominant pests (Lange & Bronson, 1981).

On fresh market tomatoes, aphids cause fruit deformation and produce honey-dew on which sooty moulds develop. Both factors lower the quality and the market value of the fruit. In processing tomatoes, aphids damage fruit directly and also indirectly by transmitting viruses. Both types of tomato can be damaged seriously by viruses transmitted by aphids such as *M. persicae* and *M. euphorbiae* (Kennedy *et al.*, 1962).

The preliminary work was done to determine the aphid species which infest processing tomatoes and their relative abundance during the growing season. The ultimate aim of this work is to produce a more rational system of pest control. This current work is part of a major project that involves monitoring alate numbers, studying the relationships between aphid numbers and virus infection, and determining the factors that produce the major mortalities in aphid populations.

Materials and methods

The work was carried out in a crop of processing tomatoes, cv. H.30 in a field near Thiva in Central Greece in 1992. Aphid populations were monitored by taking samples at weekly intervals during the growth period of the crop, from the end of May until the end of September.

The aphid samples were taken were from an 0.2 ha experimental plot, sited alongside a 2 ha commercial tomato crop. On the first three sampling occasions, when the plants were still small, 100 complete plants were taken from the plot. From the fourth sample onwards, two leaves, one young and one old, were taken from each plant, and hence a total of 100 new and 100 old leaves were collected from the plot.

Insecticide was not applied during the growth of the crop, but the plants were sprayed with a mixture of the fungicide propineb "Antracol" and a foliar fertiliser (33-0-0). The plants were also dusted with sulphur on 4 August. Most of the tomatoes were harvested between 6-11 September, but a second smaller harvest was made between 19-22 September.

Samples were examined using a binocular stereomicroscope. Live aphids were stored in preservative fluid (Eastop & van Emden, 1972) and later separated into species and instars.

Results and Discussion

Two aphid species, *M. persicae* and *M. euphorbiae*, were found infesting plants of processing tomatoes.

The fluctuations in the *M. persicae* population are shown in Fig. 1 and those in the *M. euphorbiae* population in Fig. 2. The aphid populations on young and old leaves of processing tomato are also shown for each aphid species.

Although aphid numbers were generally low, the green peach aphid produced higher infestations on young than on old leaves. The highest infestations on both young and old leaves were recorded on the same day, 21 July. In general, highest numbers were found in July and then aphid numbers declined gradually during August. No aphids were found in September.

On most sampling dates, higher infestations of potato aphid were also found on young than on old leaves. Aphid numbers remained high on old leaves from late July through August. On young leaves, peak numbers of aphids were recorded during August. Most aphids were found during mid-August, after which their numbers began to decline.

The total numbers of aphids per sample were plotted against time from the beginning to the end of the sampling period (Fig. 3), for both species of aphid. The *M. persicae* data showed, that apart from the large peak recorded on 21 July, another earlier and smaller peak occurred on about 9 June. There was no peaki earlier that that of 17 August for *M. euphorbiae*.

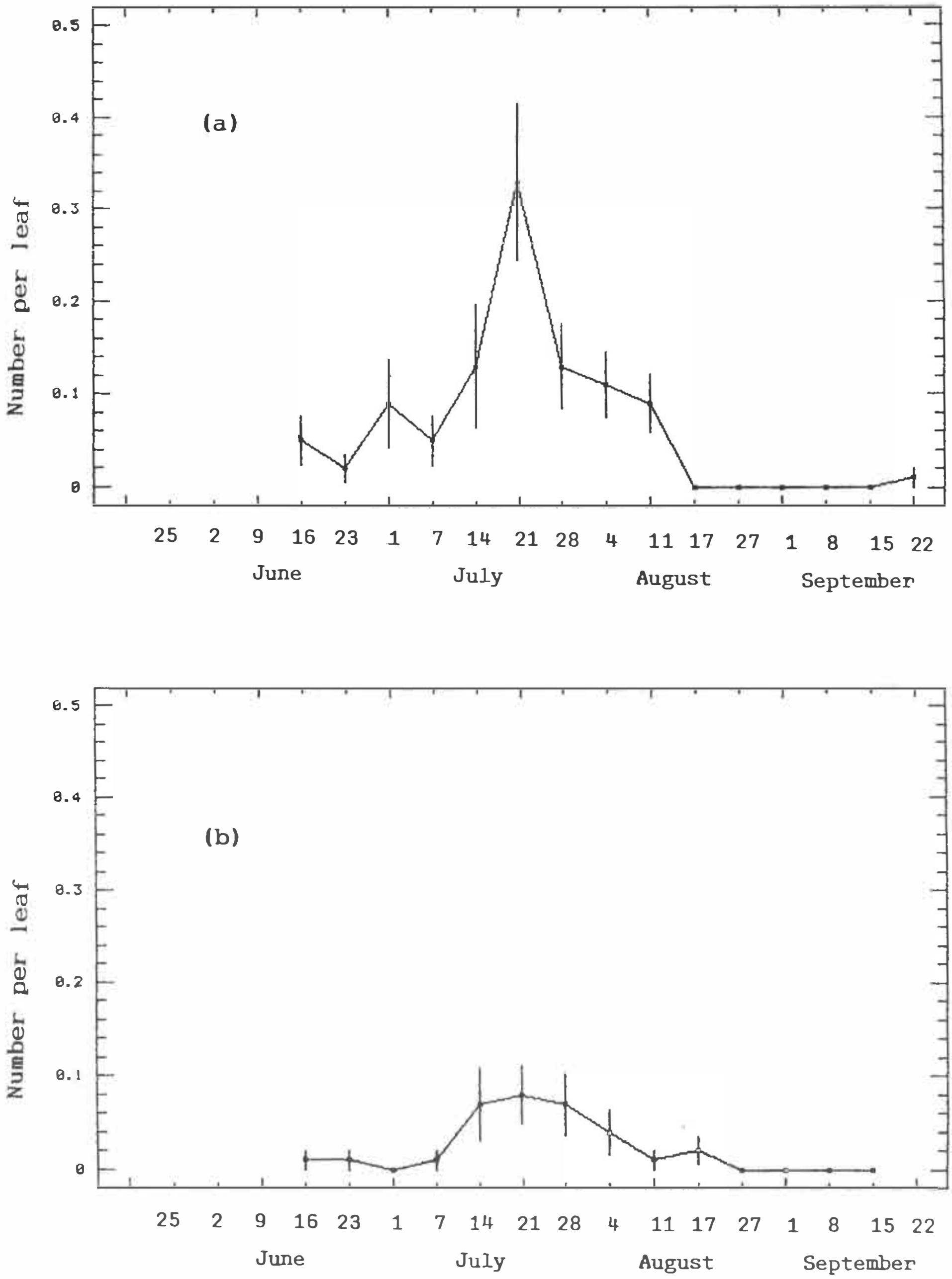

Fig. 1: Population fluctuation of *Myzus persicae* on (a) young and (b) old leaves of a tomato crop in Boiotia in 1992

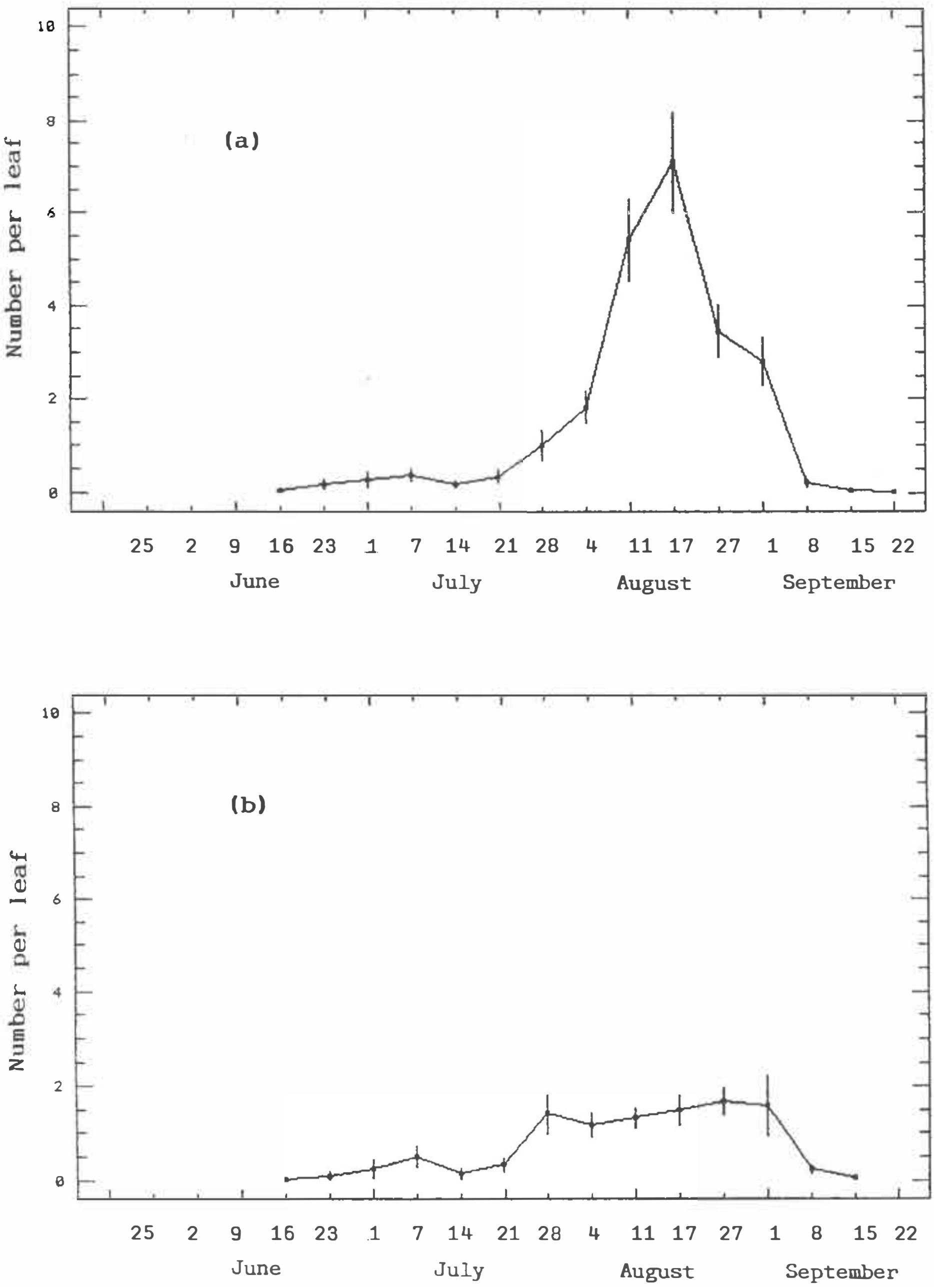

Fig. 2: Population fluctuation of *Macrosiphum euphorbiae* on (a) young and (b) old leaves of a tomato crop in Boiotia in 1992

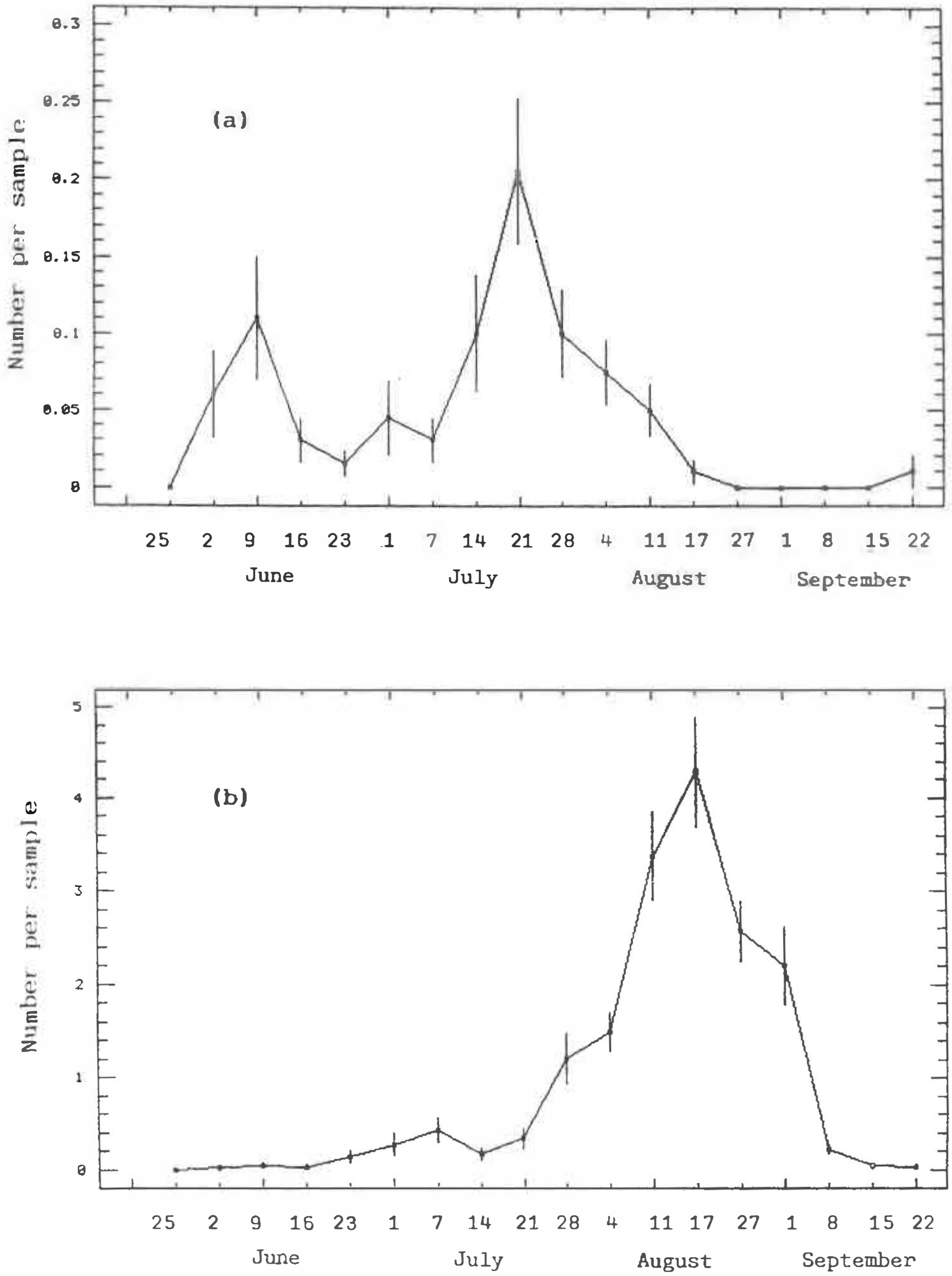

Fig. 3: Population fluctuation of (a) *Myzus persicae* and (b) *Macrosiphum euphorbiae* in a tomato crop in Boiotia in 1992

Conclusions

On processing tomatoes, neither species of aphid produced high infestations throughout the entire growth period of the crop. However, *M. euphorbiae*, whose population peaked in August, produced higher infestations than *M. persicae.* The latter aphid had two peaks of activity, a small one in early June and a larger one during July.

This study shows that most aphids of both species, developed on young leaves. Therefore, a better estimation of aphid numbers would be obtained if sampling was restricted solely to young leaves.

Résumé

Phénologie des puçerons attaquant la tomate

En 1992, la phénologie des espèces de puçerons trouvées sur des tomates destinées à la conserverie, cv H.30, a été étudiée en Grèce centrale.

Seules deux espèces de puçerons, *Myzus persicae* et *Macrosiphum euphorbiae*, ont été trouvées sur les plants de tomate. *M. persicae* a été trouvé à un faible niveau et a deux pics d'activité, un petit tôt en saison et un plus important à l'automne. Les deux espèces provoquent des infestations plus grandes sur les feuilles jeunes que sur les feuilles agées. Les résultats de cette étude qui se poursuit, pourraient aider à fournir une meilleure compréhension du rôle des puçerons comme ravageur sur les tomates destinées à la conserve et éventuellement à fournir les éléments d'une lutte intégrée pour cette culture.

Acknowledgement

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Trapping carrot fly *(Psila rosae* F.) – the effect of wind direction

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Summary

According to Finch and Collier (1989), more carrot fly were caught on the lower surface of traps (Rebell) inclined at 45° to the vertical. By using traps angled in this way, the sticky compound was protected from the adverse effects of rain and the traps were more selective, making it much easier to count the carrot flies. When the upper surface of the trap is covered with plastic foil, it may be possible to use the trap twice and hence halve the cost.

In 1992, wind-direction also appeared to influence considerably the numbers of flies caught. When the lower surface of an angled (45°) trap was placed into the wind, more flies were caught on the upper (sheltered side) than on the lower surface. If only one side of an angle trap is to be used, the trap should be attached to a pole with a wind vane, that ensures that the lower surface is always the sheltered side. When this was done, the catch was approximately the same for one side of an angled trap as for two sides of a vertical trap.

Introduction

Owing to the adverse effects of insecticides on the environment, there is now growing concern to ensure that insecticides are applied more economically and efficiently. In controlling the first flight of the carrot fly (*Psila rosae* F.), the amount of insecticide was reduced significantly by applying the insecticides to the carrot seed as a film-coating (Ester & Neuvel, 1990).

Research into monitoring carrot fly was started in the Netherlands in 1992. Sticky traps (Rebell) were used at an angle of 45° to the crop as proposed by Finch and Collier (1989). The purpose was to use the trap twice, by covering the upper surface with plastic foil, and catching carrot flies only on the lower surface.

For comparative purposes, both sides of the traps were left uncovered in the initial experiments. When this was done, more flies were sometimes caught on the upper than on the lower surface, an affect that appeared to be influenced by the direction of the prevailing wind. Hence, observations were made, in a field in central Holland that had a high population of carrot fly to determine:- 1) how wind direction influenced fly catch, 2) whether the trap remained equally efficient throughout the week of exposure, and 3) what correction was required so that "threshold catches" from angled traps could be compared directly with those from vertical traps.

Materials and Methods

Wind direction and trap position

Trapping was carried out in a field that was drilled on 75 cm wide ridges with carrot seed, cv. Panther, on 4 March 1992. At five positions in the field, the numbers of flies caught were recorded daily from both sides of six, 15 x 21 cm, sticky traps (Rebell; Fa, CA-8820 Wadeswill, Switzerland).

The traps were placed just above the top of the leaves of the carrot plants and were coded as follows:-

From West to East	:	8W:4E	7W:3E	6W:2E
From North to South	:	8N:4E	7N:3S	6N:2S

The number indicates the inclination of the trap as described by Finch and Collier (1989), in which 7 and 3 represent vertical surfaces.

In 22 commercial fields, three sticky traps were placed at an angle of 45° with the top of each trap pointing East. The numbers of carrot flies caught on the upper and lower surfaces of the traps were recorded during 7 weeks of the second flight in 1992.

Trapping capacity during a week

Further observations were made during the flight of the first generation in 1992 on three sticky traps/site. Flies were counted on both sides of sticky traps, one vertical trap with the sides facing W & E, one vertical trap with the sides facing N-S, and one angled trap with the upper surface facing W and the lower surface facing E (code 8N:4E).

Cumulative counts were made on these traps 2, 5 and 7 days after the traps were placed into the crops.

Moveable sticky trap

In June 1993, a simple construction was made to ensure that the lower surface of the trap always faced away from the wind, that is towards the "leeward side".

The trap was clamped to a plastic pipe that had a windvane of galvanised iron bolted to the top. The whole structure pivoted on a pointed bar of mild steel (Fig. 1).

During the second flight in 1993, flies were caught on both sides of this moveable trap and on both sides of a trap angled at 45° with the top pointing towards the East (code 8W:4E). The numbers of flies caught were recorded for 8 weeks in 10 fields.

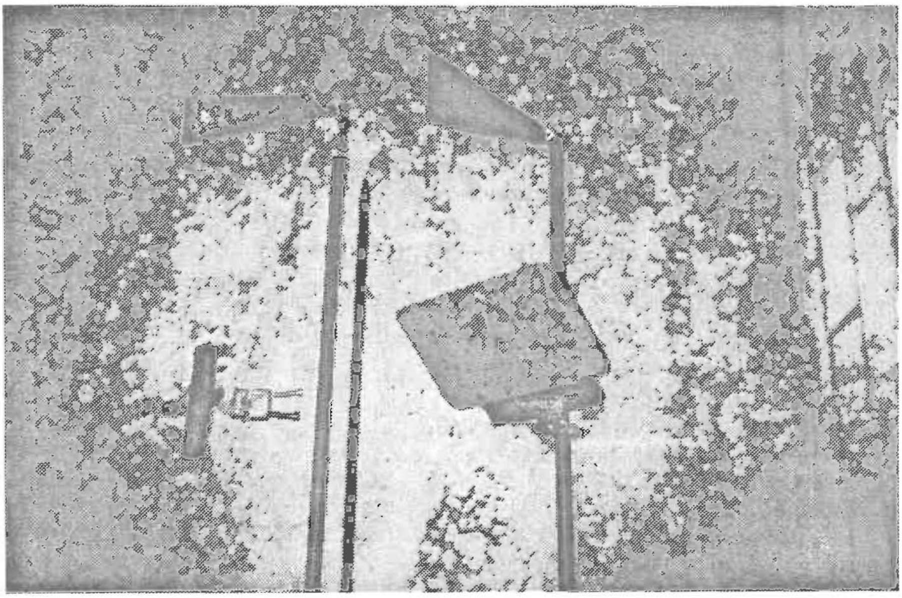

Fig. 1: Photograph of components and assembled unit for ensuring that the lower surface of the Rebell trap (shown) faced away from the wind

Results

Influence of wind direction and trap position

During the week of observation, the wind force was between 3-5 on the Beaufort scale. The direction of the wind appeared to influence the numbers of flies caught on the various sides of the trap (Table 1).

Table 1. Number of carrot fly caught on the exposed (Ex) and sheltered (Sh) faces of three sticky traps on two days when the wind blew predominantly from opposite directions

	Flies caught/trap face					
	Ex	Sh	Ex	Sh	Ex	Sh
Wind from south	16	21	5	12	14	22
Wind from North	5	14	1	10	4	9

On days 1 and 3 (14 & 16 May) the direction from which the wind blew changed frequently. On day 2 (15 May) the wind came predominantly from the South, on days 4 and 5 mainly from the North and on day 6 from the East (Table 2).

Table 2. Mean numbers of carrot flies caught/side/day in relation to the direction of the prevailing wind during 14-20 May 1992

Code	Trap type	Inclination of trap	Side of trap	Number of flies/side/day under the prevailing wind conditions: 15/5 S	17/5 N	18/5 N	19/5 N	20/5 N	Mean flies /side	Mean flies /trap
P1	Ang	Bottom edge of trap into wind	Upper	13.5	5.0	2.2	4.2	1.8	5.4	17.2
P2	Ang		Lower	22.4	13.8	6.0	9.0	8.0	11.9	
P3	Vert	Vertical	N	4.8	1.4	1.8	2.6	0.6	2.2	9.6
P4	Vert		S	11.6	10.4	2.8	7.0	4.8	7.3	
P5	Ang	Top edge of trap into wind	Lower	16.2	3.6	2.8	5.0	2.2	6.0	14.3
P6	Ang		Upper	21.4	8.8	1.0	7.8	2.8	8.4	
P7	Ang	45° edge of trap into wind	Upper	12.6	10.8	2.2	3.8	1.6	6.2	14.1
P8	Ang		Lower	10.6	11.6	2.4	8.8	6.0	8.9	
P9	Vert	Vertical	E	4.6	5.2	1.4	0.4	4.4	3.2	6.8
P10	Vert		W	4.0	7.6	1.4	3.2	2.0	3.6	
P11	Ang	45° edge of trap into wind	Lower	20.5	9.0	1.6	3.4	4.2	7.7	14.0
P12	Ang		Upper	6.6	8.4	3.2	4.4	9.0	6.3	
Mean number of flies caught/trap/day on vertical trap										8.2
Mean number of flies caught/trap/day on 45° angled trap										14.9

LSD ($P = 0.05$): mean flies day: 1.6; mean flies side: 2.5; position x day, horizontal: 5.5 and diagonal: 7.8.

More flies were caught on the leeward side (p2, p4, p6) than on the windward side (p1, p3, p5) when the surface of the sticky traps were at right angles to the wind direction. When the traps faces were parallel to the direction of the wind, little difference occurred between the numbers of flies caught on the two sides. During the first week of the experiment (Table 2), fewer flies were caught on the vertical traps than on those held at an angle. Independent of wind direction, traps placed at the 45° angle, (mean catch = 14.9), caught 1.8 times as many flies as vertical trap (mean = 8.2).

At an angle away from the wind direction (p1 + p2), 2.1 times as many flies were caught on the angled that on the vertical trap, and more flies were caught on the lower (p2) sheltered surface than on the upper (p1) exposed surface. When the top of the trap faced into the wind, fewer flies were caught on the lower (p5) exposed side than on (p6) the upper sheltered side. Therefore, in windy conditions, the effect of shelter is more pronounced than the effect of trap inclination. When the windvane maintained the trap so that the underside (p2) was kept as the sheltered side of the trap, 1.4 times as many flies were caught on this one side as on 2 sides of a vertical trap.

Under the changeable wind directions that occurred during the rest of the first generation flight in 1992, the angled trap with the top facing East caught 1.4 times as many flies as the vertical trap (Table 3). However, similar numbers of flies were caught on the lower and upper surfaces of the trap.

Table 3. Mean numbers of carrot fly caught/week on each trap side during the first flight in 1992

Week number	Vertical		Vertical		45° angled, top towards east	
	E	W	N	S	Upper surface	Lower surface
21	32a*	40a	30a	54b	59b	48b
22	14a	18a	21a	19a	31b	31b
23	5a	12b	8ab	12b	13b	11b

* Means within a line followed by the same letter are not different (P = 0.05)

During the flight of the second generation in 1992, the tops of the angled traps were placed towards the East. 82% of the flies caught were trapped on the lower surface. The coefficient of variation was 51%.

Trapping capacity during one week

The data are shown in Table 4. The number of flies caught/trap/day were always higher in count 1 (day 2) than in counts 2 (day 5) and 3 (day 7). In addition, count 1 of the week was always substantially higher than count 3 of the previous week. Therefore, the trapping capacity of the Rebell traps decreased during the week of exposure.

Table 4. Mean number of carrot fly/trap/day during the first flight in 1992

Week number	Part of the week Count 1 [Day 2]	Count 2 [Day 5]	Count 3 [Day 7]
21	22a	10b	7b
22	15a	3ba	4b
23	5a	1b	1b

* Means within a row followed by the same letter are not different (P = 0.05).

Pivoting (moveable) sticky trap

During the second flight in 1993, a comparison was made between the numbers of flies caught on a pivoting sticky trap and a non-moveable trap whose top pointed towards the East. For the pivoting trap to operate successfully, it had to remain vertical at all times and the wind had to exceed a value of 2 on the Beaufort scale.

From the end of July until the end of September 1993 the wind blew from the West, South or North West. No differences were observed in the numbers of flies caught on the different sides of the trap (Table 5). In no case did the pivoting trap reduce the numbers of flies caught. This method, however, ensured that most of the flies were trapped on the leeward side so that only one side of the trap needed to be used. Under low wind speeds, wind direction had little influence on the numbers of flies caught (Table 5).

Table 5. Numbers of carrot flies trapped/week on the upper and lower surfaces of fixed and moveable, angled, sticky-traps. Data recorded during the second flight of carrot fly in 1993

Week number	Trap fixed, top towards East		Trap moveable	
	Upper surface	Lower surface	Upper surface	Lower surface
29	9	63	9	59
30	6	29	7	38
31	20	87	10	87
32	19	88	20	97
33	17	70	26	85
34	27	114	29	94
35	19	79	13	77
36	9	50	6	49
37	18	45	8	37
38	14	116	4	139
Total catch	158	741	132	762
% of total catch	18	82	15	85

Discussion

Holopainen *et al.* (1991) reported low catches of carrot fly on sticky traps placed at an angle of 45° compared to vertical or even horizontal traps (1984 data). The differences between their results and those of Finch & Collier (1989) were supposed to represent the differences between two-sided and one-sided sticky traps. Our result shows that this is not the case.

As shown in the results obtained with one-sided sticky traps by Finch & Collier (1989), it appears from the present research that Rebell sticky traps, glued on both sides and inclined at an angle of 45°, trap approximately twice as many flies as vertical traps. Under a rather strong wind, the flies were caught mainly on the sheltered side, which depending on the direction of the wind with fixed traps, could be either the upper or the lower surface.

Holopaninen *et al.* (1991) reported higher catch on the South- than on the North-facing side of a vertical trap. This again could simply be due to the influence of wind.

By attaching the trap to a pole with a windvane, the underside of the trap can always be maintained in the sheltered position. By adopting this approach, one-sided traps can be used and have the added bonus that because fewer insects are caught the carrot flies are easier to count (Finch & Collier, 1989).

In general, the effectiveness of the Rebell trap declined during the week of exposure. This decline may be less when only the lower surface is used for catching flies, as the Tangletrap on this surface will be sheltered from the adverse effects of both rain and sunshine.

Collier & Finch (1990) found that most flies were caught at 0-20 cm above the soil surface, when the traps were placed on bare soil between 5 cm high rows or carrots. Holopainen found highest catch between 5-25 cm above the soil surface during the first flight and 35-55 cm during the second flight, when the carrot foliage was much higher. When the second flight was monitored in commercial carrot fields, the number of flies caught was sometimes relatively low compared to the amount of subsequent damage. Observations should be made, when the carrots are grown on a wide row spacing, say 75 cm, and it would probably be more productive to place the traps between the rows instead of above the plant leaves as we did in this experiment.

The threshold for vertical traps of 1 fly and 0.5 fly/trap/day for the flights of the first and second fly generations, respectively, can probably be increased by a factor of 1.4 if moveable traps are used instead of fixed vertical traps. With a coefficient of variation of 50%, the mean number of flies caught on 5 traps has to be lower than 0.7 times the above threshold value to be certain (95%) that the population is lower than the threshold.

Résumé

Piégeage de la mouche de la carotte (*Psila rosae* F.). Effet de la direction du vent.

D'après Finch & Collier (1989) la plupart des mouches de la carotte est capturée sur la surface inférieure des pièges (Rebell) incliné à 45° de la verticale. En utilisant les pièges inclinés de la sorte, la glu est protégée des effets de la pluie et les pièges sont plus sélectifs de sorte qu'il est beaucoup plus facile de compter les mouches de la carotte. Lorsque la face supérieure du piège est recouverte d'une feuille de plastic, il est possible d'utiliser le piège deux fois et ainsi de diviser le coût par deux.

En 1992, il est apparu que la direction du vent a une influence considérable sur le nombre des mouches capturées. Quand la face inférieure du piège incliné à 45° est placée dans le vent, elle capture davantage de mouches sur la face supérieure (côte abrité) que sur la face inférieure. Si seul un côté du piège incliné doit être utilisé, le piège peut être fixé à un axe de girouette qui permet à la face inférieure d'être toujours du côté abrité. En procédant de cette manière, le piège a les mêmes performances qu'un piège incliné à une face ou celle d'un piège vertical à deux faces.

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Monitoring and forecasting the times of attack of the lettuce root aphid, *Pemphigus bursarius L.*

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Summary

Yellow water traps, with and without vertical baffles, were used to monitor the immigration of winged lettuce root aphids into lettuce crops. More aphids were caught in traps fitted with baffles. Aphid immigration occurred over a 2-3 week period during early June to mid July. The precise timing varied from site-to-site and from year-to-year. A preliminary forecast, using air day-degrees accumulated above a base temperature of 6°C from 1 February, showed that most of the migration occurred between 500-750D°. In 1993, the start of the aphid immigration at three sites was forecast to within 1-5 days by using this relationship. Non-woven crop covers prevented migrating lettuce root aphids settling on lettuce crops, provided the covers were applied before aphid migration started.

Introduction

In the United Kingdom, the lettuce root aphid (*Pemphigus bursarius L.*) is now an important pest of lettuce crops. The biology and life-cycle of the lettuce root aphid has been described by Dunn (1959). At the end of the summer, winged female aphids migrate from lettuce to Lombardy poplar and black poplar to lay their eggs. The eggs overwinter in cracks in the bark of the poplars and in March-April hatch into nymphs, which feed on the developing leaf petioles, causing them to enlarge into galls (Dunn, 1959). The nymphs live and mature within the galls and produce a further generation of aphids. Winged aphids emerge from the galls over a 4-5 week period in late June-July (Dunn, 1959; Ramert, 1977) and migrate to lettuce or wild Compositae. The immigrants contain mature embryos, so that young are produced as soon as the aphids reach the roots of a suitable host plant, such as lettuce (Dunn, 1959). The wingless progeny feed on the roots and produce several wingless generations. The large aphid infestations that result cause lettuce plants to suffer water stress and in severe cases much of the crop may die. The damage caused by lettuce root aphid is exacerbated by hot, dry weather (Gratwick, 1992).

Lettuce root aphid was once considered an infrequent pest in the United Kingdom, but is now believed to be a constant threat to lettuce crops established during the late spring and summer, particularly to iceberg varieties, which take longer to mature than butterhead lettuce and therefore remain at risk for longer. Ellis (1991) suggested that a number of factors may have contributed to the change of pest status of this insect. They include the recent series of warm, dry summers that favoured aphid multiplication, the relatively mild winters that favoured overwintering survival, the intensification of lettuce production and the use of some varieties of iceberg lettuce which are highly susceptible to lettuce root aphid damage. In addition, the soil-applied insecticide diazinon, which was used previously to control this pest has now been withdrawn. Similarly, phorate, which can only be used at planting (off-label approval), has a 7-week harvest interval and may be rejected by growers, as it can give rise to residue problems. As a result, lettuce root aphid has recently become a much greater problem for lettuce growers in the UK.

Lettuce root aphid infestations can also develop from residual populations of aphids that overwinter in the soil in fields planted to lettuce in the previous year. This causes problems for new crops planted into such fields as crop infestations can occur much earlier in the year than at sites where aphids have to immigrate into the crop. Although problems from aphids that overwinter in the soil are currently rare in Eastern and Northern England, they could become more common if the current trends continue for production to be intensified by just a few specialist lettuce growers.

As insecticidal methods of lettuce root aphid control now appear to be less effective, efforts are being made to develop alternative methods of control, targetted at critical stages in the life-cycle of the pest. One such approach is to use crop covers to prevent the migrating aphids from reaching susceptible crops (Antill *et al.*, 1990). Since temperatures are relatively high during the late spring and summer, lettuce crops will not tolerate covers from planting until harvest without loss of quality. Thus, the application of covers must be timed to coincide with the period of aphid immigration into the lettuce crops. Data shown by Dunn (1959) indicate that it may be possible to predict the time of emergence of winged aphids from galls, and thus the time of aphid immigration into lettuce crops, using accumulated day-degrees. This paper describes studies on the timing of the lettuce root aphid migration and the development of a preliminary aphid forecast, based on accumulated temperatures.

Materials and Methods

The initial studies were made during 1987 at a site near to Ely (Cambridgeshire). Migrating aphids were trapped as they arrived in a commercial crop of lettuce cv. Saladin. The numbers of aphids caught in an 'Xpelair' suction trap (120 cm high) were compared with the numbers caught in four water traps (45 x 55 x 8 cm deep) made from plastic photographic trays. The insides of two of the water traps were left white and the other two were painted lemon-yellow. The outsides of all four traps were painted black. One white trap and one yellow trap were fitted with vertical baffles (Coon & Rinick, 1962), constructed from two sheets of white or yellow perspex (30 cm wide x 42 cm high) that were slotted together to form a cross. The baffles were placed in the centre of each trap which was filled two-thirds deep with water. The traps were placed on the ground in the crop in late May and were emptied daily. Lettuce root aphid activity was also monitored during 1989, using one yellow water trap with a baffle.

Following the preliminary work, aphid activity was monitored during 1991-93 as part of a project to evaluate crop covers as barriers for excluding lettuce root aphids. Each year, aphids were monitored at three sites: ADAS-Arthur Rickwood, Ely, Cambridgeshire; HRI-Kirton, Boston, Lincolnshire and HRI-Stockbridge House, Selby, Yorkshire. Plots of lettuce cv. Saladin were planted at all three sites prior to the start of aphid migration. In 1991 and 1992 lettuce root aphids were monitored using the yellow water traps with baffles described above. During 1993, a smaller water trap (with and without baffles) was compared with the original trap at Kirton and at Stockbridge House. The new trap consisted of a yellow plastic tray (25 x 36 x 6 cm deep) with a baffle (21.5 cm wide x 29 cm high) was constructed from yellow Correx^{R}.

At Stockbridge House, in 1992, plots of lettuce (4 rows x 26 plants) were planted on 10, 23 and 30 June and were covered, for periods of 1-4 weeks, with non-woven fleece (Agryl^{R} P17) on 18, 23 and 30 June, respectively. Each treatment was replicated four times in a randomised block design. At harvest, 30 heads of lettuce were cut from each plot and the plant roots were then assessed for the level of lettuce root aphid infestation by scoring them on a logarithmic scale (Table 1) (Wright & Wheatley, 1953).

Table 1: Scoring system used to assess lettuce root aphid infestations on individual plants (Wright & Wheatley, 1953)

No. of lettuce root aphids/plant	Infestation score	No. of lettuce root aphids/plant	Infestation score
0	0	34-100	4
1-4	1	101-300	5
5-11	2	301-900	6
12-33	3	901-2700	7

Results

Trap efficiency

The white water traps were discarded soon after the aphid monitoring was started, as they captured few aphids. Although the suction trap was effective in 1987, most aphids were captured in the yellow water traps, particularly those with the baffles (Table 2). Similar results were obtained when the smaller yellow water traps were tested at Kirton in 1993.

Table 2: The numbers of lettuce root aphids captured/trap/during June through August by two different yellow water traps and a suction trap

	Yellow water trap	Yellow water trap + baffle	Suction trap
1987 - large trap (Ely - 1 trap)	16	60	10
1993 - small trap (Kirton - 3 traps)	22	44	-

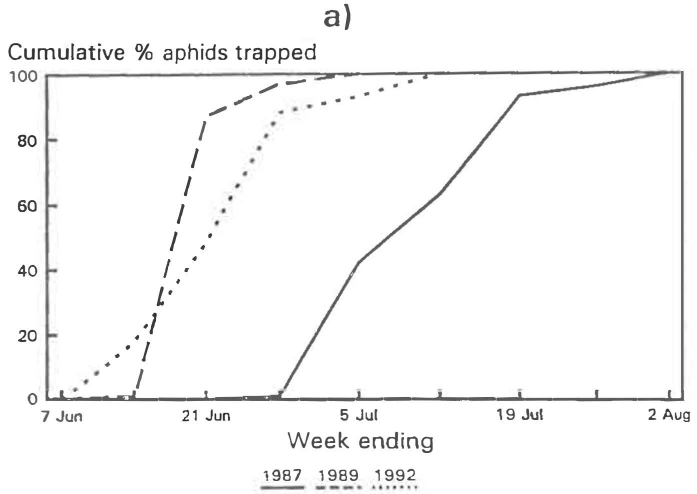
Comparisons between large and small yellow water traps (both with baffles) are shown in Table 3. Although the larger trap caught more lettuce root aphids at Kirton than the small traps, both traps were equally effective when compared on the basis of catch/unit area of trap.

Table 3: The numbers of lettuce root aphids captured/trap/during June through August by yellow water traps with baffles

	Large trap			Small trap		
	Actual catch ($0.25m^2$)	Catch/m^2	No. traps	Actual catch ($0.09\ m^2$)	Catch/m^2	No. traps
Kirton	122	496	1	44	486	3
Stockbridge House	12	48	1	7	78	2

Timing of the lettuce root aphid migration

Figure 1a shows the timing of lettuce root aphid migration in Cambridgeshire during 1987, 1989 and 1991. The data are plotted as cumulative percentages of the numbers of aphids trapped. Figure 1b shows similar data for sites at Arthur Rickwood, Kirton and Stockbridge House during 1992 where most activity occurred within a 2-3 week period between early June and mid July. The precise timing of the immigration differed from site-to-site and from year-to-year.



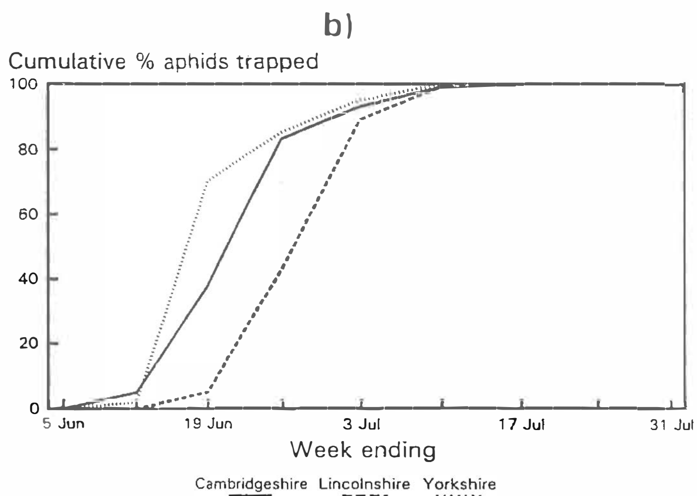


Fig. 1: a) Lettuce root aphid activity near Ely (Cambridgeshire) during 1987, 1989 and 1992 and b) sites at Arthur Rickwood (Cambridgeshire), Kirton (Lincolnshire) and Stockbridge House (Yorkshire) in 1992

The monitoring data from Figure 1 were re-plotted against accumulated air day-degrees above a base temperature of 6°C (Fig. 2). This was a first estimate of the base temperature for lettuce root aphid development. The lettuce root aphid migration occurred between 500-750D° from 1 February and was never earlier than 500D°.

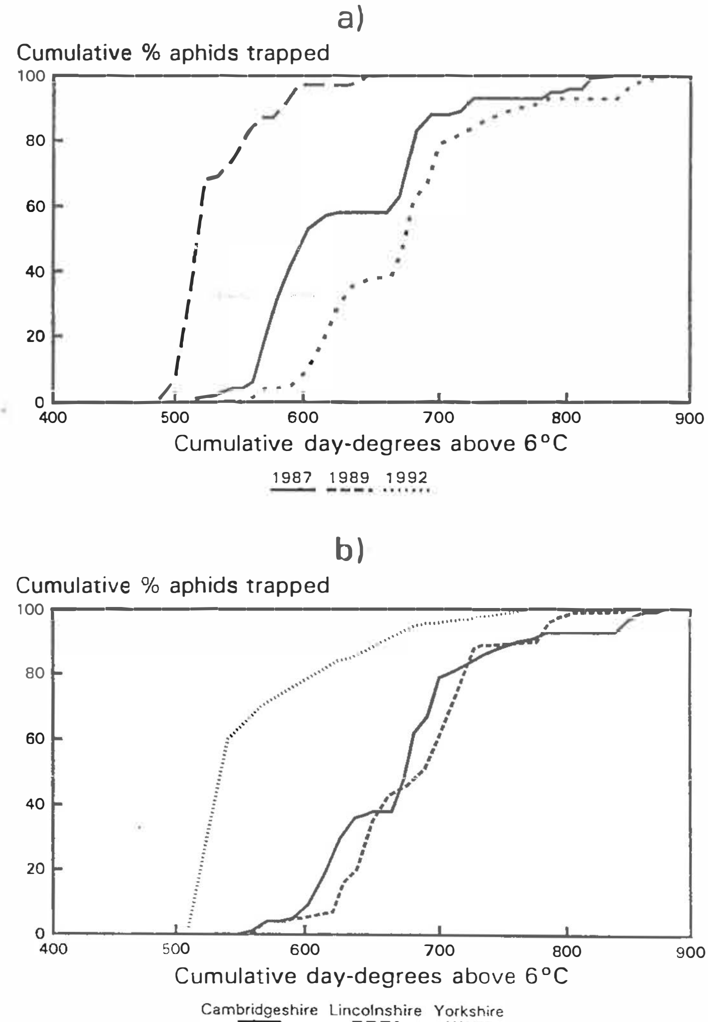


Fig. 2: Lettuce root aphid activity plotted against accumulated day-degrees. Data from sites a) at Ely (Cambridgeshire) during 1987, 1989 and 1992, and from b) Arthur Rickwood (Cambridgeshire), Kirton (Lincolnshire) and Stockbridge House (Yorkshire) in 1992.

The 500D° sum was used to predict the start of the lettuce root aphid migration at the three sites in 1993. Comparisons of the observed and the predicted times of the lettuce root aphid migration are shown in Table 4.

Table 4: The observed and predicted (forecast) times of the start of lettuce root aphid immigration into three localities in 1993

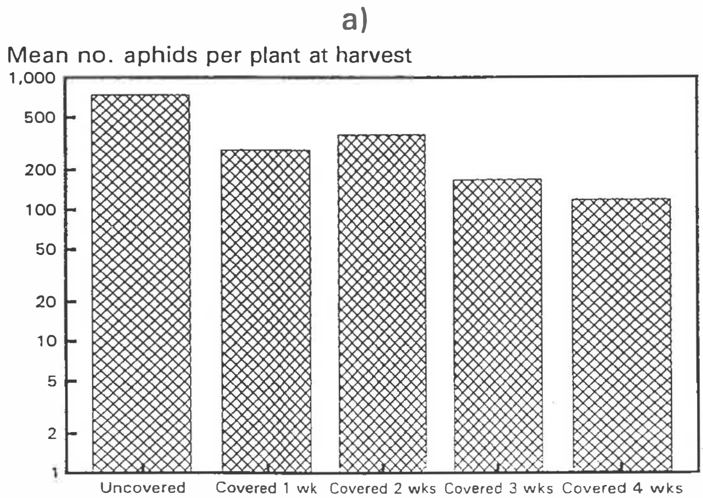
	Predicted start of immigration (500D°)	Observed start of immigration
Arthur Rickwood	9 June	8-10 June
Kirton	16 June	17-21 June
Stockbridge House	11 June	15-16 June

Use of crop covers to exclude lettuce root aphid

In 1992, the first planting of lettuce at Stockbridge House was on 10 June and the covers were applied on 18 June, approximately one week after the start of lettuce root aphid migration (Figure 1b). Figure 3a shows the mean numbers of aphids recovered at harvest from plots left uncovered (control) and from the plots that were covered for 1-4 weeks. Large numbers of aphids were found on all plots because the plants were covered too late, that is a week after the aphids had started their migration. The second group of plots were planted on 23 June and covered immediately. This was towards the end of the period of peak migration, when fewer aphids were trapped. Figure 3b shows the numbers of aphids recovered at harvest from the second planting. Infestation levels were considerably lower than from the first planting but there was a greater difference between covered and non-covered plots, the covers effectively excluding the majority of aphids. A similar effect was observed from the third planting but, by then, aphid numbers were extremely low. Finally, the data from all three plantings indicate that the number of aphids at harvest was related directly to the number of aphids trapped whilst the lettuce plants were exposed (Fig. 4).

Discussion

In the present study, the migration of lettuce root aphids into lettuce crops occurred during a period of 2-3 weeks. This was shorter than the 4-5 weeks recorded in other years in Cambridgeshire (J. Blood Smyth - unpublished data) and described by Dunn (1959) in Warwickshire and by Ramert (1977) in Sweden. This is probably due to climatic differences. Compared with many pest species, lettuce root aphid migration occurs during a short, discrete period, and hence is ideal for targetting with effective, but short-term, control measures. Figure 3b shows that when crop covers were applied at the appropriate time, infestations of lettuce root aphid could be largely avoided, confirming the results of Antill *et al.* (1990). Unfortunately, covers protect lettuce crops only from infestations that arise from lettuce root aphids migrating into crops. Infestations that arise from repeated plantings into the same area of soil must be controlled by other means.



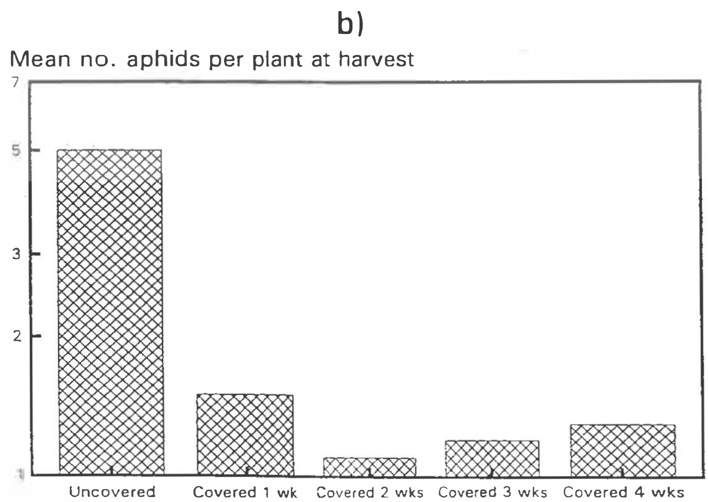


Fig. 3: Mean numbers of lettuce root aphids recorded at harvest from lettuce plots that were left uncovered and from plots covered for 1,2,3 or 4 weeks. The lettuce were a) planted on 10 June and covered on 18 June and b) planted on 23 June and covered on 23 June.

The start and duration of aphid immigration into lettuce crops was monitored effectively using yellow water traps. Adding baffles to water traps appeared to increase the numbers of aphids caught. However, as the present findings are based on catches from low numbers of traps at only a few sites, further data should be collected to confirm the results.

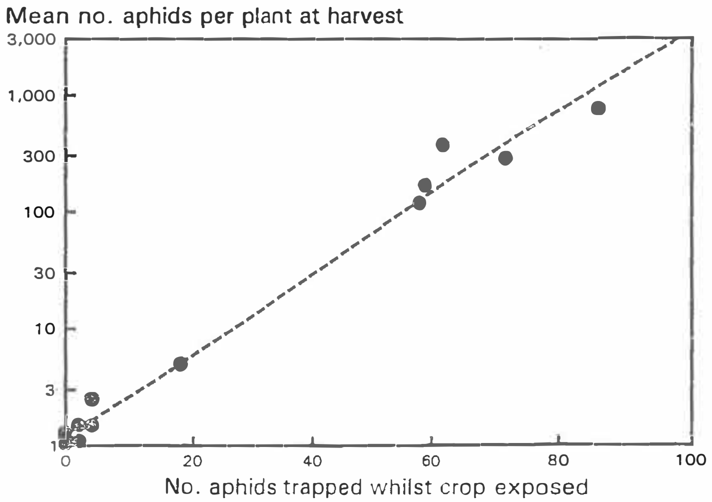


Fig. 4: Relationship between the numbers of lettuce root aphids recorded on plant roots at harvest and the numbers of aphids trapped whilst the crop was uncovered.

Routine monitoring, to decide when to apply control measures, has its drawbacks. Lettuce root aphid identification requires trained personnel, sorting and identifying the insects is time-consuming, and it may be inconvenient to service traps frequently. However, this preliminary study suggests that it may be possible to forecast the timing of the lettuce root aphid migration into lettuce crops quite accurately from accumulated day-degrees. Lettuce crops could then be covered for the shortest time possible, to minimize any adverse effects of the covers on crop quality. In the present study a threshold of 6°C was chosen as a first estimate, whereas Dunn (1959) used a threshold of 40°F (4.4°C) for the emergence of winged aphids from galls. It is likely that determination of the true threshold temperature for lettuce root aphid development might provide an even better forecast. Despite this, covering the crop for a period of 250D°, or less, may be all that is required to keep a crop "free" from lettuce root aphids.

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Résumé

Détermination et prévision des périodes d'attaques du puçeron des racines de la laitue *Pemphigus bursarius* L.

Des pièges à eau colorés en jaune, avec ou sans écrans verticaux ont été utilisés pour enregistrer le vol d'immigration des ailés du puçeron de la laitue dans les cultures de salade. On capture beaucoup plus de puçerons dans les pièges présentant des écrans. La migration des puçerons s'étend sur une période de 2-3 semaines, située du début juin à la mi.juillet. La période exacte varie de site en site et d'année en année. Une prévision préliminaire basée sur la somme des températures, en prenant les températures supérieures à 6°C à partir du 1er février, montre que la plupart des vols de migration s'effectue entre 500-750 degrés jours. En 1993 le début de la migration des puçerons dans trois sites a été prédit avec une précision de 1 à 5 jours en utilisant cette méthode.

La couverture de la culture par un film non tissé empêche l'installation du puçeron de la laitue sur les plantations de salades et l'application de ce type de couverture doit se faire avant le début de la migration des aphides.

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Supervised control of foliar pests of Brussels sprouts and calabrese crops

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Summary

Two systems of supervised pest control were tested on brassica crops during 1992. One system was based on a complex sequential sampling method, taking completely random samples, and was tested only on research farms. The other more practical system was based on a systematic sampling method and was tested on commercial farms. The systems were used to test the same set of sampling methods and tolerance levels for cabbage aphid (*Brevicoryne brassicae*) and cabbage caterpillars (e.g. *Pieris rapae*). In the trials on the research farms, there was a marked reduction between routine and supervised treatments, in the number of sprays used, especially for caterpillar control. In the trials on the commercial farms, there was an overall reduction in pesticide usage of 53% compared with routine controls and 25-33% compared with equivalent grower practice. The average loss in marketability was just 4%. However, at one of the research farms, where the pressure from cabbage aphid was high, control was inadequate.

To improve the sampling techniques used in supervised control systems on brassica crops, further information is required on the within-crop distribution of cabbage aphid and cabbage caterpillars.

Introduction

Supervised pest control in brassica crops has been practised in the Netherlands for more than a decade (Theunissen & Den Ouden, 1985). The IOBC/WPRS - Working Group on Integrated Control in Field Vegetable Crops undertook a joint project, in five European countries, to test simple damage thresholds for cabbage aphid and cabbage caterpillars on cabbage (Hommes *et al.*, 1988). Following this, a three year MAFF funded project was set up on research farms in England. The work was carried out by entomologists and horticulturalists from ADAS and HRI (Horticulture Research International). The objective of the work was to evaluate sampling methods for monitoring cabbage aphids and caterpillars on brassica crops and to establish and test a series of spray thresholds.

In this study, thresholds are expressed as the percentage of infested plants. Theunissen (1984) defined them as "tolerance levels" because they specify the tolerance of the crop to cabbage aphids and caterpillars at various times during the growing season. In the first year of the trials on the research farms, fixed tolerance levels were used. Some of these results (1991) were presented at the previous IOBC workshop (Blood Smyth *et al.*, 1992). After the first year, variable tolerance levels were used instead of fixed ones. Variable tolerance levels include the growth stage of the crop in the decision making process (Theunissen, 1984). Variable tolerance levels were reduced markedly once the marketable parts of the plant began to form.

In this paper, results are presented from the trials on the commercial farms during the first year and from the trials on the research farms during the second year. Sequential sampling techniques, using completely random samples, were used on the research farms to validate tolerance levels. However, they were considered too complex for farm use. In the trials on the commercial farms, a more practical sampling system was evaluated but, using information on tolerance levels gained from previous trials on the research farms.

Materials and Methods

Research farm trials

In 1992 Brussels sprouts and calabrese were grown in field plots at three research farms, namely ADAS Arthur Rickwood, HRI Kirton and HRI Stockbridge House. The plots were a minimum of 200 sq m and the treatments were laid out in a 3 x 3 Latin square. The pest tolerance levels used were modified from earlier experiments and are shown in Table 1.

Table 1. Pest tolerance levels used on Brussels sprouts and calabrese plants

	Growth stage		
	Initial	**Leaves just touching in rows**	**Button initiation**
	Percentage Plants infested		
Brussels sprouts			
Cabbage aphid	20	10	5
Cabbage caterpillars	40	40	5
	Initial		**Crown (10 mm) to harvest**
	Percentage Plants infested		
Calabrese			
Cabbage aphid	10		5
Cabbage caterpillars	40		5

Treatments were as follows:-

1. Untreated control
2. *Routine treatment - sprayed at two week intervals with a tank mix of deltamethrin (5 ml a.i./ha) and pirimicarb (75 g a.i./ha) in 600 litres water/ha.
3. Supervised treatment - insecticides and water volumes as above, applied singly or as a tank mix, but only when the tolerance levels were reached.

* The routine treatment is not necessarily current grower practice. Some growers are inspecting their crops for pests, usually in a cursory manner. However, in other areas, crop consultants carry out much of the crop walking, with more rigourous crop inspection. As a consequence, growers often spray their crops less frequently than once every two weeks.

Supervised plots were sampled every two weeks, starting two weeks after transplanting. The sequential sampling system was based on Wald's Sequential Probability Ratio Test (Wald 1947). Samples were recorded using charts similar to those constructed by Theunissen (1988) (see Lynn & Mead, 1994), for the tolerance levels shown in Table 1. For each plot on each sampling occasion, a set of random plant co-ordinates were generated by a Genstat 5 program. Plants were inspected for live cabbage aphids and cabbage caterpillars. Pests were not counted. Once a chart boundary was crossed, sampling stopped and the appropriate action was taken. The sequential sampling method is described in Paterson *et al.* (1994).

At harvest, a systematic sample of 40 Brussels sprouts or 60 calabrese plants was taken across the whole plot. Pest damage/presence both internally and externally was assessed on a sample of buttons from each harvested Brussels sprout plant, or on the primary spear of each harvested calabrese head. Marketable yields of Brussels sprouts buttons (grades 12.5-20 mm, 20-30 mm, 30-40 mm and > 40 mm) and calabrese spears (grades < 100 mm, 100-125 mm, 125-150 mm, 150-175 mm and 175 mm) were also recorded.

For both crops, a cross-site analysis of variance was carried out on both yield and pest damage. The percentages of buttons, or spears, in each category were transformed to angles prior to analysis. The analyses allowed site differences, treatment differences, and site by treatment interactions to be estimated.

Trials on Commercial Farms

Trials were done in Brussels sprout crops on five commercial farms in England. The experimental plots were 26 x 52 m and were located along the field edge to give a headland area that was 26 m wide. There were three replicates of the two treatments. The set of variable tolerance levels used was derived from the Brussels sprouts trials on the research farms.

Treatments were as follows:-

1. Routine treatment - sprayed at two week intervals from three weeks after transplanting until two weeks before harvest, with a tank mix of demeton-S-methyl (325 g a.i./ha) and deltamethrin at 3.75 g a.i./ha.
2. Supervised treatment - insecticides and water volumes as above, applied singly or as a tank mix, only if threshold(s) exceeded. When applied singly, deltamethrin was used at a higher rate (7.5 g a.i./ha) (non-routine manufacturer's recommendation).

NB: Growers followed their own programme of pest control in the rest of the crop.

The supervised plots were sampled every two weeks using a systematic sampling method. Two separate sets of samples were taken from each plot, one from the headland (the first four rows) and the other from the rest of the plot. For the headland sample, every fourth plant was assessed in each of the four rows, giving a total sample of 50 plants. Another 50-plant sample was assessed for the rest of the plot by making two traverses into the crop from the fifth row, sampling every fourth plant on each traverse. As on the research farms, each plant was inspected for the presence of aphids and caterpillars. The level of infestation was recorded simply as the percentage of plants infested.

At harvest a systematic sample of 40 plants was taken. To assess the levels of pest damage at increasing distances from the headland, each plot was divided into eight zones of equal area. (The first zone was the headland and the last was at the opposite end of the plot). The 40-plant sample consisted of five plants taken from each zone. Pest presence/damage and marketable yield were recorded using the methods employed in the trials on the research farms.

A cross-site analysis of variance was carried out on yield and pest damage. The percentages of buttons, or spears, in each category were transformed to angles prior to analysis. These analyses allowed site differences, treatment differences, and site by treatment interactions to be estimated.

Results

In the 1992 trials on the research farms, there was a marked reduction in the number of sprays between routine and supervised treatments, particularly for caterpillar control (Table 2).

On the supervised plots, more sprays were applied to both brassica crops than in the previous year, when, on average, spray treatments were reduced from 6.6 on the routinely treated plots to 1.3 on the supervised plots.

The results of the overall assessments of aphid presence/damage on Brussels sprout buttons at harvest are shown in Table 3.

Table 2. Mean number of sprays applied to control aphids and caterpillars on routinely-treated and supervised plots (averaged over 3 sites)

Crop	Mean no. of sprays applied	
	Routine	Supervised
Brussels sprouts		
Cabbage aphid	9.6	6.1
Cabbage caterpillars	9.6	1.2
Calabrese		
Cabbage aphid	3.6	2.4
Cabbage caterpillars	3.6	1.1

Table 3. Assessment of the overall percentage of Brussels sprout buttons with aphid presence/damage at harvest

Sites	Treatments					
	Untreated		Routine		Supervised	
Arthur Rickwood	89	(70.3)	5.3	(13.3)	24.8	(29.9)
Kirton	50	(45.2)	0.8	(5.0)	3.2	(10.3)
Stockbridge House	55	(48.1)	3.8	(11.2)	8.4	(16.8)

L.S.D. (P = 0.05) = 7.635

Back-transformed means with transformed data in parentheses

At Kirton and Stockbridge House, where the aphid infestation was low, there was no difference in the number of aphid-infested and damaged buttons between the routine and supervised treatments (Table 3). However, at Arthur Rickwood, where the aphid infestation was higher, 25% of the buttons from the supervised plots were infested, that is nearly five times more than from the routinely-treated plots.

Similar results were obtained from the calabrese trials (Table 4). Once again, at Arthur Rickwood, where the pest pressure was greatest there was unacceptable aphid damage on the spears from the supervised treatments.

Table 4. Assessment of the overall percentage of calabrese spears with aphid presence/damage

Sites	Treatments					
	Untreated		Routine		Supervised	
Arthur Rickwood	34.5	(40.0)	8.1	(16.6)	19.4	(26.0)
Kirton	0.2	(2.5)	0.0	(0.0)	1.7	(7.4)
Stockbridge House	0.4	(3.5)	0.2	(2.5)	0.7	(5.0)

L.S.D. (12 d.f., 5%) = 4.885
Back-transformed means with transformed data in parentheses

However, averaged across all three sites, there was no difference in marketable yield between supervised and routine treatments, for either Brussels sprouts or calabrese (Tables 5 and 6).

Table 5. Yield (t/ha) of Brussels sprouts buttons (average of 3 sites)

Treatment	Total	Waste	Marketable
Untreated	24.3	8.7	15.7
Routine	25.6	1.2	24.5
Supervised	24.9	1.5	23.4
L.S.D. (P = 0.05)	3.8	2.0	4.2

Table 6. Yield (t/ha) of calabrese spears (average of 3 sites)

Treatment	Marketable yield in grades (mm)					
	< 100	100-125	125-150	150-175	> 175	Total marketable
Untreated	0.07	1.4	3.5	3.8	3.5	12.3
Routine	0.19	1.4	3.4	4.5	3.8	13.3
Supervised	0.17	1.3	3.7	4.2	4.0	13.3
L.S.D. (P=0.05)	0.4	0.6	1.4	0.7	2.3	1.8

Table 7. Numbers of sprays applied to control aphids and caterpillars in trials on commercial farms

	Routine		Grower practice		Supervised	
	Aphid	Caterpillar	Aphid	Caterpillar	Aphid	Caterpillar
Beds	6	6	6	5	3	3
Berks	5	5	5	5	1	1
Lincs	7	7	5	5	5	5
Warks	6	6	5	5	5	6
Yorks	7.5	7.5	<7.5*	<7.5*	2.7	0
Mean (for first 4 sites)	6.0	6.0	5.25	5.0	3.5	3.75

* Incomplete farm records

In the trials on the commercial farms the use of variable tolerance levels reduced the numbers of spray applications from six 'routine' applications or five 'grower' applications, to an average of three. Overall, the supervised control treatment reduced pesticide usage by 53% compared with 'routine' treatments and 25-33% compared with grower practice but incurred a loss in marketability of only 4.2% compared with the routine. The mean percent marketable buttons for the five sites are shown in Table 8. Up to 8% reduction in marketable sprouts was due to slug damage, which was worse in the supervised than in the routinely-sprayed plots.

Table 8. The percentage of marketable Brussels sprouts harvested from trials on commercial farms

Site	Treatment	Field position Headland	 Field	 Overall
Bedfordshire	Routine	100 (90)	99.3 (86)	99 (86)
	Supervised	96 (83)	98.7 (86)	98 (86)
Berkshire	Routine	71 (58)	89.2 (71)	87 (69)
	Supervised	58 (50)	81.9 (65)	79 (63)
Lincolnshire	Routine	96 (80)	97.5 (83)	97 (81)
	Supervised	87 (69)	98.7 (85)	97 (81)
Warwickshire	Routine	73 (62)	94.3 (79)	92 (76)
	Supervised	64 (55)	91.1 (74)	88 (71)
Yorkshire	Routine	96 (80)	98.1 (82)	98 (82)
	Supervised	96 (80)	88.9 (71)	90 (71)
Overall	Routine	87 (74)	95.7 (80)	95 (79)
	Supervised	80 (67)	91.9 (76)	90 (74)
L.S.D. (P=0.05) for comparing treatment means within a site		(21.9)	(8.1)	(6.8)
L.S.D. (P=0.05) for comparing overall treatment means		(9.8)	(3.6)	(3.0)

Back-transformed means with transformed data in parentheses.

Discussion

As this is the second year of three year's work on the research farms and the first of two years on the commercial farms, only tentative conclusions can be drawn. Where pest control was based on variable tolerance levels, fewer sprays were applied compared with the routine sprays applied every two weeks and compared also with grower practice. Savings on aphicidal sprays were smaller in 1992 than 1991 because cabbage aphid migration was late in 1991 (Blood Smyth *et al.*, 1992) and hence sprays were not required early in the season. Both systems of supervised control usually worked well. However, pest pressure, especially from aphids, was greater at Arthur Rickwood than at any other site. Over 88% of untreated Brussels sprout buttons were infested with aphids at harvest. With this level of pest pressure, supervised control did not work.

Several aspects of the sampling method could be altered to improve systems of supervised pest control. During hot weather, a sampling interval of two weeks is too long, as aphid populations increase rapidly. Sampling on a physiological time scale rather than on calendar time scale would lead to better detection of changes in cabbage aphid and caterpillar populations. It is likely that the cost of supervised pest control could be reduced by targeting crop visits to critical stages in the life-cycle of the pest. This could be achieved with pest forecasts. A forecast for cabbage aphid is being developed currently by HRI entomologists. The use of a robust cabbage aphid forecast would have saved two months of visits during 1991.

The sequential method used to validate tolerance levels on the research farms is unlikely to be adopted by growers because of the time required to take completely random samples. The method is complicated and, at low tolerance levels, is extremely time consuming. Whilst the method used currently is not practicable, if a were possible to develop a sequential sampling method which did not require completely random samples then this would certainly be less time-consuming than the systematic sampling method used on commercial farms. The distribution of pests within large crop areas must be determined so that an accurate, but also practical, sampling technique can be developed. In the Netherlands, tractor wheelings are used as sampling paths (Theunissen, 1991). However, the use of tractor wheelings or traverses could give misleading results if, as suspected, the distribution of pests is not uniform.

Whatever method of sampling is developed, it must be "grower-friendly", that is straightforward to use and not too time-consuming. It should also be of similar cost to current grower practices, thus the additional cost of crop monitoring has to be offset by savings in insecticide and spray applications.

Acknowledgements

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Résumé

Lutte dirigée contre les ravageurs du feuillage des cultures de choux de Bruxelles et de brocoli à jets.

Deux systèmes de lutte dirigée contre les ravageurs ont été testés sur les cultures de Brassica en 1992. Un système est basé sur une méthode d'échantillonnage séquentiel complexe en prenant les échantillons complètement au hasard et qui a été testé seulement en fermes expérimentales. L'autre système plus pratique est basé sur une méthode d'échantillonnage systématique et a été testé en fermes commerciales. Les systèmes ont servi à tester les mêmes séries de méthode d'échantillonnage et les niveaux de tolérance pour le Puçeron cendré du chou (*Brevicoryne brassicae*) et la Piéride du chou (*Pieris rapae*). Dans les essais en fermes expérimentales, on observe une réduction marquée entre les traitements de routine et

les traitements dirigés, dans le nombre de pulvérisations réalisées particulièrement dans la lutte contre la piéride. Dans les essais en fermes commerciales il y a une réduction général de l'usage des pesticides de 53% comparée à la lutte de routine et de 25-33% en comparaison avec la pratique des agriculteurs. La perte moyenne de produit commercialisé atteignait juste 4%. Toutefois, dans une des fermes expérimentales ou la pression des aphides était élevée la lutte a été insuffisante.

Pour améliorer les techniques d'échantillonnage employées dans les systèmes de lutte dirigée en culture de Brassica, des connaissances supplémentaires sont à acquérir sur la distribution du puçeron cendré et des piérides dans la culture.

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Current status of monitoring populations of *Delia radicum*, *Psila rosae* and *Agrotis segetum* in field vegetable crops in Denmark

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Summary

In Danish field vegetable crops, only three major pests; the cabbage root fly, the carrot fly and the turnip moth are monitored regularly. The monitoring and forecasting of these pests have been developed over the last 13-14 years and the information presented in this paper gives the key information on the current status of all three systems.

Cabbage root fly (*Delia radicum*)

Crops monitored: Mainly cauliflower, but sometimes white cabbage and Chinese cabbage.

Monitoring method: Swiss "egg traps" using 10 "traps"/field.

Servicing: Farmers count the numbers of eggs on two occasions each week.

Information flow: The numbers of eggs are reported to the Department of Plant Pathology and Pest Management (DPPPM). Farmers report by telephone or telefax once each week. A few "leading farmers" report by telephone after each egg count is made. The DPPPM issues Crop Protection Leaflets (CPL) which, when a warning is imminent, give information about fly catches and information about timing of treatments at both regional and country levels. In 1993, seven Crop Protection Leaflets and the same number of tele-text messages were sent out. Thermal summation is used to estimate the start of the flight period.

Age of system and participation: This monitoring system was started at the experimental level in 1985 (Bromand, 1988a,b). The system has never involved more than 25 farmers and in most years about 15 farmers participate throughout the season. In 1993, 20 farmers participated.

Perspectives: New methods of recording the flight activity and oviposition of the cabbage root fly are now being considered and will be tested in 1994.

Carrot fly (*Psila rosae*)

Crops monitored: Carrot, parsnip (as root crop) and celeriac.
Monitoring method: Swiss-produced, Rebell®, yellow sticky-traps supported on a post and covered with a green "Phillipsen-net". 5 traps used/field.
Servicing: Traps are replaced once a week. Since 1992 the counts have been made by members of the Advisory Service based in the particular locality.
Information flow: During peak flight periods, the DPPPM receives the data on the numbers of flies caught via Crop Protection Leaflets and tele-text. Local and processing-factory advisors, belonging to the Advisory Service, inform farmers about when and where to apply insecticide treatments. A control threshold is used as a guideline, but local farm conditions and experience are also taken into consideration.

The data on the numbers of carrot fly caught in each field, are sent to the DPPPM once a year for further interpretation, and are used to validate the development models that are based on thermal summation.
Age of system and participation: Based on experience gained between 1979-1983, the system was introduced in 1984 (Esbjerg *et al.*, 1988) to 14 growers. The number has grown as follows: 1985: 24, 1986: 33, 1987: 96 ... 1993: 163. At the beginning, the system was run by the DPPPM with back-up from KVL, but at present DPPPM and KVL act only as specialist advisors for when problems arise.
Perspectives: The relationship between the numbers of flies caught and crop damage needs to be improved by further research. The current system has reached a high level of implementation.

Turnip moth/cutwork (*Agrotis segetum*)

Crops monitored: Carrot, red beet, leek, onion, potato and fir in plant nurseries.
Monitoring method: Sex traps (tray type) with synthetic pheromone, using 3 traps/field.
Servicing: Counting the numbers of moths caught at least twice a week and replacing the sticky base of the trap at least once a week. If the number of moths caught exceeds 25, the trap base has to be replaced and the counting intervals shortened accordingly. The pheromone dispenser is replaced after approximately 5 weeks. All servicing is carried out by the grower. (In Sweden members of the Advisory Service and consultants do the servicing).
Information flow: The numbers of moths caught are recorded by growers on printed forms and mailed or faxed to the DPPPM once a week. Interpretation of the numbers of moths is carried out by the DPPPM and KVL and a letter containing information for the individual is sent each week from the DPPPM to each participating growers. When needed, Crop Protection Leaflets and teletext messages are issued with advice on where and when to apply control. The array of control thresholds used takes into account: crop type, soil type, numbers of moths caught, temperature, rainfall and irrigation after catch. Advice is given on control involving insecticide, virus and/or water.
Age of system and participation: The period over which the system has been

operating and the numbers of Danish farmers that have participated are shown in Fig. 1.

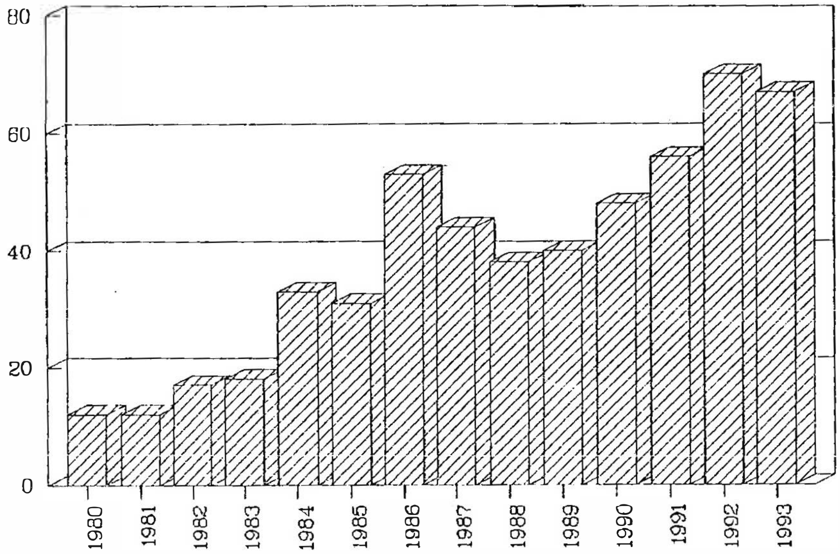

Fig. 1: Numbers of Danish farmers monitoring *Agrotis segetum* between 1980 and 1993.

In 1993, 69 Danish farmers and an additional 34 farmers from Sweden participated in the scheme.

The data management and individual advisory system have been done on a computerized system since the beginning of 1993 (Boll & Ravn, 1993), but the evaluation, developmental & survival rates of the eggs and young larvae, and the ultimate advice on how to control the infestation, are still done manually.

Perspectives: Models for egg and larval development, larval mortality and treatment thresholds could be computerized in future. In the long-term, the system will be decentralized so that it can be run by the local Advisory Services.

Résumé

Statut actuel de la prévision des populations de *Delia radicum, Psila rosae et Agrotis segetum* en cultures légumières de plein champ au Danemark

Seuls trois ravageurs principaux existent dans les cultures légumières de plein champ danoises: la Mouche du chou, la Mouche de la carotte et la Noctuelle du navet font l'objet d'avertissements régulièrement. Les avertissements et la prévision des attaques ont été mis au point au cours des 13-14 années précédentes et les

informations présentées dans cet article donnent les informations clés sur le statut actuel des trois systèmes.

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The introduction of systems for the supervised control of carrot fly (*Psila rosae* F.) in The Netherlands

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Summary

This research was done in co-operation with the Plant Protection Service (P.D. at Wageningen).

In 1992, the carrot fly was monitored in The Netherlands at 15 sites during the first flight and at 45 sites during the second flight. The timings of the two flights were forecast by Collier using soil and air temperatures. Damage varied between 1 - 3% at 6 sites and exceeded 3% at only 5 sites, where carrot fly control had not been applied. The latter were not commercial sites, but were fields on organic and experimental farms. The internationally accepted thresholds of 1 & 0.5 flies/trap/day, for the first and second flight, respectively, corrected by a factor of 1.8 to compensate for a new trapping method, appeared appropriate when the maximum crop damage recorded was about 3%.

In 1993, 109 sites (43 first and 66 second flight) were monitored, 65 of which were subjected to supervised control. A commercial firm contracted carrots to be grown on about 90 sites using supervised control systems rather than the usual commercial pesticide régimes. The supervised control took into account date of drilling, date of harvest, the safety period of the insecticide, the number of flies caught and the date on which the flies were caught. In 1993, the numbers of flies caught exceeded the threshold at 18 sites. Eight of these sites were commercial fields. An insecticide with a shorter safety period than 8 weeks is needed urgently for inclusion in systems of supervised control of the carrot fly.

Introduction

The reason for this research was the withdrawal by the manufacturer of the insecticide bromofos. This insecticide had been used previously to control the second flight of the carrot fly in The Netherlands.

Also, following a three year survey by Ester *et al.* (1991), there were doubts about the efficacy of the crop protection methods being applied. However, few complaints were received from growers. This was due either to the treatment being effective or because carrot fly numbers were low in certain regions of The Netherlands.

The national policy within crop protection (Multi-Year Crop Protection Plan (M-YCPP)) is to make substantial reductions in the use of pesticides in the next few years in comparison with 1984-1988. In 1991, a decision was made to monitor carrot fly activity in carrot producing regions in The Netherlands, in attempts to answer the following questions:

1. How large are carrot fly infestations in the different regions of The Netherlands?
2. Can a fly developmental model based on temperature help to determine the appropriate time to place sticky traps into the field?
3. What is the relationship between the numbers of carrot flies caught and subsequent crop damage?
4. How does damage vary between the edge (border) and the middle of a field?
5. What treatments do farmers use against the carrot fly, and are they effective?
6. Is there any possibility of using methods of supervised pest control?
7. Should carrot fly control be improved by applying different chemicals or simply by improving the methods of application?

Materials and Methods

Locations

The research was started in 1992 as a combined project between the Plant Protection Service (PD) in the various regions and the PAGV in Lelystad.

The Netherlands is divided into 7 regions, each with a Regional Research Centre that records temperature data. In the preliminary work, traps were placed in two fields in each region to determine the start of the first flight, and to gain experience in servicing traps and identifying the flies. During the second flight in 1992, and both flights in 1993, traps were placed into fields in each region.

Temperature

The prediction of the flight period (start and peak) was generated by Collier at HRI Wellesbourne, in England. The prediction involved using the maximum and minimum air temperature recorded 1.5 m above ground level and the maximum and minimum soil temperature recorded at a depth of 5 cm in bare soil. The temperatures were recorded daily (8 a.m.) from 1 February at six sites.

The numbers of flies caught

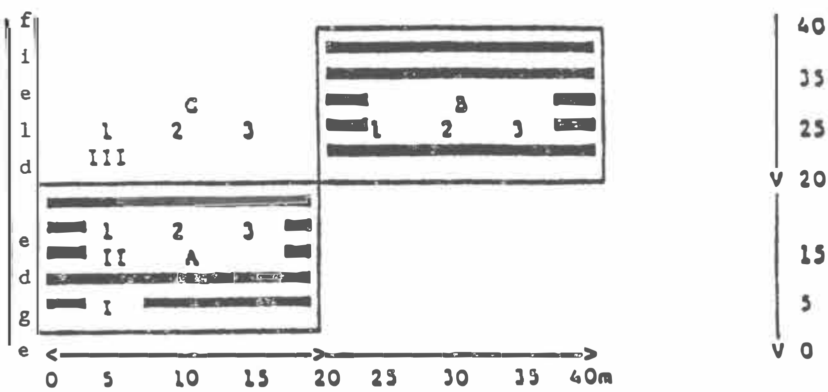
Three Rebell traps were spaced 5 metres apart and 5 metres away from a field boundary. The site chosen was, in order of preference, on the leeward side of: a forest edge, a line of trees, a tall crop, or a ditch.

In 1993, the source of flies from previous umbelliferous crops were noted. All traps were placed just above the crop, at an angle of 45°, with the top facing East. Each week the sticky traps were replaced and the flies on each side of the trap were identified and counted. The height of the trap was adjusted during the season to keep the trap just above crop height.

In 1993, the farmers could choose whether to use a threshold of 10 or 20 flies/trap/week for the first flight and 5 or 10 flies/trap/week for the second flight. Using these thresholds, the grower could decide whether to control the flies in the boundary of the field or in the whole crop, respectively.

Estimation of crop

On each field, three 20 m long plots were marked out, each plot being either 18 m or 24 m wide to match the spread of the sprayboom. Plots A and B were used as the controls and plot C received the normal spray treatments (Fig. 1).



■ - no second treatment or no treatment at all

I, II, III - place of the sticky trap

A1,A2,A3,B1 etc - sampling place

Fig. 1: Schematic plan treated of the positions of the treated and untreated plots within the carrot field.

Eight weeks after the flight peak, three samples were taken per plot. The samples were taken 5 m, 10 m, and 15 m away from the field boundary in Plots A and C and 25 m, 30 m and 35 m away from the field boundary in Plot B. A total of 50 large and 100 small carrots were taken at 10 random spots, parallel to the field boundary. After washing, the carrots were classified into 3 groups; not infested, slightly infested and severely infested. "Slightly infested" meant that the damage was not visible from a distance of one metre.

Cropping and treatment information

During the first visit to a crop, information was taken about the crop and the number of treatments planned. The actual controls applied against the fly were recorded by the grower. Distinctions were made between the following situations.

Code	Treatment applied at drilling?	Treatment applied > 2 weeks after drilling?
1	no	no
2	no	yes
3	yes	no
4	yes	yes

Results

Number of carrot flies caught and subsequent crop damage

In 1992, due to dry weather, few flies were caught in the regions of Groningen, Zeeland, Noord-Brabant and Limburg and crop damage was minimal (Table 1).

Table 1. Number of fields inspected in the 7 regions in 1992, in which carrot fly damage occurred in the untreated areas.

Region	1st Flight			2nd Flight			Total		
	<1%	1-3%	>3%	<1%	1-3%	>3%	<1%	1-3%	>3%
Groningen	0	0	1	5	0	0	5	0	1
Drenthe	2	0	0	6	2	0	8	2	0
Flevoland	2	0	1	5	1	1	7	1	2
Noord Holland	1	0	0	5	3	2	6	3	2
Zeeland[1)]	5	0	0	5	0	0	10	0	0
Noord Brabant	2	0	0	5	0	0	7	0	0
Limburg	1	0	0	5	0	0	6	0	0
The Netherlands	13	0	2	36	6	3	49	6	5
		15			45			60	

1) Same field used for the second flight. Complete records were not taken from the first flight because the crops were drilled late (monitored and supervised control sites).

No more than 3% damage was recorded from the untreated areas of all farmers' fields. The only crop in Groningen with reasonably high numbers of flies and damage was grown on an allotment. In Drenthe, although some flies were caught on 2 of the 8 properties, crop damage was limited. In Flevoland, damage occurred in 3 fields, 2 on an organic farm and 1 on our own research farm. In Noord-Holland, 2 fields had relatively high numbers of flies but little or no damage. The 2 fields were at a Regional Research Centre and on an organic farm. On certain areas of the organic farm, although relatively few flies were caught damage was severe (A = 61%, B = 30%).

In 1993, carrot fly was recorded from 109 fields, 73 of which were subjected to a system of supervised pest control (Table 2). During the first flight, the damage threshold was exceeded in 2 farmers' fields and in 4 special fields (Regional Research Centres and organic farms). Damage of more than 3% occurred only in 3 of the special fields. During the second flight, in a generally wet season, the damage threshold was exceeded in 6 farmers' fields and damage of more than 3% was recorded on the untreated parts of 8 farmers' fields. For the special fields the threshold was exceeded in 7 fields and damage was above 3% in 6 fields. Damage exceeded 3% in 3 fields drilled on ridges 75 cm high, in windy parts of Noord-Holland and West-Brabant even though the numbers of flies caught did not exceed the threshold.

Table 2. Number of crops during the first and second generation of the carrot fly in 1993, in which the damage threshold of 3% was exceeded (C = commercial, S = special site, research centre or organic crop).

Region	First flight						Second flight					
	monitoring	supervised control	>threshold		damage >3%		monitoring	supervised control	>threshold		damage >3%	
			C	S	C	S			C	S	C	S
Groningen	3	0	0	1	0	1	8	8	0	0	0	0
Drenthe	18	16	1	0	0	0	11	10	1	1	0	1
Flevoland	7	0	0	3	0	2	9	5	0	3	0	3
N.Holland	4	0	0	0	0	0	11	9	1	2	3	2
Zeeland	3	0	0	0	0	0	5	5	1	0	1	0
N.Brabant	5	0	0	0	0	0	12	10	3	0	4	0
Limburg	3	0	1	0	0	0	10	10	0	1	0	0
Netherlands	43	16	2	4	0	3	66	57	6	7	8	6

Flight prediction

When using supervised control of the carrot fly it would be an advantage to know when to place the sticky traps into the Field to determine whether to treat a field preventatively at a certain sowing or harvesting date.

The English model, predicts the timing of the flight. Until sufficient data are collected to validate this model, the prediction will contain variation.

In 1992, the prediction made on 13 April of the beginning of the first flight (10%) was 1 - 12 days later than the actual flight, which occurred between 7 - 16 May. The peak of flight activity that occurred on May 19-26 was predicted well on April 13. The difference between the predicted and the observed values was only 0-3 days.

In 1992, the start of the second flight was predicted less accurately than the first flight. This might have occurred because the forecast was made too early, temperatures used for the forecast were predicted inaccurately, low numbers of flies were recorded per field and because the majority of such flies had to come from other fields.

The predicted peak occurred within 0-7 days of the actual peak.

In 1993, the flights were predicted reasonably well. It appeared essential not to generate the prediction too far in advance, as the temperatures changed rapidly immediately prior to fly activity.

Relation between number of flies caught and subsequent crop damage

The relationship between the number of carrot flies caught and carrot damage in 1992 and 1993 was extremely variable (Fig. 2). However, there was a difference between the first and second flight. In many fields (88%), the overall damage was close to zero. In other cases damage occurred when the threshold of 10 and 5 flies/trap/week was exceeded for the first and second flight, respectively. In 1993, damage exceeded 3% in 3 fields even though the numbers of flies caught did not exceed the damage threshold.

Damage to crop alongside field boundary

As the distance from the field boundary is increased, crop damage decreases (Fig. 3). At high levels of damage, penetration into the field is much greater than at low levels of damage. Only when a low number of flies are present, will spraying the field boundary be sufficient to control the larvae.

The effects of the control measures applied against the carrot fly

The effects of the treatments were difficult to assess because of the low numbers of crops that contained flies and damage.

In practice, farmers already use 70% less insecticide than they did during the period 1984-1988 (M-YCPP). When crops of large carrots and bunching carrots are grown, much of the insecticide is applied as a seedcoating. The second treatment is applied mainly as a row treatment to crops grown to produce large carrots. When small (< 25 grammes) carrots are grown, only 1 treatment is applied. Granules are usually applied at sowing or a full spray is applied between the first and second flight, depending upon the dates of sowing and harvesting.

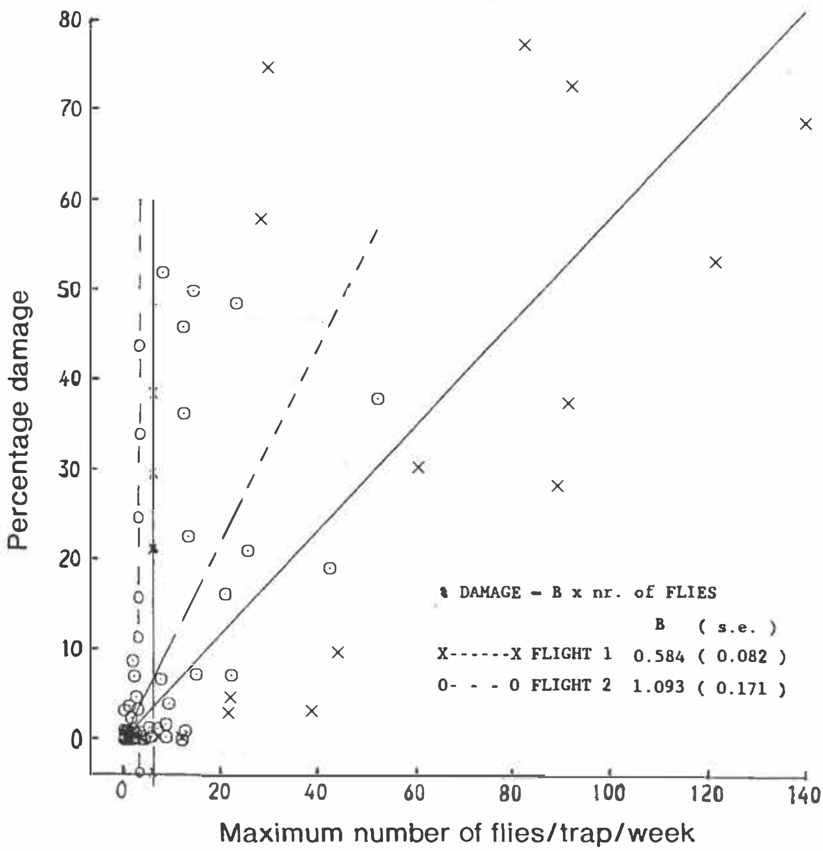


Fig. 2: Relationship between number of flies caught and the percentage of the crop damaged.

Supervised control of the carrot fly

A preliminary supervised control system, produced following the 1992 season, was tested in 1993 on a large number of fields by the PAGV/PD and Groene Vlieg (Green Fly, commercial advice office at Nienwe Tonge). In carrot production, crops are sown and harvested at many different times of the year. (Schoneveld, 1991). Using sowing and harvesting date, it is possible to predict if a preventative control measure should be applied, or if it is possible to wait and make the decision from the numbers of flies caught on yellow sticky traps. A number of adaptions to the preliminary strategy will be carried out during 1994.

The number of sticky traps will be increased from 3 two-sided to 5 one-sided. The traps will be attached to a pole with a windvane. The damage threshold will be lowered to 6 or 12 flies/trap/week for the first flight and 3 or 6 flies/trap/week for the second flight. The two figures quoted are for the field boundary and the whole field, respectively.

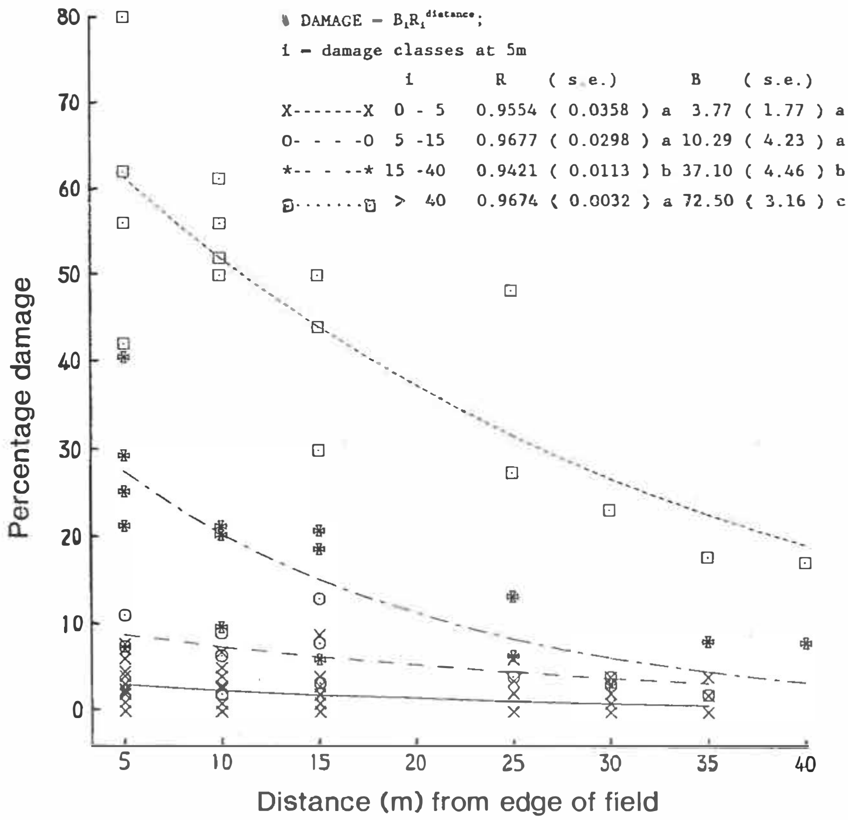


Fig. 3: Relationship between the distance from the edge of the field and the percentage of damaged carrots.

Improvement in controlling the carrot fly

In practice, a great number of growers apply chemicals along the row against carrot fly during the second treatment, particularly in crops of large carrots where the spray is aimed at the top of the storage-root.

To get the chemical onto the ground, the effects of natural rainfall and irrigation also need to be taken into account. A search will be made for an effective treatment that is less persistent and can be applied at a lower dose of active ingredient than at present.

Discussion

Crop damage was apparent in more fields in 1993 than in 1992. This may have resulted from selecting fields likely to contain carrot fly, or to the moist weather conditions during the second flght favouring insect survival. More eggs may have hatched under such conditions.

The trapping method needs to be investigated further. A pole with a windvane, by which the underside of the sticky trap is kept away from the prevailing wind, still has to be tested under different wind directions. Only having to use the underside of the trap makes determination of the flies simpler (less pollution) and also reduces the influence of the weather on the glue. (Finch & Collier, 1989) To increase the reliability of the sample, 5 one-sided sticky traps will be used in future instead of 3 two-sided traps. When the sticky traps are being sited, attention will also be paid to the source of the flies from the previous generation. In windy areas, the height and position of the sticky trap will be recorded in crops growing on ridges. Finally it will be decided if a cumulative damage threshold can be produced. (Freuler *et al.* 1982).

In many instances, no carrot fly damage is tolerated in the harvested crop. Hence, a 3% damage threshold was used as the starting point, largely because damage up to 5% is not picked up in practise. However, damage does occur in carrots treated against the carrot fly. On such plots, 1 to 17% damage was found by Ester & Neuvel (1990).

Additional research is necessary to recommend a control method that has a period of persistence of less than 8 weeks and in which less active ingredients can be applied per ha.

In 1993, dimethoate (40% x 0.5 litre/ha) was applied to control aphids in a number of fields. In these fields, carrot fly adults were killed when the sprays were applied during the evening. On small trials, the same did not occur when the plots were sprayed in the afternoon. This chemical has a persistence period of 3 weeks.

Conclusion

A supervised system of control for the carrot fly seems possible because of the interest shown in it by growers. The costs of preventative control are high and the chances are relatively small that spraying still needs to be carried out. A private advice bureau can be paid to catch and determine the flies caught in growers' crops. The amounts of chemical used to control the carrot fly can be reduced even further than at present. In future, fewer problems are expected in soil adaptation, insect resistance, insecticide residue in the product, and in the wastewater from the carrot cleaning plant.

Résumé

Introduction des méthodes de prévisions et de lutte raisonnée de la Mouche de la carotte (*Psila rosae* F.) aux Pays-Bas

Cette recherche a été réalisée en coopération avec le Service de la Protection des Végétaux. En 1992, la mouche de la carotte a été suivi aux Pays-Bas dans 15 sites au cours du premier vol et dans 45 sites au cours du deuxième vol. Le déroulement des deux vols a été prédit par Collier en utilisant les températures du sol et de l'air. Les dégâts varient entre 1 - 3% dans 6 sites et excédent 3% sur seulement 5 sites où une lutte contre la mouche a été appliquée. Ces derniers sites n'étaient pas des champs commerciaux mais des parcelles sur sol organique et en fermes expériementales. Le seuil accepté internationalement de 1 et 0,5 mouche par piége et par jour pour le 1er et le 2eme vol respectivement, corrigé par un facteur de 1,8 pour compenser les différences de méthode de piégeage, semble approprié lorsque le dégât maximum de la culture observée est d'environ 3%.

En 1993, 103 sites (43 pour le 1er et 66 pour le 2ème vol) ont été suivis, parmi ceux-ci 65 sites ont fait l'objet d'une lutte dirigée. Une firme commerciale a cultivé des carottes sous contrat sur environ une centaine de sites en utilisant la lutte dirigée plutôt que la lutte systématique. La lutte dirigée prend en compte la date de semis, la date de récolte, la durée d'efficacité de l'insecticide, le nombre de mouches capturées et la date à laquelle les mouches ont été capturées.

En 1993 le nombre de mouches capturées excédait le seuil dans 18 sites, 8 de ces sites étaient des champs commerciaux.

Il est nécessaire de trouver de façon urgente un insecticide dont la rémanence est inférieure à 8 semaines pour l'inclure dans un système de lutte dirigée contre la Mouche de la carotte.

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APPENDIX
Intended system of supervised control for the carrot fly in 1994

FIRST FLIGHT

Circumstances	Should insecticide be applied?
Crop harvested less than 3 weeks after peak of flies	No
Crop drilled after peak of first flight	No
Crop drilled before peak of flies and harvested 3 - 8 weeks after peak of first flight	Yes
Crop drilled before peak of first flight and harvested more than 8 weeks after peak of first flight	Supervised (traps)
Less than 6 flies/trap/week	No
Between 6 - 10 flies/trap/week	Only border (20m)
More than 10 flies/trap/week	Yes

SECOND FLIGHT

Crop harvested within 3 weeks after the peak of the second flight	No
Crop harvested between 3 - 8 weeks after peak of second flight	Yes
Crop harvested more than 8 weeks after peak of the second flight	Supervised (traps)
Less than 3-4 flies/trap/week	No
Between 3-6 flies/trap/week	Only border (20m)
More than 6 flies/trap/week	Yes

Trapping for supervised system

Minimum of 5 Rebell traps per site, on pole with windvane, one side per week.

Traps to be placed where the flies aggregate. Priority to be given to areas that contain 1) carrot fly pupae, 2) shelter from trees, shrubs, other crops and ditches/canals.

Traps sited 5 m from edge of crop, 10 m between traps. Traps positioned parallel to source of shelter.

Angle of 45°. Sticky side held in the direction of the crop and supported just above the leaves of the crop.

Action thresholds for pests of leek - Results from a co-operative experiment

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Summary

In practice, leek (*Allium porrum* L.) crops are usually sprayed intensively during the whole season to control the two most important foliage pests; thrips (*Thrips tabaci* Lind.) and leek moth (*Acrolepiopsis assectella* Z.). In particular, attack by thrips can cause high losses in crop quality and simultaneous severe reductions in plant weight. In a co-operative field experiment done in Belgium, Germany and Switzerland, simple action thresholds based on sampling for the presence-absence of thrips (50% infested plants) and leek moth (5% infested plants), were tested in 1992. The results obtained were satisfactory in only one experiment. The number of sprays applied against the two pests could be reduced by 50% when compared to an intensive spraying scheme based on nil tolerance (1% infested plants by thrips or leek moth). There were no differences in the proportion of marketable plants and the average plant weights between the two insecticide treatments in Germany. In the other two countries, thrips control failed because the insecticides applied were not effective. Development of strains of thrips resistant to insecticide and other possible reasons for control failure are discussed.

Introduction

In many European countries, leek is a major field vegetable crop. In practice, many leek crops are sprayed intensively during the summer months against the two main pests, thrips and leek moth, as methods of supervised control are not available currently. Growers and the public asked for such methods to be developed as their general aim is to reduce the usage of pesticides and hence minimise the possible side-effects of such products on the environment. Furthermore, growers need to include such methods in their Integrated Production (IP) programs. However, systems of supervised control will be accepted by growers only if the systems are simple, reliable and not time consuming. In Europe at present, supervised control systems are used only in a few commercially-grown field vegetable crops like brassica, carrot, pea and bean (Theunissen, 1992).

Based on the positive results obtained in Germany (Hommes, 1992), a collaborative field experiment was started within the IOBC/WPRS-Working Group "Integrated Control in Field Vegetables" to test the Germany system of supervised control in leek crops grown in various cropping systems and under different climatic conditions. The results of the 1992 experiment are presented in this paper.

Materials and Methods

Group members from Belgium (Van de Steene & Vanparys), Germany (Hommes) and Switzerland (Hurni) participated in the experiment. Cultivation of leek was done with the systems used commercially. The dates of transplanting, and of final damage and weight assessment are shown in Table 1.

Table 1. Date for transplanting leek, and for estimating damage and plant weight

Country	Date for:-		
	transplanting	final damage assessment	final plant weight
Belgium	2 July 92	27 October 92	1 February 93
Germany	22 June 92	24 November 92	24 November 92
Switzerland	23 June 92	21 October 92	21 October 92

The treatments used in the field are shown in Table 2. Field sampling was started one week after transplanting and then every two weeks till autumn. For each treatment, sub-samples of 5 leek plants inspected at 10 positions distributed regularly across each plot. The heart and the leaves of each plant were inspected carefully for 1) living thrips and for 2) fresh feeding mines or larvae of the leek moth. As the system is based on presence-absence sampling, only the number of plants infested by thrips or leek moth were recorded. The percentages of infested plants were recorded

Table 2. Treatments tested in the collaborative field experiment:

1	untreated, no insecticide used	**(untreated)**
2	intensive spraying - using the extremely low threshold of 1% plants infested by thrips or leek moth	**(intensive T1/L1%)**
3	spraying according to thresholds - when 50% of plants infested with thrips or 5% of plants infested with leek moth	**(thresholds T50/L5%)**

separately for thrips and leek moth and then compared with the threshold values shown in Table 2.

Once the threshold values in treatments 2 or 3 were reached or exceeded, sprays of insecticide were applied as soon as possible. As control agents recommended pesticides (Table 3) for usage in leek crops were applied. Where possible, the untreated plot was also sampled to obtain information on the periods of attack and the infestation pressures of the two main pests.

At harvest, 100 plants (20 plants per sub-plot) from each treatment were weighed, trimmed for market and than checked individually for damage by the two pests. Damage by thrips was graded on a scale of 1 to 9; in which 1 = clean (no damage); 3 = slight; 5 = moderate; 7 = severe; and 9 = very severe. The values of 2, 4, 6 and 8 were also used as intermediate grades. Plants were classified as non-marketable if the damage grade by thrips was equal to or higher than 5.

Damage by leek moth or other lepidopterous larvae was recorded separately. All plants with marked feeding sites were graded as non-marketable.

Results and Discussion

The amounts of damage at harvest in the three countries are shown in Table 3.

Results from Belgium

In Belgium, each of the recommended insecticides, acephat, endosulfan, and permethrin were sprayed 4 times at two-weeks intervals, starting on 11 August and ending on 25 September. None of the three insecticides tested controlled the thrips. Only 58% of the plants were marketable when the most effective insecticide, acephat, was applied. Permethrin was more or less ineffective. All insecticides tended to increase yield with a maximum increase of 28% for endosulfan.

Preliminary results from an experiment conducted in 1993 indicated that at infestation pressures lower than the ones recorded in 1992, the efficacy of the insecticides was better.

Results from Germany

In Germany, during the summer of 1992 the temperatures were very high and there were long dry periods, both of which favour thrips attack. Therefore, infestation pressure by thrips was extremely high in 1992. Practically no plants could be marketed from the untreated plots. The infestation levels in the untreated plot for the two key pests thrips and leek moth are shown in Fig. 1. Close to 100% of the plants were infested with thrips throughout the whole growing period. In contrast, infestations by leek moth were extremely low and never exceeded the 5% tolerance level.

Due to the high infestation (nearly 90%) of thrips at the first sampling, thrips control had to start immediately (Fig. 2). The insecticide applied marketly affected the infestation levels of the thrips. Two further insecticide sprays were required 4 and 6 weeks later to control thrips. Following the third insecticide application, the infestation level of thrips stayed below the corresponding control threshold of 50% till harvest. For leek moth control, only one spray had to be applied in August.

Table 3. Results of the co-operative experiment using action thresholds for pests of leek

Country/participant treatment	% plants marketable showing crop loss due to: thrips	leek-moth	No. of sprays	Relative yield
Belgium/F. Van de Steene & L. Vanparys				
untreated	3	-	0	100
routine/acephat (490 g a.i./ha)	58	-	4	106
routine/endosulfan (700 g a.i./ha)	43	-	4	128
routine/permethrin (50 g a.i./ha)	12	-	4	113
Germany/M. Hommes				
untreated	2	85	0	100
intensive/cypermethrin (30 g a.i./ha)	91	100	8	117
thresholds/cypermethrin (30 g a.i./ha)	99	99	4	125
Switzerland/B. Hurni				
untreated	38	30	0	100
intensive/3 x deltamethrin (7.5 g a.i./ha) +2 x furathiocarb (300 g a.i./ha)	20	92	5	113
thresholds/3 x deltamethrin (7.5 g a.i./ha) +2 x furathiocarb (300 g a.i./ha)	8	94	5	114

<u>Treatment:</u>

untreated: no insecticide used
routine: sprayed at 2-week-intervals from 11 August to 25 September
intensive: sprayed when 1% of plants infested by thrips or leek moth
thresholds: sprayed when 50% of plants infested by thrips or 5% of plants infested by leek moth

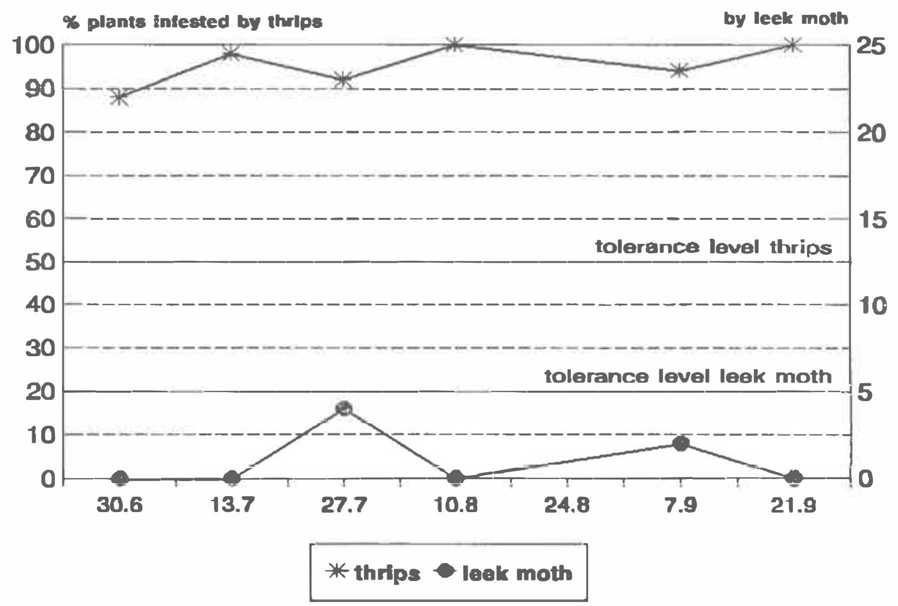

Fig. 1: Level of pest attack in untreated plot (Germany, 1992)

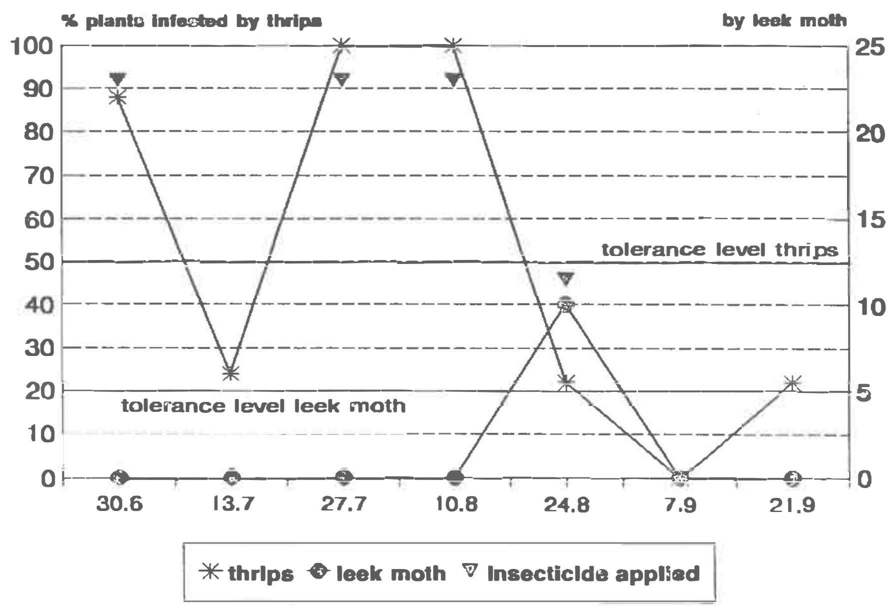

Fig. 2: Level of pest attack in threshold plot (Germany, 1992)

At harvest, only 2% of the plants were marketable in the untreated plot, whereas more than 90% of the plants from the sprayed plots were marketable (Table 3). Differences were also recorded for leek moth, even though the level of infestation was low during 1992. Crop yields much higher in the treated plots than in the untreated one. In comparison to intensive for a nil tolerance value, the number of sprays could be reduced by 50% when the tolerance levels were set at 50% of the plants infested by thrips or 5% of the plants infested by leek moth. This result confirms those obtained earlier (Hommes, 1992).

Results from Switzerland

The levels of pest attack in untreated and threshold plots are shown In Figs. 3 & 4. At the beginning of the experiment, nearly half the plants were already infested and during the following weeks the level of infestation in the untreated plots rose to 100% and stayed there till end of the growing period. Leek moth was observed first about 4 weeks after sampling started. About 50% of the plants were infested at the end of the sampling period. In the threshold plot (Fig. 4), thrips infestations exceeded the 50% tolerance level during the whole season, so that regularly sprays were necessary. Therefore, there were no differences in the number of sprays applied in the two insecticide treatments. In contrast to Germany, there were no clear effects of the insecticide application on the thrips despite two different insecticides being sprayed alternately. Only the population of leek moth was controlled for several weeks. The complete failure to control thrips is obvious from Table 3. It also appears that the insecticides applied to control thrips appears to have increased crop damage. This indicates that the thrips population is probably resistant to the used insecticides applied. In contrast, the insecticides were clearly effective against leek moth. The insecticides applied were ineffective against the thrips but could have killed their natural enemies and hence increased overall crop damage. Even though the insecticides failed to control the thrips, they still produced small increases in crop yield.

The results of the collaborative experiment show clearly that problems of controlling thrips in leek with insecticide can occur in some regions. Thrips control was effective in only one of the three countries involved in this co-operative experiment. Problems concerning the control of thrips in leek crops have also been reported from other areas of Europe. Obviously, if there is no effective way of controlling thrips, then the development supervised control systems for use in leek crops is pointless.

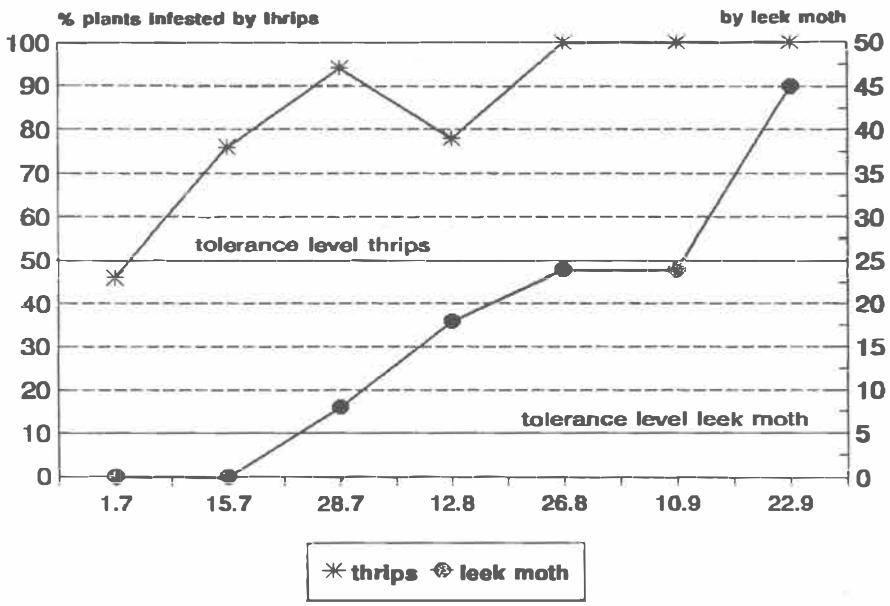

Fig. 3: Level of pest attack in untreated plot (Switzerland, 1992)

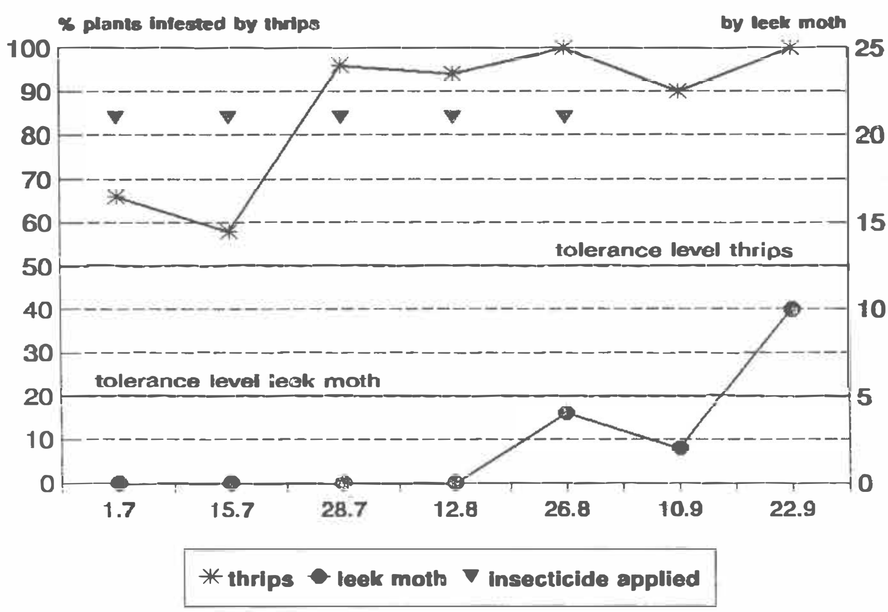

Fig. 4: Level of pest attack in threshold plot (Switzerland, 1992)

The possible reasons for this unsatisfactory control of thrips could be due to:

- development of insecticide-resistant thrips populations
- thrips outbreaks favoured by weather conditions that are unfavourable to the efficacy of the insecticides applied
- increased areas of *Allium*-crops which promote thrips attack
- infestation by new imported thrips species (e.g. *Frankliniella occidentalis*) known to be highly resistant to several insecticides

In future, experiments will concentrate on determining why the insecticides failed to control the thrips and how to overcome such problems.

Résumé

Seuils d'intervention pour les ravageurs du poireau - résultats d'une expérience de coopération

En pratique, les cultures de poireaux (*Allium porum* L.) sont habituellement traitées par pulvérisation de façon intensive pendant toute la saison pour lutter contre deux ravageurs importants du feuillage: les thrips (*Thrips tabaci* Lind.) et la teigne du poireau (*Acrolepiopsis assectella* Z.). En particulier, les attaques de thrips peuvent provoquer des pertes élevées sur le plan qualitatif et également des réductions sévères en poids de la plante. Dans une expérience au champs réalisée en coopération entre la Belgique, l'Allemagne et la Suisse, de simples seuils d'intervention basés sur l'échantillonnage furent testés en 1992 sur la base de la présence/absence des thrips (50% des plantes attaquées) et de teigne (5% de plantes infestées). Les résultats obtenus sont satisfaisants dans seulement une expérience. Le nombre des pulvérisations appliquées contre les deux ravageurs peut être réduit de 50% quand on le compare au schéma de pulvérisations intensives basé sur aucune tolérance (1% de plante infestée par les thrips ou la teigne du poireau). Il n'y a pas de différences dans les proportions de plantes vendables et le poids moyen des plantes entre les deux types de traitements en Allemagne. Dans les deux autres pays, la lutte contre les thrips échoue car les produits insecticides appliqués ne sont pas efficaces. Le développement de souches de thrips résistantes aux insecticides et les autres motifs de l'échecs de la lutte sont discutés.

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Damage to white cabbage by the aphid *Brevicoryne brassicae* (L.): influence of aphid density and stage of plant growth

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Abstract

The effects of feeding by the aphid *Brevicoryne brassicae* (Linnaeus) on white cabbage, *Brassica oleracea* Linnaeus were studied in a glasshouse experiment. The weight and size of the cabbage heads at harvest were not affected by the aphid infestations tested, but most of the unfolded leaves were deformed seriously and the shoot weight and leaf area were reduced significantly by aphid feeding. Aphid feeding resulted in proportionally heavier heads and higher moisture content in the plants. This experiment showed clearly that the test cultivar could compensate, in terms of head weight and head size, for the effect of aphid feeding. It is suggested that if similar compensation occurs in the field, reduction of crop quality (i.e. leaf deformation and soiling by aphids), rather than head weight/size, should be the critical criterion when determining the control tactics in this aphid-plant system.

Introduction

A quantitative understanding of a crop plant's response to insect injury is fundamental to any attempt at insect pest management, as the relationships between insect injury and crop yield are complex and variable (Pedigo *et al.*, 1986). It is now generally recognised that compensation is a widespread phenomenon by which the plant may mitigate or nullify the effect of insect feeding (Bardner & Fletcher, 1974).

This paper describes a glasshouse experiment, in which the response of cabbage to feeding by the cabbage aphid, *Brevicoryne brassicae* (L.), was examined at several aphid densities during various stages of plant growth.

Material and methods

Cultivation of the cabbage plants

Seed of white cabbage, *Brassica oleracea* var. *capitata* cv. 'Erdeno', was sown in a tray containing Floraton 2 potting soil produced by Torfstreuverband GmbH. This commercial potting soil was used throughout the experiment. Seedlings were transplanted individually into 7 cm plastic pots each containing 200 cm^3 potting soil. When the seedlings had about six true leaves, they were transplanted individually into 18 cm diameter plastic pots each containing 4000 cm^3 potting soil and grown in these pots until the final, destructive harvest.

The whole experiment was carried out in three adjacent glasshouse compartments, each containing ca. 28 m^2 bench space. The pots were spaced 35 x 45cm apart, so that the plants had a spacing similar to that used in the field. The control of temperature, light, and humidity in each compartment was carried out continuously by a central computerized system. During the period of the experiment, from 28 September 1989 to 28 February 1990, a mean daily temperature of 18.5 ± 0.5°C, a daily mean relative humidity of 60-70%, and a photo period of 16L:8D were maintained. The 16h photophase was provided by natural and fluorescent lights, which maintained the light intensity on the plant foliage above the minimum requirement of 7 Klux.

The aphid culture

A culture of the cabbage aphid was established from ca. 200 aphids collected from a field of Brussels sprouts near Bonn in September 1989. The culture was maintained on potted white cabbage plants under a regime of 19-21°C, 16L:8D and 60-90% R.H., conditions that prevented sexual reproduction.

The experimental design

The experiment was started originally as a 4 x 4 split-plot design, in which the stage of plant growth and aphid density were treated as factors A and B, respectively (Table 1, but see the section of "Statistical analysis"). Although the three replicates were run in parallel, intervals of three days were left between the start of each new replicate because of the large amount of work involved.

The designation of plant growth stages follows that of Andaloro *et al.* (1983), with each stage being divided further into sub-stages. The observed number of leaves and head size of the uninfested plants at each stage of growth (Table 1) are shown in Table 2.

At each stage of plant growth, three levels of aphids, comparable to "moderate", "high" and "very high" infestations, were tested plus a "no-aphid" control. Five plants per replication were tested at each aphid density. Clear plastic plates were placed upright between the treatments but they did not completely prevent cross-infestation. Therefore, the light infestation treatment could not be maintained. The aphids in the "moderate" and "high" densities reached much higher infestations than expected.

Table 1. Mean number of aphids per plant in the four aphid-density treatments in four seperate plant growth stage experiments

Aphid density	Plant growth stage of infestations			
	4.0 - 5.5		5.5 - 7.0	
	initial	final	initial	final
None	0	0	0	0
Moderate	2	393 (16)	4	4167 (59)
High	10	1368 (57)	20	10528 (153)
Very High	50	4428 (216)	100	21623 (339)

Aphid density	Plant growth stage of infestations					
	4.0 - 7.0				7.0 - 8.5	
	initial	5.5	6.0	final	initial	final
None	0	0	0	0	0	0
Moderate	2	253 (10)	42	4512 (64)	4	1971 (22)
High	10	1042 (42)	98	5346 (81)	20	4723 (53)
Very High	50	4853 (240)	183	10765 (186)	100	6443 (74)

initial = initial number of aphids per plant
final = final mean number of aphids per plant
( ) = number of aphids per 100 cm^2 leaf area

Infestation of the plants

Fourth instar apterous nymphs were inoculated onto the plants. The nymphs were taken directly from the aphid culture and were placed onto small leaf discs of white cabbage. Inoculation was done by placing the small leaf discs containing the appropriate numbers of aphids onto growing, unfolded leaves.

Two days after inoculation, the plants were examined thoroughly to count the number of aphids. Aphids were then either added or removed to produce the required levels of infestation. Under the experimental conditions, the growth period of each plant stage lasted for about two weeks. Thus the actual numbers of days the aphids infested plant stages "4.0-5.5", "5.5-7.0" and "7.0-8.5" were 18, 22 and 25 days, respectively.

At the end of each treatment period, all of the aphids on each plant were counted *in situ* and then the plants were sprayed with a high dosage of pirimicarb to kill all of the aphids. In the plant growth stage "4.0-7.0" treatment, the plants were sprayed with a reduced dosage of pirimicarb at stage 5.5 and the aphids that survived were then allowed to build-up again until plant growth stage 7.0.

Plant measurements

Measurements of plant height, the number of leaves unfolded or deformed, and the length (L) and width (W) of each leaf were recorded from all plants at each of the four growth stages 4.0, 5.0, 7.0, 8.5. A leaf with more than half of the lamina area deformed by aphid feeding was classified as deformed. No further classifications were attempted. Lamina area (A) was estimated from the equation:-

$A = 0.714 + 0.762\ (L \times W)$,

which was derived in a separate experiment by plotting accurately leaf areas against the product of L x W ($r = 0.99$, d. f. = 50).

The final, destructive measurements were made at plant growth stage 8.5. Plants were cut just above the soil. Fresh and dry weights were obtained separately for the head and the rest of above-ground plant parts (shoot) for each plant.

Statistical analyses

The data in Table 1 show that the final aphid densities/leaf area differed markedly between the four plant growth stages. Therefore, the whole experiment was not analysed in the original 4 x 4 two factors split-plot design. Preliminary analysis of the data showed that aphid densities for each plant growth stage were similar between the three replicates. Thus, the four plant growth stage treatments were analysed as four separate "experiments", and each "experiment" had a one factor (aphid density) randomised complete block design that had five sub-samples (plants) in each treatment and three replicates. Analysis of variance was performed for each of the four "experiments". Further comparisons of groups of mean values were carried out by Duncan's multiple range test when the F-values were significant.

Results and analysis

The experimental conditions seemed adequate, as the plants in the no-aphid control were similar to those in well-cultivated field crops (Table 2). However, there

Table 2. Mean number of unfolded leaves and average head diameter of cabbage plants at four growth stages in the absence of aphids

	Plant growth stages			
	4.0	5.5	7.0	8.5
Number of leaves	9.3	17.7	20.9	21.7
Head diameter (cm)	-	-	5.8	10.0

was considerable variation in the rates of increase in aphid numbers between the four plant growth stage "experiments". The major sources of these variations were differential plant suitability for the aphid between the various growth stages of the plants, crowding effect from the aphids and aphid movement between treatments.

The correlations between the various plant measurements were complex and variable (Table 3). With the exception of the correlation between fresh and dry head weights, none of the other correlations were close, though many of them were significant. Thus, several plant measurements had to be compared to elucidate the effects of aphid density. Three measurements of the head and two of the shoot were chosen for the Analysis of Variance. In addition, three ratio values were chosen to reveal changes in plant structure and physiology caused by aphid feeding.

Table 3. Coefficients of correlation (r) between various measurements of cabbage plants in the absence of aphids (d.f. = 88).

Plant measurements	Head fresh weight	Head dry weight	Shoot fresh weight	Shoot dry weight	Head diameter	Leaf area	No. of leaves
Head dry weight	0.98**						
Shoot fresh weigh	0.47**	0.41**					
Shoot dry weight	0.59**	0.64**	0.71**				
Head diameter	0.72**	0.70**	0.33**	0.39**			
Leaf area	0.03	-0.07	0.68**	0.21*	-0.02		
No. of leaves	-0.01	-0.05	0.56**	0.16	-0.83**	0.75**	
Plant height	0.43**	0.43**	0.23*	0.30**	0.35**	0.04	0.04

* $P<0.05$; ** $P<0.01$

The results of the Analysis of Variance are summarised in Table 4. The mean plant measurements are presented in Tables 5 & 6, and the ratio values in Table 7.

Table 4. F-values of Analysis of Variance for aphid density treatments

Plant measurements	Plant growth stage of infestations			
	4.0-5.5	5.5-7.0	4.0-7.0	7.0-8.5
Head fresh weight (HFW)	0.3	3.7	8.4*	2.1
Head dry weight (HDW)	0.4	1.8	10.2**	3.1
Head diameter (HD)	1.2	2.1	5.3*	2.3
Shoot dry weight (SDW)	6.3*	6.8*	22.2**	2.9
Leaf area (LA)	3.1	5.8*	7.7*	2.8
HDW/SDW	1.0	5.3*	6.0*	3.2
HDW/HFW	2.5	5.7*	1.4	4.5
SDW/Shoot fresh weight	2.5	1.3	16.1**	5.2*

$F_{0.05(3,6)} = 4.76$; $F_{0.01(3,6)} = 9.78$

When the plants were infested with aphids at either plant growth stage 4.0-5.5 or 5.5-7.0, the head weights and the size of the cabbage heads were unaffected by aphid feeding (Table 5). However, the shoot weight and the leaf area decreased and the number of deformed leaves increased as aphid density increased (Table 6). In the plants infested at growth stage 4.0-7.0, head weight and head size were unaffected, except at the very high aphid density when all the unfolded leaves and 2-4 head leaves were seriously deformed by aphids (Table 5). As mentioned previously, shoot weight and leaf area were reduced and the number of deformed leaves increased as aphid density increased (Table 6). In the plants infested by aphids at growth stage 7.0-8.5, neither head weight or head size, nor shoot weight or leaf area were affected by aphid feeding (Table 5 and Table 6). These results provide strong evidence for the nullification, or at least strong mitigation, of the effect of aphid feeding by the plants in terms of head weight and size. These effects are remarkable considering the severity of the infestations, shown by the number of aphids and the number of deformed leaves per plant (Table 1 and Table 6).

As the analysis of the data in Tables 5 and 6 showed unequal effects of aphid feeding on head and shoot weight, further analysis was performed on three ratio values in four plant measurements (Tables 4 and 7). The plants infested at growth stage 5.5-7.0 had higher HDW/SDW ratios, indicating that infested plants had proportionally heavier heads than uninfested plants. Such a change of plant structure was also suggested by the values of HDW/SDW ratios in the plants infested at growth stage 4.0-5.5. In the plants infested at growth stage 4.0-7.0, the HDW/SDW ratio in the moderate aphid density treatment was increased, and that in the very high aphid density was decreased compared to that of the "no-aphid" control. In the plants

Table 5. Mean head fresh weight (HFW), mean head dry weight (HDW) and mean head diameter (HD) at harvest of cabbage plants infested with aphids at four densities at four stages of plant growth.

	Plant growth stage of infestations					
	4.0 - 5.5			5.5 - 7.0		
Aphid density	HFW	HDW	HD	HFW	HDW	HD
None	457	35.8	9.5	453	36.3	10.1
Moderate	421	30.9	9.7	645	47.5	12.4
High	487	34.9	10.1	584	42.7	12.1
Very high	441	31.9	10.1	512	37.5	11.7
	Plant growth stage of infestations					
	4.0 - 7.0			7.0 - 8.5		
phid density	HFW	HDW	HD	HFW	HDW	HD
None	484a	37.8a	9.9b	581	46.8	9.8
Moderate	520a	36.2a	11.8a	516	38.6	10.7
High	459a	33.2a	9.8b	556	40.3	10.5
Very high	281b	19.3b	9.1b	576	42.7	10.7

Means in the same column followed by different letters are significantly different at the 5% level.

infested at growth stage 7.0-8.5, the HDW/SDW ratios were unaffected. The differences in the data from the four "experiments", together with the data of Table 7, suggest that in the early stages of plant growth a shift to a proportionally heavier head is produced by aphid feeding up to quite high levels of infestation (during plant growth stage 4.0 to 7.0), and then the reverse effect occurs if the level of infestation continues to increase.

The ratios of both HDW/HFW and SDW/SFW were lower in infested plants than in the "no-aphid" controls, indicating that the infested plants had a higher moisture content as a result of aphid feeding (Table 7).

Discussion and conclusions

The data show clearly that the cultivar of white cabbage tested in this glasshouse experiment has considerable potential to compensate for the effect of aphid feeding. This finding is remarkable but not unique, as there are many cases in the literature in which aphid feeding caused little direct damage to host plants (reviewed by Miles, 1989). In fact, there have been studies which show that aphids may, in appropriate circumstances, increase the yield of crop plants. For example, feeding of *Myzus persicae* at low densities increases the growth of potato plants (Harrewijn, 1976). In China, it has been demonstrated repeatedly that infestation of cotton plants by relatively high infestations of *Aphis gossypii*, during the vegetative stages of plant growth, either increases, or has no effect on, the final lint yield (Zhang *et al.*, 1982; Zhong *et al.*, 1989; Dai *et al.*, 1990;).

Compensation by plants, as a result of aphid feeding, should also be observable at the physiological level. Way & Cammell (1970), working with *Brevicoryne brassicae* on Brussels sprouts plants, showed that infested leaves assimilated more CO_2 than uninfested leaves. In addition, aphid feeding on relatively old plants increased the assimilation rate of the uninfested mature leaves on the same plant. The data collected suggested that cabbage plants infested by the cabbage aphid in the early

Table 6. Mean shoot dry weight (SDW), mean leaf area (LA) and mean number of deformed leaves (NDL) at harvest of cabbage plants infested with aphids at four densities at four stages of plant growth

	Plant growth stage of infestations					
	4.0 - 5.5			5.5 - 7.0		
Aphid density	SDW	LA	NDL	SDW	LA	NDL
None	102.6a	9144	2.6	96.1a	9159a	1.0
Moderate	87.2b	8655	9.1	95.5a	7824b	14.5
High	85.6b	8581	13.5	79.5b	7695b	18.1
Very high	78.0b	7929	18.0	73.6b	7215b	19.3
	Plant growth stage of infestations					
	4.0 - 7.0			7.0 - 8.5		
Aphid density	SDW	LA	NDL	SDW	LA	NDL
None	98.0a	9272a	3.0	111.4	8256	3.0
Moderate	76.8b	8448ab	16.9	100.4	8821	6.3
High	74.5b	7763bc	20.7	100.1	8869	8.9
Very high	68.5b	7166c	27.9	95.1	8686	11.7

Means in the same column followed by different letters are significantly different at the 5% level. The NDL data were not analyzed.

growth stages tested, produced heavier heads and had a higher moisture content than uninfested plants. Although lighter heads were observed in the plants of the "very high aphid density" treatment during growth stage 4.0-7.0, the loss of yield was not considered important as this level of aphid infestation was unrealistically high. In this treatment, all plants were virtually covered by aphids for about a week. Such high levels of infestation do not occur in the field except on a few individual plants. An increase in moisture content was also recorded in Brussels sprouts infested by the cabbage aphid (van Emden, 1990). It is notable that in van Emden's experiment, infested plants were affected adversely in virtually all the growth characteristics that were measured. Such a result is understandable, as his lowest infestation (i.e., in terms of accumulative aphid-days) was greater than the highest used in our experiment. This comparison was produced from the initial inoculations and the durations of infestation used in the two studies.

Table 7. Mean ratios of head dry weight to shoot dry weight (HDW/SDW), head dry weight to head fresh weight (HDW/HFW) and shoot dry weight to shoot fresh weight (SDW/SFW) at harvest of cabbage infested with aphids at four densities at four stages of plant growth

	Plant growth stage of infestations					
	4.0-5.5			5.5-7.0		
Aphid density	HDW/SDW	HDW/HFW	SDW/SFW	HDW/SDW	HDW/HFW	SDW/SFW
None	0.35	7.84	10.70	0.38b	8.11a	10.81
Moderate	0.35	7.36	9.59	0.52a	7.49b	11.51
High	0.41	7.15	9.12	0.53a	7.36b	10.81
Very High	0.41	7.25	9.49	0.52a	7.28b	10.66
	4.0-7.0			7.0-8.5		
Aphid density	HDW/SDW	HDW/HFW	SDW/SFW	HDW/SDW	HDW/HFW	SDW/SFW
None	0.39b	7.87	10.68a	0.43	8.27	12.82a
Moderate	0.48a	7.01	9.58b	0.39	7.86	11.20b
High	0.45a	7.49	9.50b	0.41	7.32	11.25b
Very High	0.30c	7.08	8.70c	0.45	7.54	10.83b

Means in the same column followed by different letters are significantly different at the 5% level. The values of HDW/HFW and SDW/SFW have been multiplied by 100.

From the results of this experiment, it is reasonable to suggest that plant compensation and growth stimulation occur in the field, though the degree to which they occur will depend on a wide range of environmental factors. In our experiment, the compensation was so strong that both head weight and head size were unaffected up to a level of aphid infestation which seriously deformed most of the wrapper leaves. Serious leaf deformation is usually associated with soiling of the marketable parts of the plant by aphids, and this reduces considerably the marketability of the produce. This aspect of damage is intolerable for fresh-market cabbage, though may be relaxed somewhat for processing cabbage. Thus, reduction in quality (leaf deformation and soiling by aphids), not decrease in head weight, seems to be the most important criterion we must consider in determining control tactics, if similar compensation occurs in the field. Extensive field experiments, conducted over 5 years on more than 100 commercial farms and experimental stations in Germany, confirmed that white cabbage had a high potential to compensate for yield losses under field conditions (Hildenhagen *et al.*, 1993). In the untreated control plots, yield was reduced on average by only about 4%.

As compensation by the cabbage was so strong, it seems that a similar experiment should be conducted under field conditions, to obtain quantitative data that can be used for decision-making under field conditions. The effect of aphid infestations in the hearts of plants during the early growth stages should be investigated also, as such attacks often take place during early summer. An investigation of the response of this cultivar to feeding by chewing insects is of more general interest. Such studies are essential if rational measures for pest insect control are to be developed for commercial cabbage production.

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Résumé

Dégâts sur chou blanc par le puçeron, *Brevicoryne brassicae* (Linnaeus): influence de la densité des puçerons et du stade de croissance de la plante

Les effets de l'alimentation des puçerons, *Brevicoryne brassicae* (Linnaeus), sur le chou blanc, *Brassica oleracea* Linnaeus, ont été étudiés en serre expérimentale. Le poids et la taille des têtes de choux à la récolte ne sont pas affectés par les infestations de puçerons testés, mais la plupart des feuilles déployées ont été sérieusement déformées et le poids de la partie déformée ainsi que la surface de la feuille ont été réduits significativement par l'alimentation des puçerons. L'alimentation des puçerons agit particulièrement sur les têtes les plus grosses et sur

la concentration d'humidité plus élevée des plantes. Cette expérience montre clairement que le cultivar testé est capable de compenser, en terme de poids de tête et de taille, à l'action de l'alimentation des puçerons. Il est suggéré que si une compensation similaire a lieu aux champs, la réduction de la qualité de la culture (par exemple les déformations des feuilles et les souillure par les puçerons) plutôt que le poids et la taille de la tête, cela pourrait être un critère pertinent pour déterminer les stratégies de lutte du système plante - puçeron.

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Integrated production in vegetables - the present status in Switzerland

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The Ministry of Agriculture administers the guidelines and co-ordinates integrated production (IP) in field crops, fruits, vegetables and vines. It also is the regulatory body for private organisations and has decided on the subsidies to be paid to farmers since 1993. The Research station is involved in the development of "guidelines". The Swiss vegetable union, which represents growers and trade members, is responible for control at the farm level. The local professional organisations are responsible for the continuing education of growers. Growers have to adhere to the "guidelines" and control other growers.

Table 1. The status of integrated vegetable production in Switzerland in 1993

			Proportion of total vegetable production or trade using IP	
	Numbers of farmers or traders involved	Hectares of crop in IP	Proportion of farmers or traders involved	Area of crop in IP
Fresh vegetables	313	2900*	1/3	1/2
Processed vegetables	388	not known	1/2	1/2
Trade	53		1/3	

* SFR 400.-/ha federal subsidies; (150 ha of greenhouses excluded from subsidies)

Guidelines

A vegetable grower receives permission to use the appropriate label for his produce if his method of production conforms to the minimum requirements shown in Table 2.

Table 2. Guidelines: The minimum requirements for growing IP vegetable crops in Switzerland in 1993.

Parameters for field-grown crops	**Minimum requirements**	**Method of control**	**Objectives**	**Remarks**
Farm manager	1. Member of professional organisation; 2. Continue to educate			
Marketing	List of trading partners			IP vegetables should be marketed separately and displayed on separate shelves
Crop rotation	1. 2-year intervals between growing vegetables from the same botanical family if the growth period exceeds 12 weeks. 2. Cover crop more than 25% of the total field area during winter	1. Plan of crop rotation over the last 3 years 2. Field control	1. Longer interval for specific vegetables 2. Use a cover crop as often as possible during the winter	
Soil analysis and Fertilization	1. Fertiliser plan of at least 3 plots according to a soil analysis done within the previous 4 years. 2. Total fertilizers brought onto the farm 3. Composting of vegetable residues on the farm, or in the field	1. Soil analysis 2. Fertiliser plan 3. Field control	1. Analysis of biological soil activity included in the soil analysis 2. Import-export nutrient balance	Any system of soil analysis is acceptable

Parameters for field-grown crops	**Minimum requirements**	**Method of control**	**Objectives**	**Remarks**
Plant protection (herbicides, insecticides, fungicides growth-regulators)	1. Complete record of pesticides application based on field observations of pests and diseases 2. Correct amount and time of application 3. Dosage control of the sprayer	1. Pesticide record book 2. Pesticides residue analysis 3. Certification of sprayer control	1. Maximum reduction of pesticides 2. Development of biological and biotechnical pest and disease management 3. Apply damage threshold principles	
At least 3 out of the following 7 requirements must be attained	1. Crop rotation with longer intervals 2. Control of pests and diseases by traps 3. Use of nets against carrot fly 4. Use less herbicides than conventional systems of production 5. More green-manure and under-cropping 6. Quick test of nitrate in soil and vegetables 7. At leat 5% of the field area not used for production should be kept as a buffer zone	Field control		

Prices for IP vegetables do not differ from those of vegetables grown conventionally. However, IP vegetables should be given preferential treatment when marketed.

Future developments

The main goal for the future is to standardize guidelines, initially within Switzerland and later within Europe. The amount of federal subsidies given to farmers using conventional, integrated and organic systems of crop production should be allocated according to the impact that the different production systems have on the environment.

Résumé

La production intégrée en culture légumière - Status actuel en Suisse

Le Ministère de l'Agriculture administre les directives et coordonne la production intégrée (IP) dans les cultures de plein champs, les fruits, les légumes et la vigne. Il est aussi l'organe régulateur pour les organismes privés et décide des subventions payés aux fermiers depuis 1993. La Station de Recherche est impliquée dans le développement des "directives". L'union légumière Suisse qui représente les producteurs et les représentants du commerce est responsable de la lutte au niveau des exploitants. Les organisations professionnelles locales sont responsables de la formation permanente des agriculteurs. Les agriculteurs adhérent aux "directives" et contrôlent d'autres agriculteurs.

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Can factors which influence the relationship between *Brevicoryne brassicae* and its host plants be exploited in integrated pest management?

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Summary

The sequence of events in host plant-finding, acceptance and colonisation by aphids is described. Opportunities for exploiting factors which influence the relationships between cabbage aphid, *Brevicoryne brassicae*, and its host plants, natural enemies and the environment are discussed. Several alternatives to insecticides, such as host plant resistance, biological control, crop covers, reflective mulches and undersowing/inter-cropping, clearly have potential and may be exploited as pressures increase to reduce the inputs of pesticide.

Introduction

This paper examines each stage in the host plant finding, acceptance and colonisation of brassicas by cabbage aphid, *Brevicoryne brassicae* (L.), and discusses ways in which these may be exploited to reduce crop damage. The sequence of events, reviewed by Klingauf (1990), is followed in this review.

Cabbage Aphid Biology

To exploit the relationships between the cabbage aphid and its host plants, it is necessary to understand the insect's biology and life cycle. Cabbage aphid is an oligophagous, monoecious insect that is restricted almost entirely to the Cruciferae. The characteristic chemicals produced by cruciferous plants, serve as attractants for winged cabbage aphids and stimulate aphids that land to feed. In regions where winters are mild, as in much of Great Britain, the aphid is anholocyclic and the sexual phase is rare or absent. In colder regions the aphid is holocyclic, males are alate and the insect overwinters as an egg. Winged forms of cabbage aphid are produced in response to interactions between day length/temperature or in response to host plants senescing. In central England there are two main migrations of the aphid, one in late June/early July and a second in early autumn (Dunn & Kempton, 1971). Alate females migrating from overwintering sites, or migrant aphids colonising plants at other times of the year, produce apterous virginoparae which multiply parthenogenetically on plants. The large colonies of aphids produced consist mainly of apterous females and their nymphs.

Host Plant Finding

Migrating aphids fly actively towards vegetation in response to long wavelengths of light which are emitted from soil contrasting with plants. The migrating aphid recognises and selects a host plant using visual and olfactory cues.

Monitoring and Prediction - Cabbage aphid migration can be monitored using yellow traps. It may be possible to relate the numbers of aphids caught to temperature and thus develop a predictive model that can be used by growers and advisers to improve pest control.

Crop scheduling - The sowing of brassica crops can be adjusted to avoid peak periods of aphid migration. There are two peak periods of migration of *Brevicoryne brassicae* at Wellesbourne (Dunn & Kempton, 1971). Hence, opportunities exist to adjust the sowing dates of brassica crops to avoid these peaks, or at least to sow the plants so that they will have not reached an attractive stage by the time peak aphid migration occurs. At present, however, sufficient information is not available to predict accurately the peak periods of cabbage aphid migration.

Crop covers and mulches - Aphids can be prevented from alighting on crops by crop covers (Antill *et al.*, 1990; Ester, 1993), though at present these are expensive. Mulches, which reflect uv light, and which deter aphids and whiteflies from alighting on plants, are used in Israel (Loebenstein *et al.*, 1975). Results from preliminary trials using reflective mulches to reduce infestations of cabbage aphid were inconclusive.

Plant apparency - The visual apparency of a plant is an important cue to colonising aphids (Feeny, 1976). The resource concentration hypothesis (Root, 1973) suggests that *B. brassicae,* is more likely to find and remain on host plants that occur in pure and/or dense patches. There is a strong preference for insect pests of cultivated crops to select plants that stand out against a background of bare soil. Weedy backgrounds make cultivated brassica plants less apparent to aphids, while monocultures make them more apparent. Cromartie (1975) suggested that aphids remained longer in large stands of collards because short-distance movements were likely to end on another host plant. In small plots, or on isolated plants, such movements were likely to end on a non-host plant, which then stimulated the aphids into long departure flights. One of the principal objectives of under-sowing or intercropping is to reduce the apparency of the crop plants. This approach has great potential for reducing attack by *B. brassicae* on brassica crops.

Plant colour - Foliage colour influences the attractiveness of plants to *B. brassicae.* Fewer aphids alight on red brassicas than on green ones, even though red brassicas are perfectly adequate for colony development (Dunn, 1978; Radcliffe & Chapman, 1966; Ellis & Hardman, 1988). Although this differential attractiveness confers antixenosis resistance onto certain plants, it is subject to seasonal variations. Thus, the red Brussels sprout cultivar 'Rubine' was less preferred than green cultivars by *B.*

brassicae early in the season but became heavily infested later (Dunn, 1978). This change in attractiveness reduces the benefits arising from using red cultivars.

Semiochemicals originating from the plant - The behavioural response of aphids to plant volatiles was demonstrated by Petterson in 1973. Alate virginoperae of *B. brassicae* were attracted to butenyl isothiocyanate, a volatile released from brassica plants (Nottingham *et al.*, 1991). In contrast, volatiles from *Tanacetum vulgare*, tansy, and *Satureja hortensis*, summer savory, both non-hosts, repelled *B. brassicae*. Such volatiles may have potential for disrupting *B. brassicae* behaviour in the field. Recently, Pickett *et al.* (1992) reviewed aphid chemical ecology and discussed its commercial exploitation.

Host Plant Acceptance

Once an aphid has alighted on a plant, it selects or rejects the plant using physical and biochemical stimuli that are detected by tactile and gustatory receptors on the antennae, tarsi and epipharyngeal organs. The aphid uses its labium and stylets to probe the cuticle, or upper epidermis, of the plant to determine whether it is a suitable host.

Plant hairs or trichomes - Trichomes may interfere with plant colonisation by aphids by preventing the aphids from moving freely on the leaf surface or by releasing sticky/repellent chemicals which interfere with host acceptance. The wild species of *Brassica* found to be resistant to *B. brassicae* at Wellesbourne possess many trichomes, but it is not known whether such trichomes have any physical or chemical effects on aphid colonisation. Observations of behaviour on the resistant rape variety 'Rangi' in New Zealand showed that *B. brassicae* had considerable difficulty reaching the growing point of the plant because of an inpenetrable barrier of strong hairs. This characteristic may be the resistance mechanisms of this plant (Ellis & Farrell, 1994).

Leaf surface waxes - Differences in the thickness and composition of epicuticular waxes on brassica plants can influence an insect's initial contact with the plant and can confer resistance to aphids. Glossy plants, which lack the waxy bloom typical of most brassica plants, are preferred less by *B. brassicae* and insect development is much reduced. Way & Murdie (1965) showed that the fleshy pads on the tarsi of *B. brassicae* have difficulty gripping the surface of these glossy partially-resistant brassicas. However, glossy brassicas are not acceptable either to growers because of their poor yields or to consumers because of their appearance. Plant breeders are trying to improve the quality of glossy cultivars.

Interference in Feeding and Reproduction

The next stage in the relationship between *B. brassicae* and its host plants concerns the development of the aphid colony.

Semiochemicals from insects - Several semiochemicals have been identified that may be used for pest control in the future (Pickett *et al.*, 1992). The presence of another insect species on a plant can influence aphid behaviour through the release of allelochemicals. For example, physical disturbance by *B. brassicae* colonies reduces cabbage root fly egg-laying (Finch & Jones, 1989) and deterred attacks by coccinellids (Dixon, 1958). It is not known whether other insects, or the allelochemicals they release, can reduce plant colonization by *B. brassicae*.

Plant chemicals - The development of *Brevicoryne brassicae* is influenced by the nutritional quality of its host plants. The word quality, in its broadest sense, includes levels of amino acids, soluble nitrogen, sugars, etc. Van Emden (1966) showed that an increase in nitrogen in the soil, or a decrease in potassium, increased the soluble nitrogen in the leaves of Brussels sprout plants and this then influenced the fecundity and reproductive rate of *B. brassicae*. Although this response to the nutritional quality of the plant has been known for about 30 years, nothing practical has been developed from it for aphid control. There are three reasons for this. Firstly, the level of soluble nitrogen changes both with plant age and environmental conditions and hence is extremely difficult to control. Secondly, growers are unlikely to change their fertiliser practices and, thirdly, changes in fertiliser levels may reduce one pest but produce more favourable conditions for another.

The glucosinolates are the compounds within brassica plants that have received most attention. Plant breeders have bred plants with reduced levels of certain glucosinolates. The breeding programmes have concentrated mainly on fodder and oil-seed brassica crops, where low levels of glucosinolates are desirable. The new varieties can still be infested heavily by pests and so breeding solely for reduced glucosinolate content is unlikely to produce adequate control.

Certain wild brassica species, such as *Brassica fruticulosa* and *Brassica spinescens* are highly resistant to *B. brassicae* (Singh, *et al.*, 1994). Such plants exhibit antixenosis, which limits aphid colonisation; and possess antibiosis, which reduces the development of aphid populations. Investigations of the mechanisms of resistance have shown that the stylets of the aphid penetrate the plant tissues but fail to take up sap from the phloem (Cole, 1994a). The resistance appears to be correlated with the lectin content of the tissues (Cole, 1994b). If such sources of resistance could be bred into new brassica varieties they could make a valuable contribution to pest control.

Natural enemies - *B. brassicae* is parasitised and preyed upon by many species of natural enemy. Factors which influence the behaviour of *B. brassicae* also affect the behaviour of its parasitoids and predators. One major objective in integrated pest control is to select systems which reduce pest numbers but encourage natural enemies. For example, a single application of the selective aphicide pirimicarb may be sufficient to control an aphid infestation if natural enemies are well-established on the crop. Similarly, systemic insecticides kill relatively few natural enemies and should be used in situations where there are high populations of natural enemies.

Conclusions

The relationships between *B. brassicae* and its host plants, natural enemies and the environment have been studied. The most promising alternatives to insecticides are host plant resistance, crop covers and undersowing/intercropping. Information on aphid activity and development will be used also to improve the timing of insecticide treatments.

Résumé

Est-ce que les facteurs qui influencent les relations entre *Brévicoryne brassicae* et ses plantes hôtes peuvent être exploités dans un programme de lutte intégrée?

La séquence des évènements concernant la découverte de la plante hôte, l'acceptation et la colonisation par les puçerons est décrite. Les possibilités d'exploitation des facteurs qui influencent les relations entre le Puçeron cendré du chou, *Brévicoryne brassicae*, et ses plantes hôtes, ses ennemis naturels et l'environnement sont discutées. Plusieurs alternatives à l'utilisation des produits insecticides, tels que la résistance de la plante hôte, la lutte biologique, la couverture des plantes, le couvert par paillis et des cultures dérobées/intercallaires ont de toute évidence des potentialités et peuvent être exploitées comme une pression accrue destinée à réduire les intrants phytosanitaires.

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Attempts to quantify the role of antixenosis and antibiosis in plant resistance to the carrot fly, *Psila rosae* (F.) (Dipt., Psilidae)

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Summary

The oviposition preferences of carrot flies and the development of their larvae on various plants were studied to estimate the importance of antixenosis and antibiosis. The relationship between oviposition and semiochemicals in the leaf surface of host plants was investigated to obtain a better understanding of host plant selection by the carrot fly.

Introduction

Host plant selection has not yet been studied in as much detail for the carrot fly *Psila rosae* (F.) as it has for some other important vegetable pests (e.g. cabbage root fly *Delia radicum*). From observations under laboratory conditions, Bohlen (1967) first described the behavioural sequence prior to egg-laying and determined the acceptability of various umbelliferous and non-umbelliferous species as possible host plants. He suggested that the host plants of the carrot fly are confined to the Umbelliferae (Apiaceae). In an attempt to establish the host range more thoroughly, Hardman et al. (1990) tested several non-umbelliferous plants and a wide range of umbelliferous plants under field conditions. Various new host plants were reported. The wild and cultivated umbellifers that were tested differed considerably in their susceptibility to carrot fly as measured by the numbers of flies that emerged from potted plants. Ellis & Hardman (1981) and De Ponti & Freriks (1980) found consistent differences between carrot cultivars and between breeding lines in terms of the damage caused by carrot flies. However, these workers did not study the factors that contributed to the observed differences in resistance: such as antixenosis reducing the initial infestation of flies (i.e. the tendency of flies to reject "unfamiliar" plants as hosts) and antibiosis against larvae (i.e. the unsuitability of the plant for larval development). Since the ability of larvae to move through the soil is rather restricted,the influence of antixenosis on larvae is probably of only minor importance (Overbeck 1978, Guerin *et al.* 1981).

Städler and Buser (1984) identified six oviposition stimulants (propenylbenzenes, furanocoumarins, polyacetylenes) in dichloromethane extracts from the surface of carrot leaves. However, it is still not known whether these compounds are responsible for the differences in attractiveness between the various species of host plants. The quantities of known oviposition stimulants in the leaf surface failed to account for the relatively small differences in antixenosis among carrot cultivars (Visser & dePonti 1983, Guerin & Städler *et al.* 1990). This project attempts to correlate the stimulating compounds from surface extracts of host plants with the numbers of eggs laid alongside intact leaves of the corresponding plant species. The study includes a broad spectrum of host plants with a wide range of differences in susceptibility. A knowledge of the mechanisms involved in resistance is helpful to plant breeders trying to produce less susceptible carrot cultivars. In this paper, only preliminary qualitative results will be presented. The following subjects are currently being studied:

- The relative importance of antixenosis and antibiosis.
- The optimal physical properties of artificial leaves for use in oviposition bioassays involving plant extracts and pure chemicals.
- The relationship between semiochemicals in the leaf surface and antixenosis.

1. Antixenosis and antibiosis

About twenty different wild and cultivated plant species that had different levels of resistance in the field (Hardman et al. 1990) were chosen for these experiments.

1.1 Antixenosis against adult flies - Method

Oviposition experiments were carried out using a laboratory culture of flies kept in climate chambers under a 16:8 L:D regime. Eight oviposition dishes (Städler 1971) that contained leaves cut from plants grown in the field were arranged in a circle in each test cage (70 x 70 x 70 cm). Each test involved four leaves of one test species, alternated with four leaves of the standard plant, the susceptible carrot cultivar "Danvers". After exposure to flies, usually for one day, the eggs were counted and the positions of the leaves were then reversed for the subsequent test period. If sufficient plant material was available, 8 leaves from eight individual plants were tested at both positions to obtain 16 replicates for each test species.

Results and Discussions

In the 1992 experiments, only a few plant species, e.g. *Carum carvi* (caraway) and *Anthriscus cerefolium* (garden chervil) were preferred to the standard cultivar "Danvers". Some test species, e.g. the "partially resistant" carrot cultivar "Sytan", *Pastinaca sativa* ssp. *sylvestris* (wild parsnip) and *Foeniculum vulgare* (wild fennel), were as attractive as Danvers. More than half of the species tested, were less acceptable to the flies than the standard. Such plants included *Pastinaca sativa* ssp. *sativa* "Halblange" (cultivated parsnip) and *Pimpinella major* (greater burnet-saxifrage). In general, the differences recorded in these laboratory tests were one to two orders of magnitude less pronounced than those obtained in the field by

Hardman *et al.* (1990). Hence, this laboratory method is of only limited potential for detecting the small differences in susceptibility expected between carrot cultivars.

The following three major difficulties occurred in the oviposition experiments:

1. Some eggs were laid on dishes (controls) that did not contain leaves.
2. Discrimination between non-host plants (e.g. the fern *Dryopteris filix-mas*) and host plants was relatively poor, partially as a consequence of the first problem.
3. There was an age dependent variability in the quality of the leaves from the "standard" plants, as leaves from younger plants tended to be more attractive.

In 1993, the oviposition experiments were repeated using a slightly modified system. Plastic covers were used to prevent the flies from leaving the oviposition dishes, or invading them, without performing the typical leaf and stem run prior to egg-laying. This lead to an improvement of the levels of discrimination between non-host plants and host plants. With few exceptions, there was a good agreement between the results of both years. Thus the differences observed appeared to be consistent. Other plant properties which may play a role in host-finding and acceptance under field conditions, such as plant size, long-range attractants and volatiles emanating from the roots of the plant (Maki & Ryan 1989) were eliminated with this method. They could, however, be important cues contributing to antixenosis resistance. Therefore, intact plants should be considered for future studies.

1.2 Antibiosis (relative survival and growth of fly larvae) - Method

Data were collected using two methods. In the first, roots of plants grown in the field were transplanted into clay pots filled with sand. In the second, plants were grown from seed in clay pots containing sand and supplied regularly with soluble fertiliser. Six weeks after the plants were inoculated with fly eggs, the pots were washed out and all pupae and larvae were collected, counted and weighed. The pupae were then stored individually in compartments of elisa-plates to determine the date and rate of subsequent fly emergence. The difficulties encountered included a high susceptibility to rotting and in some cases there were already natural fly infestations in the field-collected carrots. In the seeded pots, the growth of the plants was often slow and irregular and many of the roots remained small. In both cases, the yield of pupae was highly variable.

Results and Discussion

In the 1992 experiment, in which the plants were grown in the field, *Pimpinella major* and *Smyrnium olusatrum* (Alexanders), failed to support larval development. The highest numbers of insects completed their development on the carrot variety "Tip Top", the other *Daucus* species, including the cultivars "Danvers" and "Sytan", supported intermediate numbers. Other highly suitable species were *Pastinaca sativa* ssp. *sylvestris, Foeniculum vulgare*, *Apium graveolens* var. *rapaceum* (celeriac cv. "Balder"). Species that gave rise to low numbers of flies e.g. *Levisticum officinale* (lovage) and *Aegopodium podagraria* (ground-elder), were characterized typically by a high percentage of pupae from which flies did not emerge and a high percentage of larvae that failed to pupate before the pots were washed out. This phenomenon is probably due to varying food quality, as pupal weights also differed considerably between host plants. (It is difficult to decide if these larvae indeed failed to pupate or simply were delayed in development, as they rarely pupated after being removed from the soil). Mean weights tended to be high for pupae that originated from roots of species on which the numbers of pupae produced was high. There was a clear relationship between pupal weight and emergence rate: the higher the weight, the higher the probability that a fly would emerge. It must be mentioned that antibiosis is used *sensu lato* in this paper, as nonchemical factors such as root weight, side root density or toughness of rhizodermis could also have contributed to the results obtained. However, larval antixenosis could be ruled out, as larvae were not allowed to choose among plants. According to Overbeck (1978), larval development (on carrots) proceeds in two distinct phases: first instar larvae feed on side roots, and then the later larval instars attack the main root. Initial survival rates and subsequent growth rates were often, but not always, correlated within a certain plant species. Although many larvae and pupae developed on the roots of *Carum carvi* the insects produced were only of medium weight and often failed to pupate or give rise subsequently to adults. In contrast, carrots often gave rise to only moderate numbers of pupae, but most of them were large.

1.3 Correlation between antixenosis, antibiosis and field-data

In the 1992 data, there was a weak, but significant correlation between oviposition and antibiosis. The situation with *Smyrnium olusatrum* was especially noteworthy as it was unsuitable as a host in the antibiosis experiments and in the field (Hardman *et al.* 1990), but was accepted readily by females for oviposition in laboratory experiments. The data on antixenosis and antibiosis recorded in 1992 were also compared to susceptibility indices (log transformed) from the field data of Hardman *et al* (1990). The field data were correlated significantly to oviposition, but not so to the data on antibiosis. These preliminary results need to be substantiated with additional data.

2. Influence of physical properties of artificial leaves on egg-laying activity

To develop an artificial leaf suitable for use in oviposition tests to bioassay plant extracts and/or pure compounds, the influence of different leaf characteristics (e.g. shape, colour, size, surface coating) on egg-laying was studied. The finding that pinnate (cut) leaves were preferred to uncut leaves (Städler 1977) was confirmed. It was shown that umbelliferous-like leaves received more eggs than leaves with simple geometric forms (circle, square, triangle). More eggs were also recovered from around three-dimensional leaf models with folds than from around the corresponding flat models. It is not yet known if such differences are induced during pre-alighting and/or post-alighting behaviour.

3. Planned future experiments; secondary substances in leaf surface and oviposition preferences

The activity of dichloromethane extracts from selected plant species will be compared on artificial leaves in oviposition bioassays. If the results from the extracts reflect the differences in oviposition recorded on the corresponding intact leaves, the extracted oviposition stimulants will be quantified by GC, using the method of Städler *et al.* (1990).

Solvents with different polarity will be used to try to obtain extracts that stimulate oviposition. Hexane, methanol and hot water extracts (Zobel & Brown 1988) will be compared to the standard dichloromethane extracts (Städler et al. 1990).

Acknowledgements

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Résumé

Essais de quantification du rôle de l'antixenose et de l'antibiose chez les plantes résistantes à la Mouche de la carotte, *Psila rosae* (F.) (Dipt., Psilidae)

Les préférences de ponte de la Mouche de la carotte et la survie de leurs larves sur différentes plantes ont été étudiées pour estimer l'importance de l'antixenose et de l'antibiose. Les relations entre la ponte et les substances sémiochimiques issues de la surface de la feuille des plantes hôtes sont étudiées afin de mieux comprendre les mécanismes de reconnaissance et de choix de la plante hôte par la mouche de la carotte.

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Preliminary field studies of the resistance of cabbage to *Thrips tabaci* in three countries in Europe

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Summary

A range of commercially important white cabbage varieties were evaluated in Austria, England and Germany for their resistance to the onion thrips, *Thrips tabaci* between 1988 and 1993. Thrips damage was assessed from the severity and extent of the feeding marks and from the depth the damage penetrated the cabbage head. Although the studies were conducted independently in the three countries, certain varieties were used in more than one experiment. The variety, 'Zerlina', was partially resistant in all three countries and appears worthy of further study. In the future it should be possible to maximise progress in studies of plant resistance to thrips by collaboration between scientists in different countries.

Introduction

The onion thrips, *Thrips tabaci* Lindeman, is a severe pest of cabbage crops in northern Europe and the USA. Large populations of thrips may develop on cabbage crops and render the crop unmarketable. Thrips may invade the spaces between the wrapper leaves of white cabbage heads, feed on the leaf tissues and cause the disorder known as oedema. Cabbages affected by oedema are generally rejected by the supermarkets. Yield losses from oedema in Britain have been estimated to be as high as 20% for some crops (Ellis & Kazantzidou, 1993) and in New York State, oedema is the most severe problem of cabbage (North & Shelton, 1986).

Thrips are particularly difficult to control. Their presence may go un-noticed by growers as they are difficult to see. Even small numbers of thrips can cause severe losses in fresh and stored produce and therefore growers need to achieve high levels of control. Chemicals often fail to kill thrips deep in the developing heads and so repeated applications are necessary. In north east USA, prophylactic insecticide treatments are used on cabbage (North & Shelton, 1986). Problems in achieving satisfactory control with insecticides, and the pressures from the public, media and governments to reduce pesticide inputs, have led to the search for alternative control measures. Host plant resistance is one alternative which is receiving attention in several countries. In the USA, varieties of cabbage differ significantly in their resistance to thrips attack (Shelton, Becker & Andaloro, 1983). However, none of the varieties tested possessed high levels of resistance. The variety 'Titanic 90' was the most resistant. In this paper the results are reported of preliminary studies of resistance in cabbage to thrips done in three countries in Europe.

Experiments in England

Materials and Methods

The experiments were done in 1992 at Horticulture Research International, Wellesbourne, England. Four varieties of Dutch white cabbage were chosen for the experiment: 'Zerlina', 'Rivera', 'Polinius' and 'Slawdena'. The first two varieties were considered by growers and a seed company to possess resistance to thrips while the other two were susceptible to the pest. Seed of the four varieties was sown in a glasshouse on 27 May 1992 in 2 x 2 cm peat blocks in 308 Hassy trays. The cabbages were transplanted in the field on 30 June 1992, using a randomised block design with four plots in each block. Each plot consisted of 40 plants, spaced 50 cm apart, in eight by five rows. On 14 July 1992, all blocks were covered with Agralan Envirofleece (Agralan Ltd.), a non-woven synthetic material, supported on a 1 m high metal frame. This semi-permeable cover excluded all large cabbage pests but allowed thrips to enter. On 14 August 1992, one block (chosen as the control) was treated with 5 g deltamethrin/ha (2.5% a.i., e.c.; Decis, Hoechst) to control thrips. The experiment received no other pesticide treatments. During the period 10-18 August 1992, the thrips population in all plots except the control was supplemented with insects from a culture maintained in polyethylene tunnels.

The cabbages were harvested on 17 November 1992. Four 50 x 30 x 30 cm plastic crates were filled with marketable cabbage heads from each plot and labelled appropriately. Each of the crates was enclosed in polyethylene, packed into large wooden boxes, and placed in a cold store at 1°C. Thrips damage was assessed over a four-month period (December 1992 - March 1993). On each occasion, the contents of a single wooden box (four crates) was transferred to the laboratory for examination. Each cabbage head was weighed, then the numbers of infested leaves were determined by removing and inspecting each leaf in turn. The presence of live and dead thrips was recorded.

Results

Live thrips were found on all sampling occasions, and hence can survive at low store temperatures. Thrips damage was found on practically all cabbage heads and was higher on the cabbages from the cages which had received additional insects. There were differences (P = 0.05) between the cabbage varieties in the number of infested leaves per plant (Fig. 1). 'Zerlina' was the least damaged variety, 'Slawdena' the most damaged.

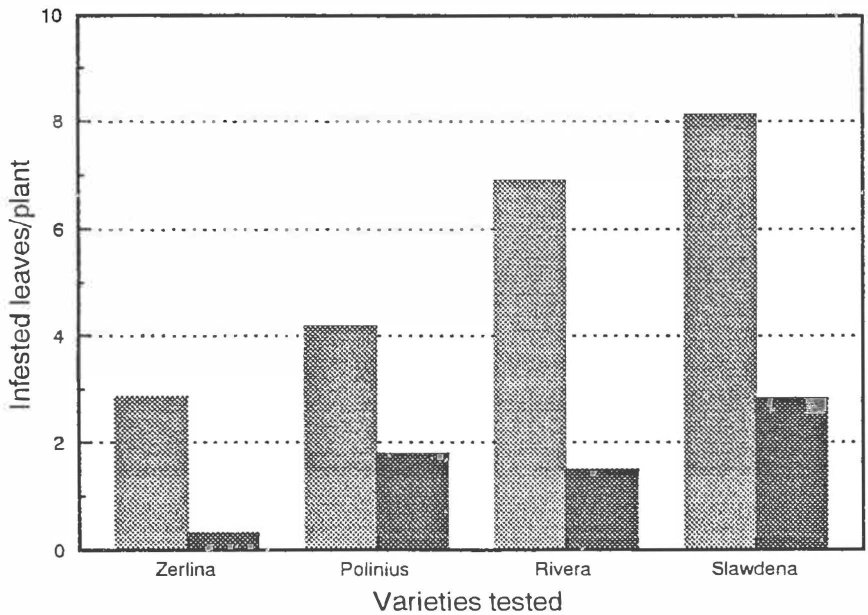

Fig. 1. *Thrips tabaci* damage to four cabbage varieties grown at HRI Wellesbourne in 1992.

Experiments in Germany

Materials and Methods

In 1988 and 1989, a range of cabbage varieties was tested at two sites in Germany; Clauen in south-east Hannover (Bundessortenamt experimental field) and Hoetzum in south-east Braunschweig (Federal Biological Research Station experimental field). At Clauen, two replicates of 13 plants of each variety were included and at Hoetzum a randomised block design was used in which four replicates of 20 plants of each variety were grown. Cabbage seed was sown mid- to late-April and transplanting took place in May of each year at both sites. Harvest date depended on the time of maturity of the variety. Thus, 'Pedrillo', 'Picolo' and 'Quisto' were harvested at the end of August, 'Apex', 'Erdeno' and 'Filderkraut' in the middle of October and the remaining varieties in the beginning of November. At Clauen, 24 plants were harvested for each variety and at Hoetzum 40 plants were harvested.

Each leaf in every cabbage head was examined for damage and assigned to one of five classes:-

Class	Leaf symptoms
0	no damage
1	slight damage (< 10 cm^2)
2	moderate damage (10-100 cm^2)
3	heavy damage (100-200 cm^2)
4	very heavy damage (> 200 cm^2)

The thrips damage on the individual leaves was used to classify the heads of each variety:-

Class	Whole cabbage head symptoms
0	no damage (marketable)
1	slight (< 10 cm^2) (marketable)
2	moderate (10-100cm^2) (marketable)
3	heavy (> 100cm^2) (marketable after removal of 3 leaves)
4	very heavy (> 100cm^2) (damage deeper than 3 leaves, not marketable)

Results

The thrips infestation level differed between sites and years but there were consistent differences between varieties, 'Zerlina' being the least damaged. Because of the consistent performance of varieties the results for the two years at the two sites have been combined in Fig. 2. Early-maturing varieties were damaged more than late-maturing types and thus the period of head formation was believed to be critical in determining the susceptibility of a variety to thrips attack.

Experiments in Austria

Materials and Methods

The experiments were done at Goggendorf in lower Austria in 1991 and 1993 in a different 0.7 ha field in each year. Two rows of each variety were grown according to local commercial practice. Seed was sown in the middle of April and the plants harvested at the beginning of October. Thrips damage was assessed by lifting 40 plants at random from each row and peeling off the wrapper leaves until symptoms of oedema were no longer visible. Four classes of damage were recorded:-

Class	Symptoms
1	no damage
2	isolated oedema
3	moderate damage
4	heavy damage

Mean damage values were derived for each variety.

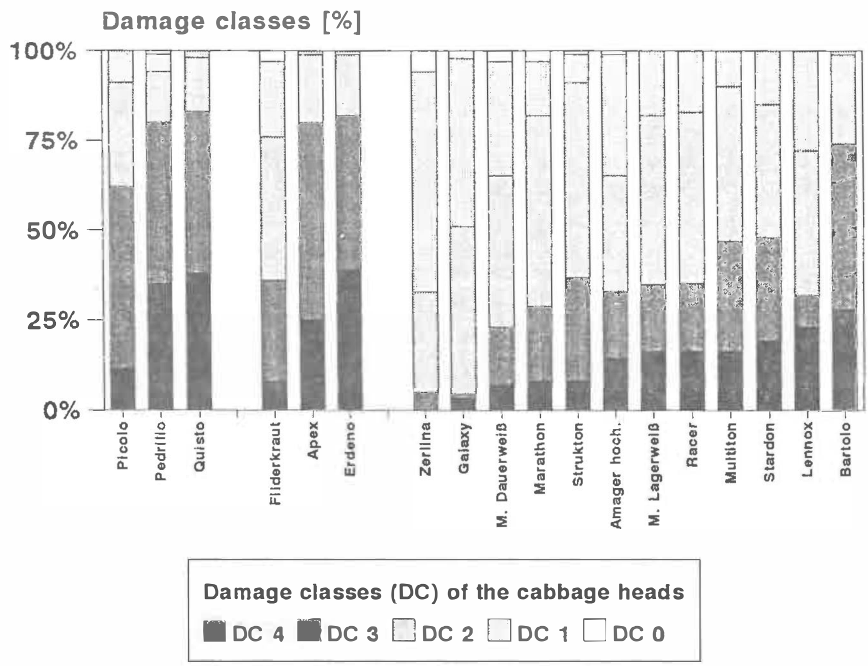

Fig. 2. ***Thrips tabaci*** **damage to 18 cabbage varieties grown at Clauen and Hoetzum in Germany in 1988 and 1989. Results for two sites and two years combined.**

Results

The results for the two years are shown in Figs. 3 and 4. The more resistant varieties included 'Horizon', 'Provita', 'Scanner', 'Scandic' and 'Zerlina'.

Discussion

Direct comparisons between the results for the three countries are limited because very few varieties were tested at more than one site and the methods of damage evaluation differed. However, in all three countries oedema damage was recorded on the leaves of the experimental cabbage. In Austria and Germany, assessments were made at harvest whereas in England they were made after a period of storage. The variety 'Zerlina' was included at all sites and was the most resistant variety in England and Germany and one of the most resistant in Austria. These results confirm the observations of growers in England and in Germany (Kretschmer, 1984) suggest that this variety is worthy of further study. In contrast, the variety 'Apex' was one of the most susceptible in both Germany and Austria. 'Polinius' was tested in England and Austria and found to be more severely damaged than 'Zerlina'. Two other varieties, 'Multiton' and 'Lennox' were common to experiments in Austria and Germany and were intermediate in their susceptibility.

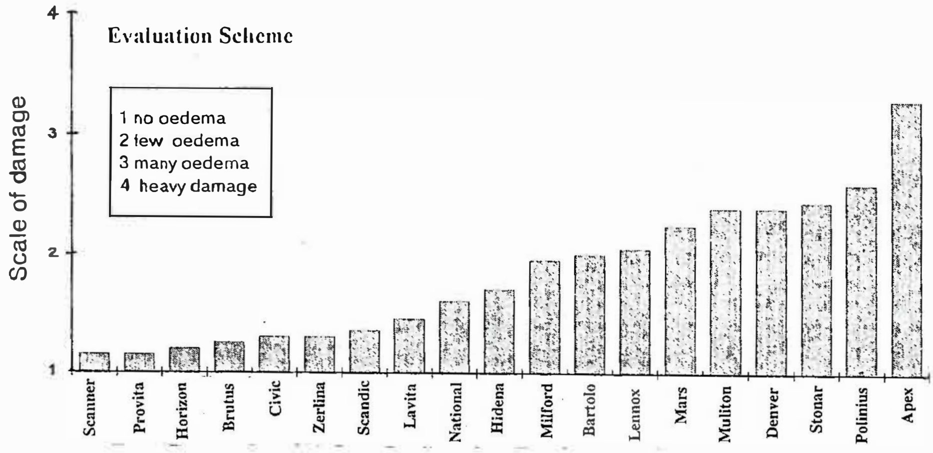

Fig. 3. ***Thrips tabaci*** **damage to 19 cabbage varieties grown at Goggendorf, Austria in 1991.**

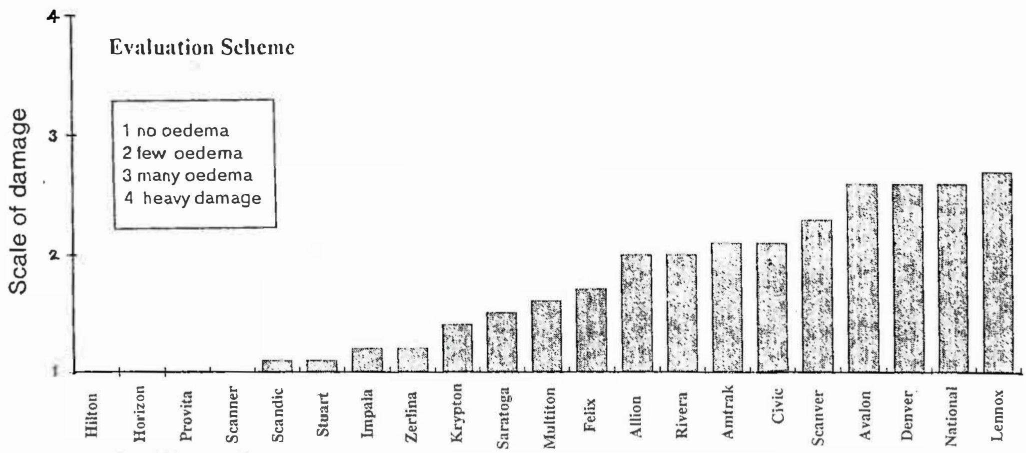

Fig. 4. ***Thrips tabaci*** **damage to 21 cabbage varieties grown at Goggendorf, Austria in 1993.**

By evaluating a range of varieties, it has been possible to identify which varieties to recommend to growers/advisors to minimise oedema. It is also valuable to identify highly susceptible varieties so that these can be avoided. It is important that crop varieties are tested at several sites to investigate possible genotype/environment interactions. 'Zerlina' was shown to be partially resistant in all three countries at all sites, and hence is a suitable candidate for a detailed study of the mechanism of its resistance.

Résumé

Etudes préliminaires aux champs de la résistance du chou à *Thrips tabaci* dans trois pays d'Europe

Une série importante de variétés de chou blanc commercialisées a été évaluée en Autriche, en Angleterre et en Allemagne pour leur résistance au Thrips de l'oignon, *Thrips tabaci*, entre 1988 et 1993. Les dégâts des thrips sont mesurés à partir de la sévérité et de l'étendue des piqûres de nutrition et de la profondeur des dégâts à l'intérieur de la tête de chou. Quoique les travaux aient été réalisés indépendamment dans les trois pays, certaines variétés sont présentes dans plus d'une expérience. La variéte 'Zerlina' était partiellement résistante dans les trois pays et semble digne d'une étude ultérieure. Dans le futur il serait possible d'obtenir des progrès importants dans l'étude de la résistance des plantes aux thrips à partir d'une collaboration entre les scientifiques des différents pays.

Acknowledgements

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Predation of cabbage root fly eggs and larvae by carabid ground beetles - fact or fantasy?

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Summary

Greenhouse trials with artificially-infested cauliflower plants indicated that ground beetles were effective predators of cabbage root fly eggs only when the eggs were exposed on the surface of the soil. None of the beetles tested seemed able to find eggs just below the soil surface, the position in which they are normally laid by the female flies. The extremely high (>90%) levels of egg predation recorded in fields at HRI Wellesbourne during the late 1950s and early 1960s do not relate to natural predation (the fantasy), but merely to predation of eggs exposed on the soil surface (the fact).

In no-choice situations, about half of the eleven species of carabid beetles tested ate some third-instar larvae of the cabbage root fly. On artificially-infested cauliflower plants, most larvae, about 50% of those that would otherwise have survived, were destroyed by *Abax parallelopipedus* and *Amara familiaris*. Laboratory findings on beetle predation of root fly larvae should not be extrapolated to field situations before further information has been collected.

Introduction

Work at Wellesbourne in the late 1950s (Hughes, 1959; Hughes & Salter, 1959) and early 1960s (Hughes & Mitchell, 1960; Wright *et al.*, 1960; Mitchell, 1963; Coaker & Williams, 1963) showed that predators exerted an important check on populations of the cabbage root fly, with ground beetles alone killing more than 90% of the eggs and first-instar larvae of the first and second fly generations. In recent years, however, averages of 150 third-instar larvae/plant have been recorded in some crops. As such numbers are unlikely to represent only 10% of the pest population, it appears that the earlier estimates of egg-predation were too high. Similarly, insecticides that kill 60%-70% of the newly-hatched larvae frequently prevent crop damage, whereas predators do not, again indicating that the earlier estimates of predation were probably too high.

Recent research has shown that although the total mortality during the life-cycle of the fly is frequently in excess of 90%, only about 30% of the mortality occurs at the egg and first-instar larval stages (Finch & Skinner, 1988).

This paper examines why the earlier estimates of predation were too high and whether there are species of ground beetle that are effective predators of the egg and larval stages of this fly.

Experimental work

Materials and methods

In earlier studies, Coaker & Williams (1963) indicated that five species of ground beetles found commonly in the HRI Wellesbourne locality were important predators of cabbage root fly eggs. These five species, and a further four that could be collected in large numbers from fields at HRI Wellesbourne, were included in the egg predation part of this study (Fig. 1). Once collected, the beetles were separated into species and maintained in batches of 50-100 individuals in ventilated plastic boxes (28 cm x 16 cm x 9 cm deep) in a room at 18 ± 2°C. Twice weekly, the beetles were provided with dry cat biscuits as food (Powell, W. - personal communication) and water.

Predation of cabbage root fly eggs

Tests were carried out by placing beetles individually into small (12.5 cm x 8 cm x 2 cm deep) ventilated boxes lined with dampened white filter paper. Each beetle was provided with 120 freshly-laid cabbage root fly eggs obtained from the HRI Wellesbourne culture (Finch & Coaker, 1969). Batches of 60 fly eggs were counted out onto 1.5 cm square pieces of black filter paper, two of which were placed into each beetle box to supply the beetle with 120 eggs/day. The mean numbers of fly eggs eaten day, calculated from 100 records for each species, are shown in Fig. 1.

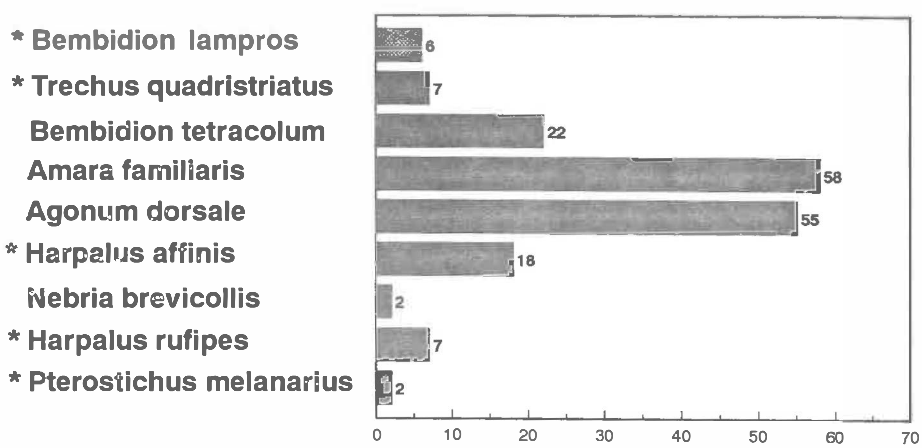

Fig. 1: Mean numbers of cabbage root fly eggs eaten/day by individuals of the nine carabid species ordered from the smallest (*B. lampros*) to the largest (*P. melanarius*). *Five species tested by Coaker & Williams (1963)

Most eggs were eaten by the intermediate-sized beetles, such as *Amara familiaris* and *Agonum dorsale*. Although small beetles, like *Bembidion lampros* and *Trechus quadristriatus*, ate relatively few eggs/day, these two species were much more numerous in brassica crops than intermediate-sized beetles and hence could still be the most effective predators under field conditions.

Carabid predation of cabbage root fly eggs under glasshouse conditions

To determine the numbers of beetles required to control a given level of cabbage root fly infestations, six-week old cauliflower plants were transplanted into 17.5 cm diameter pots of Levington compost. Each plant was surrounded with a 15 cm diameter beetle barrier (Finch & Elliott, 1992) and allowed to establish for one week. Twenty-five of the "barriered" plants were used in each test. The numbers of fly eggs and beetles added to each of the 5 plants (replicates) within each of the five treatments are shown in Table 1.

In earlier studies (Finch & Elliott, 1992), the numbers of cabbage root fly that survived from egg to pupa was reduced from 17 to 3 (82% decrease) by *Bembidion tetracolum* and from 27 to 14 (48% decrease) by *Amara familiaris*. However, these results were obtained when the eggs were washed onto the plants so that most of the eggs remained on the soil surface. Under more natural conditions, the female flies push their ovipositors into the soil leaving very few eggs exposed on the soil surface. To determine whether this affects egg predation, tests were carried out in which the eggs were either left exposed, or covered with a dusting (approximately 0.5mm deep) of soil. Data are shown only for *Bembidion lampros* and *Trechus quadristriatus*, though *Amara aenea, A. familiaris, Bembidion tetracolum* and *Calathus melanocephalus* were also tested.

Table 1: Final plant weight and numbers of cabbage root fly (CRF) pupae recovered from brassica plants inoculated with 40 cabbage root fly eggs and 2, 4 or 8 individuals of the beetles *Bembidion lampros* and *Trechus quadristriatus*

Insects/plants		Fly eggs covered		Fly eggs exposed	
Fly eggs	Beetles*	Plant wt(g)	No. of CRF pupae	Plant wt(g)	No. of CRF pupae
	**Bembidion lampros*				
0	0	198	0	229	0
40	0	6	24	12	19
40	2	36	21	159	4
40	4	39	20	136	2
40	8	81	16	131	3
	**Trechus quadristriatus*				
0	0	191	0	215	0
40	0	12	19	4	25
40	2	64	20	60	9
40	4	71	18	98	4
40	8	91	17	215	<1

The results (Table 1) show that although *B. lampros* and *T. quadristriatus* ate root fly eggs, they ate only those that are on the surface of the soil. The four other species tested behaved similarly. None of the beetles tested appeared to burrow in the soil alongside brassica plants to search for fly eggs.

Predation of cabbage root fly larvae

These experiments were done in the same way as the egg predation experiments, except that each beetle was provided with 10 third-instar larvae/day instead of 120 eggs.

Small beetles, like *B. lampros* and *T. quadristriatus*, were not capable of killing third-instar larvae of the cabbage root fly even in a "no-choice" situation,. In general, the larger the beetle the more larvae it consumed. *B. tetracolum, A. familiaris* and *N. brevicollis* ate on average 1, 2 and 4 larvae/day, respectively. *A. dorsale* and *H. affinis* both ate about 8 larvae/day, whereas the large *P. melanarius* and *H. rufipes*, which is normally considered to feed mainly on vegetable matter, ate all 10 larvae each day.

Carabid predation of cabbage root fly larvae under glasshouse conditions

The experimental set-up was similar to that used in the glasshouse egg-predation tests. The difference was that following egg inoculation, 150 day-degrees were allowed to elapse (Collier & Finch, 1985) so the larvae reached the third-instar before the beetles were added. Eight small, 4 intermediate or 2 large beetles were added to each test plant.

The data in Fig. 2 show that five beetles species (5 on abscissa - Fig.2), namely *A. dorsale*, *A. albipes*, *B. lampros*, *Calathus fuscipes* and *Pterostichus cupreus* had no effect. *H. affinis* (1) appeared to eat a few larvae and *B. tetracolum*, *H. rufipes* and *P. melanarius* (3) to eat slightly more. Even the two most-effective beetles tested, *A. familiaris* and *Abax parallelopipedus*, (2) only reduced the numbers of larvae pupating by about 50%.

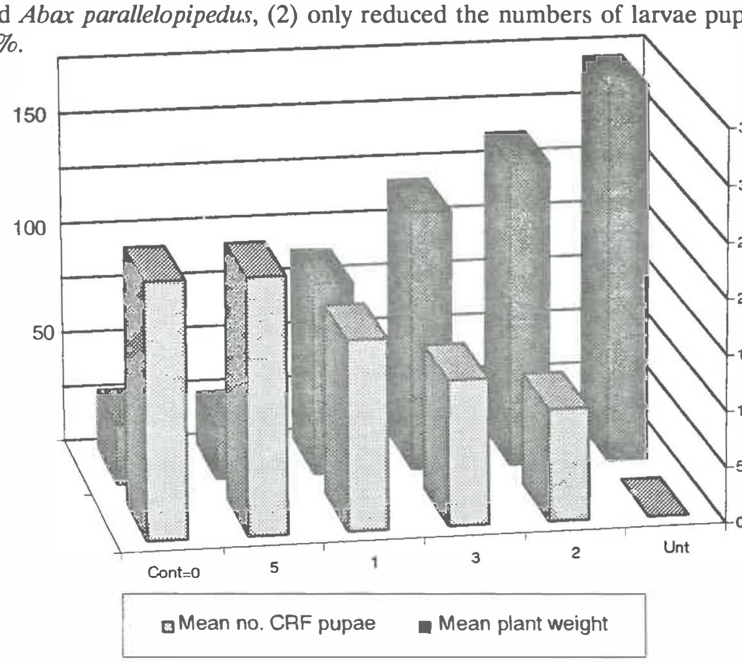

Fig. 2. Final plant weights and mean numbers of cabbage root fly larvae that managed to pupate in the presence of eleven species of ground beetle, shown as 5:1:3:2 on the abscissa and described in detail in the legend.

Discussion

Data collected at Wellesbourne in the late 1950s and early 1960s indicated that more than 90% of the eggs and first-instar larvae of the cabbage root fly were destroyed by carabid ground beetles. Although field studies are generally considered more meaningful than laboratory studies, this is true only if the field studies reflect natural situations. Unfortunately, in the earlier studies, Hughes (1959) obtained his egg-predation data from an unnatural situation "by smoothing down an area of soil about 5cm away from the stem of a host-plant, pushing in two support stones, adding freshly-laid cabbage root fly eggs and covering the eggs with a flat stone to prevent predation by birds." In effect, therefore, the eggs were presented on the surface of the soil. The data in Table 1 show that high levels of egg predation occur only when eggs are presented in this way. Hence, presenting eggs on, rather than in, field soil, considerably overestimates the numbers of eggs eaten by ground beetles.

As egg-predation was much lower than recorded previously, attempts were made to determine whether certain beetle species were effective predators of cabbage root fly larvae. This work was instigated because, although a mean of 150 (mainly third-instar) root fly larvae were found per plant in a cauliflower crop in June 1983, only 2-3 pupae/plant were recovered from the same field one week later. Hence, in certain instances it appears that larval predation can be high, as large numbers of dead larvae were not found in the soil samples. The data in Fig. 2, however, indicate that even the most effective beetles, *A. parallelopipedus* and *A. familiaris*, destroyed only about half of the larvae. Care is needed before extrapolating such findings to field situations, however, as plants with roots infested with high numbers of fly larvae in the field often rock in the wind which results in a gap alongside the plant stem that is highly attractive to beetles. It appears that both root fly eggs and larvae are eaten mainly in those locations where they become exposed on a surface, be it horizontal or vertical. Consequently, carabid ground beetles appear to feed primarily on prey they find on the surfaces they walk over. As their general description indicates, many of them appear to be truly epigeic.

Résumé

Prédation des oeufs et des larves de Mouche du chou par les carabes - réalité ou fantasme?

Dans des essais en serre réalisés avec des plants de choux-fleurs infestés artificiellement, on montre que les carabes sont des prédateurs efficaces des oeufs de Mouche du chou seulement lorsque les oeufs sont exposés à la surface du sol. Aucun carabes testé ne semble être capable de trouver des oeufs posés juste au dessous de la surface du sol, position qui correspond à la ponte naturelle de la femelle. Les niveaux extrémement élevés (90%) de la prédation des oeufs notés dans les champs de la Station International de Recherches en Horticulture (HRI) de Wellesbourne durant la fin des années 1950 et le début des années 1960 ne sont pas reliés à la prédation naturelle (le fantasme), mais simplement à la prédation des oeufs exposés sur la surface du sol (la réalité).

Dans des situations de non choix presque la moitié des espèces de carabes

testés s'alimentent du troisième stade larvaire de mouche du chou. Sur des choux-fleurs infestés artificiellement la plupart des larves, environ 50% de cells qui ont survécues par ailleurs, furent détruites par *Abax parallelepipedus* et *Amara familiaris.* Les recherches en laboratoire sur la prédation de larves de mouche du chou par des carabes ne peuvent être extrapôlées en situation de plein champ avant que d'autres informations n'aient été collectées.

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Effects of organic treatments on beetle predators of the cabbage root fly and on alternative prey species

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Summary

The egg predator, *Bembidion lampros*, and carabid beetles in general, were more numerous in brassica plots to which organic materials had been applied. The increase in beetle numbers persisted into the year following the last application of organic material and was due, at least in part, to more beetles breeding in the organically-treated plots. Predation of cabbage root fly eggs was not increased in organically-treated plots, probably because the numbers of fly eggs were low and hence they formed a relatively small part of the diet of the predators, and because the organic treatments also increased the numbers of alternative prey.

The presence of straw on the soil surface reduced the numbers of cabbage root fly eggs around plants but increased the number of slugs. Percentage parasitism of fly pupae was reduced when either straw or slurry was added to the experimental plots.

Introduction

Eggs of the cabbage root fly *Delia radicum* (L.) are laid within 5 cm of the host plant (Hughes & Salter, 1959) so that, in a spaced crop, they are readily targeted by predatory beetles. The level of predation of the fly eggs varies with the size of the fly population (Benson, 1973) and has exceeded 90% (Hughes & Salter, 1959). The survival of *D. radicum* eggs has also been related inversely to numbers of *Bembidion lampros* Hbst (Wright, Hughes & Worrall, 1960; Coaker, 1965; Ryan & Ryan, 1973; Mowat & Martin, 1981).

This paper describes experiments to determine whether populations of beneficial predatory species, and subsequent predation of the pest, could be increased by applying certain organic materials to brassica crops.

Methods

Four treatments, each replicated 5 times, were randomised in 10 m x 10 m plots on a light-to-medium sandy loam at Newforge Lane, Belfast. After ploughing and rotavating, all plots received 100 kg N, 50 kg P and 100 kg K ha^{-1} on 8 May 1985.

The four treatments were 1) "control" which received only herbicide; 2) 0.5 tonnes cattle manure per plot (0.15 t DM, 2.63 Kg N, 0.36 Kg P and 2.64 Kg K) applied on 3 May; 3) 455 l cattle slurry per plot (0.03 t DM, 0.71 Kg N, 0.27 Kg P and 1.99 Kg K) applied on 3 May, and 4) three bales of winter barley straw applied to each plot on 21 May.

The ground was rotavated to incorporate the manure and slurry. Propachlor (4.8 kg a.i. $10l^{-1}$ ha^{-1}) was then applied, followed by straw which was not incorporated into the soil. Brussels sprouts, cv Bastion, were planted on 27 May 1985 and remained in the plots until 19 February 1986. Paraquat (600 g a.i. $3l^{-1}$ ha^{-1}) was used subsequently for weed control in the unplanted areas. The plots were hand weeded.

Twenty soil cores, each 13 cm depth and 2.3 cm in diameter, totalling 1080 cc, were taken from each plot on 14 occasions from 30 April to 18 December. The animals were extracted from the cores using Tullgren Funnels. The numbers of beetles caught in three pitfall traps/plot were recorded on 1 and 20 May and then weekly from 10 June to 16 December. Each trap consisted of 8.1 cm-deep perspex jar with a constriction 1.5 cm below the neck, giving a diameter of 6.3 cm at the mouth and 7.6 cm below the constriction. Traps were protected from rain by a clear perspex cover mounted on 15 cm nails.

Soil was removed from the base of 10 plants in each plot, five of which were protected from egg predation by plastic barriers (6 cm high, 38 cm diameter). Raising the internal soil level to the top of barriers allowed escape, but not entry, of beetles. Eggs around the 'barrier' and 'no-barrier' plants were recorded every two weeks from 17 June to 23 September.

In 1986, the treatments used in 1985 were applied again to the same plots. The manure used contained 81 Kg DM, 1.34 Kg N, 0.43 Kg P and 1.41 Kg K per plot. The slurry contained 13 Kg DM, 0.01 Kg N, 0.17 Kg P and 0.12 Kg K per plot. Each plot was planted on 21 May with 64 Brussels sprout plants, cv. Bedford Fillbasket, weed control was as in 1985. Soil samples were taken on 20 January, 20 April, and then each month from 15 June to 18 December.

The numbers and species of beetles caught in three pitfall traps/plot were recorded at weekly intervals from 6 January to 2 December. The traps were removed temporarily from February to April, and in early May, to allow the ground to be prepared and the test treatments applied.

Beetles were collected weekly from 22 April to 2 December from 10 pitfall traps/plot, surrounded by plastic barriers in which the soil was not raised on the inside.

The numbers of cabbage root fly eggs around the plants were recorded from 10 June to 21 October. Pupae were recovered by flotation from soil samples taken on 10 January from around the roots of four plants on each plot. The numbers of flies and parasitoids that emerged from the pupae were recorded.

To determine if any of the four treatments affected slug numbers, bran bait was placed under four 15 cm x 15 cm tiles per plot and slug numbers recorded on 7, 12 and 14 August.

The plots used in the previous years were maintained in 1987 but no further organic or inorganic fertilizers were applied. After ground preparation, thirty-six cauliflowers, cv. Elgon, were planted at 1 m x 1 m spacing in each plot so that a 2.5 m wide border was left unplanted around the perimeter of each plot. Propachlor and paraquat were applied, at the rates described previously, on 23 April and 22 May respectively.

Soil samples were taken on 28 January, 16 February and 2 June. Within the planted area of each plot, there were six pitfall traps; three with 'barriers' and three 'without-barriers'. The numbers of cabbage root fly eggs recovered were recorded on 6 dates from 6 May to 12 June, and the data collected were then subjected to Analysis of Variance.

Results

i) Soil fauna

Most soil-inhabiting Collembola were found in the manure plots and fewest in the control plots in 1985 and 1986 ($P<0.05$). This was mainly attributable to members of the Poduridae, (mainly *Hypogastrura denticulata* Bagnall), and Onychiuridae, (mainly *Onychiurus* spp. and *Tullbergia krausbaueri* (Borner)). Isotomidae (mainly *Isotomurus palustris* (Muller)) were commonest ($P<0.01$) in the straw plots in 1985 and 1986. In 1987 the numbers of Collembola present were reduced considerably and differed little between treatments (Table 1). Sminthuridae were found also, but their numbers did not differ between treatments. Acarina showed little effect of treatment, although slurry plots tended to have fewest. Numbers of dipterous larvae and Lumbricidae appeared to be increased slightly in

Table 1. Mean numbers of animals from 25 litres of soil/plot in 1985/96 and 3 litres/plot in 1987. Observed means with (log transformation).

		Control plots	Manure plots	Slurry plots	Straw plots	SE
Acarina	1985/86	258 (5.3)	326 (5.7)	178 (5.2)	255 (5.5)	(0.2)
	1987	47 (3.6)	39 (3.6)	26 (3.2)	27 (3.3)	(0.3)
Collembola						
Isotomidae	1985/86	197 (5.3)	270 (5.6)	223 (5.4)	393 (6.0)	(0.1)
	1987	33 (3.4)	27 (3.0)	21 (3.0)	26 (3.1)	(0.8)
Onychiuridae	1985/86	415 (5.9)	653 (6.4)	578 (6.2)	486 (5.9)	(0.2)
	1987	52 (3.8)	100 (4.4)	66 (3.5)	29 (3.3)	(0.3)
Poduridae	1985/86	67 (3.7)	386 (5.5)	87 (4.0)	235 (5.3)	(0.3)
	1987	42 (3.1)	130 (4.1)	40 (3.3)	29 (3.2)	(0.4)
Total fauna caught	1985/86	1513 (7.3)	2230 (7.7)	1645 (7.4)	2115 (7.6)	(0.1)
	1987	208 (5.2)	354 (5.7)	195 (5.2)	155 (5.0)	(0.2)

1985 and 1986 in the manure and straw plots, but the increases were not significant (Humphreys, 1987).

ii) Carabidae

A total of 15,043 carabid beetles, comprising 40 species were trapped (Humphreys, 1987). More carabid beetles were caught on the manure plots, and fewer on the straw plots than on the control plots ($P<0.01$) over the three years in the 'no-barrier' traps (Table 2). In 1987 however, most beetles were trapped in the straw plots. Barrier traps captured most carabids in the manure plots and fewest in the straw plots in both 1986 ($P<0.05$) and 1987 (Table 2).

Year 2. Mean numbers of total carabids caught/trap/day. Square root transformation. Observed means with (square root transformations).

Year	Control plots	Manure plots	Slurry plots	Straw plots	SE
'no-barrier'					
1985	0.37 (0.60)	0.46 (0.67)	0.38 (0.62)	0.21 (0.46)	(0.028)
1986	0.26 (0.51)	0.36 (0.60)	0.29 (0.54)	0.16 (0.37)	(0.028)
1987	0.87 (0.93)	1.02 (1.01)	0.96 (0.98)	1.08 (1.04)	(0.034)
Total	0.36 (0.60)	0.46 (0.67)	0.39 (0.62)	0.26 (0.51)	(0.023)
'barrier'					
1986 pr	0.24 (0.48)	0.29 (0.54)	0.26 (0.51)	0.27 (0.51)	(0.041)
1986 po	0.08 (0.27)	0.11 (0.33)	0.09 (0.30)	0.07 (0.25)	(0.025)
1987	0.27 (0.52)	0.38 (0.57)	0.27 (0.51)	0.25 (0.48)	(0.048)

pr = pre-treatment 23.4.86 - 7.5.86, po = post-treatment 10.6.86 - 2.12.86

B. lampros was the commonest species and hence contributed most of the data used in the analyses (Table 3). In the 'no-barrier' traps, most *Trechus obtusus* were caught in the manure plots, and fewest in the straw plots in 1985 ($P<0.05$) and 1986 ($P<0.01$). However, in contrast to *B. lampros*, no effect was detectable in 1987. The total numbers of *B. lampros* caught in pitfall traps ('no-barrier' and 'barrier') during the three years were 3,234 in the manure plots, 2,462 in the slurry plots, 2,265 in the control plots and 1,661 in the straw plots. Barrier traps caught 58% fewer carabids than 'no-barrier' traps (Table 2). The exclusion efficiency was probably higher than this, as carabids would have been present in the plots when the barriers were erected.

Table 3. Mean numbers of *Bembidion lampros* caught/trap/day. Observed means with (square root transformations).

Year	Control plots	Manure plots	Slurry plots	Straw plots	SE
'no barrier'					
1985	0.22 (0.46)	0.30 (0.54)	0.28 (0.48)	0.07 (0.27)	(0.028)
1986	0.15 (0.38)	0.24 (0.48)	0.16 (0.40)	0.08 (0.28)	(0.027)
1987	0.48 (0.69)	0.64 (0.80)	0.56 (0.74)	0.61 (0.78)	(0.040)
'barrier'					
1986 pr	0.07 (0.26)	0.13 (0.38)	0.11 (0.32)	0.34 (0.12)	(0.047)
1986 po	0.04 (0.19)	0.06 (0.25)	0.20 (0.04)	0.14 (0.02)	(0.015)
1987	0.13 (0.35)	0.17 (0.40)	0.13 (0.36)	0.13 (0.34)	(0.049)

pr = pre-treatment, po = post-treatment

Other *Bembidion* species, although numerous, showed no treatment effects. *Nebria brevicollis* adults were trapped in greater numbers in both the control plots and the slurry plots.

Six species of the genus *Pterostichus* were trapped (Humphreys, 1987). Although most were trapped in the manure plots in 'no-barrier' traps, the genus did not show any particular preference for any type of plot.

iii) Delia radicum *oviposition*

Where beetles were excluded, most eggs ($P<0.05$ in 1985; $P<0.001$ in 1986) were collected from the slurry plots followed by the control, manure and straw-treated plots (Table 4). The differences were less pronounced in 1987 when no treatments were applied. Plants had fewer eggs when not surrounded by barriers in 1985 (39%, $P<0.001$) and 1986 (26%, $P<0.001$) and showed the same trend in 1987 (13%, $P=0.067$) (Table 4). The decrease was similar in all treatments.

iv) Pupal and parasite numbers

Fewer pupae tended to be recovered from the straw plots than from other plots (Table 5). Three species of parasitic Hymenoptera, namely *Trybliographa rapae* (Westw.), *T. diaphana* (Hartig) and *Phygadeuon trichops* (Thompson), emerged from some of the pupae (Table 5). More *Trybliographa* emerged from the pupae recovered from the control plots and the manure plots than from the slurry or straw plots

($P<0.001$). More insects failed to eclose from the pupae from slurry plots (Table 5) than from the pupae from the other plots ($P<0.01$, angular transformation).

Table 4. Number of cabbage root fly eggs recovered per 25 plants. 1985 = 8 samples between 17.6.85 - 23.9.85; 1986 = 19 samples between 10.6.86 - 21.10.86; 1987 = 6 samples between 6.5.87 - 12.6.87. Observed means with (log transformations).

Year		Control plots	Manure plots	Slurry plots	Straw plots	SE
1985	nb	81 (4.4)	60 (4.1)	93 (4.5)	44 (3.8)	(0.12)
	b	137 (4.8)	79 (4.4)	163 (5.0)	75 (4.3)	(0.12)
1986	nb	553 (6.2)	566 (6.3)	737 (6.5)	337 (5.7)	(0.17)
	b	858 (6.7)	551 (6.3)	1014 (6.9)	554 (6.3)	(0.09)
1987	nb	232 (5.2)	287 (5.6)	327 (5.6)	225 (5.3)	(0.17)
	b	244 (5.5)	354 (5.9)	373 (5.8)	264 (5.4)	(0.17)

nb = no barriers, b = barriers

Table 5. Number of *Delia radicum* pupae recovered/4 brassica plants/plot on 10.1.86, with percentage giving rise to adult cabbage root fly and parasitoids

	Control plots	Manure plots	Slurry plots	Straw plots	SE
Total pupae	47	44	46	18	13
Delia radicum %	54	72	48	65	9
Trybliographa rapae %	16	12	4	2	3
Phygadeuon trichpops %	6	5	2	7	3
Failed to emerge %	7	9	47	29	8

v) Slug numbers

Slugs were present in higher numbers in the straw-treated plots ($P<0.05$). The mean number of slugs per plot, recovered from four tile traps on three occasions in August 1986, were 7 in the slurry plots, 8 in the control plots, 11 in the manure plots and 21 in the straw plots.

Discussion

The significance of *B. lampros* as a predator of *D. radicum* eggs is well-established (Coaker & Williams, 1963). The aim of the present experiments was to determine whether the numbers of predatory species, and hence predation on *D. radicum* eggs, could be increased by the addition of organic materials. Disposal of such materials on farms can be difficult, and demonstration of how such materials could be used as a benefit to crop protection could be important.

Earlier investigations into the effects of organic manures on carabids have shown either no significant increases, or increases that could be explained by temporary attraction to a treated plot from the adjoining area (Pietrasko & de Clercq, 1982). In sugar beet, the beneficial effects of surface-applied manure on the abundance of some carabids, such as *B. lampros*, were either short-lived (Purvis & Curry, 1984) or not significant (Gregoire-Wibo, 1983).

The present work differed from the earlier studies in that the effects were studied over a longer period by treating the same plots in successive years. Carabids were more abundant in the plots treated with manure. *B. lampros*, in particular, was more abundant even in the year after the last application. Incorporation of manure may, therefore, prolong the beneficial effects of *B. lampros*. Total catches of carabids in the planted area of the plots in 1985 and 1986 were 13% greater in the manure, 5% greater in the slurry and 26% lower in the straw than in the control plots. Obstruction of movement of carabids probably accounts for the lower numbers of beetles caught in the straw plots. This is supported by the relative increase in the numbers trapped in the straw plots in 1987, emphasizing the difficulties of using pitfall traps as indicators of abundance (Greenslade, 1964). The application of straw to the soil surface, although incorporated during cultivation in the following year, together with the slow rate of decomposition of straw, made it unlikely that a beneficial effect on predators would occur immediately. The fact that the straw plots were second only to the manure in numbers of *B. lampros* by year 3 of the experiment, and already significantly higher than the control, suggests that over a longer period straw would increase the numbers of some carabid species. The observations on traps in an enclosed area were included in the experiment primarily to detect differences in the breeding population, by preventing the entry of immigrant beetles. Between-plot differences were greater in such situations and showed that increased breeding of carabids in preferred plots was at least partly responsible for differences between treatments. This suggests that the effects of straw and manure treatments could be accumulative.

Alternative prey species for carabid beetles were also commoner in the organically-treated plots. In laboratory tests, *B. lampros* would not eat the commonest podurid, *H. denticulata*. Therefore, this species has little effect on *B. lampros* distribution. However, other Collembola were accepted as food.

Differences in the abundance of the principal predator in the various plots were not reflected in predation rates. As egg predation was lower (24%) than in previous studies, other food sources were clearly more significant. In view of the switching of polyphagous predators to the most abundant/convenient food sources, it remains likely that enhanced populations of *B. lampros* would increase predation where *D. radicum* eggs were commoner and a more prominent source of prey.

Straw appeared to deter flies from laying. The deterrent was probably visual, as the straw was not dense enough to prevent flies from reaching the oviposition site. Clover, green paper strips and clear polythene strips reduced oviposition, when compared with bare soil, though the effect was short lived (Ryan, Ryan & McNaeidhe 1980). Straw and slurry reduced parasitism by *Trybliographa* spp.

The failure of adult insects to emerge from a substantial number of the pupae collected from the plots treated with slurry was interesting. There was no obvious explanation, as the slurry did not seem to affect the production of pupae (Table 5).

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Résumé

Effet des fumures organiques sur les carabes prédateurs de la mouche du chou et sur les espèces de proies alternatives

Le prédateur d'oeufs, *Bembidion lampros*, et les carabes en général, sont plus nombreux dans les parcelles de chou où des fumures organiques ont été appliquées. L'augmentation du nombre de carabes se maintient pendant l'année qui suit l'application de matières organiques et elle est due en partie à une multiplication accrue dans les parcelles où du fumier a été apporté. La prédation des oeufs de mouche du chou n'a pas augmentée dans les parcelles ayant reçu un apport de matières organiques, probablement parce que le nombre de mouches était trop bas et ainsi ils ne représentaient qu'une petite partie de l'alimentation des prédateurs et parce que la fumure organique augmente également le nombre des autres proies.

La présence de paille sur la surface de sol réduit le nombre des oeufs de mouche du chou autour des plantes mais augmente le nombre des limaces. Le pourcentage de parasitisme des pupes de mouche était réduit quand on ajoutait dans les parcelles expérimentales soit de la paille soit du lisier.

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Detection of predation of the eggs and pupae of the cabbage root fly using isoelectric focusing and ELISA

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Summary

Four serological and two electrophoretic techniques were tested for use in confirming the presence of cabbage root fly protein in the gut contents of carabid predators. Of the six methods tested, isoelectric focusing, which includes staining for phosphoglucose isomerase enzyme activity, and an enzyme-linked immunosorbent assay proved to be the most promising. The two methods could detect predation up to 28 h and 48 h after consumption, respectively.

Introduction

Serology has been used successfully for many years to evaluate invertebrate predator-prey relationships (Boreham & Ohiagu, 1978). Of these the most precise, sensitive and cost-efficient method is the enzyme-linked immunosorbent assay (ELISA). This method has been used recently to determine the digestion rates of the prey of both *Bembidion lampros* and *Nebria brevicollis* (Lovei *et al.*, 1990). Isoenzyme electrophoresis (EP), although employed less frequently, has also been used to detect predation by arthropods (Fitzgerald *et al.*, 1987).

No work published to date on predation has used the electrophoretic technique of isoelectric focusing (IEF). The advantages of this technique over electrophoresis is that 1) it produces constant banding patterns irrespective of running time (due to the proteins focusing at their isoelectric point or pI), 2) it has higher resolution, and 3) it is more sensitive.

The work initially compared EP, IEF, the precipitin test, double diffusion, counter immunoelectrophoresis and an ELISA test to detect, in the laboratory, predation of cabbage root fly eggs and pupae by carabid beetles. Of the six techniques mentioned above, IEF and ELISA were successful and are described below.

Materials and Methods

Insect preparation

Cabbage Root Fly (*Delia radicum*) eggs and pupae were obtained from a laboratory culture. Adult *Bembidion lampros* Hbst., obtained by pitfall trapping in agricultural land, were fed on chopped earthworms, active baking yeast, aphids and Collembola until required for tests. Beetles were kept in plastic petri-dishes on moist filter paper and were starved for 48 h before being presented with food, which consisted of 20 eggs or two pupae of the cabbage root fly, or 20 *Myzus persicae*.

Decapitation of the live beetle after it had been fed or starved allowed the gut plus its contents to be removed through the thorax. Samples, consisting of three *B. lampros* guts, were macerated in their own volume of 1% glycine buffer. Ten μl was then applied to a 5 mm x 10 mm piece of Whatman No. 1 filter paper positioned on the gel. The filter paper was removed half way through the run to reduce smearing.

Isoelectric focusing (IEF)

Preparation and running of gels - A range of isoenzymes were studied initially to find ones with potential for detecting predation of cabbage root fly. Starch gel electrophoresis was used for this appraisal (see Humphreys, 1987). The enzymes tested in various buffer solutions were adenylate kinase, enolase, esterase, hexokinase, glycerol-3-phosphate dehydrogenase, malate dehydrogenase, malic enzyme, peptidase, phosphoglucose isomerase and phosphoglucomutase. Of these, only phosphoglucose isomerase (PGI) produced characteristic zymograms for all three test species (the fly *Delia radicum*; the aphid *Myzus persicae*; and the collembolan *Onychiurus armatus*). PGI could, using agarose IEF, detect 0.06 of an unconsumed cabbage root fly egg. Full details of the development work are described in Humphreys (1987). Polyacrylamide gels were used subsequently to improve the resolution of the banding patterns.

Polyacrylamide gels, 0.5 mm thick were produced at pH 3.5-9.5 by the method outlined in the LKB Instruction Leaflet 1818P-000-IME. Gels were focused for 1 h at 8°C using Multiphor (LKB 2117) and Multitemp apparatus. Current, power and voltage were set to 50mA, 25W and 2000V respectively. Anode and cathode electrode strips were soaked in 1M H_3PO_4 and 1M NaOH, respectively. The macerated insect samples were applied 1.5 cm from the anode.

Staining of gels - The PGI banding patterns were made visible by adding 1 ml $MgCl_2$, 20 mg fructose-6-phosphate, 10 mg NADP, 10 mg MTT, 6 mg PMS and 10 μl glucose-6-phosphate dehydrogenase to 10 ml Tris-HCl stain buffer, pH 7.4. This was added to an equal volume of a 2% agar solution maintained at 55°C, before being poured over the gel and allowed to set. After development in the dark for approximately 30 mins, the gels were photographed for future reference. On one occasion, the gel was scanned using a laser densitometer (LKB 2202 Ultroscan linked to an LKB dual pen potentiometric recorder) to calculate the area under each peak.

Testing of field collected beetles - Ten *B. lampros* were collected from each of twenty brassica plots, in a replicated field experiment consisting of three organic and one "control" treatment (see Humphreys & Mowat, this Bulletin). To ensure that the beetles tested were recently caught, five beetles were collected by searching the soil and five from pitfall traps that had been emptied earlier the same day. This test was carried out to determine if the rates of predation differed between the four treatments. The beetle guts were tested in groups of five individuals (giving a total of forty samples from the field) along with laboratory samples of starved and fed *B. lampros*.

Enzyme-linked immunosorbent assay (ELISA)

Antiserum preparation - A double antibody sandwich ELISA, based on the principle of message amplification inherent in enzyme action, was developed to detect cabbage root fly egg protein within the gut contents of the beetles. Cabbage root fly eggs were macerated in 0.01M phosphate buffered saline (PBS), pH 7.3, and then centrifuged at 3,000 rpm for 3 min. The supernatant was decanted, spun again at 25,000 rpm for 30 min, and then retained.

A rabbit was injected intramuscularly with the supernatant plus Freund's Complete Adjuvant (17 parts light paraffin oil: 3 parts emulsifier (Arlacel A): 10 mg dried *Mycobacterium tuberculosis*). Three booster injections, containing 1 mg protein in 1 ml saline were given intravenously at two week intervals with Freund's incomplete (lacking *M. tuberculosis*) adjuvant. The rabbit was test bled one month after the fourth injection, given a booster one month later, and exsanguinated two weeks after that.

Antibody purification and conjugation - Antibody purification followed the procedure of Clark & Adams (1977) after absorbing antibodies that might have cross-reacted, by adding to the antiserum freeze-dried material of the common field collembola (*Hypogastrura denticulata*, *O. armatus* & *Onychiurus* sp) and the aphid *M. persicae*. Conjugation of the purified immunoglobulin G (IgG) fraction to alkaline phosphatase was as follows: centrifugation of 1 ml alkaline phosphatase, addition of precipitate to 1.7 ml IgG, dialysis (three times in a 24 h period) against phosphate buffered saline at 4°C, addition of glutaraldehyde to a final concentration of 0.06% for 4 h, repeat dialysis, and finally the addition of bovine serum albumin (5 mg ml^{-1}). This was then stored at 4°C. The ELISA test followed that of Clark & Adams (1977), in which the test samples were added in PBS-Tween. Full details of the preliminary work and results are given in Humphreys (1987).

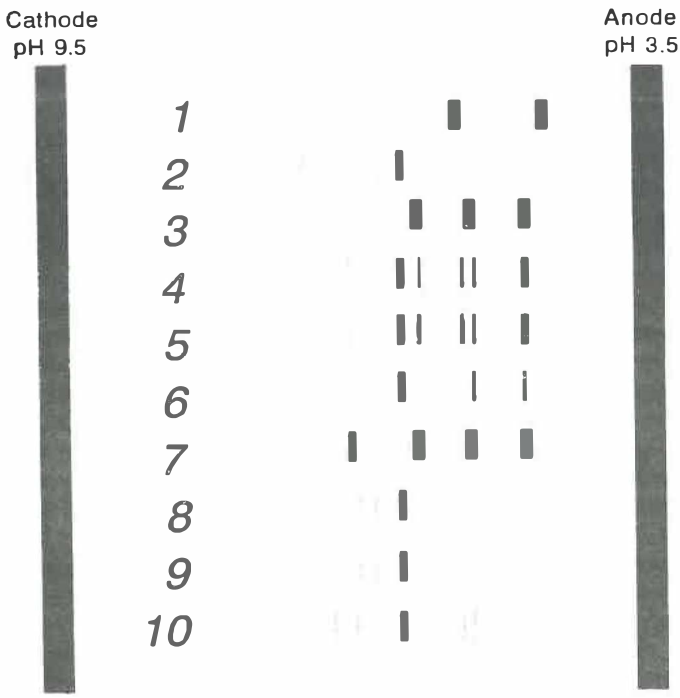
Identifying positive wells - Mean (X) and standard error (SE) of photometric readings were calculated for starved and fed beetles. The 99.9% confidence limits were determined for starved (control) beetles using the student t-test with the equation $X + t \times SE$, where t has n-1 degrees of freedom (n = the number of sample replicates). Values above this threshold value differed significantly.

Results

Isoelectric focusing (IEF)

Laboratory feeding experiments -

a) *Detection of predation* - The PGI banding patterns of *Bembidion lampros*, *Myzus* *persicae* and *Delia radicum* eggs and pupae were easy to distinguish (Fig 1). Although the major bands were consistent, there was some variation in the minor bands of *B. lampros* (Fig. 1).



Key:
1 - Unconsumed aphid
2 & 10 - *B. lampros* fed on aphid
3 - CRF pupae
4 & 5 - *B. lampros* fed on CRF pupae
6 - *B. lampros* fed on CRF eggs
7 - CRF eggs
8 & 9 - *B. lampros* starved for 72 hrs

Fig. 1: Phosphoglucose isomerase zymograms of the beetle *Bembidion lampros*, the aphid *Myzus persicae* and the cabbage root fly (CRF) using polyacrylamide focusing at pH 3.5-9.5

Predation on *M. persicae* was not detected. Predation of cabbage root fly eggs and pupae was observed and was also evident from the banding patterns (Fig. 1).

b) *Duration of detection period* - Predation on cabbage root fly could be detected from the PGI isoenzyme banding patterns for at least 28 h after feeding. This was confirmed by laser densitometry readings (480 nm) of the bands (Table 1). Two of the major cabbage root fly bands (1 and 2) occur only in *B. lampros* fed cabbage root fly material and not in starved individuals. Where pupal material had been digested, band strength decreased with time.

Table 1. Laser densitometry readings (480 nm) of phosphoglucose isomerase isoenzyme banding patterns obtained from *B. lampros* and cabbage root fly eggs and pupae

Sample	Band number (in order from anode)										
	1	2	3	4	5	6	7	8	9	10	11
B. lampros fed on pupae											
5 h previously	28	20	0	4	0	28	0	6	14	0	17
20 h previously	17	9	10	0	0	24	0	8	8	0	0
28 h previously	9	4	17	0	0	22	0	10	11	0	10
B. lampros fed on eggs											
5 h previously	13	7	8	6	0	17	0	6	6	0	0
24 h previously	14	7	6	6	0	13	0	0	9	0	8
CRF pupae (1)	32	33	0	0	65	0	0	0	0	0	0
CRF eggs (5)	22	16	0	0	18	0	6	0	0	11	0
Starved *B. lampros*	0	0	14	0	0	12	0	4	4	0	0

Field collected beetles - Predation on cabbage root fly eggs was not detected in field collected beetles, despite *B. lampros* bands being clearly visible in all samples, suggesting that the quantity of fly eggs consumed in the field was below the detection level.

Enzyme-linked immunosorbent assay (ELISA)

Of the four serological tests developed (precipitin, double diffusion, counter immunoelectrophoresis and ELISA), only the ELISA test identified successfully protein from cabbage root fly eggs.

Laboratory feeding experiments - Spectrophotometric readings for eggs were higher than those for any other protein tested. Over 70% of the wells that contained samples from beetles that had consumed eggs in the laboratory were positive, and time after feeding (within the range 2 to 48 h) had no obvious effect on the rate of detection (Table 2). Positive results were not obtained for beetles which had consumed *Onychiurus* species.

Table 2. Sample absorbence readings (405 nm) using 10 $\mu g\ ml^{-1}$ coating IgG to detect predation of cabbage root fly by *B. lampros*, having been provided with 20 fly eggs and then starved for the number of hours stated

Sample	Number of reps	Mean Abs.	SE	Positive wells %
PBS-Tween (Blank)	10	0.121	0.0023	-
Starved *B. lampros*	5	0.331	0.0234	-
Collembola	5	0.444	0.0164	0
CRF pupae	5	0.402	0.0407	20
CRF egg	10	2.000*	-	100
B. lampros given eggs, 2h	5	0.629	0.0554	80
B. lampros given eggs, 24 h	5	0.629	0.0582	60
B. lampros given eggs, 48 h	5	0.616	0.0465	80
B. lampros given Collembola, 1 h	5	0.371	0.0102	0

* maximum photometer reading

Conclusions

Using IEF and staining for PGI, the consumption of cabbage root fly eggs could be detected up to 28 h after feeding. Two of the three major bands from eggs also occurred in the samples taken from beetles that had fed on fly eggs. The bands were fainter in beetles that fed on eggs than on pupae, possibly due to the amount of food consumed. Beetles often consumed only part of the material presented and some beetles did not feed during the allotted time. In the beetles that fed, the stength of the cabbage root fly bands decreased with time after consumption. However, the amount of prey consumed could not be determined, as it depends on several factors, such as time since the last meal and rate of digestion.

The IEF technique failed to indicate that the beetles had fed on aphids or Collembola. This was not unexpected, as observation of the gut contents prior to analysis showed that little, or no, food had been consumed, despite the presence of large numbers of prey items. It is likely, therefore, that aphids and Collembola are not a major part of the diet of *B. lampros* in the field. Although advances in the identification of alternative prey species were not made in this study, IEF is ideal for such work.

As IEF failed to indicate that predation had occurred in the field, data on egg predation in the different organic treatments were not available.

The antiserum used in the ELISA test produced higher ($P < 0.001$) spectrophotometric readings for cabbage root fly egg material than for any other protein. However, this test was less successful than IEF, as only about 70% of the samples from the beetles that were fed gave positive readings. This could be due to the antigenic determinants being broken down rapidly in the beetle gut.

This test did not detect predation of cabbage root fly pupae (the antiserum was raised specifically against eggs), and thus offers more specific information than the IEF technique. However, to develop the ELISA technique further would probably require monoclonal antibody production. The benefits that would accrue, in terms of information on the predatory value of carabid and staphylinid beetles, do not warrant the considerable additional expense.

It appears that IEF is faster and more adaptable than serological techniques, and will require less development than ELISA to obtain information on the diet of polyphagous predators.

Résumé

Détection de la prédation des oeufs et des pupes de mouche du chou en utilisant l'électrophorèse et le test ELISA

Quatre techniques sérologiques et deux életrophorétiques ont été testées en vue de confirmer la présence de protéines de mouche du chou dans le contenu digestif des carabes prédateurs. Sur les six méthodes testées, l'électrophorèse ou iso focalisation qui comprend l'activité enzymatique de l'isomèrase phosphoglucose et al méthode ELISA parasissent être les plus prometteuses. Lex deux méthodes peuvent détecter la prédation 28 h et 48 h après ingestion respectivement.

Acknowledgements

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Effects of cropping sequence on cabbage root fly and predatory carabid beetles

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Summary

In an experiment to examine the effect of cropping sequences on carabid distribution, *Bembidon lampros* was the most commonly trapped adult beetle and constituted 30% of the total catch. *B. lampros* and carabids in general were more numerous in brassica plots, even before eggs of the cabbage root fly had been laid in the plots. Certain carabid species tended to avoid brassica plots. Differences were not detected in the population sizes of any species of alternative prey within the microfauna.

Introduction

The cabbage root fly (*Delia radicum* L.) is reported to be the most important pest of brassica crops in Britain (Bevan, 1968). In Northern Ireland, the first of two generations in the year usually emerges from overwintering pupae in mid-May (Mowat & Martin, 1981). The level of predation of fly eggs varies according to the size of the fly population (Benson, 1973) and has exceeded 90% (Hughes & Salter, 1959). This is attributable most often to numbers of *Bembidion lampros* Hbst. (eg Mowat & Martin, 1981).

This work set out to determine whether populations of beneficial predatory beetles were a) affected by the presence of a crop and b) whether their numbers would increase under certain cropping sequences.

Methods

Five treatments, each replicated three times, were tested in randomized 10 m x 10 m plots at Loughgall, Co. Armagh. The treatments were:-

1) Brussels sprouts, cv. Bastion, grown from 22 May to 29 October 1985 followed by fallow until 18 February 1986.
2) Cauliflowers, cv. Elgon, grown from 30 May to 15 August 1985 followed by fallow to 18 February 1986.
3) Cauliflowers, cv. Elgon, grown from 30 May to 15 August 1985 followed by, cv. Snow's winter white until 18 February 1986.

4) Fallow from 22 May to 15 August 1985, followed by cauliflowers, cv. Snow's winter white, until 18 February 1986.
5) Fallow throughout the complete period.

Each plot consisted of 81 plants, spaced at 1 m x 1 m, and an unplanted 1 m perimeter. Propachlor was applied to the experimental area at the rate of 10 l ha^{-1} (480 g a.i. l^{-1}) on 11 June 1985. All unplanted areas were treated with 3 l paraquat ha^{-1} (200 g a.i. ha^{-1}) on 6 & 20 August 1985, and 3 l glyphosate ha^{-1} (360 g a.i. ha^{-1}) on 10 September 1985, both applied from a knapsack sprayer.

Twenty soil cores, each 13 cm deep and 2.3 cm in diameter, totalling 1080 cc, were taken from each plot. Soil sampling began on 7 May 1985, before planting, and continued at two-weekly intervals from 11 June 1985 to 21 January 1986. Animals were extracted from the sample using Tullgren Funnels.

Three pitfall traps were used in each plot. Each trap consisted of an 8.1 cm-deep perspex jar with a constriction 1.5 cm below the neck, giving a diameter of 6.3 cm at the mouth and 7.6 cm below the constriction. Traps were protected from rain by a clear perspex cover mounted on 15 cm nails. Trapped beetles were collected weekly from 11 June until mid-November, and thereafter less frequently until 18 February 1986. After recording, the beetles were returned to the plot from which they had been collected.

Results

i) Soil fauna

The numbers of the possible species of prey for carabid beetles did not differ between treatments. A total of 7,365 soil-dwelling animals were identified, of which 3,844 were collected during the first cropping period (Table 1). Despite similar numbers of animals in the two periods, there were large differences between taxonomic groups (Table 1). Onychiuridae (Collembola) and Acarina were commoner during the first cropping period and most other taxa during the second.

ii) Carabidae

A total of 3,361 adult and 730 larval carabids, consisting of 33 species (full listing in Humphreys, 1987) were caught. Most species were caught in higher numbers during the first cropping period (Table 1). *Bembidion lampros*, the most frequently trapped adult beetle, was more common in planted plots ($P < 0.001$) but was scarce during the second cropping period (Table 1). *Clivina fossor* L. and *Trechus obtusus* Erichs. were commoner in the fallow plots ($P < 0.05$). *Nebria brevicollis* F. and *Pterostichus melanarius* Ill. were captured less frequently in Brussels sprout plots late in the season but became commoner in cauliflower and fallow plots.

Table 1. Mean number of animals recovered from soil cores (11 litres) and from 9 pitfall traps in cropped (B = Brussels sprouts, C = cauliflowers) and fallow (F) areas. Period 1 = 22 May 1985 - 15 August 1985, Period 2 = 22 August 1985 - 18 February 1986.

Field cover	**B**	**B**	**C**	**C**	**C**	S.E.	
Period	**1**	**2**	**1**	**2**	**1**	**1**	**2**
Soil cores							
Acarina	167	20	194	23	81	46	8
Isotomidae	54	173	59	106	24	33	70
Onychiuridae	156	33	152	33	154	36	8
Sminthuridae	73	117	67	103	86	12	15
Pitfall traps							
Bembidion lampros	263	2	190	1	305	33	2
Clivina fossor	38	6	35	14	25	15	5
N. brevicollis larvae	2	141	2	87	13	4	29
N. brevicollis adults	32	19	32	80	29	9	25
P. melanarius	18	2	19	45	25	3	11
Trechus obtusus	1	23	5	30	0	2	15
Other species	211	7	185	13	176	25	7

Field cover	**F**	**F**	**C**	**F**	**F**	S.E.	
Period	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Soil cores							
Acarina	21	135	22	174	20	46	8
Isotomidae	124	87	174	23	235	33	70
Onychiuridae	33	177	36	137	41	36	8
Sminthuridae	132	94	92	87	87	12	15
Pitfall traps							
Bembidion lampros	0	96	2	133	3	33	2
Clivina fossor	10	78	25	79	25	15	5
N. brevicollis larvae	131	2	100	7	234	4	29
N. brevicollis adults	97	18	77	23	104	9	25
P. melanarius	41	13	21	14	17	3	11
Trechus obtusus	35	4	85	4	73	2	15
Other species	31	205	10	189	18	25	7

Discussion

The significance of *B. lampros* as a predator of *D. radicum* eggs is well-established (Coaker & Williams, 1963). Twice as many *B. lampros* were trapped in planted as in fallow plots. This pattern was established immediately after planting and no between-plot differences in alternative prey were found that would account for this phenomenon. This suggests an evolved association by *B. lampros* between the plants and a prey source, and the rapid invasion of the planted area implies that *B. lampros* may be an even more significant predator, compared with other carabids, than supposed previously.

No other common carabid showed this behaviour (see Humphreys, 1987). *Clivina fossor* initially preferred fallow plots and was relatively slow to adapt in the second cropping period. *Trechus obtusus*, although rare in the first period, showed a similar pattern.

It was interesting to note that *N. brevicollis* and *P. melanarius* emigrated from Brussels sprout plots as the plants grew. There was no obvious explanation for this behaviour.

It was not possible to continue this experiment for the two additional years proposed in the original programme. Had the experiment been continued, differences in the soil-dwelling microfauna, and concomitant effects on the distribution of carabid beetles, might have been expected.

Résumé

Effet des successions de culture sur la mouche du chou et les carabes prédateurs

Dans une expérience dont l'objectif était d'examiner le rôle des itinéraires de culture sur la distribution des carabes, on a montré que *Bembidion lampros* était le carabe le plus communément capturé et qu'il représentait 30% des captures totales. *B. lampros* et les carabes en général étaient plus nombreux dans les parcelles de choux, avant même que les oefs de mouche du chou n'aient été pondus.

Certaines espèces de carabes émigrent des parcelles de chou. Parmi tous les types de proies alternatives dans la microfaune, on n'a constaté aucune différence de taille des populations.

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Developmental time of the parasitoids *Aleochara bilineata* and *A. bipustulata* - the influence of temperature and host size

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Summary

Laboratory studies were carried out to determine the time required by *Aleochara bilineata* and *A. bipustulata* to develop from the first instar larva to the adult stage. The parasitoids were allowed to develop on cabbage root fly (*D. radicum*) pupae of different sizes (3 mg - 25 mg) maintained at constant temperatures of 12°C-32°C. Developmental time was influenced by both temperature and the size of host pupa. The smaller the host pupa and the higher the temperature, the less time the parasitoid required for its development. The influence of host size synchronizes the developmental time of the parasitoid with that of its host.

Introduction

Aleochara bilineata Gyll. and *A. bipustulata* (Linnaeus) (Coleoptera: Staphylinidae) are among the most important parasitoids of the cabbage root fly, *Delia radicum* (L.) (Diptera: Anthomyiidae) (Wishart *et al.*, 1957).

In northern Europe, *A. bilineata* generally has 2 generations each year and hibernates as a first-instar larva within the host puparium (the hardened skin of the fully-grown fly larva, inside which the fly pupa forms). In contrast, *A. bipustulata* has 3 generations and hibernates in the adult stage. At 20°C, the average developmental time of *A. bilineata* and *A. bipustulata* are 46 days and 33-34 days, respectively (Fuldner, 1960).

The adult beetles are non-specific predators, but because their larvae develop as parasitoids on larvae of anthomyid flies, the adults are found commonly in fly-infested vegetable fields. *Aleochara* spp. can parasitise several species within the Anthomyiidae including the cabbage root fly (*Delia radicum*), the turnip fly (*D. floralis*) (Fall.), and the bean seed flies (*D. platura*) (Meig.)/*D. florilega* (Zett.) (Wishart, 1957; Fuldner, 1960). The question to be answered is "How do these parasitoids manage to develop on fly species of different size that also require different times for development?"

In this paper, the time for *A. bilineata* and *A. bipustulata* to develop from the first instar larva to the adult stage was studied in detail to determine whether developmental time of the parasitoid 1) was dependent on the size of the host insect, and 2) was equal to the mean developmental time of the host on which it developed?

Materials and Methods

Developmental time of *Aleochara* spp. in the laboratory

The time for development of *A. bilineata* and *A. bipustulata* was studied in the laboratory at Wellesbourne, England in 1992, and at Alnarp, Sweden in 1992-1993. Cultures of *A. bilineata* and *A. bipustulata* were maintained using the methods of Samsoe-Petersen *et al.* (1989). For simplicity only *D. radicum* was used as the host species. By manipulating the amount of food available per *D. radicum* larva, pupae were produced that varied in size from 3 mg to 25 mg. This wide range of sizes was produced so that the smaller pupae were similar in size to those of *D. platura* and the larger pupae similar in size to those of *D. floralis*.

D. radicum pupae were weighed and grouped according to size. The pupae were placed into vermiculite in polythene pots and then *Aleochara* larvae were placed onto the surface of the vermiculite. The pots were placed into incubators maintained at constant temperatures between 12°C and 32°C.

Shortly before *Aleochara* adults were expected to emerge, the puparia were removed from the vermiculite and placed individually into the cells of ELISA-plates so that it was easy to inspect the pupae each day to record the emergence of beetles. These plates were covered with elastic plastic film. At the time of beetle emergence, the species of *Aleochara* was noted and records were taken of temperature, original weight of pupa, width of puparium, width of beetle pronotum, and time (in days) for the beetle to complete its development.

Developmental time of *Aleochara* spp. from field-collected puparia

On seven occasions during 1990 and 1991, puparia of *D. radicum* and *D. platura/D. florilega* were collected from brassica plots in Sweden. The pupae were maintained at laboratory temperatures in ELISA-plates. Emergence was recorded as in the previous experiment except that pupal weight was not recorded.

Results

Developmental time of *Aleochara* spp. in the laboratory

The results showed that developmental time of *Aleochara* depended not only on temperature but also on the weight of the host pupa. At 20°C, the developmental time for *A. bilineata* seemed shorter than that for *A. bipustulata*. There was a significant regression equation for each species based on the model:

log (1 + 100/developmental time) = k + a x temperature - b x pupal weight

The higher the temperature and the smaller the host pupa, the shorter the time the parasitoid needed to complete its development. There was a strong correlation between beetle pronotum width and weight of the host pupa, but pronotum width was also correlated negatively with temperature.

Developmental time of *Aleochara spp.* from field-collected puparia

It was not possible to estimate accurately the developmental time of the parasitoids that emerged from the field collected puparia, as the days on which they were parasitized were not known. In one of seven samples collected, there was a significant positive correlation between time from field collection to beetle emergence in the laboratory and puparium width.

Discussion

Small fly species of the genus *Delia*, that are pests of vegetable crops, require less time to complete their development than larger species. The developmental time of *D. platura/D. florilega* is 32 days at 20°C (Kim & Eckenrode, 1987), while *D. radicum* has a developmental time of 41-61 days at 19-22°C (Harris & Svec, 1966). It is interesting that the developmental time of *Aleochara* is dependent on host pupal weight and approximately equals the developmental time of its host. According to the present data, the development times of *A bilineata* & *A. bipustulata* at 20°C is 31 & 36 days, respectively in puparia similar in size to *D. platura* puparia and 38 & 45 days in average-sized *D. radicum* puparia. This plasticity in developmental time seems to permit these two species of *Aleochara* to parasitize a wide host range.

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Résumé

Durée de développement des parasitoides *Aleochara bilineata* et *A. bipustulata*. Influence de la température et de la taille de l'hôte

Des travaux ont été réalisés en laboratoire pour déterminer la durée nécessaire au développement du premier stade larvaire jusqu'au stade adulte chez *Aleochara bilineata* et *A. bipustulata*. Les parasitoïdes ont pu se développer dans des pupes de mouche du chou (*Delia radicum*) de différentes tailles (3 mg - 25 mg) maintenues dans les conditions de température constantes, de 12°C à 32°C. La durée de développement était influencée à la fois par la température et par la taille de la pupe hôte. Le développement des parasitoides qui demande le moins de temps concerne les plus petites pupes hôtes et la température la plus élevée. L'influence de la taille de l'hôte se manifeste par une synchronisation de la durée de développement du parasitoides sur celle de l'hôte.

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Comparison of the rate of penetration of pupae of *Delia radicum* and *D. antiqua* by first-instar larvae of the parasitoid *Aleochara bilineata*

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Summary

Owing to the increasing objections to the use of insecticides, studies were carried out to determine the possibilities of using the parasitoid *Aleochara bilineata* as a biological agent for controlling the cabbage root fly and the onion fly. The influence of temperature, relative humidity of the substrate, and the age of the host pupae on the rate of penetration of host pupae by parasitoid larvae was studied.

Of the three humidities (50%, 70%, and 90%) tested, the lowest resulted in the highest penetration (87%) of cabbage root fly pupae. Too much water in the substrate restricted the movements of the larvae and hence lowered their chances of encountering a host pupae. Many larvae also drowned in the excess water and this lowered the overall level of parasitization. Low humidities prevented the larvae from settling on a pupa and penetrating into it.

The physiological stage of the host pupa is a major factor regulating penetration by staphylinid larvae. Maximum larval penetration occurred in two day-old cabbage root fly pupae and in four day-old onion fly pupae.

Temperature had an effect both on the staphylinid larvae and their host pupae. High (25°C) temperatures increased the speed of development of the nymphal stage of the fly and this created an air space between the pupa and the puparium wall which was essential for penetration by the parasitoid. Low (10°C) temperatures slowed the movements of the larvae of *A. bilineata* and this reduced their chances of finding a host pupa.

The optimum conditions for the penetration of *A. bilineata* larvae into pupae of *D. radicum* and *D. antiqua* were defined by analyzing three parameters.

Introduction

Faced with the difficulties now recognised in the continuous use of insecticides, attempts were made to find an alternative strategy for control of the cabbage root fly (*Delia radicum* L.). In the west of France, as in the rest of Europe, protection of the environment is now considered to be an important aspect of pest control. Biological control of the cabbage root fly in field vegetable crops, using the staphylinid parasitoid *Aleochara bilineata* Gyll., has been considered in Belgium (Hertveldt *et al.*, 1984a & b), Denmark (Bromand, 1977, 1980, 1983), Russia, (Bakosova, 1987; Adaskevich & Perekrest, 1977; Zorin, 1927) and Canada (Tomlin *et al.*, 1992).

To start such biological studies it was essential to rear the parasitoids in the laboratory. A number of studies indicated that the parasitoids could be reared on pupae of their natural host, the cabbage root fly, produced on swedes or turnips (Finch & Coaker, 1969; Van Keymeulen & Hertveldt, 1982), or on pupae of the onion fly *Delia antiqua* Meig. produced on an artificial diet (Ticheler, 1971; Loosjes, 1976).

The first detailed account of the biology of *Aleochara bilineata* was made by Fuldner in 1960. There are many methods describing how to rear the parasitoid (Zorin, 1927; Adaskevich & Perekrest, 1973; Bromand, 1980; Van Keymeulen & Hertveldt, 1982; Whistlecraft *et al.*, 1985; Bakasova, 1987; Naton, 1989; Samsoe-Petersen *et al.*, 1989). Published work on how to use this insect for biological control are much rarer (Adaskevich & Perekrest, 1977; Bromand, 1983; Tomlin *et al.*, 1992).

To rear the beetle under the climatic and cultural conditions that occur in the field in Brittany, it seemed important to determine the precise conditions required by the first-instar larva of the parasitoid to penetrate cabbage root fly pupae. The preliminary results presented in this paper describe the effect of temperature, humidity of the substrate and age of fly pupae on the subsequent rate of parasitization by *A. bilineata*. The effect of each factor was studied separately.

Materials and Methods

The beetles were obtained from cabbage root fly pupae collected in September 1992 from fields at Le Rheu, in the neighbourhood of Rennes. The rearing method was that developed by Van Keymeulen and Hertveldt (1982) and modified subsequently by other workers (Hertveldt *et al.*, 1984b; Samsoe-Petersen, *et al.*, 1989). The adult beetles were kept in a room maintained at 19-20°C, 80-90% r.h. and illuminated for 16h/day at 220 lux. The beetles were fed on chopped meat, which was renewed daily. The beetle eggs were inspected daily (Samsoe-Petersen, 1987) and before being used were kept on damp filter paper within Petri dishes maintained at 20°C in a dark room.

The method was based on the test tube principle used by Fuldner (1960), and used haemolysis tubes 10.5 mm in diameter and 80 mm long. Pupae were reared at 20°C, the cabbage root fly on turnip and the onion fly on an artificial diet based on powdered carrot. Fly pupae aged 1, 2, 4 and 6 days-old were buried about 1 cm deep in the test tubes in a mixture of equal parts of Fontainbleau (type F_1) sand and sieved Loire sand (particle size 0.25 - 1 mm).

The sand substrate was dampened initially with water. The different relative humidities were obtained by squeezing water from the substrate to produce the desired conditions. Humidities of 50%, 70% and 90% were used in the experiments. Several tubes that contained the appropriate humidities were placed at temperatures of 10-16°C, 15-16°C, 20°C and at 25°C.

Shortly after the staphylinid larvae emerged from the eggs, they were carefully placed onto the surface of the substrate in each experimental tube using a fine moistened paintbrush. The tubes were then re-sealed to prevent loss of water through evaporation.

The rate of larval penetration was recorded during the four days following the start of the experiment. This period was chosen because after 96 h the larvae have used up all of their reserves and are no longer be capable of entering pupae (Fuldner, 1960). Larval penetration was recorded when we saw a hole (open or re-closed) in the pupa, or when we saw the actual larva through the transparent wall of the puparium.

Analysis of the rate of penetration is a function of temperature, humidity and age of the host pupae. The effect of all three factors will be analysed using the RSREG programme of the SAS (SAS Institute, 1987).

Results

The mean rate of penetration of larvae of *A. bilineata* into laboratory-reared pupae of the cabbage root fly and the onion fly was 80% and 78%, respectively.

Analysis of Variance indicated that temperature and age of pupae affected ($P = 0.05$) the rate of penetration of cabbage root fly pupae but relative humidity did not. In contrast, pupal age and relative humidity had a significant effect ($P = 0.05$) on penetration of onion fly pupae but temperature did not.

Effect of temperature

At temperatures of 10°C and 25°C, about 72% and 87% of the pupae were parasitized, respectively. Intermediate values were obtained at temperatures of 15°C and 20°C. The rate of penetration of onion fly pupae was 75% at 10% and 83% at 25°C.

Effect of relative humidity of the substrate

For cabbage root fly pupae, the rate of parasitization decreased from 86% at 50% r.h. to 74% at 90% r.h. The reduction in the rate of penetration was more pronounced in onion fly pupae. With the onion fly, 88%, 82% and 66% of the pupae were penetrated at 50%, 70% and 90% r.h., respectively.

Effect of pupal age

For the cabbage root fly, the variation between the two groups was less distinct. Parasitization of the one day-old pupae was 76%, whereas the mean parasitization of the 2, 4 and 6 day-old pupae was 82%.

For the onion fly, there were also two distinct groups with 85% of the pupae aged 2, 4 and 6 days-old being parasitized compared to only 58% of the one day-old pupae.

Interaction between factors

D. radicum: effect of combination of temperature and pupal age - It was possible to identify three characteristic groups of pupae from the way they responded to the test parameters.

The first group consisted of pupae 1-2 days-old. In this group, larval penetration depended almost entirely on the temperature used in the test. Minimum penetration occurred at 10°C, when 64% of the 1 day-old and 60% of the 2 day-old pupae were penetrated. Pupal age did not affect larval penetration (P = 0.05), as 76% of the one day-old pupae and 82% of the two day-old pupae were parasitized. In the rearing conditions in which there was a mixture of pupae of different ages within the fly culture, increases in the levels of parasitization were correlated positively with increasing temperatures (Index of correlation = 0.97).

In the second group, which consisted of pupae of 4 days-old, penetration was not affected by temperature. Although the results varied between 73% and 90%, the rate of penetration could not be correlated with temperature.

In the third group, which contained the 6 day-old pupae, there was a negative correlation between larval penetration and temperature. Two different responses occurred when the pupae were placed at 10°C or at 15-25°C. The rate of penetration was highest (90%) at the lowest temperature (10°C) and then fell rapidly. The mean penetration at 15°C, 20°C and 25°C was 81%.

D. antiqua: effect of combination of relative humidity and pupal age - Whatever age of pupae were considered, raising the humidity in the haemolysis tubes caused a decrease in the rate of penetration by the larvae. Above 70% humidity, the rate of larval penetration dropped dramatically whatever the age of the pupae.

Irrespective of pupal age, maximum penetration occurred at 50% r.h. The values at the other levels of humidity did not differ from each other and the mean rate of penetration was 89%.

At 70% and 90% r.h., two different rates of penetration were recorded. In the first group, represented by 1 day-old pupae, penetration fell sharply to 55% (70% r.h.) and then to 38% (90% r.h.). In the second group, which contained pupae aged 2, 4 and 6 days-old, penetration decreased slowly from 88% (70% r.h.) to 75% (90% r.h.).

Conclusions

The possibility of using *A. bilineata* as a biological control agent of certain fly pests of vegetable crops depends largely on being able to mass rear the parasitoid. For this, the beetles would have to be reared under standard conditions.

The first stage would involve rearing large numbers of the pupal hosts of the beetles. Rearing the cabbage root fly on turnips at Le Rheu (INRA) enabled us to provide a stock containing a large number of pupae. Rearing onion flies on an artificial medium is now done under license at Brest (SRPV Bretagne).

The second stage consists of producing the staphylinid larvae. The review of the biology of *A. bilineata* by Fuldner (1960) and the more recent experiments (Bromand, 1980; Hertveldt *et al.*, 1984; Whistlecraft *et al*, 1985; Samsoe-Petersen *et al.*, 1989), concluded that penetration of the larvae of the first-instar of the staphylinid into pupae of its host was the important factor that determined beetle survival.

The success of rearing *A. bilineata* depends on the first-instar larvae managing to infest dipterous pupae. This penetration, which depends on biotic (age of pupae) and abiotic factors (temperature and humidity) has been studied in the laboratory. The data are still being analyzed.

Analysis of the three factors studied indicates that there is one action at two levels.

At the level of the beetle larva, the temperature and humidity that the larva needs to search for and reach its host, does not depend on the species of fly being considered. A temperature between 20 and 25°C, and a relative humidity of 50%, allows larvae in the immediate vicinity of pupae to express their full potential for penetration.

The second level concerns the physiological state of the pupa when it is found by a parasitoid larva. It is of primary importance that, when found by a parasitoid larvae, the fly pupa is of an age in which it has a space between itself and the puparium. The speed of development of cabbage root fly and onion fly pupae differ considerably during the days immediately after pupation. As a consequence, cabbage root fly pupae are most suitable for penetration 2 days after pupation and onion fly pupae after 4 days. Temperature also affects speed of development and hence has an effect on the pupal stage at the time the parasitoid is ready to enter the pupa. In addition, a suitable relative humidity helps the parasitoid to penetrate the wall of the puparium.

This study is restricted to the penetration of dipterous pupae by the first-instar larva of the staphylinid. Perhaps percentage penetration is reflected in the number of beetles that finally emerge. In mass rearing trials, however, the numbers of beetles that emerge finally are relatively small compared to the numbers of larvae that manage to burrow into the pupae.

The next stage will be to ensure that maximum parasitization occurs throughout the whole developmental phase of the beetle. It is essential to avoid low temperatures (10°C) as they have an adverse effect on the development of the parasitoid larvae and cause high mortalities. At the same time, it is essential to avoid high temperatures as these promote the development of micro-organisms (nematodes were found in pupae kept at 25°C) which lower the level of beetle parasitization.

For a parasitoid larva to be successful, it must penetrate a fly pupa that is not too young and not too old. Larvae which penetrate young pupae, in which the tissues have still not differentiated, tend to drown in the haemolymph of the pupae (observation of Adushkevich & Perekrest, 1973). In contrast, few larvae of *A. bilineata* are capable of penetrating old pupae.

Résumé

Comparison du taux de penetration de la larve de premier stade d'*Aleochara bilineata* Gyll. (Staphlinidae) dans les pupes de *Delia radicum* L. et *Delia antiqua* Meig (Diptera, Anthomyiidae)

Devant les difficultés croissantes que pose la lutte chimique contre la mouche du chou, la possibilité d'utiliser la lutte biologique au moyen de *Aleochara bilineata* Gyll. (Coleoptera ; Staphylinidae) parasite et prédateur, est envisagée. La réalisation d'un élevage de masse passe par l'optimisation du parasitisme. L'influence de la température, de l'humidité relative du substrat et de l'âge de la pupe sur la pénétration de la larve parasite a été étudié.

Sur les trois humidités proposées (50, 70 et 90%), la plus faible permet d'obtenir les meilleurs résultats. Une trop forte présence d'eau dans le substrat réduit les déplacements de la larve et donc sa probabilité de rencontrer un hôte. De plus, celle-ci provoque de nombreuses noyades et diminue d'autant l'accessibilité des pupes. Une trop faible humidité du substrat empêche la larve de se fixer sur la pupe et de la pénétrer.

Le stade physiologique de la pupe est primordial pour la pénétration de la larve de staphylin. La pénétration de la larve est maximale pour des pupes de mouches du chou âgées de 2 jours et des pupes de mouches de l'oignon ayant 4 jours.

La température agit sur la larve et son hôte. Au niveau de la pupe, une température élevée (25°C) augmente la vitesse de développement nymphal et favorise la création de l'espace nécessaire à la pénétration du parasite dans les pupes jeunes. Une température trop faible (10°C) réduit fortement la mobilité de la larve de *A. bilineata* et diminue ses chances de trouver une pupe hôte.

L'utilisation de l'analyse combinée des trois paramètres a permis de définir les conditions optimales de pénétration du parasite dans les pupes de *Delia radicum* et *Delia antiqua*.

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Laboratory investigations of the relationship between the cabbage root fly, *Delia radicum* and its parasitoid, *Trybliographa rapae*

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Summary

Trybliographa rapae (Westw.) is the main hymenopterous parasitoid of *D. radicum*. This study was carried out in a laboratory maintained at 20-21°C. Male parasitoids emerged earlier than females. The females laid 46 ± 6 eggs and lived for 15 ± 2 days. *T. rapae* females preferred to lay when the numbers of fly larvae were high (24,48). They also preferred to lay their eggs in first and second instar fly larvae.

Introduction

T. rapae is the most numerous parasitoid of *D. radicum* (Smith, 1927). Wishart (1959) found that in Canada the percentage parasitism of *D. radicum* by *T. rapae* varied from 0.4% to 46.3%. Applications of insecticides for the control of *D. radicum* generally lowered the rate of parasitism.

Jones (1986) described the life-history and biology of *T. rapae* under laboratory and field conditions. According to Jones (1986), the interaction between *D. radicum* and *T. rapae* is an ideal host-parasitoid system to study because cultures of host and parasitoid can be maintained throughout the year in the laboratory.

The aim of this study was to describe some of the relationships between *D radicum* and one of its parasitoids, namely *T. rapae*.

Materials and Methods

The cabbage root fly and its parasitoid were reared at 20-21°C and 60 ± 5% RH in a culture room. The cages, used to rear both insects had aluminium frames and were covered with terylene netting. *D. radicum* and *T. rapae* were provided with 10% sucrose solution, water and yeast extract as food (Finch & Coaker, 1969).

D. radicum were reared on swede (*Brassica napus* var. *napobrassica* (L.). The flies laid around a piece of swede resting in a Petri dish of damp sand. These eggs were then washed onto swedes potted into sand to continue the culture. Swedes were dissected two weeks after inoculation to obtain the second instar larvae required for certain of the tests. Undisturbed insects pupated 4-5 weeks after egg inoculation. Fly pupae were separated from the sand and placed onto moist vermiculite to obtain adults (Finch & Coaker, 1969).

To rear *T. rapae*, *D. radicum* eggs were collected each week and then placed onto swede discs that had been scored lightly to aid larval entry. The discs were left for one week to allow time for the eggs to hatch and for the small larvae to burrow into the swede. The discs were then left for seven days in a cage containing *T. rapae* adults. The swedes were then collected and placed onto moist vermiculite in a plastic box that also contained fresh pieces of swede. After the flies pupated, the parasitised pupae (recognised by their smaller size and the dark at the end of the puparium) were removed and placed into plastic boxes containing damp vermiculite to allow the adult parasitods to emerge (Jones, 1986).

In this study, the original flies and parasitoids were obtained from pupae donated by Dr S Finch of Horticulture Research International (HRI), Wellesbourne.

Emergence, longevity and oviposition of *T. rapae*

One day-old females of *T. rapae* were allowed to lay for 24 hours into two day-old fly larvae feeding on discs (diameter 35 mm, thickness 5 mm) of swede. The parasitized pupae were collected later and the date of the emerging insects were noted.

The studies on oviposition and longevity were carried out at the same time. Males and females, that were 0-2 hours old, were placed into glass tubes. After copulation, the females were placed into a dish (diameter 9 cm, height 4 cm) with a swede disc. Thirty fly larvae had been placed onto each disc 24 hours earlier. The parasitoids were provided with 10% sucrose solution and a moist filter paper. The larvae and discs were replaced every 2 days. The parasitised fly larvae were left for 24 hours, prior to dissection, to minimise errors in egg counts. The larvae were then dissected from the discs and the numbers of parasitoid eggs were recorded. The posterior end of each fly larva was cut open, so that the eggs were easier to count. The life-span of the female and male was found from the oviposition study.

Preference of *T. rapae* for various stages of its host

This experiment was carried out in plastic dishes. Fly larvae were placed onto each swede disc and left for 24 hours. Thirty larvae were used in each test and were presented in the following ratios: 1:1, 3:2, 2:3. First-, second- and third-instar larvae were obtained from fly cultures that were 0-12 hours, 5-6 days, and 14-16 days after hatching, respectively (Jones 1986). Single mated, 1 day-old female parasitoids were presented with a choice of two host instars. The host combination tested were first-versus second-instar; first-versus third-instar; and second-versus third-instar. After 2 days the fly larvae were dissected and the numbers of parasitoid eggs were recorded.

Preference of *T. rapae* for different densities of its host:

A 0-12h old female parasitoid was placed into a small plastic box with two males and provided with sucrose as food and an excess of *D. radicum* larvae on which to gain experience (the preconditioning period).

Prior to the start of each experiment, 3, 6, 12, 24 or 48 second-instar cabbage root fly larvae were placed onto individual swede discs. The larvae were left for 24 hours to allow them to burrow into the swede. Five discs were then placed into a plastic arena (40 x 40 x 10 cm). The floor of the arena was covered with 0.5 cm of dry, washed sand. A single pre-conditioned female was placed into the arena. After 12 hours, the swede discs were removed and left for a further 24 h. The larvae were then collected from the swede discs and dissected to record the numbers that had been parasitised.

The biological studies and the preference studies were each repeated ten and five times, respectively.

Results and Discussion

At 20-21°C, *T. rapae* males and females emerged 45 ± 5 days and 48 ± 4 days, respectively, after the eggs had been laid.

According to the data obtained from the biological studies, at 20-21°C *T. rapae* females laid an average of 46 ± 6 eggs. Males lived for 11 ± 4 days and females for 15 ± 2 days. Male parasitoids emerged earlier than the female parasitoids.

Makarenko (1968) reported that the duration of development of *T. rapae* averaged 56, 39.5, 38.5 and 25.5 days at 15, 18, 20 and 25°C, respectively. The potential fecundity averaged 140-149 eggs per female for the overwintered generation and 104-109 for the first generation. In addition, the male and female parasitoids lived for 20 and 28 days, respectively, when fed on 20% sugar solution. Jones (1986) found that, at 20 ± 1°C, *T. rapae* males emerged after approximately 45.5 days and females took an extra 2-2.5 days longer to complete their development. Females laid 38 ± 6 eggs during their lifetime. In addition, *T. rapae* males and females had a mean lifespan of 9.5 ± 1.2 days, 14.4 ± 1.8 days, respectively.

The data on the preference of *T. rapae* for different developmental stages of *D. radicum* are shown in Table 1.

First- and second-instars were preferred equally when they were presented together. However, significant preferences occurred when the first- and second- instar fly larvae were presented with third-instar fly larvae. Makarenko (1968) reported that this Cynipid lays its eggs in second- and third-instar larvae. Jones (1986) found that there was a marked preference for first- and second-instar larvae when such larvae were presented with third-instar larvae.

The results show that the parasitoid was able to attack each of the three larval instars. However, the younger larvae were preferred more than third-instar larvae. Jones (1986) suggested that this preference may be explained by the increased thickness of the larval skin of the third instar, which makes it more difficult for the parasitoid to penetrate with its ovipositor.

Table 1. The preference of *Trybliographa rapae* for different larval instars of the cabbage root fly

Instar combinations	Ratios of larval instars 1:1 t	df	p	3:2 t	df	p	2:3 t	df	p
1st instar-2nd instar	0.445	8	>0.1	0.57	8	>0.1	0.32	8	>0.1
1st instar-3rd instar	.60	8	<0.01	5.14	8	<0.01	3.41	8	<0.01
2nd instar-3rd instar	3.67	8	<0.01	3.75	8	<0.01	3.11	8	<0.01

The parasitoid was also more effective (P = 0.01) at high (24 & 48) densities of its host (Table 2). Hence preference tends to be density-dependent. Jones & Hassell (1988) found that the parasitoids spent proportionally more time on patches in which the host density was high (16 or 32 host larvae) than in patches in which host density was low (2, 4 or 8 host larvae). Consequently, in laboratory experiments percent parasitism depends directly on host density.

Table 2. The preference of *Trybliographa rapae* for different densities of cabbage root fly larvae

Number of hosts larvae placed onto swede disc	Number of hosts parasitised Replicate 1	2	3	4	5
3	0	0	0	0	0
6	0	0	0	0	0
12	0	1	0	1	0
24	2	3	2	2	3
48	5	4	6	4	5

Conclusions

The structuring of a general strategy for biological control emphasises various aspects of pest-natural enemy population dynamics. A detailed knowledge of the life-histories of both the host and the parasitiod is vital for understanding their interactions (Jones, 1986). The interaction between the cabbage root fly, *Delia radicum* and *Trybliographa rapae* is, in many ways an ideal host-parasitoid system to study as both laboratory and field studies can be carried out with relative ease (Jones, 1986). Attempts should be made to investigate using *T. rapae* under field conditions, as it is the most important, and promising, parasitoid of *D. radicum*.

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Résumé

Recherches en laboratoire sur la relation existante entre la mouche du chou, *Delia radicum*, et son parasitoïde *Tribliographa rapae*

Tribliographa rapae (Westw.) est le principal parasitoide hyménoptère de *D. radicum*. Cette étude a été réalisée à une température de 2-21°C en laboratoire. Les parasitoides mâles émergent plutôt que les femelles. Les femelles pondent 46 ± 6 oeufs et vivent 15 ± 2 jours *T. rapae* préfère pondre quand le nombre de larves est élevé (24,48). Elles préfèrent également pondre leurs oeufs sur des larves de premier et de deuxième stade.

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Effects of intercropping on pest populations in vegetable crops

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Summary

Minimizing pesticide applications in crops is one of the main ways towards achieving sustainable agricultural systems. However, in most agricultural crops grown according to methods considered to be modern, both fertilizer and pesticide inputs are still relatively high. In the unstable agro-ecosystems of intensively-grown European field vegetable crops, many growers consider that high inputs of pesticide are essential. Increases of the areas under cultivation, year-round cropping and the availability of cheap pesticides are factors that tend to increase the use of pesticides. Such situations can lead to the failure of chemical protection. For example, infestations of thrips (*Thrips tabaci*) in leek and heading cabbage are now virtually uncontrollable in Western Europe and during the last few years the control of leek rust (*Puccinia allii*) by the fungicide chlorthalonil (Daconyl) has decreased dramatically. Consequently, in the Netherlands, a combination of overproduction and unavoidable pest damage has started to affect the social-economic situation of growers and their families. Under such circumstances, the idea of sustainable agriculture seems more remote than ever.

During the last few years, however, it has been shown that intercropping can reduce pest insect populations in certain vegetable crops. Intercropping (or undersowing) is an ancient method of crop protection in which the main crop is grown with another, economically unimportant, crop. In the tropics mixed cropping is practised widely; for example by growing crops such as cassava, maize and peanuts in the same field. In Europe, mixed cropping is not used, and the adoption of such systems is unthinkable to many growers of field vegetable crops. However, several pest insect problems could be solved if this principle could be incorporated into a practical cropping system. This paper describes the results obtained to date in the Netherlands using intercropping.

Observations

Several field vegetable crops can be introduced with various other plants. The practical requirements limit the number of acceptable combinations but, while still in the experimental stage, a great number of combinations can be tested.

The first combination tested in the Netherlands was cauliflower undersown with *Sedum acre* (Theunissen & den Ouden, unpublished data). Slightly lower numbers of eggs and larvae of *Mamestra brassicae* L. were found in the intercropped plots. *Pieris rapae* L. and *Evergestis forficalis* L. larvae were equally abundant in both the monocropped and intercropped plots, whereas fewer *Plutella xylostella* L. larvae were present in the intercropped plots. In spite of the relatively small differences in caterpillar populations, there were large and clear differences in the corresponding feeding injury to the respective plants. No differences were in *Brevicoryne brassicae* L. infestations. Competition between the cauliflower and *S. acre* was high, and reduced considerably the growth of the cauliflower plants. The epigaeal fauna in *S. acre* was dominated by staphilinidae, which moved easily through the dense carpet of *Sedum*.

When Brussels sprouts crop were intercropped with different densities of spurrey (*Spergula arvensis*) the effects were pronounced on some pests but not on others (Theunissen & den Ouden, 1980). Numbers of caterpillars of *Mamestra brassicae* and *Evergestis forficalis* were reduced by the presence of spurrey, whereas those of *Pieris rapae*, *P. brassicae* and *Plutella xylostella* were not. Cabbage aphid populations declined progressively with increasing density of spurrey.

Grasses, particularly *Lolium perenne*, have been used as intercrops in endive, spring cabbage, white cabbage and Brussels sprout crops. *L. perenne* does not seem to affect the oviposition behaviour or larval populations of *M. brassicae, P. rapae* , *P. brassicae*, or *P. xylostella*. However, larval populations of *Evergestis forficalis* became much lower as the density of *L. perenne* was increased. The effect of *L. perenne* on infestation of *B. brassicae* was not established. Individual grasses like *L. perenne* and *Poa annua*, and certain mixture of grasses, were all extremely competitive with the main crop. For this reason alone, they are unsuitable for intercropping.

Results from intercropping experiments carried out in greenhouses and in the field can differ considerably. For example, under greenhouse conditions, *M. brassicae* females do not prefer the monocrop to the same extent as they do in the field. Under greenhouse conditions, host plant selection by the cabbage aphid, *B. brassicae,* is influenced more by spatial factors within the greenhouse than by the preferences that operate under field conditions. In addition, the effect of background colours on preference (Smith, 1976) could not be confirmed in the greenhouse (van de Fliert & Theunissen, unpublished data). In principle, greenhouse data should not be extrapolated to indicate what is likely to occur under field conditions, or should be used only with extreme caution.

In field experiments in which Brussels sprouts were intercropped with various densities of *Trifolium repens* fewer eggs of *P. rapae* were found in the higher density clover plots (den Belder & Meerman, unpublished data). Such differences became clear only during periods of high egg-laying activity. Unlike spurrey (see Theunissen & den Ouden, 1980), clover apears to effect the behaviour of females of *P. rapae*. In this case, an intercrop-specific factor appears to regulate the effect. Factors that are not specific to a particular intercrop appear to operate to suppress larval populations of *M. brassicae*, as the effect can be produced by both spurrey and clover.

Because of competition and the resulting loss of weight of intercropped cabbage, *T. repens* is considered to be unsatisfacory as an intercrop even though it is extremely good at suppressing weeds. At present, subterranean clover, *T.*

subterraneum, appears to be the most promising plant to use as an intercrop, though there are considerable differences among the many varieties available of this species. When cv. Geraldton was used as the intercrop in cabbage and leek, the effects of competition were limited. In leek crops, the growth of the intercropped plants lagged two weeks behind that of the monocropped plants. Such delays in attaining the expected weight is acceptable to growers as, by delaying harvest, the expected yield loss from competition can be eliminated. In both fresh-market and storage cabbage (Theunissen *et al.*, 1994) reductions in pest populations were recorded for the cabbage aphid (*B. brassicae*), flea beetles (*Phyllotreta* spp.) and thrips (*Thrips tabaci*). Lower numbers of cabbage root fly eggs were also recorded in intercropped plots of fresh-market and storage cabbage (Theunissen & Schelling, 1992). A similar reduction was recorded in broccoli, intercropped with *T. subterraneum*, cv. Esperance. *Thrips tabaci* populations were reduced in leek (Theunissen & Schelling, 1993) and fennel (*Foeniculum vulgare*) intercropped with *T.subterraneum*, cv. Geraldton (Fig. 1). The thrips population was suppressed sufficiently to prevent the brown discoloration to the leek stems that results in economic losses.

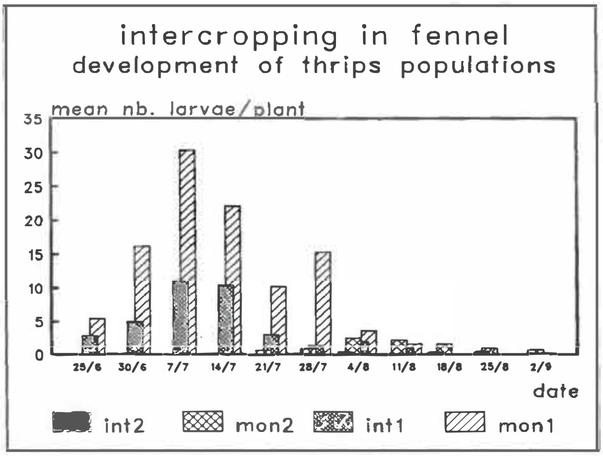

Fig 1: Population of larvae of *Thrips tabaci* in two plantings of monocropped fennel and fennel intercropped with subterranean clover.

Discussion

A few general principles are beginning to emerge from the several intercropping situations that have been tested to date.

Obviously not all pests are affected equally by the intercrop, at least not by the types of intercrop that have been tested to date. Intercrop-specific factors could play a role, as for example where clover has an effect on egg laying by *P. rapae* in Brussels sprout crops but where spurrey does not.

Intercrop-nonspecific factors include effects produced in the main crop irrespective of the intercrop used. For example, the suppression of populations of *M. brassicae* caterpillars on Brussels sprouts intercropped with spurrey, white, red or subterraneum clover.

Some intercrops appear to have similar effects in a range of vegetable crops. For example, *T. tabaci* populations are much lower in intercropped plots of leek, heading cabbage and fennel. The mechanism involved appears to be of a general nature and not crop-specific.

Crop-specific factors act mainly on a specialized herbivore in a given intercrop. It is possible that pests of cruciferous plants could behave differently on undersown crops of cauliflower compared to undersown crops of Brussels sprouts; or pests of Alliaceae behave differently on undersown crops of leek compared to onions.

The principle of intercropping, as reflected in the results obtained to date in field vegetable crops, has appealing advantages. These include 1) suppression of important pest populations; 2) minimal need for insecticides; 3) increased chances for natural enemies to exert biological control; 4) protection of the soil from erosion and solarization; 5) diversification of the agro-ecosystem within field vegetable crops; 6) improving the quality of the products; and 7) contributing to sustainable horticulture. From a practical point of view there are certain disadvantages. These include: 1) growing vegetables would become more complicated; 2) increased problems of weed control; 3) loss of yield in weight; 4) costs associated with the intercrop; and 5) the present extremely limited choice of intercrops.

Weeds are suppressed considerably by intercrops, such as *T. repens* and *T. pratense*, that grow high and dense. The type of intercrops used, however, must not compete unduly with the main crop and hence are generally not too efficient at controlling weeds. At present, this is a major problem. Research on weed management in intercropping systems is required urgently.

A second problem is where competition between the main crop and intercrop leads to significant losses of yield. This effect must be minimised by using intercrops that do not compete aggressively for light, water and nutrients. Our data indicate that by using low growing varieties of *T. subterraneum* as the intercrop, yield losses can be decreased (cabbage, Brussels sprouts) or eliminated (leek). However, some interaction between the main crop and the intercrop seems essential for the production of the pest suppressing effects. Where an interaction does not occur, the effects on the pest population cease immediately. The nature of this interaction is still obscure. However, I suggest that the competition between the two plants species causes physiological changes in the host plant in such a way that it becomes less attractive, or less suitable, for pests. This working hypothesis may describe an important group of mechanisms which produce the intercropping effects on pests. The behaviour of certain pest species can be explained by adopting the above hypothesis, but it is clear that other mechanisms are also involved. Interactions between mechanisms further complicate the situation, as the intercrop/crop-specific and non-specific factors involved all contribute to a truly wide-ranging series of causes and effects.

Résumé

Effet des cultures intercalaires sur les populations de ravageurs en cultures légumières

La réducation des applications insecticides dans les cultures est une des principales voies choisie pour s'orienter vers des systèmes d'agriculture durable. Cependant, dans la plupart des types d'agriculture, ou les cultures sont faites selon des méthodes considérées comme modernes, les apports de fertilisation et de pesticides sont encore relativement élevés. Dans les agro-écosystème instables des cultures légumières de plein champ européens cultivés de façon intensive, beaucoup de cultivateurs considèrent l'utilisation des intrants élevés de pesticides comme essentiels. L'augmentation des surfaces non cultivées, les rotations sur l'année et l'utilisation de pesticides peu coûteux sont des facteurs qui tendent à augmenter l'usage des pesticides. De telles situations peuvent conduire à l'échecs de la protection chimique. Par example, les infestations de thrips (*Thrips tabaci*) sur le poireau et les choux pommés sont maintenant incontrôlables en Europe de l'Ouest et au cours des dernières années la lutte contre la rouille du poireau (*Puccinia allii*) par le fongicide chlorthalonil (Dacronyl) a chuté dramatiquement. En conséquence aux Pays-Bas, la combinaison de la surproduction et la présence inévitable des attaques de ravageurs ont commencé à affecter la situation socio-économique des producteurs et de leurs familles. Dans de tells circonstances, l'idée d'une agriculture durable semble plus éloignée que jamais.

Au cours des dernières années récentes, cependant, il a été montré que les cultures intercalaires pouvaient réduire les populations d'insectes ravageurs dans certaines cultures légumières. La culture intercalaire (ou semis sous coverts) est une méthode ancienne de protection des plantes dans laquelle la culture principale est cultivée avec une autre plante, économiquement moins inportante. Dans les pays tropicaux la pratique des cultures en mélange est largement répandue, par exemple, en cultivant des plantes telles que le manioc, le maïs et la cacahuette dans le même champ. En Europe les cultures en mélange ne sont pas pratiquées et l'adoption de tels systèmes est impensable pour beaucoup d'agriculteurs de cultures légumières de plein champ. Toutefois plusieurs problèmes posés par les ravageurs pourraient être résolus si ce principe pouvait être inclus dans les systèmes de culture. Ce papier décrit les résultats obtenus à cette date aux Pays-Bas en utilisant les cultures intercalaires.

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Undersowing cabbage crops with clover - the effects on pest insects, ground beetles and crop yield

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Summary

Plots of white cabbage, cv. Minicole, were treated with pesticides, left untreated, undersown with white clover (*Trifolium repens*), or with subterraneum clover (*T. subterraneum*). The undersowing did not affect pest insects until the clover completely covered the soil. Once this occurred, fewer cabbage root fly eggs were laid, and fewer cabbage aphids settled, on the undersown cabbage plants. Pest Lepidoptera and the subsequent damage done by their caterpillars were not affected by undersowing. The distribution of ground beetles, that feed on pest species, showed that certain carabid species e.g. *Amara familiaris* and *Pterostichus melanarius* were caught in pitfall traps mainly in the clover plots whereas others e.g. *Agonum dorsale* and *Trechus quadristriatus* were caught mainly in the bare-soil plots. The staphylinid *Aleochara bipustulata*, a parasitoid of the cabbage root fly, was caught mainly in the bare-soil plots. The pesticides applied did not appear to affect beetle numbers. Undersowing reduced the weight of the cabbage heads by 30-40%, but the quality of the heads was similar to that on the pesticide-treated plots. Clovers less competitive with the main crop will be used in future experiments. Difficulties in establishing the cabbage crop, and in establishing and maintaining the clover at the desired height, are discussed.

Introduction

At the meeting of the Working Group held in Vienna in October 1991, participants (see Finch, 1992) from Belgium, Denmark, The Netherlands and the United Kingdom agreed to replicate the large field experiment on "Intercropping" that had been carried out in The Netherlands during 1990 and 1991 (Theunissen *et al.*, 1992; Theunissen & Schelling, 1993). The basic premise of the "Intercropping" approach is that some, but not all, pest and disease problems are reduced greatly when selected vegetable crops are undersown with clover (*Trifolium* spp.). The main purpose of this paper is to describe the difficulties encountered in the United Kingdom in 1992 and 1993 when attempts were made to repeat the Netherlands' work. This paper also suggests ways in which these difficulties may be overcome before the Group meets next in Rennes in October 1995.

Materials and Methods

White cabbage, cv. Minicole, was used as the main crop in both years. Two species of clover were used for the undersowing; *Trifolium repens*, cv. Rivendale, sown at the rate of 10kg/ha and *Trifolium subterraneum*, cv. Esperance, sown at 25 kg/ha. The experiment was laid out as a randomised block with four treatments each replicated four times. The treatments were cabbages treated with pesticides (treated control), cabbages not treated with pesticides (untreated control), cabbages undersown with *T. repens*, and cabbages undersown with *T. subterraneum*. In both years, the clover plots were drilled during the third week of March with a Ransomes' corn drill. To help clover germination and establishment, the plots were irrigated twice during early April. The cabbage plants were raised in 15 ml cells in 1992 and in 90 ml cells in 1993. They were transplanted into the field on 20 and 21 April in both years, using a spacing of 50 cm both within and between rows. In 1992, each plot measured 18 m x 16 m and contained 1221 cabbage plants. In 1993, the smaller 10 m x 10 m plots each contained 441 plants.

A base dressing of fertilizer (1000 kg/ha of 0:24:24 NPK) was applied to all plots on the day the experimental area was first cultivated. The nitrogen (Nitram 190 kg/ha) was applied to the base of each cabbage plant in three separate applications. Fifty percent was applied shortly after transplanting, 25% two weeks later and the final 25% four weeks after the second application (Theunissen *et al.*, 1992).

Birlane granules (17 mg a.i. chlorfenvinphos/plant) were applied between 23-26 April to all plants in the "treated control" plots. The same plots were sprayed with herbicide [4.3 kg propachlor (480 g/l sc; Albrass; Zeneca)/ha + 4.5 kg chlorthal-dimethyl (75% wp; Dacthal; SDS Biotech)/ha] on 4 May.

During the third week of May, weeds were removed from the "control" plots by hoeing and from the clover plots by hand-weeding. In both years, the clover was level with the tops of the cabbage plants by the first week of June and so the selective herbicide desmetryn was applied at the rate of 275 g (25% wp; Semeron; Ciba-Geigy)/ha in an attempt to reduce clover height in one half of each plot. The other half was hand-weeded.

To keep the plots "aphid free", the "treated control" plots were sprayed with pirimicarb at the rate of 210 g (50% sg; Aphox; ICI)/ha every 10 days in 1992 but on only 16 July in 1993, after the aphid infestation had become well-established.

The frequency of sampling and the data collected were similar to those suggested by Theunissen *et al.* (1992) and were as follows:-

1) Twenty plants, selected at random from each plot, were marked using small numbered canes. The numbers and species of caterpillars found on these plants were recorded weekly. Caterpillar damage was also assessed at harvest.
2) Cabbage aphid (*Brevicoryne brassicae*) infestations were estimated on the same 20 plants/plot that were used for the caterpillar assessments. The plants were scored using a system in which: 0 = clean (no aphids found), 1 = light (1-10 aphids/plant), 2 = medium (11-100 aphids/plant), and 3 = heavy (more than 100 aphids/plant).
3) Cabbage root fly adults were sampled each Monday, Wednesday and Friday using four white water-traps/plot in 1992 and one trap/plot in 1993.

4) Cabbage root fly eggs were sampled at the same time as the adults, by collecting the soil from around the base of 10 marked plants/plot and extracting the eggs in the laboratory using flotation.
5) The numbers of cabbage root fly that pupated successfully during the first generation were assessed from 15 cm diameter and 15 cm deep soil cores taken from around the roots of 20 plants, selected at random, from the plants harvested in late June (the end of the first generation).
6) The numbers of ground beetles were estimated from 6 pitfall traps/plot in 1992 and from 4 traps/plot in 1993. Each trap contained about 50 ml of 60% alcohol to preserve the beetles, as the traps were emptied once each week.
7) The effect of the clover on the growth of the cabbage was assessed by weighing twenty plants from each plot/sub-plot in late June, at the end of the first cabbage root fly generation, and again in mid-August during the final harvest.

Results

The plant growth records and pest insect data, except that for the cabbage aphids in 1993, are shown in Table 1. To avoid unnecessary repetition, the two years are considered together following the order used in Table 1.

Caterpillar damage

This was apparent only in 1992. Although caterpillar damage was lower on the cabbage undersown with *T. repens*, the level of suppression was low compared to that achieved with insecticide.

Cabbage aphid

In both years, fewer aphids landed on the cabbage plants undersown with clover (Table 1 and Fig. 1). In 1992, *T. subterraneum* had the more pronounced effect (sample of 16 June), largely because the *T. repens* was slow to establish. In 1993, however, when both species of clover covered the ground at about the same time, low numbers of aphids landed on the cabbage plants undersown with clover (Fig. 1) and much higher numbers on the cabbages growing in the bare-soil backgrounds. The maximum score of 78, recorded on the "treated bare soil" plots on 6 July, was equivalent to the majority of the plants having a light infestations of aphids. In reality, some plants were not infested whereas others had medium- and heavy-infestations. As the same plants were inspected on each sampling occasion, it was easy to observe that the increase in aphid numbers between 15 June and 6 July was due to reproduction by the aphids already on the plants rather than to further immigration.

Table 1. Plant growth and pest insect data from plots that were treated and not-treated with pesticides or undersown with one of two species of clover

1992	Bare-soil background: Tr.	Bare-soil background: Unt.	Clover background: *T. repens* Spr.	Clover background: *T. repens* Unspr.	Clover background: *T. subterraneum* Spr.	Clover background: *T. subterraneum* Unspr.	L.S.D. ($P=0.05$)
% of plants at harvest damaged by caterpillars	4	19	13	11	21	17	5
Cabbage aphid (scores)							
16 June	-	60	14		3		2.6*
6 July	-	41	12		7		
CRF adult/trap/wk							
1st Gen. Males	2	1	1		1		1
Females	7	9	6		6		2
2nd Gen. Males	2	3	1		2		1
Females	14	25	8		17		9
CRF eggs/plant/wk							
1st Gen.	8	7	3		3		2
2nd Gen.	4	4	4		5		3
CRF pupae/plant							
1st Gen.	0.2	5	5		5		2
Overwintering Gen.	3	18	10	4	13	4	8
Mean plant weight at:-							
End of 1st Gen. (g)	343	181	101		83		33
Harvest (kg)	2.0	1.6	1.1	0.6	1.1	0.6	0.1

1993	Tr.	Unt.	*T. repens* Spr.	*T. repens* Unspr.	*T. subterraneum* Spr.	*T. subterraneum* Unspr.	L.S.D. ($P=0.05$)
% of plants at harvest damaged by caterpillars	Infestation too light to be worth recording						
Cabbage aphid (scores)	Data graphed in Figure 1						
CRF adults/trap/wk							
1st Gen. Males	14	13	11		11		2
Females	3	3	3		3		1
2nd Gen. Males	44	43	15		34		7
(July only) Females	6	7	3		6		2
CRF eggs/plant/wk							
1st Gen. (1-28 May	7	7	8		6		4
28 May-7 Jul)	4	3	2		1		1
CRF pupae/plant							
1st Gen.	0.3	3	4		4		1
Overwintering Gen.	3	9	11		6		3
Mean plant weight at:-							
End of 1st Gen. (g)	1.3	1.3	0.9	1.1	1.0	0.8	0.1
Harvest (kg)	3.1	2.8	1.9	1.9	2.1	1.1	0.2

* Because the data were transformed for analysis and then back-transformed, this value is a least significant ratio (L.S.R.) and not a least significant difference (L.S.D.)

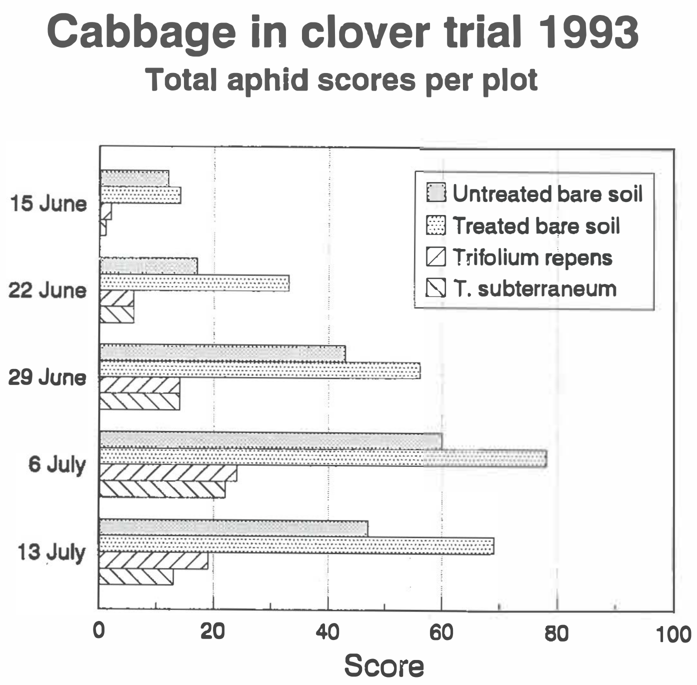

Fig. 1. Mean infestations of cabbage aphid (*Brevicoryne brassicae*), on plots of the four different treatments, assessed using the scoring system of Theunissen *et al.* (1992).

Cabbage root fly

Adults - although most of the data were too variable for any general conclusions, in both years flies of the second generation appeared to avoid the *T. repens* plots.

Eggs - during the first generation in 1992, fewer ($P = 0.05$) eggs were collected from around the plants growing in clover than from around those growing in bare soil. Partitioning the egg data into early samples, when the ground was not covered with clover (Table 1 - 1-28 May 1993), and late samples, when the ground was covered with clover (Table 1 - 29 May - 7 July 1993), indicated that good ground cover was required before fly oviposition was reduced.

Pupae - in both years, similar numbers of pupae were collected from all plots at the end of the first generation. Fewer ($P = 0.05$) overwintering pupae were found in the clover plots in 1992, but only on the unsprayed halves of the plots. Therefore, undersowing will not reduce the numbers of insects contributing to the pest population in the following year if the clover has to be sprayed to check its growth.

Plant growth and yield

In 1992, plant growth was poor even on the "treated control" plots, mainly because the first spot application of Nitram was phytotoxic. Attempts to alleviate this situation were not too successful, as the experimental area was large and it took several days to apply sufficient irrigation to dilute the phytotoxic concentrations of nitrates around the roots of the small transplants. Although larger transplants were used in 1993, even these had difficulty in producing an acceptable yield when undersown with *T. subterraneum*, unless the clover had been sprayed with herbicide to check its growth. Although the cabbages from the clover plots were only about 60-70% as heavy as those from the insecticide-treated plots, the heads were of similar quality to those from the "treated control" plots.

Ground beetles

The numbers of the ground beetle species caught most frequently in the pitfall traps during both years are shown in Table 2.

1992 - the carabid *Amara familiaris* and the staphylinid *Philonthus cognatus* were caught in higher numbers in the clover plots. The two carabids *Agonum dorsale* and *Trechus quadristriatus*, and the staphylinid *Aleochara bipustulata* were caught in higher numbers in the bare soil plots. The only other carabid caught in reasonable numbers, *Pterostichus melanarius*, was caught mainly in the plots undersown with *T. repens.*

1993 - higher numbers of *A. familiaris* were again caught in the clover plots, but the numbers recorded were lower than in 1992. More (P = 0.05) *A. dorsale* were caught in the clover plots during May, but not during June and July. Most *P. melanarius* were caught in the *T. subterraneum* plots rather than in the *T. repens* plot (see 1992 data). The staphylinid *A. bipustulatus* was caught in similar numbers on all plots, whereas the staphylinid *Philonthus cognatus* Steph., was again caught mainly in the clover plots, particularly those undersown with *T. subterraneum* (Table 1).

Discussion

It soon became clear that the large plots used in The Netherlands were difficult to manage under experimental conditions in the UK. Large plots were chosen to minimize interractions between treatments. The Wellesbourne data suggest that large plots are not essential, as the effects of the clover were still evident in the smaller plots used in 1993. Therefore, until the system is ready for testing on a commercial scale, 10 m x 10 m plots will be used for all future experimental work at HRI Wellesbourne.

To help the cabbage plants establish rapidly in the clover, their roots need to be disturbed as little as possible during transplanting. This can be achieved by using large modules, like the ones used in 1993. The transplants used in 1992, that were raised in 15 ml modules similar to those now used by most commercial producers of brassica plants, were difficult to establish in clover.

There were also difficulties in establishing the clover. Although *T. subterraneum* emerges as an even stand within 10-14 days in The Netherlands (Theunissen *et al.*, 1992), emergence was much slower in the UK and was patchy. To try to improve establishment of the clover in 1994, the clover plots will be covered with Envirofleece during germination and seedling establishment. It is essential to produce a good stand of clover as early in the season as possible, as the pest reduction benefits of undersowing become evident only after the ground is covered with clover.

Table 2: Total numbers of ground beetles caught in 6 pitfall traps/plot in 1992 and in 4 pitfall traps/plot in 1993

	Bare-soil background		**Clover background**		**L.S.D. P = 0.05**
	Treated	Untreated	*T. rep.*	*T. subt.*	
1992					
Amara familiaris May	140	140	383	352	132
Agonum dorsale May June & July	21 158	43 124	57 36	44 22	60 70
P. melanarius May - Sept	468	504	658	446	96
Trechus quadristriatus Aug & Sept	396	261	194	114	113
Aleochara bipustulata May & June	114	113	25	32	48
Philonthus cognatus June & July	8	24	423	507	218
1993					
Amara familiaris June & July	0	3	39	16	25
Agonum dorsale May June & July	7 91	10 74	32 64	59 118	20 48
P. melanarius May - July	351	491	567	1028	175
Trechus quadristriatus May - June	-	-	-	-	-
Aleochara bipustulata May & June	39	48	55	27	32
Philonthus cognatus June & July	9	24	111	241	101

At Wellesbourne in both years, establishing and maintaining a clover background of the required quality was the major problem. Although we intended to grow the clover cultivar Geralton that was used in The Netherlands, it was not available in the UK and had been superceded by the higher-yielding modern cultivar Esperance. Unfortunately, Esperance was far too competitive. For the 1994 experiments, Geralton is being obtained from The Netherlands. In the Netherlands, cv. Geralton grew only half as tall as cultivars of *T. repens*, then matured and died, leaving behind a 1-2 cm deep mulch of brown stems that covered the soil (Theunissen *et al.*, 1992). The modern alternative, cv. Esperance, never stopped growing in the Wellesbourne experiment and was as tall as *T. repens* during the whole experiment. It was difficult to keep the clover at the desired height and, as Langer indicated in 1992, regular mowing is not really a satisfactory way of managing the background.

Observation indicated that the main increase in aphid numbers resulted from reproduction by the aphids already on the plants rather than from additional immigration. To control aphids with the minimum amount of insecticide, therefore, it may be better to concentrate on the small plants at the time of aphid immigration, as at such times it is easy to obtain relatively good spray coverage of the small plants. The alternative approach, that is used as the basis of most "Supervised Control" systems, is to wait until the aphids have established reasonable infestations, by which time the plants have probably grown considerably, before spraying the plants. While this approach might convince growers of the efficacy of insecticidal sprays, it is probably not the best way of minimizing the amounts of insecticide applied to crop plants. As insecticides are effective in a density dependent manner, then a 90% effective chemical applied to plants infested with a mean of 500 aphids/plant, means that, at best, the plants will have a mean infestation of 50 aphids/plant even directly after the spray has been applied. In addition, as each aphid produces about 10 offspring a week during much of the growing season, then if 500 aphids per plant, or any other number was an accurate spray threshold, you would have to spray at least weekly to keep the infestation under control.

Although the ground beetle data are not extensive, the considerable variation within them highlight the difficulties facing entomologists currently trying to manipulate the distributions of ground beetles so that they have a greater impact in reducing pest numbers. For example, the predator *Amara familiaris* congregated in the plots undersown with clover and was caught in high numbers during May (1992 data) but not during June and July (1993 data). Therefore, this species could only be an effective predator of the first generation of the cabbage root fly. The fluctuations in the numbers of many of the other species, not only between years but also between backgrounds, indicate the difficulties inherent in relying on ground beetles to assist in pest control. The re-assuring fact from Table 1 is that the insecticides and herbicides applied to the "treated control" plots did not appear to reduce beetle numbers.

In general, for an undersown crop to have an adverse effect on a pest species, the undersown crop must cover the soil completely. When this occurs, there is considerable plant competition between the two crops and the quantitative yield of the main crop will be reduced compared to that of crops grown using bare-soil cultivation. Therefore, plant competition models are needed urgently so that crop protection scientists can predict how best to grow the optimum quality crops with the lowest yield penalty. Provided the quality of the two crops is similar, it should be possible to compensate for loss of weight yield by the savings made on insecticides. Obviously, the more expensive the insecticides, the more attractive the alternative.

Résumé

Le trèfle comme culture dérobée du chou - effets sur les insectes ravageurs, les carabes et la production de la culture

On compare différentes parcelles de chou blanc, cv. Minicole, les unes traitées avec un insecticide, les autres non traitées, avec comme plantes intercallaire le trèfle blanc (*Trifolium repens*) ou le trèfle subterraneum (*T. subterraneum*). La présence de la plante intercallaire n'affecte pas l'insecte ravageur lorsque le trèfle recouvre complètement le sol. Une fois celle-ci installée, moins d'oeufs de Mouche du chou ont été pondu et moins de Puçeron cendré du chou s'installent. Le lépidoptère ravageur et les dégâts provoqués par la présence des chenilles ne sont pas affectés par la culture intercallaire. La distribution des carabes qui s'alimentent des espèces de ravageurs montre que certains carabes tels que *Amara familiaris* et *Pterostichus melanarius* furent capturés dans les piéges de Barber principalement dans les parcelles de trèfle tandis que d'autres carabes comme *Agonum dorsale* et *Trechus quadristriatus* sont davantages capturés sur les parcelles à sol nu. Le staphylinides *Aleochara bipustulata* parasitoide de la Mouche du chou était capturé essentiellement sur sol nu. Les pesticides appliqués ne semblent pas affecter le nombre des carabes capturés. La culture intercallaire réduit le poids des têtes de chou de 30 à 40% mais la qualité des têtes était identique à celle des parcelles traitées avec un pesticide. Des trèfles moins compétitifs avec la culture principale seront utilisés dans des expériences ultérieures. Les difficultés rencontrées dans l'établissement de la culture de chou et dans l'établissement et le maintien du trèfle à une hauteur désirée sont discutés.

Acknowledgement

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Effect of intercropping swedes with clover on the level of cabbage root fly damage and numbers of carabid ground beetles

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Summary

Intercropping swedes with clover increased the numbers of carabid ground beetles but did not reduce cabbage root fly damage. As the numbers of epigeal predators was increased by intercropping, it is potentially a promising pest management technique. Much remains to be done to develop a system, based on vegetational diversity, that will lead to a reduction in pesticide use.

Introduction

Swedes (*Brassica napus* ssp. *rapifera*) are an important crop in Scotland and are grown for both forage and culinary purposes. The most important pest of this crop is the cabbage root fly (*Delia radicum*) which has two generations a year. The first fly generation is capable of killing young swede plants and is controlled normally by insecticidal granules applied into the furrow at sowing. The second fly generation is capable of severely scarring the expanding "root" and is controlled either by granules applied over the rows or sprays targeted at the crowns of the plants. Increasingly, the market is demanding minimal use of pesticides. McKinlay & Birch (1992) demonstrated that insecticide inputs to swede crops could be reduced by 50% if partially-resistant cultivars were grown. At present, the market for swede cultivars that are resistant to root fly attack is small compared to the market for cultivars which are susceptible to damage. One approach to this problem, as suggested by McKinlay and Birch (1992), is to identify and isolate the genes responsible for the resistance and incorporate them into susceptible cultivars. As this approach will require considerable time to reach a successful conclusion, a more pragmatic solution is being sought currently to minimise pesticide inputs onto susceptible cultivars. One possible approach is to use intercropping. Crop plants growing as a monoculture are likely to have a higher incidence of pests than intercropped plants (Andow, 1991). This approach was tested in eastern Scotland during 1992 on swedes intercropped with clover (*Trifolium* species). The incidence of cabbage root fly and the numbers of carabid ground beetles were monitored in swede crops both intercropped with clover and grown in a conventional way with standard insecticides. The results are reported in this paper.

Materials and Methods

The biological efficacy of undersowing swedes with clover was evaluated in field experiments done in East Lothian, Scotland during 1992. Details of the site and experiment variables are presented in Table 1. The relative numbers of carabid ground beetles in the various plots were monitored by four pitfall traps/plot. The traps were sited two on each diagonal, with each trap being 7 m from the corner of the plot. The traps were emptied every two weeks from 9 June until harvest on 10 November. The beetles were counted and identified in the laboratory. The numbers of beetles caught in the various plots were compared by analysis of variance.

Table 1. Site details and design of field experiment to assess the biological efficacy of undersowing swedes with clover in East Lothian, Scotland during 1992

Site details	
Name:	Old Cambus East Mains, Cockburnspath
British National Grid Reference:	NT 814699
Soil Association & Series:	Biel Association; Oxwell Series
Soil type:	Freely drained brown calcareous and brown forest soil
Height above sea level:	70 m
Aspect:	Slight incline, sloping down from west to east.
Experimental design	
Treatments:	1. Without insecticide. 2. Insecticide (12.5 g/10 m row carbofuran granules ('Yaltox'; 5% w/w; Bayer) at sowing; two sprays of chlorfenvinphos ec (Birlane 24; 24.8% w/w; Shell) at 3 l/ha; sprays applied on 24 July and 7 August). 3. White clover only (*Trifolium repens;* cv S184; sown at 9.8 kg/ha between rows). 4. Red clover only (*Trifolium pratense*; cv Britta; sown at 24.6 kg/ha between rows) 5. White clover + insecticide. 6. Red clover + insecticide.
Layout:	Randomised block, 6 replicates
Crop and cultivar:	Swede (*Brassica napus* ssp. *rapifera*); cv Magres
Sowing date:	15 May
Spacing between rows:	50-51 cm
Spacing within rows:	12-13 cm
Fertiliser:	N 75 kg/ha; P_2O_5 200 kg/ha; K_2O 125 kg/ha
Plot size:	20 x 20.3 m
Harvest date:	10 November

Treatment 4 (Table 1) was sown initially between the crop rows with Fenugreek (*Trigonella foenum-graecum*; cv. unknown) at 9.8 kg/ha. Owing to poor germination, the fenugreek areas were scarified on 18 June and re-sown with red clover on 19 June, as shown in Table 1.

To assess the levels of damage by cabbage root fly larvae, a 1.5 m length of row was harvested from the centre of the middle two rows of each plot of swedes. Root damage was scored and analysed using the method of McKinlay (1986).

Results

Root damage to swedes by the cabbage root fly was reduced ($P<0.05$) in each of the three treatments involving insecticide (Table 2). Damage was higher ($P<0.05$) in the red clover plots than in the untreated (no insecticide) plots (Table 2).

More ($P<0.05$) carabid ground beetles were caught in the four treatments undersown with clover than the two that were not (Table 3). The presence of insecticide reduced ($P=0.05$) the numbers of beetles caught (Table 4).

Table 2. Root damage index scores for attack by cabbage root fly on swedes

Treatment	Root damage index score*
No insecticide	0.124
Insecticide only	0.053
White clover only	0.160
Red clover only	0.193
White clover + insecticide	0.031
Red clover + insecticide	0.050
LSD $P = 0.05$	0.059

* higher scores = higher damage

Table 3. Mean number of beetles caught/plot on the plots intercropped and not intercropped with clover

Treatment	Number
Without clover	129
Red clover	159
White clover	180
LSD $P = 0.05$	29

Table 4. Mean number of beetles caught/plot on the plots treated and were not treated with insecticide

Insecticide	Number
Absent	168
Present	144
LSD $P = 0.05$	23

Discussion

Although all of the insecticide treatments reduced cabbage root fly damage, none of the clover treatments did. That the insecticide treatments were effective was expected; that the clover treatments were not effective was disappointing. It is perhaps not surprising that the clover treatments had no effect, as the clovers were sown at the same time (or later in case of red clover) as the swedes and had not covered the soil by the time the first generation of the cabbage root fly became active. As a consequence, second generation flies may have emerged from first generation pupae already within the crop and caused the root damage scored at harvest. Given that one of the reasons to intercrop is to confuse the host finding behaviour of insect pests entering the crop (Andow, 1991), it might have been better to establish a good cover of clover prior to sowing the swedes. However, clover germinates and establishes slowly when sown early in the season in northern latitudes such as Scotland. If clover is to be used as an intercrop, it may have to be sown the year before use.

Intercropping swedes with clover appears promising in that more carabid ground beetles were caught in the clover plots. A little evidence was obtained from the experiment to support the natural enemies hypothesis, one of two principal hypotheses (the other being the resource concentration hypothesis) to explain the response of arthropods to vegetational diversity (Andow, 1991). Of particular interest is the increased numbers of *Trechus quadristriatus* caught in the clover plots, as *T. quadristriatus* was shown by Wright *et al.* (1960) to be an important predator of the cabbage root fly.

Résumé

Effet des cultures intercallaires de trèfle dans des navets sur le niveau des dégâts de Mouche du chou et le nombre de carabes

L'utilisation d'une culture intercallaire de tréfle dans des navets augmente le nombre des carabes mais ne réduit pas les dégâts dus à la Mouche du chou. Comme le nombre des prédateurs épigés est augmenté par la culture intercallaire, cela peut potentiellement être un moyen technique prometteur de régulation des populations

de ravageurs. De nombreuses études restent à réaliser pour développer ce système basé sur la diversité botanique qui conduira à la réduction de l'utilisation des insecticides.

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What makes intercropped cauliflower plants less susceptible to *Brevicoryne brassicae*?

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Summary

Intercropping cauliflower with rye effected the colonization rate of the aphid *Brevicoryne brassicae*. Fewer ($P = 0.05$) aphids were found on the plants in the intercropped plots within a few days of planting. This situation remained unchanged during the first three weeks of crop growth. The treatments had no effect on the increase or decrease of the aphid populations and fertilizer treatments did not produce different rates of infestation. The parasitoid *Diaeretiella rapae* and the hoverfly *Episyrphus balteatus* showed no preference for either the undersown or the fertilized plots. The distribution of the parasitoids within the plots was not affected by the treatments. The results of this study do not support the enemies hypothesis, but question the importance of dispersion abilities and host-plant finding by both the pests species and their natural enemies.

Introduction

Intercropping is common, especially in tropical regions. Although pests and diseases are less abundant in many intercropped situations (see Risch *et al.*, 1983, for a review), the mechanisms involved in such situations are not yet clear and, in practice, most farmers still have to rely entirely on their own years of experience and skill (Altieri, 1987).

Despite the widespread use of polycultures, no one theory explains all situations (Vandermeer, 1989). The current hypotheses to explain the effects of intercropping stress, increased numbers of natural enemies (Root, 1973), greater diversity that leads to stability (Pimentel, 1961), or less concentrated resources that lead to the host plants being found less frequently by pest species (resource concentration hypothesis - Root, 1973). Many questions still need to be answered, before intercropping becomes a system acceptable to commercial growers.

In this paper we describe the results of an experiment carried out in 1993 in which cauliflower plants were undersown with rye. The results are concerned with the ability of the aphid *Brevicoryne brassicae* to colonize brassica plants growing both in bare-soil and in rye, the subsequent levels of aphid parasitism by *Diaeretiella rapae*, and finally the levels of aphid predation by hoverflies.

Material

The experiment was carried out in 1993 at the experimental research unit of the University of Hannover, Faculty of Horticulture. Cauliflower plants (cv. Montan F_1), grown for 6 weeks in a glasshouse, were planted on 23 June in a randomised block design in the field. The factorial design consisted of four treatments, each replicated nine times. Each plot was approximately 5 m x 5 m and contained 60 plants. The cabbage plants were spaced 60 cm apart both between and within the rows. Each plot were surrounded by a 60 cm wide area of bare soil.

The rye seed was sown at 20 g/m^2. One half of the plots of each treatment was fertilised with 280 kg N/ha, the other half with 330 kg N/ha. On 20 July, the experimental plants on one half of the plots of each treatment were treated individually with an insecticide (Pirimicarb) to knock down all *Brevicoryne brassicae.* The recolonization of these plants by aphids was monitored during the following weeks. During the experiment, the monocrop plots were hand-weeded three times to maintain these plots as the bare-soil treatment.

Methods

The numbers of aphids and their natural enemies were recorded twice each week. Within each plot, plants were chosen at random and labelled individually. On each subsequent sampling occasion, the plants were searched thoroughly for live aphids, mummified aphids and larvae of predators. The numbers of alatae and larvae were counted within each colony, so that it was possible to follow the population dynamics of the various aphid colonies. Sampling was by visual inspection. When syrphid pupa were found, they were labelled, removed and maintained in the laboratory so that the species could be recorded as the adults emerged.

As the developmental stages of the larvae were not separated, it was not possible to quantify the percent parasitism by the parasitoids (van Driesche, 1983). Instead, the cumulative number of mummies were counted in the colonies. We did not remove the mummified aphids for reasons that will not be reported here. The most common primary parasitoid of *Brevicoryne brassicae* was *Diaeretiella rapae*. As *Praon volucre* parasitized less than one percent of the aphids, all mummies were considered to be parasitized by *D. rapae*.

The rye seedlings within a 0.10 m^2 frame were inspected for cereal aphids to quantify any additional food supply that might be available for the aphid parasitoids and/or predators. As the numbers of cereal aphids on the rye were extremely low, their influence on the natural enemies was ignored.

Results

Undersowing cauliflower with rye affected the colonization rate and/or establishment of alatae of *Brevicoryne brassicae* (Fig. 1). On the second sampling date, the numbers of alate aphids found on the monocrop plants differed (t-Test for pooled data pure vs. undersown plots for each date: N=18,18; $t = >3.5$, $P >0.01$)

from those found on the undersown plants. The fertilizer treatments had no effect on colonisation by alatae. During the first week of sampling, the numbers of alatae were similar on all plots, due largely to unfavourable weather conditions. However, during the following four days, aphid numbers increased by a factor of more than 2 in the pure plots but by only 1.5 in the undersown plots. At that time the colonies did not produce alatae, and the increases were due to newly colonizing specimens. The numbers of alatae then declined at the same rate in all four treatments.

The numbers of larvae produced reflected the numbers of the alatae (Fig. 2). The population increase was affected mainly by the initial numbers of alatae. The numbers of larvae were higher in the pure plots than in the mixed stands not because the alatae produced more individuals per capitum on the plants in the pure plots, but because more aphids landed initially. There were no differences in the rate of increase in aphid numbers between the pure and undersown treatments. Fertilizer treatments had no effect on the population density of the aphids.

The insecticide applied on 20 July killed all of the aphids on one half of each plots. However, on the remaining plots the population of the aphids also declined and within 10 days there were only a few individuals left (Fig. 3). This large decrease in the population of *Brevicoryne brassicae* occurred on all four treatments.

The proportion of mummies of the parasitoid *Diaeretiella rapae* found the various plots was not affected by the treatments (Fig. 4). At the end of July, the plant leaves were practically free from aphids and only the mummies remained attached to the leaf surfaces. Because Fig. 3 provides only a vage indication of the possible influence of the surrounding environment on the behaviour of the parasitic wasps, we grouped the data according to the position of each plant within the plots. If the more diverse vegetational texture within undersown plots attracts (or repels) parasitoids, the proportion of parasitized larvae should differ between the margins and the centres of the pure and undersown plots. However, the results (Fig. 5) are not consistent with this hypothesis, as most mummies were generally found towards the centre of the plots. Although the differences are not significant (Tukey-Test on log-transformed data, df 7,109; $F = 0.482$, $P > 0.1$), there appears to be a trend that *D. rapae* is attracted more to aphid-infested plants alongside other aphid-infested plants than to more or less "isolated" aphid-infested plants.

The most abundant predator of the aphids on the plants was the hoverfly *Episyrphus balteatus*. Females of *E. balteatus* were found searching for aphids not only on the cauliflower plants, but also on the intercropped rye and weeds. Other syrphids (*Eupeodes corollae*, *Scaeva pyrastri* and *Sphaerophoria scripta*) visited the plants but, as only a few eggs or larvae of such species were found, they will not be considered further.

Although the numbers of larvae of *E. balteatus* increased during the sampling period, the increase in mid-July was not related to the increase in aphid numbers on the different treatments (Fig. 6). The highest number of syrphid larvae were found on the plants in the pure plots, but nearly as many were found in the undersown plots. Although the aphid density decreased dramatically at the end of July, the numbers of syrphid larvae remained high until early August, and was highest in the undersown plots. In some cases, finding syrphid larvae was difficult, because they hid between the plant leaves.

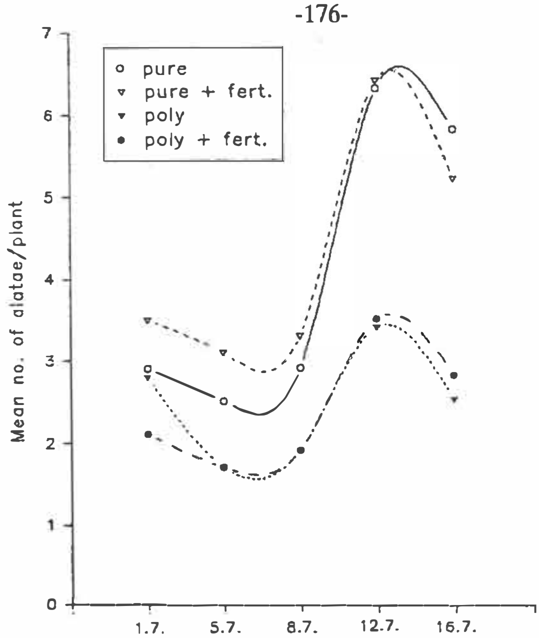

Fig. 1: Mean number of alate *Brevicoryne brassicae* on monocrop plots (pure), monocrop plots with fertilizer (pure + fert.), undersown plots (poly) and undersown plots with fertilizer (poly + fert.).

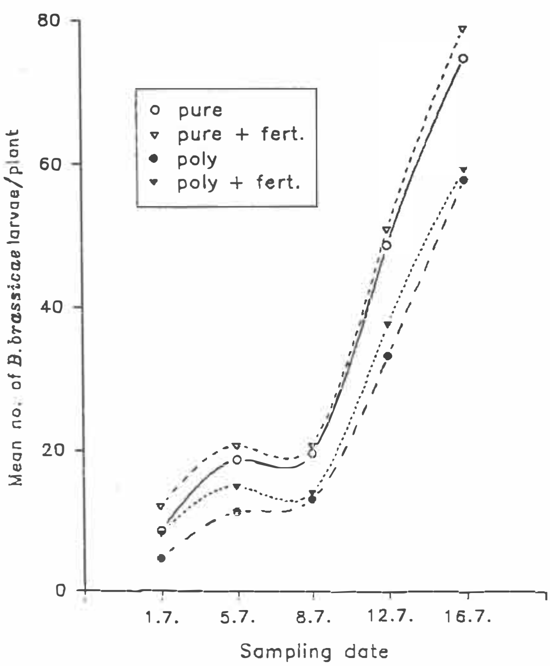

Fig. 2: Mean number of larvae of *Brevicoryne brassicae* on the the four different treatments. For explanations of the legend see Fig. 1.

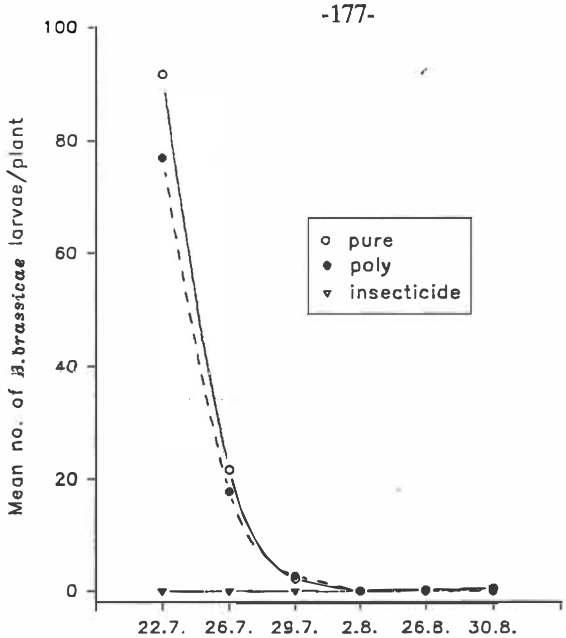

Fig. 3: Mean number of larvae of *Brevicoryne brassicae* on pure and undersown plots. Data from both of the insecticide-treated pure and undersown plots are pooled.

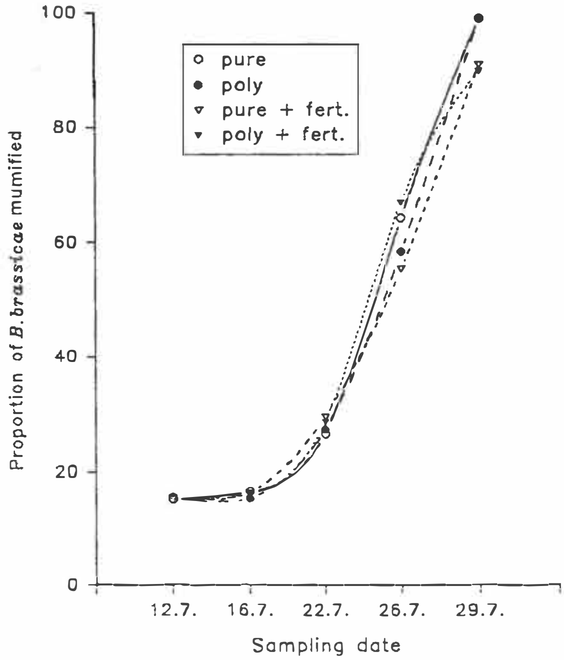

Fig. 4: Mean proportion of mummified *Brevicoryne brassicae* on the four different treatments. For explanations of the legend see Fig. 1.

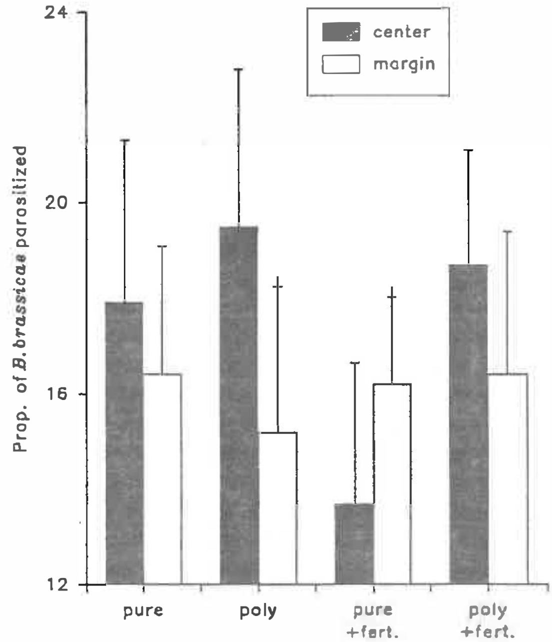

Fig. 5: The proportion of individuals (+ SD) of *Brevicoryne brassicae* parasitized by *Diaeretiella rapae* in colonies on plants growing on the margin or the centre of each plot.

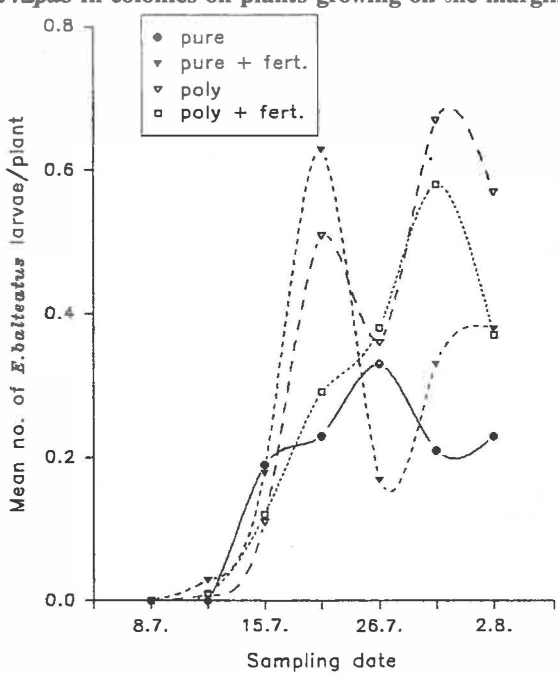

Fig. 6: Mean number of larvae of the hoverfly *Episyrphus balteatus* on plants with colonies of *Brevicoryne brassicae*. For explanations of the legend see Fig. 1.

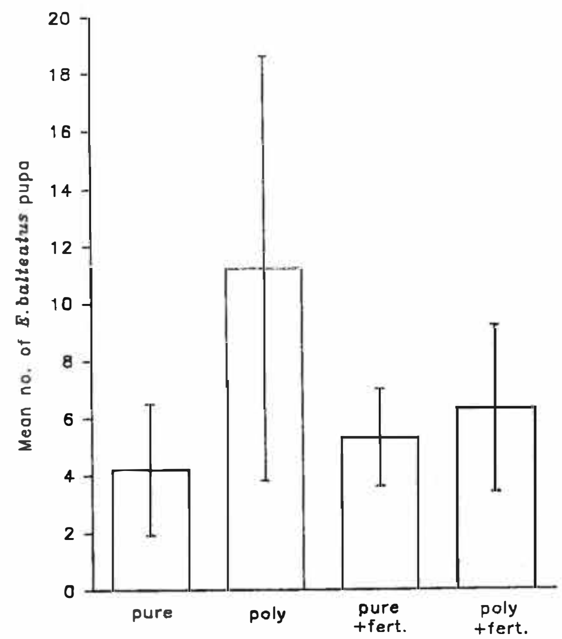

Fig. 7: Average number (+ SD) of pupae of *Episyrphus balteatus* on all plants at the end of the experiment.

To obtain a more precise estimate of the densities of the hoverflies, the numbers of pupae of *Episyrphus balteatus* were recorded at the beginning of August, as the pupae were conspicuous at this time attached to the plant leaves. The *E. balteatus* pupae tended to be more numerous in the undersown than in the pure plots (Fig. 7). Because of the high variability in the data, however, the differences were not significant (GT2-Test; $m_{0.05\,[6,12]} = 4.75$; n.s.).

Discussion

Previous work on intercropping reported reductions of pest populations in diversified cabbage systems (Andow *et al.*, 1986; Maguire, 1984; Smith, 1976; Theunissen & den Ouden, 1980; Theunissen *et al.*, 1992). In the present experiment, the densities of the aphid *Brevicoryne brassicae* were reduced significantly in cauliflower plots undersown with rye. The current experiments were started in late June, when dispersion and colonization of new plants by alatae was reported to be high (Hommes, 1983). Within a few days of starting the experiment, all of the plants sampled had been colonized by *B. brassicae*. The differences in the mean numbers of alatae initially colonizing the pure and undersown plots were apparent from the beginning of sampling and persisted throughout the subsequent sampling. Movement of apterae within a crop may be related to food plant quality, or changes in the suitability of the host plant, rather than to climatic conditions or natural enemies. The overall distribution of the aphids, once the colonies had become established remained more or less the same (Hodgson, 1991). Our results contrasts with a three year study by Tingey & Almont (1988), who found no differences of the numbers of *Aphis fabae* alatae in intercropped bean cultivars. The decline of *B. brassicae* populations, which occurred in all four treatments at the end of July, may have been caused by natural enemies (Hafez, 1961).

We could not detect any effects of climatic conditions, or natural enemies, on the rates of growth of the aphid populations, nor could we detect differences in the numbers of aphids parasitized by *Diaeretiella rapae*. These findings confirm those of Ayal (1987), that *D. rapae* search randomly within each field, but have a highly developed foraging strategy once they find a plant with aphid odour or actual aphids. The plot size used in the current experiment may have been too small to carry out meaningful studies on the host-finding ability of the parasitoid *D. rapae*.

The only important predator of the aphids was the hoverfly *Episyrphus balteatus*. Although many adult syrphids were seen hovering above the plants, the numbers of syrphid larvae within the aphid colonies were low. No relationship was found between the numbers of aphids present and the numbers of syrphid larvae present. The numbers of eggs laid by the syrphids were not recorded, but larval and pupal numbers indicated that more syrphids were present in the undersown plots. Hoverflies are known to lay more eggs in the vicinity of flowering plants (van Emden, 1965). Although Sengonca and Frings (1988) found more adult syrphids in sugar beet plots surrounded by, or mixed with, *Phacelia tanacetifolia*, they found more syrphid eggs in the plots with the high infestations of aphids. However, if females of *E. balteatus* laid more eggs on the undersown cauliflower plants, this should have resulted in a greater reductions in aphid numbers in the intercropped plots. As this did not occur, there is no evidence that the treatments influenced the behaviour of the predators. In contrast, the greater numbers of *Brevicoryne brassicae* found by Smith (1976) in monocrops could be related to the lower numbers of hoverflies and other natural enemies.

Our data on the parasitoids and predators, although important for the population dynamics of *B. brassicae*, did not confirm the enemies hypothesis of Root (1973). Instead, our data indicate that we need to know more about the mechanisms of dispersion and host-plant finding by pest species in diversified habitats. Decreased pest numbers in intercrop situations may be related to several factors of which colonization ability ("finding and leaving plants", a term coined by Sheehan & Shelton, 1989), may be of major importance for both the pest species and their natural enemies. In the next experiments, therefore, we will try to measure the ability of cabbage aphids to disperse within various intercropping systems.

Résumé

Qu'est-ce qui rend les plants de choux-fleurs associés à une culture intercallaire moins sensible à *Brevicoryne brassicae*?

La culture intercallaire du chou-fleur telle que le seigle agit sur le taux de colonisation du puçeron *Brevicoryne brassicae*. On trouve moins de puçerons (P = 0.05) sur les plantes dans les parcelles comprenant une plante intercallaire dans les premiers jours de la plantation. Cette situation reste inchangée pendant les trois premières semaines de la croissance de la plante. Les traitements n'ont pas d'effet sur l'augmentation ou la décroissance des populations aphidiennes et les apports de fertilisant n'ont pas provoqué de taux d'infestation différents. Le parasitoide *Diaeretiella rapae* et le syrphe *Episyrphus balteatus* ne montrent aucune préférence pour la culture intercallaire ou pour les parcelles fertilisées. La distribution des parasitoides dans les parcelles n'a pas été affectée par les traitements. Les résultats de cette étude apporte peu d'argument à l'hypothèse des ennemis mais pose la question de la capacité de dispersion et de découverte de la plante hôte par les espèces déprédatrices et par leurs ennemis naturels.

Acknowledgement

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Influence of background on host-plant finding and acceptance by the cabbage root fly

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Summary

An extensive set of laboratory experiments were carried out to determine why the cabbage root fly (*Delia radicum*) laid more eggs around brassica plants in bare soil backgrounds than around plants in diverse backgrounds. In choice situations, gravid female cabbage root flies landed at least twice as often on brassica plants growing in bare soil than on comparable plants growing among non-host plants. Females which landed initially on bare soil located a host-plant more frequently than females which landed initially on grass. Surrounding a brassica plant with a diverse background altered the behaviour of the flies so that their normal spiral flights around and back onto the same host-plant were replaced by short hops between the host plants and nearby vertical objects in the diverse backgrounds. In such situations, flies often left the vicinity of host-plants without laying.

Introduction

Several authors have recorded more eggs of the cabbage root fly (*Delia radicum*) on brassica plants growing in bare soil, than on similar plants growing in diverse background (O'Donnell & Coaker, 1975; Ryan et al., 1980; Theunissen & den Ouden, 1980; Tukahirwa & Coaker, 1982: Langer, 1992; Theunissen & Schelling, 1992; Theunissen et al., 1992). This paper describes laboratory experiments done to determine how changes in plant background influence the subsequent behaviour and oviposition of the CRF.

Materials and methods

Most of the bioassays were done in a flight chamber that consisted of two 160 cm x 160 cm and 63 cm high compartments one above the other (Kostal & Finch, 1994). Cauliflower was used as the standard test brassica plant in all experiments. The flies used in the tests all emerged from field-collected pupae. The landing behaviour of individual female flies was recorded for four 15-min periods in both choice- and no-choice situations. The post-aligning behaviour was recorded for females which 1) landed on either soil or grass, or 2) on a host-plant placed in soil or in a diverse background. The numbers of eggs recovered from around brassica plants growing in bare soil were compared with the numbers recovered from around brassica plants growing in diverse backgrounds. Each experiment was replicated at least four times and was done in both choice- and no-choice situations.

Results

In the choice experiments, female cabbage root flies landed four times as often on brassica plants in bare soil backgrounds than on the brassica plants in grass backgrounds (Table 1.) In addition, females landed rarely on bare soil but frequently on grass. The patterns of landings were similar when green and brown paper backgrounds were used instead of bare soil and grass. In the no-choice experiments, the females landed more often on the host-plant than on the background of bare soil, but more often on the background of grass than on the host-plant.

Table 1. Mean number of landings by female cabbage root fly when presented with brassica plants in backgrounds of bare soil versus grass, brown paper versus green paper ("choice" situations) and in backgrounds of bare soil and grass in a "no-choice" situation

	Mean no. of female landings/15 min				L.S.R. ($P=0.05$)
Choice situation	On plant 34	On soil 9	On plant 8	On grass 49	1.7
	On plant 25	On brown paper 19	On plant 12	On green paper 44	1.2
No-choice situation	On plant 109	On soil 11	- -	- -	2.2
	- -	- -	On plant 57	On grass 166	1.4

Within the 5 minute observation period, 50% of the females that landed initially on bare soil subsequently reached the host-plant. However, only 35% of the females that landed initially on the grass reached the host-plant.

After landing on a brassica plant, most females carried out spiral flights around the upper part of the host-plant. Above bare soil, these spiral flights ended almost invariably with the female landing back on the host-plant. However, many of the females that attempted spiral flights from brassica plants growing in grass landed on the grass. As a result, 36% of the females that landed on a brassica plant in bare soil were ready to lay within 5 minutes compared to only 7% when the plant was presented in grass.

In choice experiments, more cabbage root fly eggs were laid around brassica plants growing in bare soil than around brassica plants growing amongst peas, grass, clover, green artificial plants and brown artificial plants. In no-choice experiments, the backgrounds of peas, grass and clover did not affect the total numbers of eggs laid.

Discussion

The differences in 1) landing behaviour, 2) success of reaching the plant after landing in its vicinity, and 3) post-alightment behaviour were the major factors responsible for the differences in cabbage root fly oviposition around plants growing in bare soil and diverse backgrounds.

O'Donnell & Coaker (1975) suggested that the lower numbers of cabbage root fly eggs recovered from around brassica plants growing in clover were due in part to the odour of the clover repelling the ovipositing females. An alternative hypothesis, suggested by Theunissen & Schelling (1992), was that the clover and other backgrounds (Ryan et al., 1980) acted as mechanical barriers to oviposition. The latter seems unlikely to be the mechanism, as reduced oviposition occurred in our experiments in backgrounds of peas and artificial plants, neither of which completely covered the soil.

We suggest that the barrier that the insect must overcome in undersown crops is not chemical or mechanical but behavioural. The frequent loss of physical contact with a host-plant situated in a diverse background disrupted the sequence of fly behaviour that normally culminates in oviposition. The insects then moved elsewhere to search for a host-plant.

The present results indicate that undersowing might not reduce cabbage root fly oviposition sufficiently under field conditions unless the flies are allowed access to plants growing in bare soil. One way to arrange this would be to leave strips of bare soil at regular intervals through the undersown crops. The rows of brassica plants growing in such strips would then act as a "trap crop", which could be sacrificed.

Résumé

Influence du substrat sur la découverte et l'acceptation de la plante hôte par la Mouche du chou

Une série importante d'expériences a été réalisée en laboratoire pour déterminer la raison pour laquelle la Mouche du chou (*Delia radicum*) pond plus d'oeufs autour des plants de brassica en sol nu. En situation de choix la femelle gravide de mouche du chou attéri au moins trois fois plus souvent sur des plants de chou cultivés en sol nu que sur des plants comparables cultivés avec d'autres plantes non hôtes. Les femelles qui attérissent initialement en sol nu localise la plante hôte

plus souvent que les femelles qui attérissent sur herbe. L'entourage de la plante de brassica avec différent substrat amène souvent la femelle à perdre le contact avec la plante hôte, toutefois l'altération de la séquence comportementale normale culmine au moment de la ponte. Dans de telles situations les mouches quittent souvent la plante hôte sans pondre. Dans des situations de non choix, la ponte sur la plante est identique à la fois sur sol nu ou avec un environnement différent.

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Ciba's contribution to IPM in vegetables

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Vegetable crops are a plant protection market in which the emphasis on rational control techniques is being increased. Such methods of control include using economic thresholds instead of calendar sprays, monitoring pest populations, introducing macro-organisms to crops, and maintaining naturally-occurring beneficial insects. The introduction of Integrated Pest Management (IPM) and, in a broader sense, Integrated Production (IP) systems is becoming more widespread.

Geographical Trends

Europe - The methods for producing fruit and vegetable crops in Europe are undergoing a transformation. The move is towards the adoption of systems based on Integrated Pest Management (IPM). The change is in response to pressure from authorities and Governments, but has also been stimulated by national food retailers and processors over their concern about pesticides in the final produce. Vegetables with IPM labels have been on sale in Switzerland since early 1993. Throughout Europe, supermarkets and food companies are an important driving force behind the current trend to incorporate systems of IPM into the production of fruit and vegetable crops. The European Community will shortly present a document to clarify the current controversy concerning the application of pesticides (Lynch & Feeley, 1992). In addition, discussion documents from the EEC indicate a desire to achieve economically-sustainable agriculture with a limited amount of pesticide. The use of economic thresholds, the development of selective insecticides, and an emphasis on biological control will be important in this scenario (Ferron, 1992; Brandl & Flückiger, 1992).

United States - Between 1984 and 1989, the number of growers receiving IPM training in the United States rose from 500 to nearly 5,000. The area of vegetable crops under IPM increased from 740,000 acres in 1984 to 2 million acres (about 33% of the total vegetable crop area) by 1989, according to the USDA Extension Service.

Tomato is one of the most important vegetable crops in the USA and, in 1986, it was estimated that 80% of the crop was grown using IPM techniques (National Research Council, 1989). This was higher than for citrus (70%) and cotton (40%) (Teng & Battrell, 1990).

Japan - The current demand by Japanese consumers for fruit and vegetables of a extremely high quality means the inputs for pest and disease control are high. Numerous applications of pesticide to each crop has produced resistance problems for certain pests, largely because the repeated applications have been made invariably with pesticide products from similar chemical classes. For example brassica crops (cabbage and Chinese cabbage) are the most widely grown field crops, and have one major pest problem, the diamond back moth (*Plutella xylostella*). As result of excessive insecticide use, this pest is now resistant to almost all insecticides on the market.

Health and safety is of growing concern to the consumer. The elements of IPM adopted most readily in Japan are the reduced use of pesticides. This follows the widely-available spray recommendations that are based on a combination on pest thresholds and a better understanding of what results in crop damage.

Other areas - In South East Asia, the most important vegetables requiring pest control are the brassica crops. Many farmers over-apply insecticides against the key pest, the diamond back moth, and this results in pest resistance and contaminated crops. Using IPM to overcome such problems is clearly the logical step. A standing committee of the Asian and Plant Protection Commission of the FAO has recommended that the available IPM control tactics should be appraised, paying particular attention to biological control, plant resistance, cultural methods and only then to chemical control.

There are also trends in other regions of the world, e.g. India and Latin America, towards adopting control systems based on IPM.

Keyplayers in IPM and Integrated Production

Ciba Plant Protection has recognised the movement in the market towards IPM. Currently Ciba has classified growers into four distinct market segments (Fig. 1), based on their needs and their approach towards IPM. This classification is specific to Ciba, and uses parameters based on financial and ecological goals. The size of the business is not relevant, as it is expected that in time the main focus will be on the "integrated" farmer who responds to market forces that demand the use of IPM production techniques. This segment is expected to increase.

Fig. 2 illustrates the network of key players and the role of the agrochemical industry in Integrated Production (IP). In such a system, where the farmers are well-educated in IP and supported by an effective extension service, the primary task of the agrochemical industry is to supply the grower with the right tools for pest control. This will include not only the chemical and biological products, but will also involve the essential information on how best to apply these products under systems of IPM. In the following paragraphs, we describe the insect control products produced by Ciba for use in vegetable crops and emphasize their suitability for use in IPM systems.

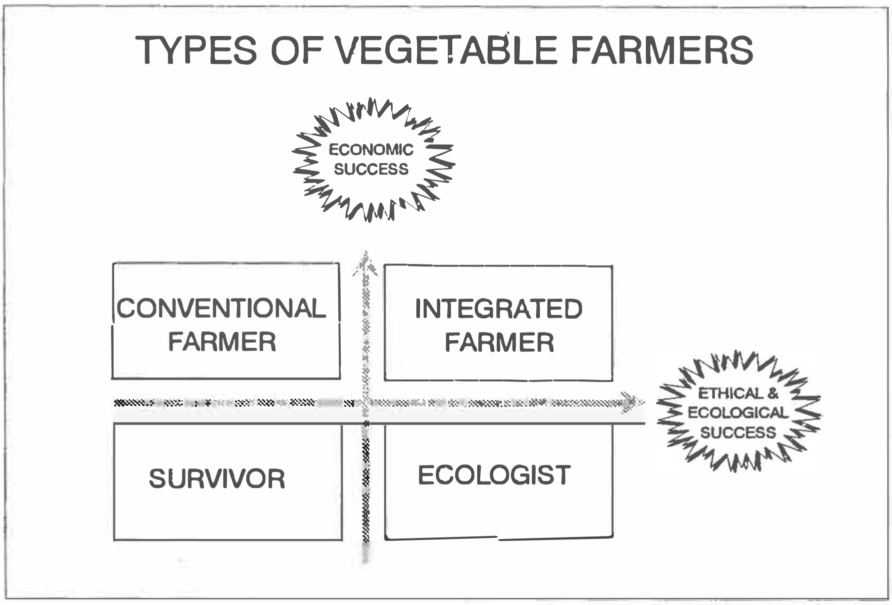

Fig. 1: Types of vegetable farmers according to Ciba classification

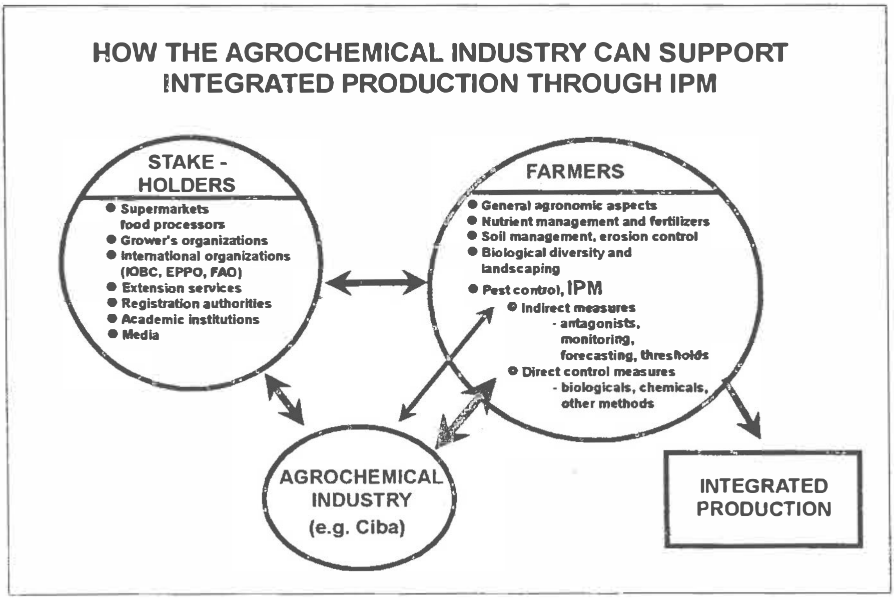

Fig. 2: Network of key players in systems of Integrated Production

Ciba Insect Control Product Line for IPM Systems

The products for insect control in vegetable crops have been reviewed recently and ranked with for their suitability in systems of IPM (Fig. 3). The ranking includes selectivity towards natural pest enemies, selectivity against non-target organisms, and soil persistence (see Figs. 3 & 4). The selectivity of the products has, of course, to be judged with respect to the impact of the respective pest enemies in a specific crop situation.

Ciba has an increasing range of products suitable for use in IPM in vegetable crops. Amongst them are pymetrozine, diafenthiuron, cyromazine and *Bacillus thuringiensis*.

Pymetrozine (Chess, Sterling, Plenum) is suited ideally to IPM programmes because of its biological performance against whitefly and aphids, and its excellent selectivity for beneficial organisms. The high selectivity of this product will even allow it to be used with macro-organisms for biocontrol.

Diafenthiuron (Pegasus, Gamba) is active against both susceptible and resistant strains of the diamond back moth (*Plutella xylostella*), other lepidoptera, and sucking pests like aphid, whitefly and certain mites. It has a unique mode of action. Because of its selectivity to beneficials, and its effect on resistant strains of certain pests, it is useful for IPM systems.

Cyromazine (Trigard) is a target-specific insect growth regulator (IGR). Its main use is for leafminer (*Liriomyza* spp.) control in vegetable and ornamental crops. Cyromazine does not affect commercially-important beneficial insects and mites.

The **Ciba *Bacillus thuringiensis*** (Agree, Turex) product currently on the market, controls several types of lepidopterous pests, including *Spodoptera*, *Heliothis* and *Plutella* species. It is a conjugated B.t. made from B.t. *aizawai* and B.t. *kurstaki*. It can be used in combination with other products, either as part of the control programme during the early stages of crop growth or close to harvest time to minimise residue problems.

In tomatoes and cucumbers grown in glasshouses in northern Europe, pest control is done almost exclusively with beneficial organisms. **Ciba Bunting** provides a whole range of macro-organisms for this market.

To prove the suitability of these modern compounds, and some established commercial products for use in IPM systems, Ciba conducts field trials all over the world, both independently and in co-operation with local officials. The results of these trials are reflected in the use recommendations for these products.

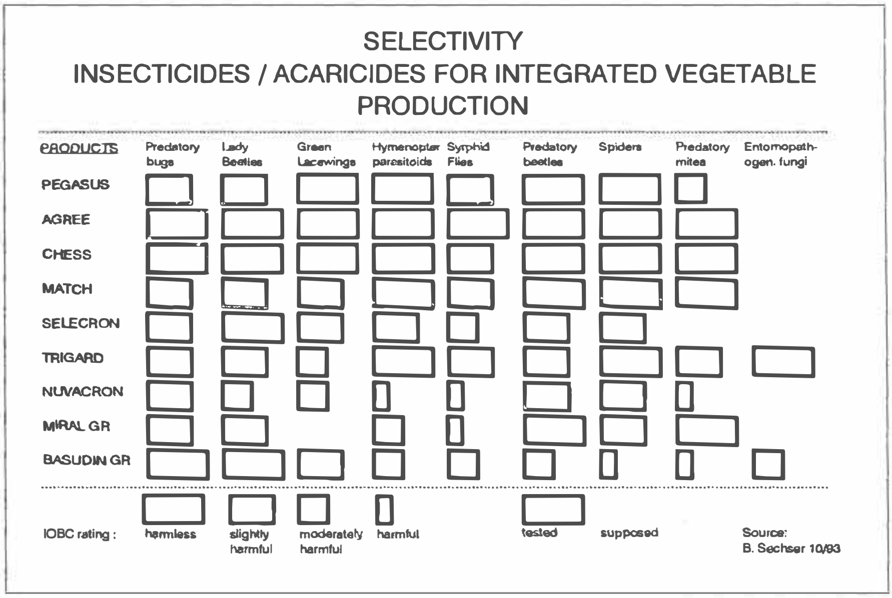

Fig. 3: Ranking of Ciba vegetable products with regard to IPM

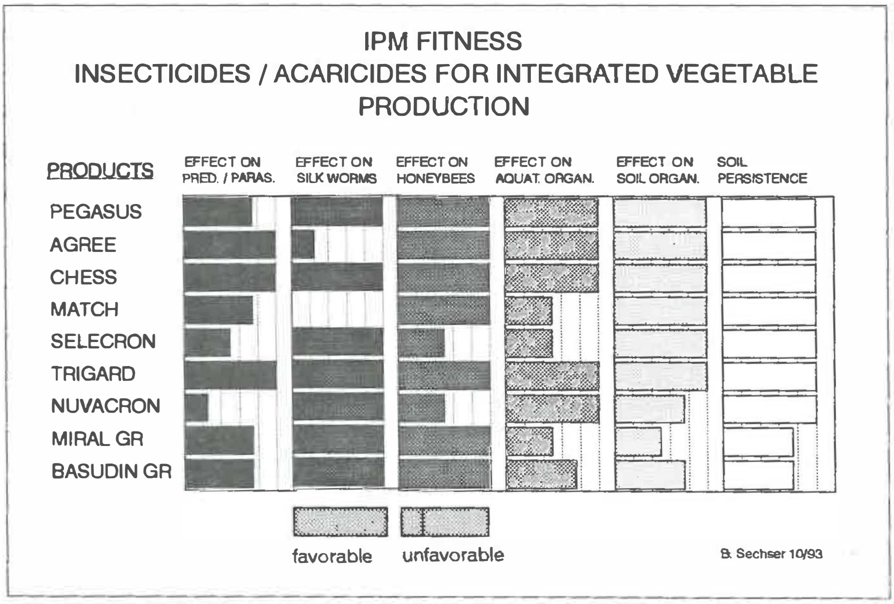

Fig. 4: Selectivity of Ciba vegetable products

Consequences of IPM to Ciba

More is required from agrochemical companies than merely delivering the right products. If the spirit of IPM is taken seriously, it is important to agrochemical companies look beyond single products and consider instead the whole crop eco-system. This means having a critical look at the current ways insecticides are used, promoting non-chemical measures and even providing services which help growers or advisors to implement IPM.

To proceed in this direction, Ciba already runs a number of IPM projects. For example, Ciba has, in conjunction with the Lembang Horticultural Research Institute (LEHRI) in Indonesia, devised a management strategy for vegetable farms in the Lembang region to reduce the number of sprays required to control diamond-back moth. The aim was to train farmers in IPM techniques and optimise their pest control by scouting their crops, using economic thresholds to decide when to spray, and applying an alternating sequence of products. Two successive seasons of trials in the Pangalengan district have shown that the number of sprays/season can be reduced from about 15 to 5, without endangering either crop yield or quality. Local growers have been extremely enthusiastic in adopting the scouting methods and following the training programme (Vorley, 1992).

Future pest control in IPM appears to be moving from input intensive to information intensive systems. The plant protection industry could take this as an opportunity to provide additional monitoring tools, expert systems and, more importantly, adequate training and information on the optimal use of both chemical and non-chemical control measures.

Summary

This paper attempts to illustrate what Ciba can offer to IPM at present and in the future. Ciba has identified the distinct changes in the market place and is responding to develop products and programmes that will be compatible with future demands. A management approach has to be developed for pest complexes, rather than following the current "short term" tactic of recommending an individual product to control a single pest. Ciba aims to participate in the development and commercial solutions to pest management, using all available control methods.

Résumé

Contribution à la gestion intégrée des ravageurs en culture légumière

Les cultures légumières représentent un marché pour la protection des plantes ou l'engouement pour les techniques de lutte rationnelle est en augmentation. De telles méthodes de lutte comprennent l'utilisation de seuils économiques pour l'établissement de calendrier de pulvérisations, la prévision des populations de ravageurs; l'introduction de macro organismes aux cultures et le maintien des insectes auxiliaires déjà présents. L'introduction de la gestion intégrée des ravageurs et de la production intégrée devient de plus en plus étendue.

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Laboratory studies on the effectiveness of insecticides against caterpillars of the cabbage moth, *Mamestra brassicae* (L.)

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Summary

The effectiveness of the insecticides endosulfan, bromofos-ethyl, methidathion, etrimfos, chlorpyrifos, permethrin, deltamethrin, bifenthrin, cypermethrin and cyfluthrin against caterpillars of the cabbage moth, *Mamestra brassicae* (L.) was studied under laboratory conditions. L_4-caterpillars and L_5-caterpillars, that were 2 - 4 days old and L_6-caterpillars, that were 3 - 6 days old, were placed onto insecticide-treated leaves of Brussels sprouts. Chlorpyrifos, permethrin, cyfluthrin and bifenthrin were extremely effective against caterpillars of the cabbage moth.

Introduction

The cabbage moth, *Mamestra brassicae* (L.) is an important pest of Brussels sprouts crops. This insect lays its eggs on the underside of the plant leaves. At first, the caterpillars feed superficially on the leaves, then make small perforations and later much larger holes. During the last two stadia, the caterpillars cause considerable damage to the crown of the plants. Treatments against the caterpillars of the cabbage moth in Belgium are applied every 2-3 weeks, or when caterpillars are seen damaging the crop. Such treatments do not always produce a satisfactory result, as the effectiveness of the insecticides tends to decrease as the caterpillars get larger. This paper reports on the effectiveness under laboratory conditions of range of doses of 10 insecticides applied to cabbage moth caterpillars of various sizes.

Materials and Methods

Experimental design

Brussels sprouts leaves treated with different doses of an insecticide were presented as food to L_4-caterpillars and L_5-caterpillars that were 2 - 4 days-old, and to L_6-caterpillars that were 3 - 6 days-old. Mortality was recorded after 3 days and at the end of the larval development period. Each experiment involved twenty caterpillars and was replicated twice. The experiments were carried out in growth chambers maintained at 20°C, 75 ± 5% R.H. and a 15 : 9 (light : dark) photoperiod.

Insecticides used and the doses recommended by the Ministerie van Landbouw (1990)

-	organochlorine		Recommended dose
	endosulfan	:	700 mg a.i./l H_2O (2 ml Thiodan 35 EC)
-	organophosphates		
	chlorpyrifos	:	480 mg a.i./l H_2O (1 ml Dursban 4E)
	bromofos-ethyl	:	740 mg a.i./l H_2O (2 ml Nexagan 40 EC)
	methidathion	:	400 mg a.i./l H_2O (1 ml Ultracid 40 EC)
	etrimfos	:	520 mg a.i./l H_2O (1 ml Ekamet 520 g/l)
-	synthetic pyrethroids		
	permethrin	:	50 mg a.i./l H_2O (0,2 ml Ambush 250 g/l)
	deltamethrin	:	7,5 mg a.i./l H_2O (0,3 ml Decis 2,5 EC)
	cypermethrin	:	50 mg a.i./l H_2O (1 ml Ripcord 5 EC)
	cyfluthrin	:	25 mg a.i./l H_2O (0,5 Baythroid 50 EC)
	bifenthrin	:	40 mg a.i./l H_2O (0,5 ml Talstar Flow)

Results and Discussion

The respective mortalities of L_4-, L_5- and L_6-caterpillars of the cabbage moth provided with insecticide treated leaves of Brussels sprouts are shown in Tables 1-3. The organochlorine endosulfan was effective only at the recommended dose against L_4-caterpillars, whereas the organophosphates bromofos-ethyl, methidathion and etrimfos had no effect and should not be used by farmers. In contrast, the organophosphate chlorpyrifos was effective at one-eighth and at one-quarter of the recommended dose against L_4- and L_5-caterpillars, respectively. Only when L_6-caterpillars are present should the recommended dose be applied.

Table 1. Mortality of L_4-caterpillars of the cabbage moth placed onto insecticide-treated leaves of Brussels sprouts. Mortality recorded at A = three days after treatment, and at B = end of larval development

Insecticide		% Mortality* (n = 60)							
		Dose **							
		R/64	R/32	R/16	R/8	R/4	R/2	R	2R
Endosulfan	A				40	68	90	100	
	B				40	70	91	100	
Chlorpyrifos	A	14	46	54	96	100	100	100	
	B	14	79	92	98	100	100	100	
Brom.-ethyl	A				9	15	40	35	
	B				13	37	84	94	
Methidathion	A				12	30	33	85	
	B				63	75	86	100	
Etrimfos	A					5	25	66	94
	B					21	54	90	99
Permethrin	A			7	50	95	95	100	
	B			18	86	95	98	100	
Deltamethrin	A			23	77	67	93	100	
	B			83	91	94	97	100	
Cypermethrin	A			18	78	85	100	100	
	B			18	79	88	100	100	
Cyflurthrin	A		10	15	47	100	100	100	
	B		25	32	62	100	100	100	
Bifenthrin	A		2	6	48	98	100	100	
	B		29	57	91	100	100	100	

* Values corrected according to Abbott (1925)

** R = recommended dose

Table 2a. Mortality of L_5-caterpillars of the cabbage moth placed onto insecticide-treated leaves of Brussels sprouts. Mortality recorded at A = three days after treatment, and at B = end of larval development

Insecticide		% Mortality* (n = 60)						
		L_5-caterpillars (2 days old)						
		Dose**						
		R/32	R/16	R/8	R/4	R/2	R	2R
Endosulfan	A			0	12	60	92	
	B			11	18	69	93	
Chlorpyrifos	A	3	13	47	92	100	100	
	B	42	80	91	100	100	100	
Brom.-ethyl	A			0	12	2	55	
	B			13	43	73	92	
Methidathion	A			0	18	48	78	
	B			6	39	71	91	
Etrimfos	A				0	15	47	98
	B				5	22	55	100
Permethrin	A			36	70	65	95	
	B			45	85	85	100	
Deltamethrin	A	14	61	79	79	100	100	
	B	29	89	95	91	100	100	
Cypermethrin	A		9	43	61	92	100	
	B		35	56	88	98	100	
Cyflurthrin	A		0	22	50	92	100	
	B		7	51	37	98	100	
Bifenthrin	A		5	13	80	91	100	
	B		22	62	95	97	100	

* Values corrected according to Abbott (1925)

** R = recommended dose

Table 2b. Mortality of L_5-caterpillars of the cabbage moth placed onto insecticide-treated leaves of Brussels sprouts. Mortality recorded at A = three days after treatment, and at B = end of larval development

Insecticide		% Mortality* (n = 60) L_5-caterpillars (4 days old) Dose**					
		R/16	R/8	R/4	R/2	R	2R
Endosulfan	A		0	0	7	48	
	B		3	11	13	37	
Chlorpyrifos	A		17	27	45	100	
	B		85	33	94	100	
Brom.-ethyl	A			0	12	68	80
	B			7	56	86	94
Methidathion	A			0	10	23	56
	B			50	48	69	85
Etrimfos	A			7	26	56	93
	B			29	46	60	100
Permethrin	A		11	32	77	100	
	B		18	59	85	100	
Deltamethrin	A			2	22	40	77
	B			9	64	79	99
Cypermethrin	A		0	3	40	87	
	B		7	32	49	94	
Cyflurthrin	A	0	15	60	93	100	
	B	4	33	83	98	100	
Bifenthrin	A	5	16	30	81	100	
	B	38	64	92	94	100	

* Values corrected according to Abbott (1925)

** R = recommended dose

Table 3a. Mortality of L_6-caterpillars of the cabbage moth placed onto insecticide-treated leaves of Brussels sprouts. Mortality recorded at A = three days after treatment, and at B = end of larval development

Insecticide		% Mortality* (n = 60)						
		L_6-caterpillars (3 days old)						
		Dose**						
		R/16	R/8	R/4	R/2	R	2R	3R
Endosulfan	A				0	0	20	43
	B				6	10	26	45
Chlorpyrifos	A		3	31	82	100		
	B		48	87	97	100		
Brom.-ethyl	A				5	32	55	100
	B				33	80	94	100
Methidathion	A				0	0	63	86
	B				13	7	100	100
Etrimfos	A			2	12	41	97	
	B			11	24	56	97	
Permethrin	A		3	26	61	100		
	B		10	29	81	100		
Deltamethrin	A			2	40	67	95	
	B			4	69	80	98	
Cypermethrin	A			12	25	26	100	
	B			11	29	48	94	
Cyflurthrin	A	0	0	7	77	100		
	B	3	3	70	89	100		
Bifenthrin	A	14	39	42	90	100		
	B	49	78	82	98	100		

* Values corrected according to Abbott (1925)

** R = recommended dose

Table 3b. Mortality of L_6-caterpillars of the cabbage moth placed onto insecticide-treated leaves of Brussels sprouts. Mortality recorded at A = three days after treatment, and at B = end of larval development

Insecticide		% Mortality* (n = 60)						
		L_6-caterpillars (6 days old)						
		Dose**						
		R/16	R/8	R/4	R/2	R	2R	3R
Endosulfan	A				5	8	3	2
	B				16	47	56	49
Chlorpyrifos	A		3	12	66	98		
	B		13	71	84	100		
Brom.-ethyl	A				2	2	1	2
	B				9	31	91	92
Methidathion	A				0	0	21	49
	B				8	8	80	95
Etrimfos	A				1	28	45	95
	B				4	39	74	96
Permethrin	A		0	25	73	91		
	B		6	40	82	98		
Deltamethrin	A		7	48	43	90		
	B		56	64	83	98		
Cypermethrin	A				0	28	83	100
	B				18	30	97	100
Cyflurthrin	A		0	0	70	100		
	B		14	67	89	100		
Bifenthrin	A	7	29	26	95	100		
	B	27	61	75	98	100		

* Values corrected according to Abbott (1925)

** R = recommended dose

The synthetic pyrethroids permethrin, cyfluthrin and bifenthrin were effective at one-quarter of the recommended dose against L_2-caterpillars, but the recommended dose was needed to kill L_4- and older caterpillars. Finally, cypermethrin at a half of the recommended dose was effective against L_4-caterpillars, whereas the recommended dose was needed to kill L_5-caterpillars. A higher dose was needed to control older caterpillars of the cabbage moth.

Conclusions

Bromofos-ethyl, methidathion and etrimfos were not effective, and endosulfan was effective only against L_4-caterpillars of the cabbage moth. Chlorpyrifos, permethrin, deltamethrin, bifenthrin and cyfluthrin were effective against L_4- and L_5-caterpillars at one-eighth to one-half of the recommended dose and against old L_5-caterpillars and L_6-caterpillars at the recommended dose. Cypermethrin was effective only against L_4- and small L_5-caterpillars of the cabbage moth at the recommended dose.

Résumé

Etudes en laboratoire de l'efficacité des insecticides utilisés contre les chenilles de la noctuelle du chou *Mamestra brassicae* (L.)

L'efficacité des insecticides tel que l'endosulfan, le bromophos-éthyl, l'étrinfos, le chlorpyriphos, la permethrine, la deltamethrine, le bifenthrin, la cypermethrine et la cyfluthrine utilisés contre la noctuelle du chou *Mamestra brassicae* (L.) a été étudiée en conditions de laboratoire. Les chenille 14 et 15 âgées de 2 à 4 jours et les chenilles 15 âgées de 3 à 6 jours ont été placées sur des feuilles de choux de Bruxelles traitées préalablement aux insecticides. Le chlorpyriphos, la permethrine et le bifendion sont extrêmement efficaces contre les chenilles de noctuelle du chou.

Acknowledgement

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Fate of insecticide deposits on the leaves of Brussels sprout plants

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Summary

The fate of endosulfan, bromofos-ethyl, chlorpyrifos, methidathion, etrimfos, permethrin, deltamethrin, cyfluthrin, cypermethrin and bifenthrin deposits on the leaves of Brussels sprout plants was studied during 1989, 1990 and 1991. The experiments were carried out at different times during the season. The organophophate insecticides chlorpyrifos, etrimfos, methiathion and, to a lesser extent, bromofos-ethyl disappeared quickly from the leaves. In contrast, 20%-25% of the initial dose of the synthetic pyrethroids permethrin, cypermethrin, cylfuthrin and bifenthrin could still be extracted from the sprayed leaves 14 days after treatment and 8 days after treatment in the experiment with deltametrin.

Introduction

The cabbage moth, *Mamestra brassicae* (L.) is an important pest of Brussels sprouts. This insect lays its eggs at the underside of the leaves and the caterpillars feed superficially on the leaves at first and then make small perforations and later much larger holes. During the last two stadia the caterpillars cause considerable damage to the crown of the plants. Many insecticides are applied against the caterpillars of the cabbage moth in Belgium.

A re-treatment is justified only when the amount of insecticide on the leaves is not effective against the caterpillars. This paper reports the rate of decline of insecticide deposits on the leaves of Brussels sprouts.

Materials and Methods

Experimental design

Brussels sprouts were sprayed at different times during the growing season. Twelve experiments were done with the insecticides endosulfan, bromofos-ethyl and permethrin; eight with the insecticides deltamethrin, cyfluthrin and bifenthrin; seven with the insecticides methidathion, etrimfos and cypermethrin and six with the insecticide chlorpyrifos. After treatment, the leaves sprayed with the various solutions were marked. Plots consisted of 2 rows of 15 plants with three replications.

Insecticides used and the doses recommended by the Ministerie van Landbouw, 1990

- organochlorine			Recommended dose
	endosulfan	:	700 mg a.i./l H_2O (2 ml Thiodan 35 EC)
- organophosphates			Recommended dose
	chlorpyrifos	:	480 mg a.i./l H_2O (1 ml Dursban 4E)
	bromofos-ethyl	:	740 mg a.i./l H_2O (2 ml Nexagan 40 EC)
	methidathion	:	400 mg a.i./l H_2O (1 ml Ultracid 40 EC)
	etrimfos	:	520 mg a.i./l H_2O (1 ml Ekamet 520 g/l)
- synthetic pyrethroids			Recommended dose
	permethrin	:	50 mg a.i./l H_2O (0,2 ml Ambush 250 g/l)
	deltamethrin	:	7,5 mg a.i./l H_2O (0,3 ml Decis 2,5 EC)
	cypermethrin	:	50 mg a.i./l H_2O (1 ml Ripcord 5 EC)
	cyfluthrin	:	25 mg a.i./l H_2O (0,5 Baythroid 50 EC)
	bifenthrin	:	40 mg a.i./l H_2O (0,5 ml Talstar Flow)

Fate of the insecticide deposits

The amount of insecticide on the plant leaves was determined by gas chromatography, 0, 3, 6, 9 and 15 days after treatment with endosulfan, bromofos-ethyl and permethrin; and 0, 2, 4, 6, 8, 10, 11 and 14 days after treatment with the other insecticides tested. The extraction and determination of bifenthrin, cyfluthrin, cypermethrin, deltamethrin, endosulfan and permethrin was as follows: 50 g of the chopped sample was homogenized for 5 min with 200 ml of an acetone/petroleum ether mixture in a blender. After filtration through a Buchner funnel, the filtrate was transferred to a separating funnel. The extract was washed twice with a mixture of 200 ml distilled water and 25 ml saturated sodium chloride solution. The water phases were discarded and the combined petroleum ether extracts were dried over anhydrous sodium sulphate. After determination of the volume, the pesticide residues were detected by gas chromatography with an electron capture detector (ECD).

For the extraction and determination of the residues of bromofos-ethyl, etrimfos and methidathion, 50 g of chopped plant material was homogenized for 50 min with 200 ml ethyl acetate in a blender. After filtration through a Buchner funnel, the filtrate was dried over anhydrous sodium sulphate. The filtrate was evaporated on a rotary evaporator and the residue was redissolved in 5 ml ethyl acetate. The pesticide residues were detected by gas chromatography with a flame-photometric detector in the phosphor mode.

Results and Discussion

The fate of endosulfan, chlorpyrifos, etrimfos, methidathion, bromofos-ethyl, permethrin, deltamethrin, cyfluthrin and cypermethrin on the leaves of Brussels sprouts after treatment are shown in Tables 1 & 2.

Table 1. Amount of insecticide recovered from leaves of Brussels sprouts plants sprayed with endosulfan, bromofos-ethyl and permethrin

Insecticide applied	Days after chemical applied to leaves				
	0	3	6	9	15
	% recovery of chemical*				
Endosulfan	100	17.8 ± 1.8	9.8 ± 1.7	7.6 ± 1.5	3.0 ± 0.7
Bromofos-ethyl	100	45.0 ± 3.7	27.7 ± 2.7	20.9 ± 2.8	13.7 ± 2.6
Permethrin	100	61.7 ± 6.6	50.3 ± 4.5	38.4 ± 5.0	28.3 ± 3.4

* means ± s.e.

Throughout the growing season, endosulfan, chlorpyrifos, etrimfos and methidathion disappeared quickly from the leaves. For example, within 2-3 days of treatment less than 25% of the endosulfan and less than 10% of the chlorpyrifos could be detected after a treatment with methidathion or etrimfos could be determined on the leaves. In contrast, 50% and 30% of the initial dose of bromofos-methyl could be detected 3 and 6 days after treatment, respectively.

Table 2. Amount of insecticide recovered from leaves of Brussels sprouts plant sprayed with bifenthrin, chlorpyrifos, cyfluthrin, cypermethrin, deltamethrin, etrimfos and methidathion

Insecticide applied	Days after chemical applied to leaves			
	0	2	4	6
	% recovery of chemical*			
Bifenthrin	100	83.7 ± 5.0	68.4 ± 5.7	58.5 ± 5.7
Chlorpyrifos	100	21.7 ± 3.3	9.2 ± 2.7	6.2 ± 0.9
Cyfluthrin	100	62.7 ± 5.2	47.9 ± 6.5	44.9 ± 6.5
Cypermethrin	100	81.7 ± 7.7	64.8 ± 5.7	51.1 ± 6.1
Deltamethrin	100	62.3 ± 7.6	42.4 ± 6.6	32.0 ± 6.7
Etrimfos	100	3.4 ± 1.2	0.7 ± 0.1	0.6 ± 0.1
Methidathion	100	15.6 ± 2.3	4.8 ± 1.9	1.2 ± 0.5
	Days after chemical applied to leaves			
	8	10	12	14
	% recovery of chemical*			
Bifenthrin	55.8 ± 5.5	47.3 ± 4.1	43.8 ± 2.2	41.8 ± 2.6
Chlorpyrifos	4.0 ± 1.1	3.4 ± 1.3	1.8 ± 0.6	0.9 ± 0.5
Cyfluthrin	40.5 ± 4.7	35.9 ± 4.7	31.3 ± 3.8	27.0 ± 3.6
Cypermethrin	42.6 ± 4.0	40.0 ± 4.3	37.4 ± 4.6	35.3 ± 3.4
Deltamethrin	23.5 ± 4.2	10.0 ± 4.0	3.3 ± 2.3	3.0 ± 2.1
Etrimfos	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1
Methidathion	0.5 ± 0.3	tr**	tr	tr

* means ± s.e.
** tr = trace

The fate of the synthetic pyrethroids differed appreciably during the growing season. However, in all tests, 20% and 25% of the initial dose could still be detected on leaves 14 days after treatment except in the experiments with delatamethrin. Such residues were still effective against fourth instar caterpillars of the cabbage moth.

Conclusions

The organochlorine insecticide endosulfan and organophosphate insecticides chlorpyrifos, etrimfos, methidathion and to a lesser extent bromofos-ethyl disappeared quickly from sprayed leaves of Brussels sprouts, whereas 20%-25% of the initial dose of the synthetic pyrethroids permethrin, cypermethrin, cylfuthrin and bifenthrin could still be detected on the leaves 14 days after treatment.

Résumé

Résidus des insecticides déposés sur les feuilles des plants de choux de Bruxelles

Les résidus de l'endosulfan, du bromophos-éthyl, du chlorpyriphos, du méthidathion, de l'étrimfos, de la permethrine, de la cyfluthrine, de la cypermethrine et du bifendion déposés sur les plants de choux de Bruxelles ont été mesurés en 1989, 1990 et 1991. Les mesures ont été réalisées à différentes dates de la saison.

Les insecticides organo-phosphorés tel que le chlorpyriphos, l'étrimfos, le méthidathion et dans une moindre mesure le bromophos-éthyl disparaissent rapidement des feuilles. Au contraire, 20% - 25% de la dose initiale des produits de synthèse comme les pyréthrinoides, permethrine, deltamethrine, cypermethrine, cyfluthrine et bifendion peuvent encore être extrait des feuilles traitées 14 jours après la pulvérisation.

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Reference

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