IOBC / WPRS

Working Group

"Integrated Control in Field Vegetable Crops"

OILB / SROP

Groupe de Travail

"Lutte Intégrée en Culture de Légumes"

PROCEEDINGS of the MEETING

COMPTE RENDU de la RÉUNION

Guitté (France)
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INTRODUCTION

Although pest control in most countries is based currently almost entirely on the application of commercially-produced insecticides, only three papers dealt specifically with insecticidal control. Members have now generally accepted that the main emphasis of this Working Group should be to develop methods that help to reduce the amounts of insecticide applied to control pest insects in field vegetable crops. At the same time, however, we recognise the importance of retaining considerable expertise on insecticides with the Group, as insecticidal control is the standard against which all alternative methods have to be judged.

The three major themes discussed at Guitté were concerned with 1) monitoring and forecasting pest insect attacks, 2) undersowing crops with clover to reduce colonization of vegetable crops by pest insects, and 3) the considerable interest now being shown, particularly in France, England and the Scandinavian countries in using the parasitoid beetle *Aleochara bilineata* to control the cabbage root fly.

Many of the pest monitoring and pest forecasting systems were being used as the basic components for developing Integrated Production systems, which people now believe should be used to produce 'Guidelines' on how crops should be produced for minimum environmental disturbance. At both the previous meeting in Einsiedeln, Switzerland and at Guitté, Group members had considerable doubts about whether Guidelines could ever be implemented satisfactorily in the major vegetable producing countries. However, as several other Working Groups have had considerable success with this type of approach, it seems to be one subject that is not going to go away. Therefore, there will be a need to find someone within the Group who would be willing to champion this cause and steer the Group into making firm recommendations concerning this subject at the next meeting in Crete.

Our other outstanding project is the Carrot Fly Bulletin, the data for which has been gathered fastidiously by Jost Freuler over the last 5 years. As it is three meetings since this Project was first proposed, it is imperative that we now complete and publish this Bulletin prior to our arrival in Crete. The major drawback to date has been the heterogeneity of the data, as some subjects have been studied in depth and others have been more or less totally neglected. I now feel that instead of trying to be all-embracing, we should set a standard concerning the type of data that is acceptable and include only that information. This will highlight the neglected areas and indicate where further work is needed for future Bulletins. Whatever happens, if this Bulletin is to be accepted by scientists other than those within the Group it must be of an appropriately high standard. It will also need to be critical rather than encyclopedic, otherwise the readers will simply refer to the references cited rather than to the publication itself.

The other major topics discussed formally at Guitté were the population dynamics of pest species, Supervised Control, the effects of fertilizers on pest and beneficial insects and crop covers. The aim of the Group is to discuss all aspects of research on our major pest species so, if anyone knows of suitable contributors, I would welcome future papers on insect behavioural studies and pest control involving entomopathogenic fungi and/or nematodes.

The meeting in Guitté was appreciated greatly by all participants. I therefore thank Dr Etienne Brunel and his colleagues from Le Rheu and Rennes for choosing an out-of-season Holiday Village as a superb venue for the meeting, for obtaining sponsorship for the excellent wines and seafood, and for all they did with the local arrangements to make our meeting in Guitté so enjoyable.

Finally, I thank Mrs Ruth Gez, secretary of the Department of Entomological Sciences at HRI Wellesbourne for her invaluable help during the production of this Bulletin and for the marvellous job she did in re-typing the manuscripts into a standard format.

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Using trapping data to decide whether or not to spray against the carrot fly

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Summary

Carrot fly traps sample a very small proportion of the overall fly population. Because of random variation and the uneven distribution of carrot fly, each trap will give a different measure not only of the size of the fly population, but also of the pattern, and/or timing, of fly activity. This paper discusses how sample size and trap location affect estimates of these aspects of the population dynamics of the carrot fly (*Psila rosae* F.).

Introduction

Carrot fly (*Psila rosae* F.) monitoring data can be used to time pesticide applications, to determine treatment thresholds or to validate carrot fly forecasts. In the UK, carrot growers use trap catches to indicate the timing of fly activity, but as yet there are no reliable thresholds to indicate whether an insecticidal treatment should, or should not be, applied.

Carrot fly traps sample a very small proportion of the overall population. Each trap will give a different measure not only of the size of the fly population, but also of the pattern, and/or timing, of fly activity. For example, Fig. 1 shows the numbers of flies captured on three traps at HRI Stockbridge House in 1992. Although the total numbers of flies captured on the three traps were similar, the pattern of fly activity differed between the traps, probably as a result of random variation.

In most commercial crops, quite low numbers of carrot flies are caught and, even at times of peak activity, it is not unusual to trap less than 10 flies/trap/week (Collier *et al.*, 1990; Philipsen, 1988), especially when relatively ineffective traps are used. When fly numbers are low, random variation may limit the amount of accurate information that can be extrapolated from the numbers of flies caught on traps (Collier *et al.*, 1992; Collier & Phelps, 1994).

Using monitoring data to estimate the timing of carrot fly activity

Studies made during the development and validation of a model to simulate carrot fly development (Phelps *et al.*, 1993) indicated the numbers of flies that should be trapped to produce reliable estimates of the timing of fly activity. When the timings for when 10% (start) and 50% (mid-point) of the flies became active in each generation were estimated from field monitoring data, more than 100 flies had to be trapped per generation to obtain estimates that were accurate to within one week (Collier & Phelps, 1994).

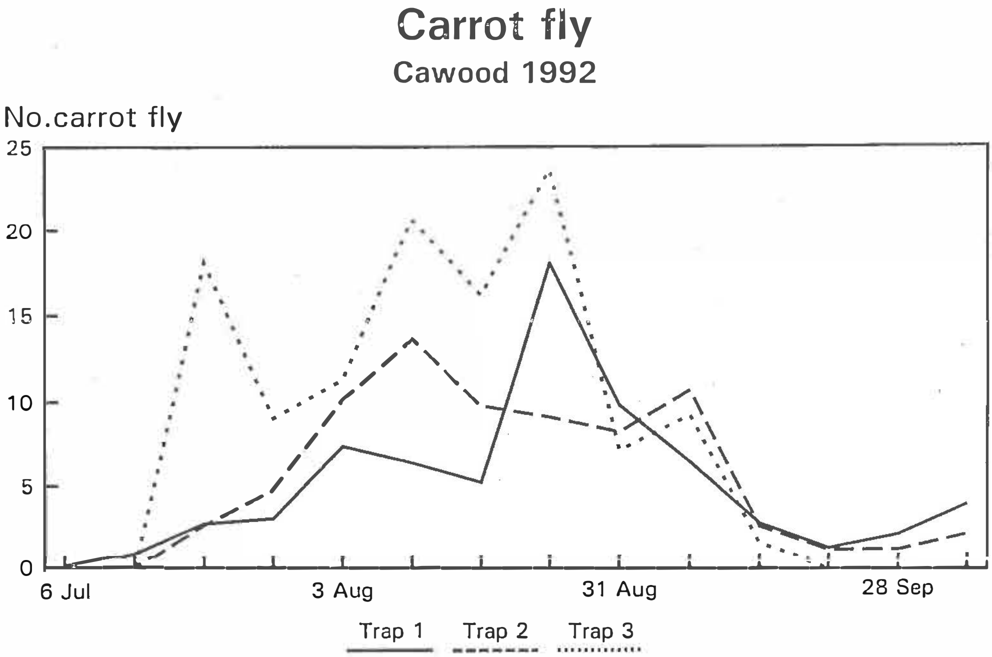

Fig. 1: The numbers of carrot flies captured on the three individual monitoring traps used in one field at HRI Stockbridge House in 1992.

Development of treatment thresholds

It is essential that the size of fly populations in commercial carrot fields can be assessed accurately, if reliable treatment thresholds are ever to be developed for the carrot fly (Vincent, 1996; Finch & Vincent, 1996).

Sample size

The carrot fly treatment thresholds used in Europe and North America have, to date, been based on the capture of low numbers of flies (Esbjerg *et al.*, 1988; Den Ouden & Theunissen 1988; Chaput, 1993) and this may limit their validity (Collier & Phelps, 1994).

Fig. 2 shows the relationship between the log variance and log mean of the numbers of flies trapped/week from sets of three traps at a site where large numbers of carrot flies were trapped. The numbers of flies trapped follow a Poisson distribution when the fly population is low (mean= <7 flies trapped/week). Trapping is then effectively random and trap-to-trap variability, due to positional effects, is not apparent (Collier & Phelps, 1994). For the Poisson distribution, the variance is equal to the mean. Hence a decision based on the capture of 30 flies will be three times more accurate than a decision based on three flies, and a decision based on 300 flies will be 10 times more accurate.

When the fly population is high (mean = >7 flies trapped/week), the slope is >1 due to the trap-to-trap variation in the numbers of flies caught. Therefore, although the Poisson formula can be applied to the total flies trapped, it will underestimate the variability in fly numbers if there are positional effects. The slope of the line will then depend on where the traps are placed and the numbers of flies captured by each of them.

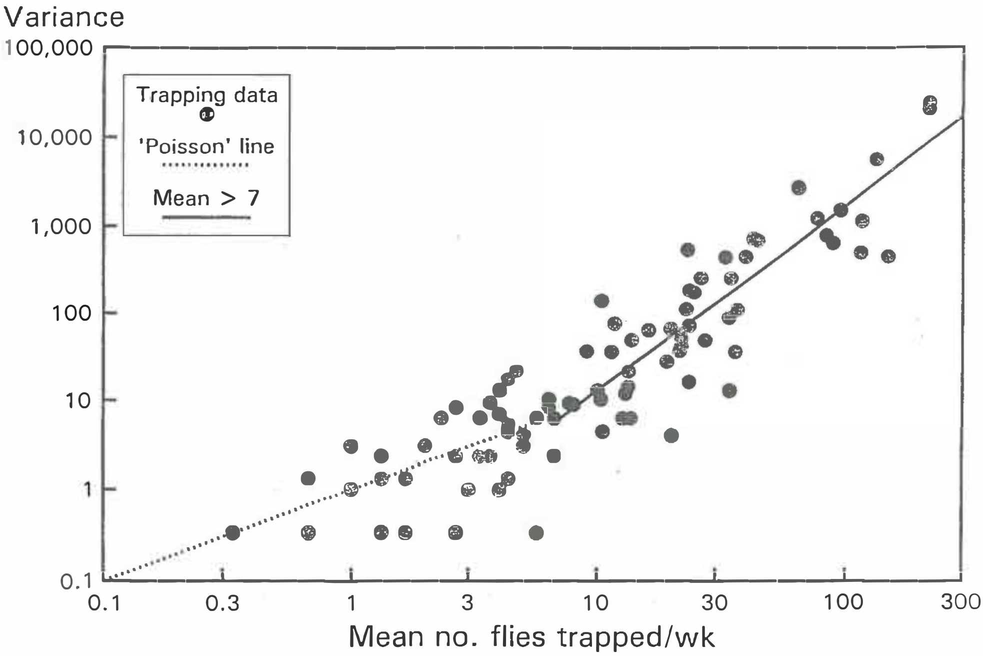

Fig. 2: The relationship between the log variance (on 2d.f.) and log mean of the numbers of carrot flies trapped each week from three replicate traps. The 'Poisson' line (variance = mean) is also shown.

Within-field distribution of carrot fly

It is well known that carrot flies and subsequent carrot fly damage are not distributed uniformly throughout a crop. Fly populations and damage are usually concentrated around field margins, particularly in sheltered fields (Petherbridge & Wright, 1943; Judd *et al.*, 1985). Thus the number of carrot fly traps used, and where they are placed, will to a great extent determine the accuracy of the estimate obtained.

Fig. 3 shows the distribution of carrot fly plotted from one corner of a carrot field in Norfolk, England. The data were obtained by setting out traps in a series of transects. At the edges of the crop, the numbers of flies trapped during the second generation of flies in 1994, changed rapidly with distance from the field margin. It is evident that placing a trap 0.5m nearer to, or further from, the 'edge' of the field would have altered considerably the numbers of flies estimated to be in the field. Thus, placing a line of traps a few metres into a crop and parallel to the field margin may provide a very unreliable estimate of the size of the fly population, although the relatively large numbers of flies caught should allow a more accurate estimation of the timing of fly activity.

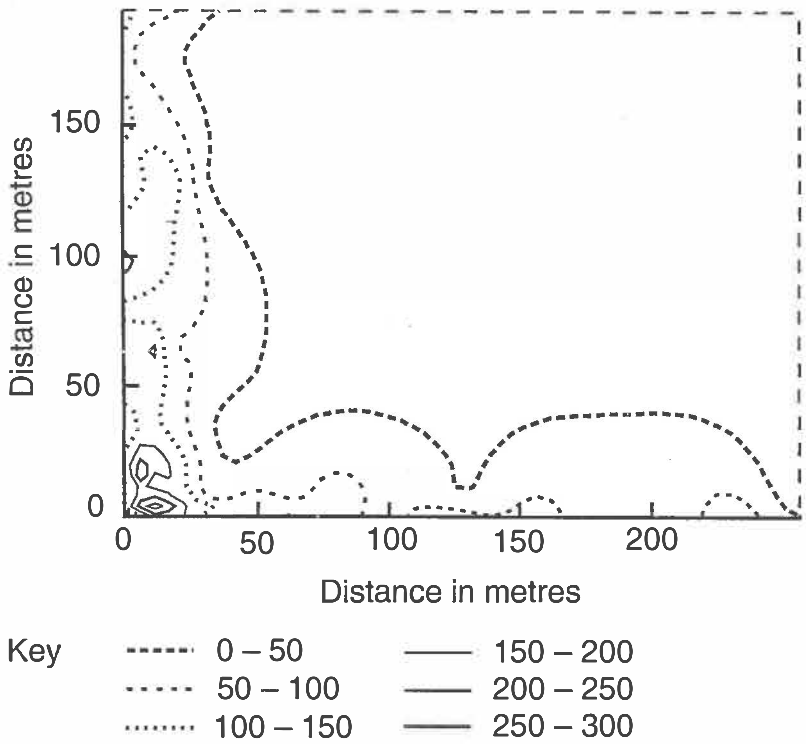

Fig. 3: The distribution of the total number of adult carrot flies captured on yellow sticky traps during the second generation in a commercial carrot crop during 1994.

Discussion

When the numbers of carrot fly caught on traps are used for timing pesticide treatments, to decide whether a treatment threshold has been exceeded or to validate pest forecasts, problems will arise whenever the decisions are based on the capture of low numbers of flies. Hence, whenever possible, growers/advisers should try to use large numbers of effective traps to capture carrot fly, as this will enable them to have more confidence in the information on which they are basing their decisions.

The uneven distribution of adult flies in commercial carrot crops means that it is difficult to estimate accurately the size of any fly population in any field using just a few traps. However, if an accurate carrot fly treatment threshold is to be developed, it is essential that field populations of flies are assessed accurately. The questions to be addressed during the next three years, therefore, are 'How many traps are needed?' and 'Where should they be placed'.

Résumé

Utilisation des données de piégeage pour décider s'il faut pulvériser ou pas contre la mouche de la carotte

Les pièges à mouche de la carotte échantillonnent une proportion très faible de la totalité de la population de mouche. En raison des variations dues au hasard et de la distribution inégale de mouche de la carotte, chaque piège donne une mesure différente non seulement de la taille de la population mais aussi du modèle et/ou de la période d'activité des mouches. Cet article discute quelle taille d'échantillon et quelle localisation du piège agissent sur les estimations de ces aspects de la dynamique des populations de mouche de la carotte (*Psila rosae* F.).

Acknowledgements

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Extracting carrot fly larvae from soil samples

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Summary

Commercially-available Tullgren funnels were shown to be suitable for extracting each of the three larval instars of the carrot fly from soil samples. The skill in using this technique lies in being able to identify the carrot fly larvae, particularly the small 0.5-2 mm long 1st-instar larvae, from all of the other fly larvae present in the samples. The method will be used to quantify the various mortality factors affecting carrot fly larvae. Such information will be incorporated into a model aimed at predicting crop damage at harvest from the numbers of flies caught on yellow sticky traps earlier in the season.

Introduction

A new three-year project to develop "Pest thresholds for the treatment of carrot fly" will be started in April 1996 (see Vincent, 1996). The main aim will be to relate the numbers of carrot flies (*Psila rosae* Fab.) caught on yellow sticky traps (Finch & Collier, 1989) to the amounts of crop damage found at harvest.

This paper describes a preliminary study to find a method suitable for extracting all three larval instars of the carrot fly, as it is essential to quantify larval mortality if fly numbers are ever to be linked to crop damage.

Materials and methods

Twice weekly, from mid June 1994 to the end of October 1995, 12 soil cores were taken from plots of carrots that had not been treated with insecticide. Each core was 10cm in diameter and 15cm deep and was taken with a Soil Sampler made in the Technical Services Department at HRI Wellesbourne. The soil cores were taken directly from along the carrot rows, so that each sample contained some carrot roots. The samples were then placed into a bank of 12 Tullgren funnels (Burkhard Manufacturing Co., Rickmansworth, Herts, UK) (see Murphy, 1962) designed to produce a temperature gradient of approximately 14°C down each soil sample. The heat source above each sample stimulated the downward movement of soil arthropods into glass collecting bottles, about one-quarter filled with 70% alcohol. The soil samples were subjected to heat for 4 days. At the end of this period, the collecting bottles were removed, labelled and taken to the laboratory. The now dry soil samples were placed individually into plastic boxes and soaked for at least an hour. Each sample was then stirred in water in a 9 litre bucket, the water and suspended material being poured onto a 0.8mm aperture sieve and any insect stages retained on the mesh rinsed clean, picked off with fine forceps and counted (Finch & Skinner, 1980). This was done to extract not only the fly pupae but also the third-instar larvae that become inactive prior to pupation. The contents of the collecting bottles were then inspected using a stereomicroscope and the carrot fly larvae were separated from all the other arthropods, and measured.

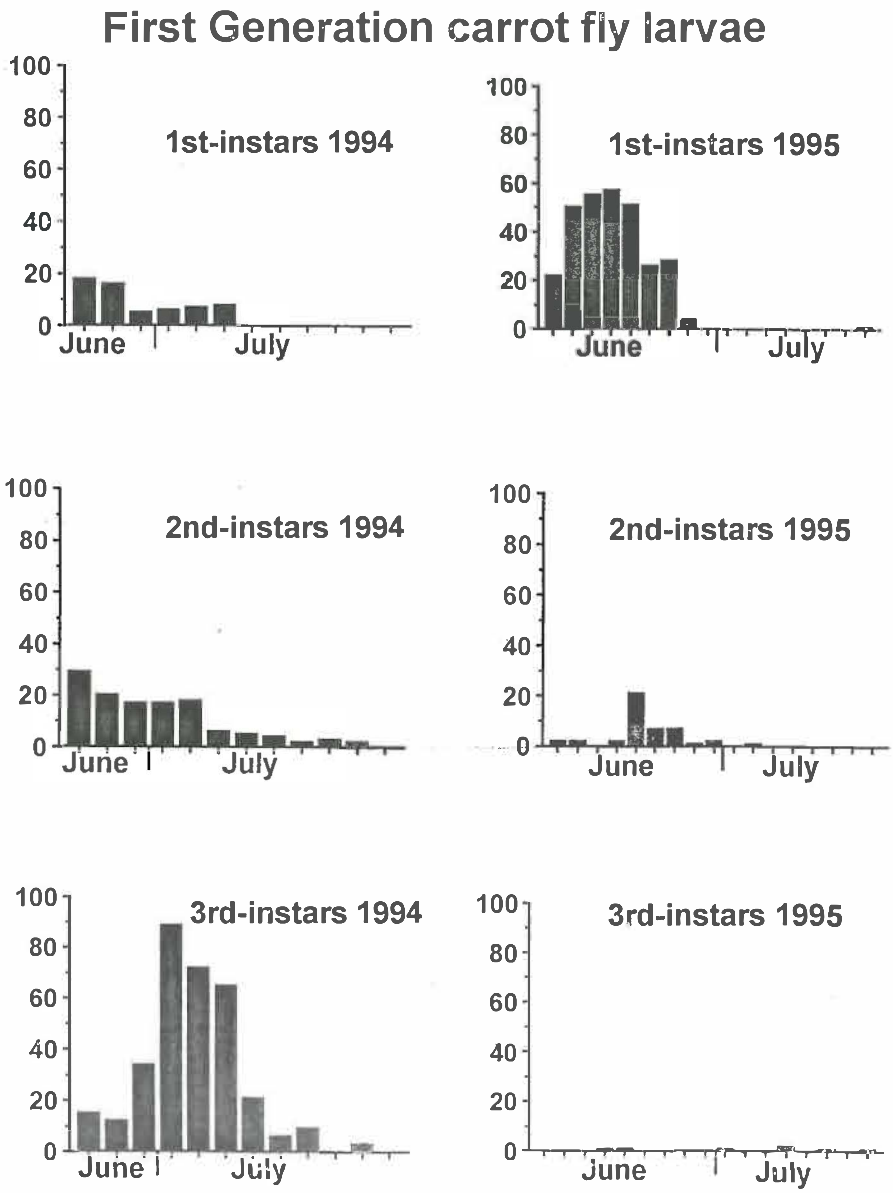

Fig. 1: The total numbers of each of the three carrot fly instars recovered from 12 soil cores taken twice weekly during the first fly generation in both 1994 and 1995.

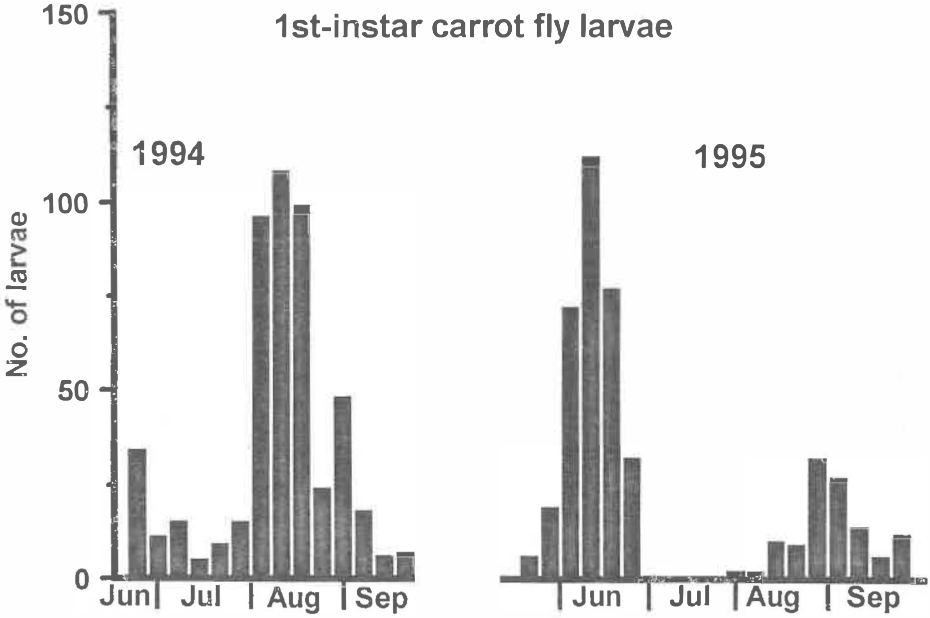

Fig. 2: The total numbers of 1st-instar larvae recovered from 24 soil cores taken each week during 1994 and 1995. The sampling was started only towards the end of egg-laying by the flies of the first generation in 1994.

Results

The carrot fly larvae recovered from the collection bottles varied in length from 0.5mm to 7.8 mm. Larvae between 0.5-2.0mm, 2.1-5.0mm and 5.1-7.8mm long were considered to be 1st-, 2nd- and 3rd-instars, respectively, as indicated by Wright (1946). The numbers of each of the three carrot fly instars recovered during the first generation (spring flight) in both 1994 and 1995 are shown in Fig. 1. The data for 1994 are not complete, as sampling was started only towards the end of June when most of the flies of the first generation had finished laying. The apparent increase in the numbers of 3rd-instar larvae, shown in the 1994 data, occurred merely because the duration of the two earlier instars occupy much shorter time intervals than that of the 3rd-instars. The 1995 data show clearly that even when high numbers of 1st-instar larvae are present in a crop, it does not follow automatically that there will also be high numbers of 2nd and 3rd-instar larvae.

Even though few insects survived to the 3rd-instar larval stage during the first generation in 1995 (Fig. 1), relatively high numbers of 1st-instar larvae may still be present in the subsequent generation (Fig. 2).

The temperatures and rainfall were similar during June and July in both years. However, during the last 5 days of June there was no rainfall in either year but the maximum temperature averaged 23.5°C in 1994 compared to 28.1°C in 1995.

Discussion

Being able to extract 1st-instar carrot fly larvae means that it is now possible to make an assessment of the effects of a wide range of treatments on the insects directly, shortly after treatments have been applied, rather than having to wait long periods before making indirect assessments based on root damage. The expertise required for using this system involves being able to identify carrot fly larvae, particularly the newly-hatched 0.5mm-long individuals, from all of the other fly larvae found in the soil beneath carrot crops. This is done by collecting larvae from a laboratory culture of the carrot fly, preserving the larvae in the same alcohol solution used in the collecting bottles, and using the preserved insects for reference. The fly larvae that are found in the samples and that are not carrot fly, are identified to family level using the information and illustrations present in Smith (1989).

Results obtained in 1995, using this Tullgren funnel system, indicated that the high temperatures (mean 28.1°C) during late June may have killed most 1st-instar larvae shortly after they emerged from the eggs, as there was an abrupt end to when 1st-instar larvae were found in July 1995 (Figs 1 & 2). As few larvae survived to the 2nd-instar and 3rd-instars (Fig. 1.), they may also be killed by a lethal combination of high temperatures and low soil moisture. Further work is needed to determine whether one, or both, factors are involved.

At an earlier meeting of this Working Group, Bodil Jönsson (1992) described a system, based on accumulated heat units, for deciding when to harvest carrot crops in Sweden to stop damage showing on the harvested produce. In essence, this was done by harvesting the crop before the fly larvae had time to moult into the 2nd-instar, the size at which they begin to produce visible damage on the carrot roots. While such an approach might be acceptable for mainland Europe where carrot crops have to be lifted and stored prior to winter to prevent them being destroyed by frost, it is unlikely to be adopted widely in the UK as carrot crops are usually left in the soil throughout the year as winters are relatively mild. Therefore, the approach that will be adopted in the new research programme (see Vincent, 1996) will be to determine how fly numbers are affected not only by the weather but also by predators, pathogens, parasitoids and resistant plants, and then to use the combined data to predict the levels of damage that will occur after any given time in any given carrot-growing system. Such information should enable growers to decide upon the optimum timing for scheduling the harvesting of their crops, or parts of crops, to ensure that damage on the harvested roots is kept to an acceptable level.

Résumé

Extraction des larves de mouche de la carotte d'échantillon de sol

Les entonnoirs de Tullgren, trouvés dans le commerce, se révèlent très utiles pour extraire du sol chacun des trois stades larvaires de la mouche de la carotte. Très facile d'emploi, cette technique permet l'identification des larves de mouche de la carotte, en particulier le premier stade larvaire, qui mesure 0,5 à 2 mm de long, des autres larves de mouche présentes dans l'échantillon. La méthode sera utilisée pour quantifier les différents facteurs de mortalité intervenant sur les larves de mouche de la carotte. Les résultats seront inclus dans un modèle dont le but est de prévoir les attaques aux champs observés à la récolte, à partir du nombre de mouches capturées plus tôt dans la saison au moyen du piége à glu jaune.

Acknowledgement

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Is there an easy method for monitoring root flies in Brassica crops?

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Summary

Most of the known methods for monitoring root flies were tested. Water traps were tried, but were soon abandoned due to the great diversity of similar fly species caught. Sorting of water trap catches was too time consuming to be of practical value. A new, selective water trap (Brassiceye®) was tested in both Norway and Denmark in 1994, and in Norway and the USA in 1995. Results indicated that the catch was much too small for use in monitoring and that the trap only began catching the flies after peak oviposition.

Direct counts of eggs in the field gave an indication of when oviposition started, but counting eggs was very difficult, and there was great variability between "scouts", especially in a grower-based system. Direct counts added the risk that the same eggs would be counted on more than one occasion. Presence-absence counts correlated well with the number of eggs in soil samples.

Collecting soil from the base of the plants should give the best indication of the actual number of eggs present at any given time. Eggs can be removed from the soil by flotation. In practice, eggs are difficult to count in some soil types due to the presence of organic matter or clay. For this reason, clean sand was used instead of soil around the base of plants used for monitoring.

Results for field experiments in several localities in Norway and Denmark produced large differences in the numbers of eggs counted using the different monitoring methods. In many instances there was a good correlation between the number of eggs recorded using soil-flotation, sand-flotation or felt traps. Under extreme conditions, or when oviposition was low, the felt traps usually did not contain eggs.

Introduction

The cabbage root fly (*Delia radicum*) is the most important pest of brassica vegetable and root crops in Denmark and Norway. It is also a pest in some years in the northeastern

USA. The turnip root fly (*D. floralis*) is equally important as a pest of both brassica root crops and some cole crops in Norway. Both of these pests have been controlled traditionally by preventative chemical methods. Withdrawal of insecticides from the market, the reduced effects of insecticides in the field, and the development of IPM programs, have created a need for methods to establish the time and intensity of oviposition in the crop.

Since the mid-1980´s, several systems have been used to monitor cabbage root fly populations in northern Europe. These systems have been based mainly on using either water traps for the adult flies or felt traps for monitoring egg numbers. In Denmark, felt traps have been used since 1985 for a centralized monitoring program co-ordinated by the Danish Institute of Plant and Soil Science, Department of Plant Pathology and Pest Management, in Lyngby (Bromand 1988).

At the outset of the Nordic project, "Reducing the Use of Insecticides in Brassica Vegetable and Root Crops", an attempt was made to adapt the Danish monitoring system for Norwegian conditions. Deficiencies in the felt traps, similar to those described by den Ouden (1988), became evident. This led to the investigation of other methods.

Materials and Methods

Seven methods of monitoring brassica root flies were investigated during 1991-95. These seven were the felt 'egg-traps', flotation of the fly eggs from soil samples, flotation of the fly eggs from sand samples, direct counts of the eggs seen around the base of crop plants, the presence or absence of eggs in the soil around crop plants, the yellow water traps, and the Brassiceye® selective traps.

The number of fly eggs found in the felt traps, the soil samples and the sand samples were counted twice weekly, as were the direct egg counts and the presence-absence counts . Flies captured in the water traps and Brassiceye® traps were counted once a week.

The felt 'egg-traps' (Freuler & Fischer, 1983) were placed around the plant base and were removed for counting the eggs. Eggs were removed before replacing the traps on the plants.

For the flotation from soil method, the soil was collected from around the plant base in a radius of approx. 5 cm and a depth of 2 cm to fill a 100 cc container. The soil was then taken to the laboratory and poured into containers of water to float out the eggs. Soil from between the plant rows was used to replace the soil removed from around the plants at sampling (Hughes & Salter, 1959).

Flotation from sand samples was done in the same way as for soil, except that sand placed previously around the base of the plant was removed and replaced with clean sand. This facilitated egg counting by eliminating problems with organic matter and other particles floating in the water.

Direct egg counts were done by moving the stem of the plant slightly and counting the number of eggs on the stem or between the stem and the soil. In the Norwegian experiments, the eggs themselves were removed, whereas in the Danish experiments the soil was removed after counting and replaced with soil from between the plant rows. Direct counts were not made in the USA trials.

The presence-absence counts were done in the same way as the direct counts, except that only the presence or absence of eggs was recorded, not the actual numbers of eggs.

The yellow water traps were placed on posts with adjustable holders to keep them just above the vegetation. In the studies in 1995 in the USA, water traps as described by Finch (1991) were used, with the inside walls painted black to exclude syrphid flies. These traps were placed on bare soil between the crop and border vegetation. Attractants were not added to the traps.

A new, selective water trap (Brassiceye®) was tested in Denmark and Norway in 1994, and in Norway and the USA in 1995. The trap uses ethyl-isothiocyanate to help attract cruciferous pests, and it was believed that this chemical would increase trap selectivity. The openings into the trap are small, to exclude unwanted insects. These traps were placed around the edges of fields. In one experiment in the USA, an extra row of holes was made in the traps to increase the rate of release of the attractant. It was hoped that this would increase the numbers of flies caught.

The data from the different egg counting methods were compared with the data from the soil flotation method using regression analysis. The data from the water traps and Brassiceye® traps were not subjected to statistical analysis.

Results and Discussion

Field experiments in several localities in Norway and Denmark showed large differences in the numbers of eggs recorded using the different monitoring methods. There was good correlation between the numbers of eggs recovered using flotation from both the soil and the sand samples. The numbers of eggs counted from the sand samples was usually higher than from the soil samples (e.g. Fig. 1). These experiments do not indicate whether this is due to the presence of more eggs or the ease with which eggs could be counted.

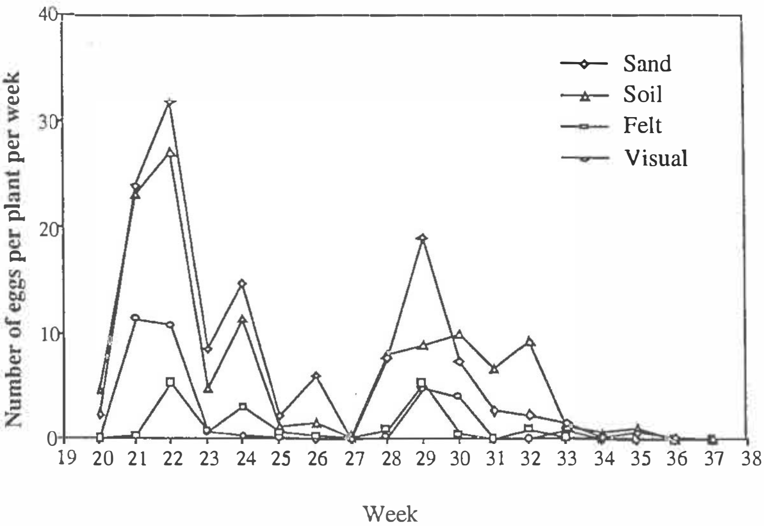

Fig. 1: Number of brassica root fly eggs (*Delia radicum* and *D. floralis*) found using four sampling methods, Ski, Norway, 1992.

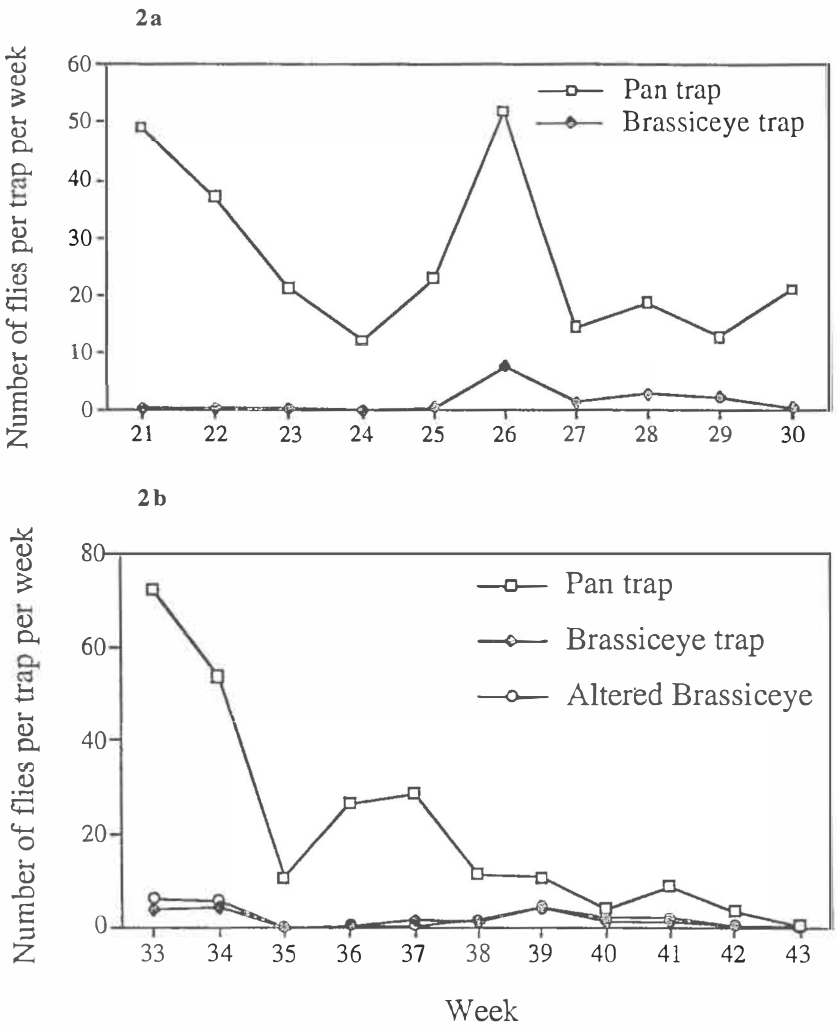

Fig. 2: Numbers of cabbage root flies (*Delia radicum*) caught in Brassiceye® traps compared to pan traps, Geneva, N.Y., USA, 1995. 2a. Early to mid-season catches. 2b. Late-season catches, including those in the altered version of the Brassiceye® trap.

While the felt traps also gave a good correlation to the other methods in many instances, under extreme conditions, i.e. very dry, very wet, very soiled, very clean or when oviposition rates were low, they tended to contain fewer eggs, or no eggs at all (e.g. Fig. 1). Freuler (1988) found a better relationship between the numbers of eggs found in felt traps and in the soil than in the current studies, whereas the current study supports den Ouden´s (1988) findings.

Direct counts of eggs in the field gave some indication of when oviposition began, but making these counts was difficult. There was too much variability between "scouts" for this method to be recommended for use in a grower-based system. Visual counts usually gave the lowest numbers of eggs. Direct counts, where the soil was not removed and replaced, added the risk that the same eggs were counted on more than one occasion. In some cases the number of plants with or without eggs (presence-absence test) was correlated surprisingly well with the number of plants infested, whereas in other cases the correlation was poor. This method was very inexpensive, both in terms of time and materials, and is used commonly in many other pest monitoring situations (e.g. Shelton *et al.*, 1994).

The yellow water traps caught a great diversity of fly species. Sorting of water trap catches was too time consuming to be of practical value. Results in Denmark indicated that the Brassiceye® trap began catching flies after peak oviposition. Field trials with the Brassiceye® trap in the USA in 1995 also showed very poor catches (Fig. 2a), even when an extra row of holes was made for release of the attractant (Fig. 2b).

After 1 year of using felt traps in Norway, advisers changed in 1993 to using the method of floating the eggs from sand samples. Participation in the monitoring program increased in 1994 and 1995. Variation in the timing of oviposition over short distances suggests that this method of sampling should be done locally, as warnings based on the numbers of eggs counted cannot be generalized even on a regional basis.

Résumé

Existe-t'il une méthode facile pour suivre les mouches du chou dans les cultures de Brassica ?

La plupart des méthodes connues pour suivre les mouches du chou ont été testées. Les pièges à eau furent essayés puis abandonnés en raison de la grande diversité des espèces de mouches semblables capturées. Le tri des captures obtenues est trop coûteux en temps pour avoir une valeur pratique. Un nouveau piège à eau sélectif (Brassica) a été testé en Norvège et au Danemark en 1994, et en Norvège et aux USA en 1995. Les résultats indiquent que le nombre des captures était trop faible pour être utilisé dans un suivi et que le piège ne commence seulement à capturer les mouches qu'après le pic de ponte.

Le comptage direct des oeufs dans le champ donne une indication sur le début de la ponte, mais il est très difficile, et on observe une grande variabilité entre les opérateurs (scouts), particulièrement dans un système basé sur les agriculteurs. Le comptage direct additionne le risque que les mêmes oeufs puissent être comptés plus d'une fois. Les comptages de type présence-absence se corrèlent bien avec le nombre des oeufs dans les échantillons de sol.

La collecte du sol à la base des plantes pourrait donner une meilleure indication du nombre réel d'oeufs présents à un moment donné. Les oeufs peuvent être récupérés du sol par flottaison. Dans la pratique, il est difficile de compter les oeufs dans certains types de sol en raison de la présence de matière organique ou d'argile. Pour cette raison, un sable propre a été utilisé et placé sur le sol autour de la base des plantes utilisées pour le suivi des populations.

Les résultats obtenus des parcelles expérimentales de plusieurs localités de Norvège et du Danemark fournissent des différences importantes dans le nombre des oeufs comptés en utilisant les différentes méthodes de suivi. Dans plusieurs cas, il y a une bonne corrélation entre le nombre d'oeufs obtenus par flottation à partir du sol, à partir du sable ou à partir des pièges en feutre. Dans les conditions extrêmes, ou lorsque la ponte est faible, le piège en feutre ne contient habituellement pas d'oeufs.

Acknowledgements

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Monitoring and threshold values for control of the carrot psyllid

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Summary

In Finland the carrot psyllid, *Trioza apicalis*, is the most damaging insect pest of carrots. Population densities of the psyllid differ considerably both between years and between cropping areas. A monitoring system is needed for this pest, as control measures are not always required.

Catch-it^{R} yellow sticky traps were used to catch the psyllid to determine whether the numbers of insects caught could be used to generate spray thresholds. A field experiment was done in both 1994 and 1995. During the 2 years, carrot plots were covered with an insect net for 13 different time periods. The threshold values were calculated from the numbers of psyllids trapped per week and the corresponding yield losses during the netting experiments.

In both years, yield losses occurred during any week of the experimental period when a mean of more than 1 psyllid was caught/trap/week. In both years, the numbers of psyllids remained above the threshold for 3-4 weeks. Two or three applications of a pyrethroid insecticide gave good control. Control using nets was also good provided the nets were applied during the periods indicated by the monitoring system.

Introduction

In Finland, carrots are grown on 17,000 ha and constitute the largest vegetable crop. The crop has two major insect pests: the carrot psyllid (*Trioza apicalis* group) and the carrot fly (*Psila rosae*). On commercial farms, the psyllid causes more severe problems than the fly. In Finland, the psyllid has been regarded as a major pest of carrots for more than 60 years. It is also of pest status in Norway and Sweden (Rygg 1976). The taxonomy of this psyllid is difficult, as the group consists of a complex of 8 species (Burckhardt 1985).

The population densities of the carrot psyllid are extremely variable. The numbers of psyllids caught vary considerably both between growing areas and years, and even between different regions of the same field. Because of this unpredictability, many carrot growers use a calendar-based spray programme. An accurate pest monitoring system would help considerably to improve this control strategy.

The aim of this study was to test if yellow sticky traps could be used to monitor changes in populations of the carrot psyllid. The numbers of psyllids caught weekly were related to yield losses, so that the numbers of psyllids caught/week could be used as the basis for deciding when to apply sprays of insecticide. In 1995, a preliminary supervised control system was tested both in a field experiment at the Institute of Plant Protection and by a few farmers.

Materials and Methods

In the experimental work, Catch-it™ traps (320 x 190 mm, Silva Miljö AB,) were used to monitor changes in the numbers of the psyllid. The sticky paper, coated on one side only with glue, was simply formed into a cylinder with the yellow sticky surface facing outwards. The cylinders were fastened onto wooden stakes so that the traps in the carrot fields could be kept just above the plant foliage. Five traps were used in each field (1 ha). The traps were renewed weekly and the psyllids caught were identified and counted under a binocular microscope.

A field experiment was done in 1995 to find the threshold values at which sprays should be applied to control psyllid. Plots measuring 1.6 x 2 m were covered with an insect net (Lanet L, mesh size 0.6 x 0.6) for 13 different and overlapping periods of time, that ranged from 0-7 weeks. Two uncovered plots were used as the control treatments in each of the four replications. The periods during which the plots were covered with nets and the numbers of psyllids caught/week are shown in Fig. 1.

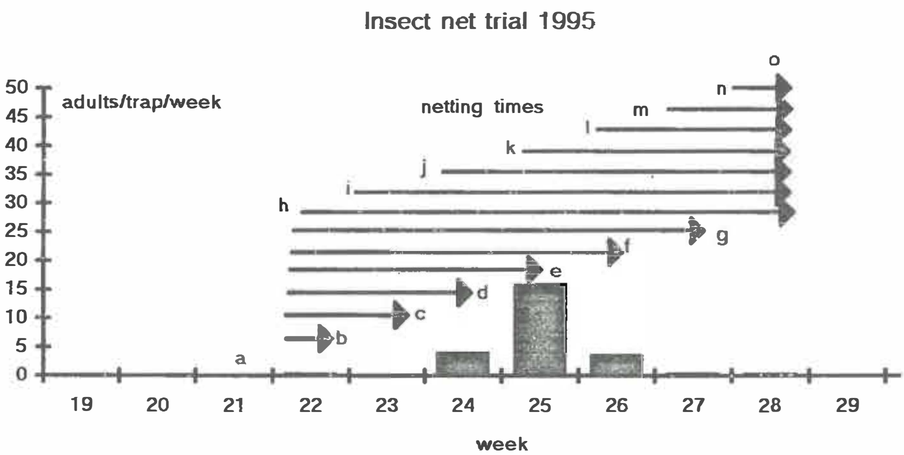

Fig. 1: The periods during which the plots were covered with nets (treatments b to p) and the numbers of carrot psyllid caught each week during 1995. Treatments a and o were the uncovered "controls".

Two weeks after the end of migration of the psyllid, a sample (0.5m length of row) of carrots was taken from each plot. The carrot roots were weighed, the healthy and injured leaves were counted and the numbers of psyllid eggs and nymphs found were recorded. A special sieving technique, developed by the current researchers, was used to extract the eggs and nymphal instars from the plant tissue. At the end of the growing season, carrots were harvested from a 0.4 m^2 area of each plot. The carrots were then graded according to commercial standards.

In 1995, six insecticides were tested in the field in which the monitoring system was tested. The design of the experiment (Table 1) followed the GLP procedure used at the Institute of Plant Protection. Untreated plots and plots covered permanently with insect net were used as the two controls. The experiment consisted of 30 different treatments of which

Bioruiskute S (pyrethrin), Cyberb, Karate EW, Malan and Roxion were applied two or three times at two different doses. Decis EC was applied two and three times at each of four different doses.

Table 1. Details of the cultural practices used in 1995 during experiments to control the carrot psyllid (*Trioza apicalis*) on carrots using different insecticide treatments.

Application date	21 June	27 June	6 July	**Trial design**	randomized block
Time	17.00	16.00	17.00	**Replicates**	4
Temperature °C	21	20	20	**Plots size**	24 m^2
Relative humidity %	60	40	60	**Locality**	SAT Kokemäki
Cloud cover %	30	10	50	**Crop/variety**	carrot/Fontana
Growth height (cm)	5-10	10-15	15-20	**Previous crop**	potato
No. of true leaves	2-4	3-4	4-6		
Nozzle	H-4110 -12	H-4110 -12	H-4110 -12	**Drilling/ Planting**	19 May
Pressure bar	3	3	3	**Soil type**	fine sand
Water volume 1/ha	200	200	200	**Fertilization N kg/ha**	80 + 20
				Harvesting	20 September

Results and Discussion

The numbers of psyllids caught on the yellow sticky trap showed clearly that populations of the carrot psyllid differed from year to year. In 1993, the period of migration of the psyllid lasted about six weeks and during the week of peak activity about 60 adults were caught. In 1994 and 1995, the migration lasted only about four weeks (Fig. 2).

The results from the netting experiment showed that the losses in crop yeild were significant when more than one psyllid was caught/trap/week. All of the variables measured: marketable yield, root weight and numbers of psyllid nymphs present in July indicated that the value of the spray threshold should be set at one adult/trap/week (Fig. 3, 4, 5).

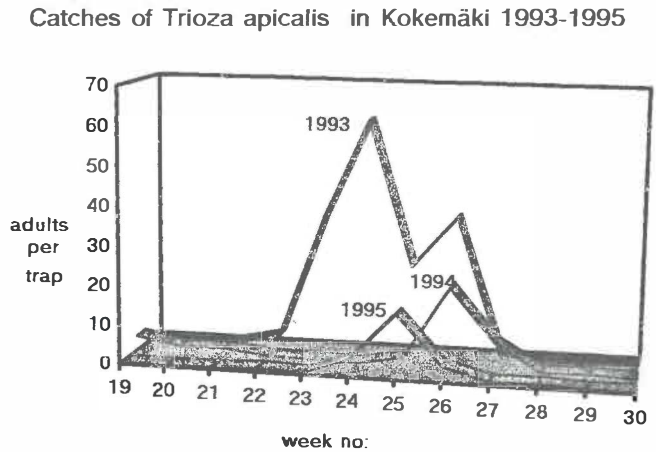

Fig. 2: The numbers of carrot *Trioza apicalis* adults caught/trap/week in 1993, 1994 and 1995 at the Research Station of Satakunta (61 16'N, 22 14'E).

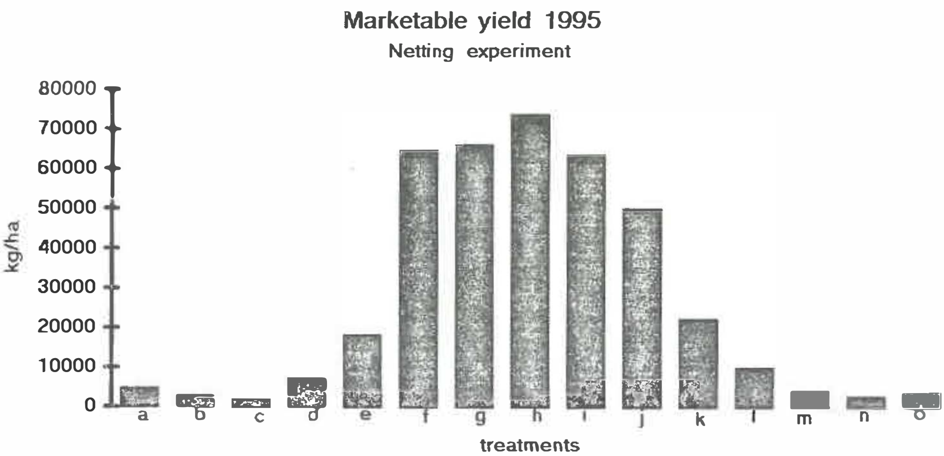

Fig. 3: Yields of marketable carrots harvested from the netted experiment. In treatments f-i, the carrots were covered with insect net during each week when more than one psyllid was caught/trap. A more detailed breakdown of these data are shown in Table 2.

The results show clearly that monitoring the psyllid with yellow traps helps in the decision of whether, or not, an insecticide treatment should be applied. The end of the migration of the psyllid is particularly difficult to predict if traps are not used. In practice, some farmers still apply insecticides much too early and in many cases continue to apply them much too late in the season.

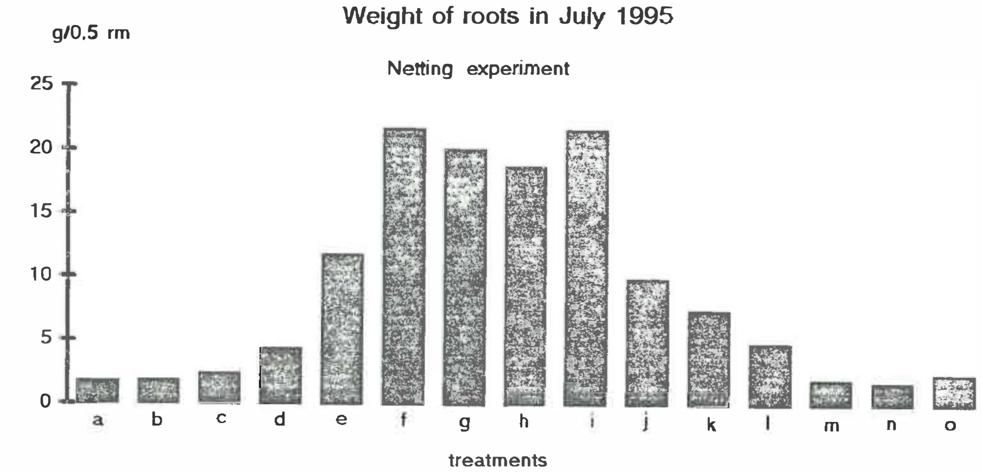

Fig. 4: The difference in weights of carrot roots/metre of row (rm) between covered (treatments b-n) and uncovered (treatments a & o) plots. Critical period to protect against the carrot psyllid are weeks f-i.

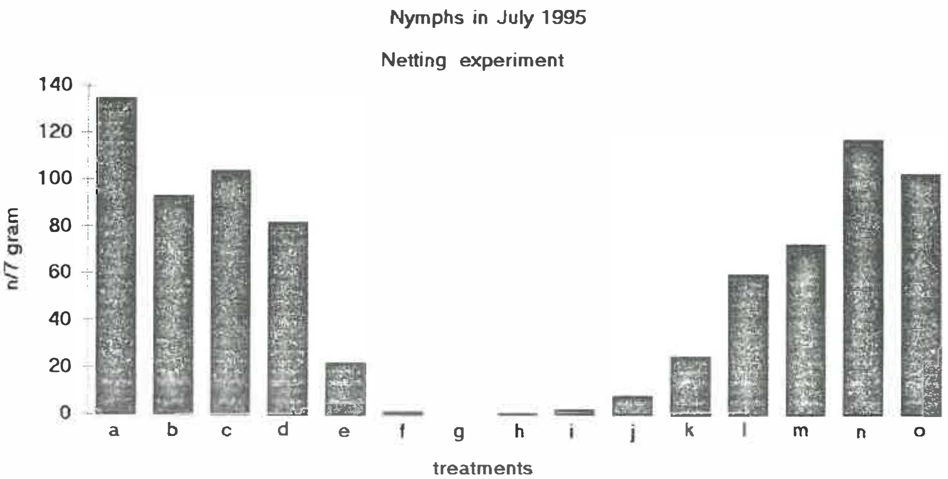

Fig. 5: Numbers of nymphs of the carrot psyllid (nymphs per 7 g of leaves) found on the plots covered with nets during the migration period of the overwintered adults.

In 1995, good control of the carrot psyllid was achieved with just two or three applications of certain pyrethroid insecticides (Table 2). When insecticide was not applied, the marketable yield was only 1 tn/ha. In contrast, when the psyllid was controlled using either the insect net or pyrethroid insecticides the yield was 45 tn/ha. In the plots treated with malathion or dimethoate, the yields varied from 24 to 32 tn/ha and 17 to 34 tn/ha, respectively. A yield of 22 tn/ha was obtained from the pyrethrin treated plots provided the highest dose was used and three applications were made. When only two applications were made, the yield dropped to 8 tn/ha.

Table 2. Details of the insecticidal treatments applied during 1995 to control the carrot psyllid (*Trioza apicalis*) and the subsequent marketable yields of carrots.

Treatment	Proportion of active ingredient	Dosages 1, kg/ha	No. of sprays	Marketable yield tn/ha	
Bioruiskute S		0.2	2	8	ghi
Bioruiskute S	Pyrethrin	0.2	3	13	fghi
Bioruiskute S	100 g/l a.i.	0.4	2	7	hi
Bioruiskute S		0.4	3	23	cdefgh
Cyberb		0.1	2	24	bcdefgh
Cyberb	Cypermethrin	0.1	3	37	abcde
Cyberb	100 g/l a.i.	0.2	2	23	cdefghi
Cyberb		0.2	3	51	a
Decis EC		0.1	2	39	abcde
Decis EC		0.1	3	38	abcde
Decis EC		0.2	2	25	bcdefgh
Decis EC	Deltamethrin	0.2	3	41	abcd
Decis EC	25 g/l a.i.	0.3	2	29	abcdefg
Decis EC		0.3	3	33	abcdef
Decis EC		0.4	2	37	abcde
Decis EC		0.4	3	50	a
Karate EW		0.2	2	38	abcde
Karate EW	Lamda-cyhalothrin	0.2	3	46	ab
Karate EW	25 g/l a.i.	0.4	2	45	abc
Control	untreated			1	i
Malan		0.2	2	25	bcdefgh
Malan	Malathion	0.2	3	24	bcdefgh
Malan	500 g/l a.i.	0.4	3	42	abcd
Malan		0.4	2	33	abcdef
Roxion		0.3	2	18	efghi
Roxion	Dimethoate	0.3	3	35	abcdef
Roxion	400 g/l a.i.	0.6	2	20	defghi
Roxion		0.6	3	33	abcdef
Netting				43363	abc
F-value				4.15	
Significance				***	

Means within columns followed by the same letter are not significantly different (P=0.05 DMRT)

On demonstration farms, the use of the monitoring system has enabled the number of insecticide applications to be reduced by about 50%. In some areas insecticide was not applied, because the spray threshold was not exceeded. Every farmer should learn to use traps in a consistent manner so that, if required, he/she can adjust the threshold values to suit his/her own field ecosystems and carrot varieties.

Résumé

Monitoring et valeurs seuils pour la lutte contre le psylle de la carotte (*Trioza apicalis*)

En Finlande, le Psylle de la carotte, *Trioza apicalis*, est le ravageur de la carotte qui fait le plus de dégât. Les densités de populations de psylle différent considérablement entre les années et les surfaces cultivées. Un système de suivi est nécessaire pour ce ravageur car les mesures de lutte ne sont pas toujours utiles.

Les piéges à glu jaunes Catch-it^{R} sont utilisés pour capturer les psylles afin de déterminer si le nombre d'insectes capturés permet de définir des seuils de traitements par pulvérisation. Une expérimentation a été faite en 1994 et 1995. Durant ces deux années, des parcelles ont été couvertes par un filet durant 13 périodes de temps différents. Les valeurs seuils ont été calculées pour le nombre de psylles piégés par semaine, et pour les pertes au champ correspondantes pendant la période des expériences de couverture.

Au cours des deux années, les pertes de récolte pendant les quelques semaines de la période d'expérimentation lorsque une moyenne de plus de 1 psylle a été capturé par piége et par semaine. Au cours des deux années, les nombres de psylles restent supérieur au seuil pendant 3 à 4 semaines. Deux à trois applications d'un insecticide pyréthroïde assure une bonne protection. La protection par la pose d'un filet est également satisfaisante si les filets sont appliqués pendant les périodes indiquées par le système de suivi.

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Flight activity of *Thrips tabaci* in leek fields and the possibility of forecasting the period of attack

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Summary

Experiments were carried out in various leek fields on the West Coast of Cotentin. Twelve fields were studied in 1993, 13 in 1994 and 10 in 1995. One field at the experimental station situated on the East Coast near Val de Saire was studied in 1994 and 1995. In each field, blue sticky traps and plant samples were used to record the number of larvae and adult thrips. A model, based on accumulated temperatures (day-degrees), was used to forecast the timing of thrips immigration into leek crops.

Over the three years of observation, one period of intensive flight occurred from the end of July to the beginning of August. Blue sticky traps gave reliable information on the risks of infestation from outside the field. The results showed that there were two populations at different life-cycle stages (overwintering adults and overwintering larvae) and two periods of adult emergence. The first of these occurred at the end of June, and the second towards the end of July. The second generation, which consisted of the progeny from overwintered adults occurred on about 15th August. As there was only one period of thrips immigration into leek crops, attempts were made to determine if chemical treatments applied only during this period would prove sufficient. Preliminary results indicate that spraying at such times may be all that is required.

Introduction

The onion thrips, *Thrips tabaci* Lindeman, is the most important pest of leek, *Allium porrum* L., crops in France, and is a particularly severe pest in the Basse-Normandie region. Large populations of thrips may develop on leeks and this causes silvery spots or stripes on the leaves, which make the crop unmarketable. The poorer appearance of such leeks lowers both their quality and the price that can be obtained for them at market.

Because of insufficient knowledge about how to set up a system of integrated pest management, growers currently rely solely on insecticides for controlling this pest. This involves 7 to 10 sprays of insecticide/crop/year at a cost of about 2.000 FF/ha.

Reducing the amounts of insecticide applied to leek crops would lower production costs for growers, protect the environment, and lower the risk of pesticide residues in the product bought by consumers. As so little is known about *T. tabaci* populations, the development of a supervised control system will not be easy. However, repeated treatments with registered chemicals is not an efficient way of controlling thrips.

Investigations have been done during the last three years by CTIFL and at the SILEBAN Experimental Station to improve our knowledge of the population dynamics of *T. tabaci*. The work has been done in major areas of leek production in the hope that being able to predict thrips infestations in such areas will assist growers in their management of this pest.

The method generally used in France for supervised control of thrips in leek is the one described by Berlese and modified subsequently by Bournier (Thicoipe, 1990). From the earlier studies and from preliminary research conducted in Basse-Normandy, a spray threshold of 5 thrips (adults + larvae)/leek was proposed (Villeneuve, 1994). However, using the currently registered insecticides, this threshold is too high and the appropriate threshold seems to be nearer to 0.5 or 1 thrips/leek. According to Theunissen & Legustowska (1991a) the distribution of thrips in leek crops is clumped. Therefore, the numbers of leeks that have to be sampled to obtain a reliable assessment of the thrips population is very large ($\geq$ 70 leeks) and cannot be done throughout the season using the Berlese technique.

For this reason, blue sticky traps (Villeneuve, 1995) were used to monitor flight activity of the thrips.

Materials and Methods

Our experiments have been carried out since 1993 in leek fields on the West coast of Cotentin. The experiments were done in 12 leek fields 1993, 13 in 1994, and 10 in 1995. Experiments were done also on the East Coast (Val-de-Saire) in a field at the Experimental Station in both 1994 and 1995. This experimental field was divided in 8 and 7 plots, in the two years respectively. The numbers of thrips were monitored twice a week using 2 different methods.

Population estimate from collected leek plants

Twice each week, 10 leeks were sampled in each field (or plot). The leek plants were cut just above the soil and were placed in Berlese extractors to record the number of larvae and adult thrips. The method used is that described by Bournier (1973) and is based on cutting the leeks lengthwise and then placing them carefully into a closed cylinder (Fig.1). A cotton cloth, soaked with turpentine, is fixed beneath the top of the cylinder. The repellent effect of the turpentine odour gradually drives the thrips down through the sample and into a collection tube containing a solution of 10% alcohol. After forty-eight hours of extraction, the thrips were removed from the collection tube, identified and counted.

Insect traps

Aerial counts of adults were recorded on 20x20 cm light blue sticky traps (Altuglass 23020). This colour was more attractive to *T. tabaci* than the other colours tested (Villeneuve, 1995).

Five traps were used in each field (or plot), and the individual traps were spaced at least 10 m apart. The traps were supported 10 cm above the crop and their height was adjusted as the leeks grew. The side of the trap, facing the prevailing wind, had been sprayed with glue and the numbers of thrips caught were counted twice each week.

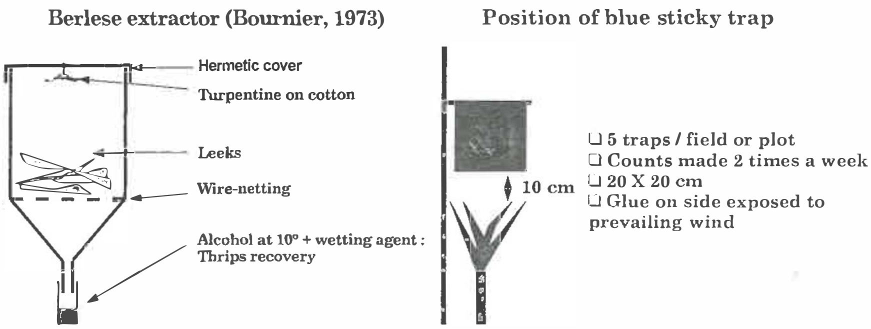

Fig. 1: Diagram of Berlese extractor and positioning of blue sticky traps.

Results and Discussions

Flight period

Data from sticky traps indicated that there was only one significant flight period and this occurred from the end of July to the beginning of August (Fig. 2). Before and after this period, smaller numbers of *T. tabaci* were caught. These smaller flights may contain sufficient thrips to cause damage to certain leek crops.

This type of flight activity has been recorded each year between 1993 and 1995 and is similar for both the East and West coast of Cotentin. However, the number of thrips caught is highly variable. Many adults were caught on the West coast during 1993 and 1994, but few adults were caught in 1995. In contrast, intermediate numbers were caught in 1994 at Val-de-Saire and high numbers in 1995.

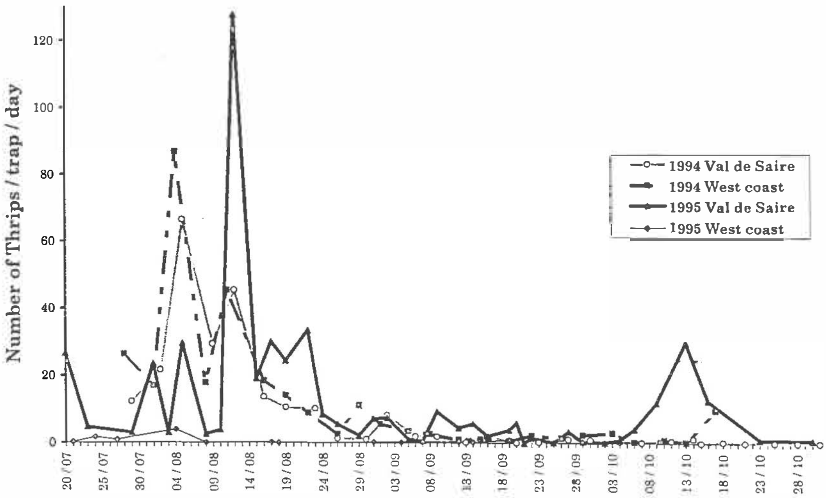

Fig. 2: Numbers of *Thrips tabaci* collected from blue sticky traps placed in leek fields on the East and West Coast of Cotentin during 1994 and 1995.

Estimate of populations of thrips living on leeks

Even within the same field, the data collected from the funnel extractors and from the blue sticky traps could be different. However, following each flight, the development of the thrips population on leeks was similar. The flights of the thrip populations living on leeks are similar every year in each area (Fig. 3 & 4).

One important peak of adult activity occurred soon after the main flight peak. Sticky traps provided information earlier that the Berlese funnel and could be used to indicate when the first adult thrips flew into leek fields.

It is important to note that blue sticky traps provided information slightly in advance of what can be obtained either from Berlese extractors or from direct observations in the field.

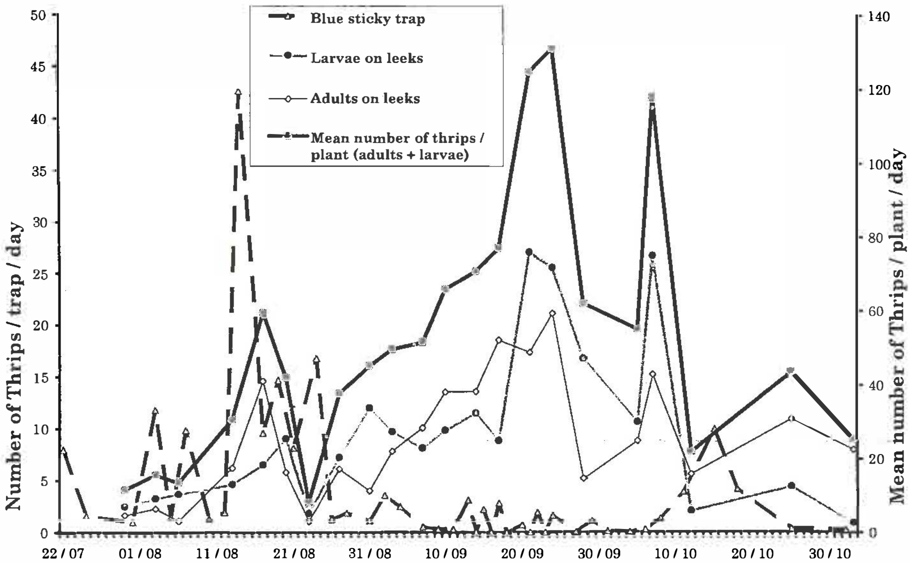

Fig. 3: Comparison of the numbers of *Thrips tabaci* collected from blue sticky traps and from Berlese extractor in leek fields on the East Coast of Cotentin in 1995.

From the data collected in the present study, the main risk period is between 25th July and 10th August. Theunissen & Legustowska (1991b) observed the first adults during the same period in The Netherlands. Adult thrips were also active during the same period in several regions of France, including Nord-Pas-de-Calais, and the Central region (Villeneuve, 1995).

Each year, similar data were collected from the Berlese funnels.

1) Large numbers of thrips were present from the end of July until early August and this corresponded to a period of intensive flight activity.
2) Following the initial immigration flight, the original adults died and their larval progeny pupated.
3) Finally there was a second peak of adults followed by another peak of larvae and then a gradual decline in the overall population.

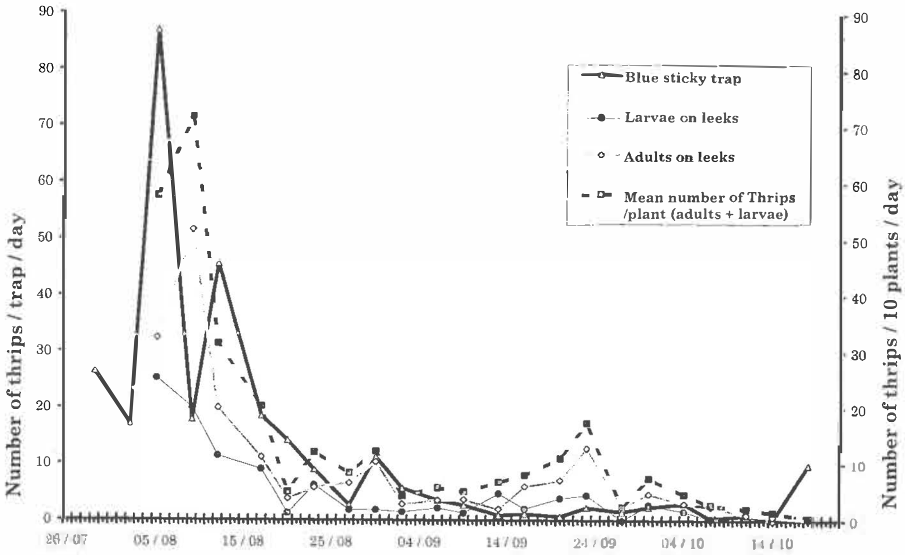

Fig. 4: Comparison of the numbers of *Thrips tabaci* collected from blue sticky traps or from Berlese extractor in leek fields on the West Coast of Cotentin during 1994.

Although the insecticides sprayed onto the leek crops were applied to control the populations of thrips, the flights of the thrips were similar in both the sprayed and unsprayed fields.

Use of a day-degree model to forecast the periods of attack by thrips

Various researchers have shown that temperature governs the rate of growth and development of *T. tabaci* (Harris *et al.*, 1936; Ghabn, 1948; Lall & Singh, 1968). Edelson & Magaro (1988) produced a day-degree model to describe the development rate of onion thrips feeding on onions and then verified their model under fluctuating temperature in glasshouse experiments.

Attempts were made to relate the data collected on leek fields in Basse-Normandie to accumulated day-degrees. Temperature data were obtained from Weather Stations, one on the East coast and two on the West coast (North and South).

Accumulated temperatures, above Edelson & Margaro's threshold of 11.5°C, were calculated from 1st January to determine when adult population peaks could be expected each year in each part of Cotentin. Both adult (Bailey, 1934) and larval thrips were included, as preliminary observations indicated that both stages overwinter on various plant species in the Basse-Normandie region.

The model indicated that there should be two periods of adult emergence, the first at the end of June and the second between 20-25th July. In 1993 (Fig. 5) and 1994 (Fig. 6), the sticky traps were put out too late to confirm the timing of infestation. However, in 1995 the timing of thrips captures on the traps agreed closely with that predicted by the forecast.

Overwintering larvae became adults towards the end of June. A second generation, that developed from the progeny of the overwintering generation, was expected towards 31st July. This was confirmed, as the largest numbers of thrips were captured on sticky blue traps at the timing indicated by the model.

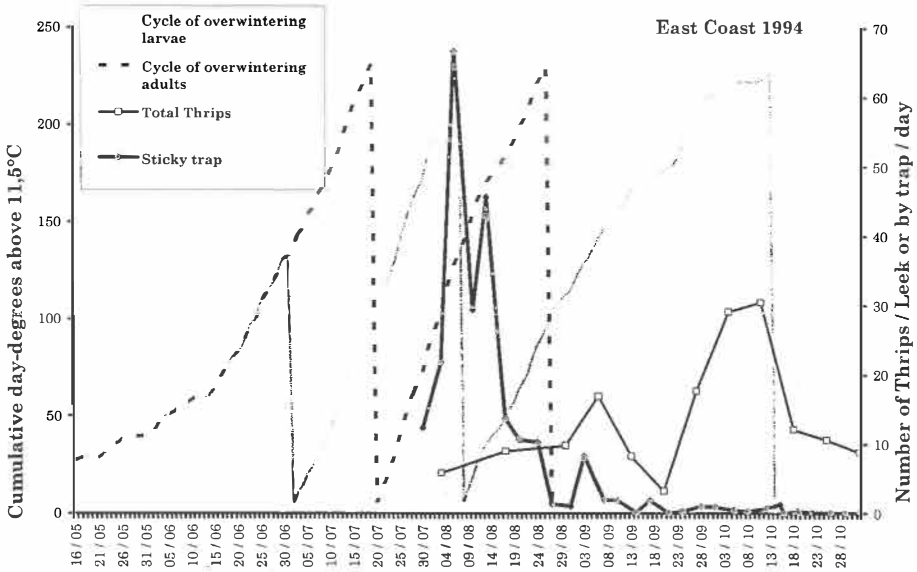

Fig. 5: Numbers of *Thrips tabaci* found on leek or blue sticky traps compared to the predicted flight timings of insects that overwintered as larvae or adults on the East Coast during 1994.

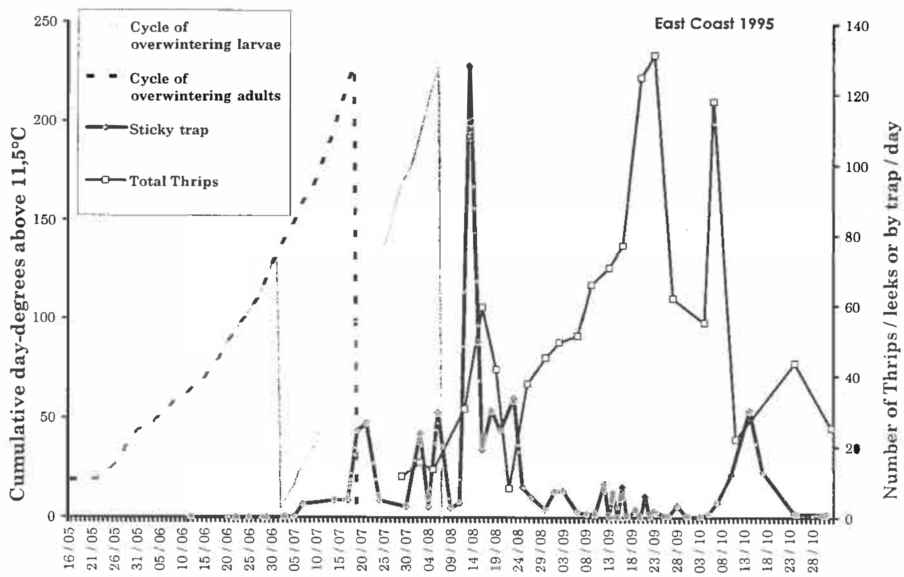

Fig. 6: Numbers of *Thrips tabaci* found on leeks or blue sticky traps compared to the predicted flight timings of insects that overwintered as larvae or adults on the East Coast during 1995.

The thrips populations that fly into leek fields from the end of July to the beginning of August, find conditions (biotic and abiotic) suitable for rapid development and low mortality. By the following generation (228 DD), although peaks were observed, most of the adults remained on the host plants.

Conclusion

Earlier results showed that it is essential to ensure that leek plants do not become infested by thrips while still in the plant nursery (Thicoïpé, 1990). This was achieved by using a combination of insect-proof nets and various insecticides. However, when the young leek plants were transplanted into the open field, they soon became infestated by thrips.

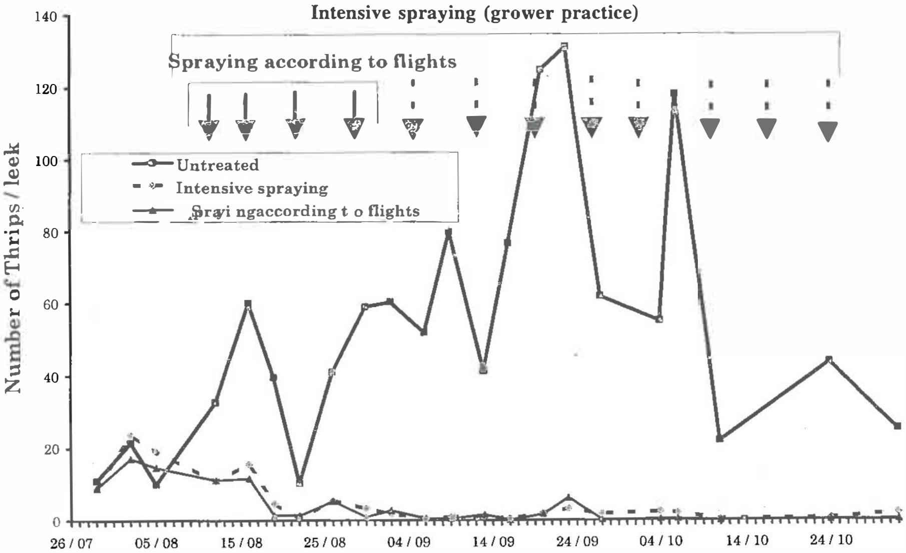

Fig. 7: Average numbers of *Thrips tabaci* recorded from unsprayed leek plots and from plots that were sprayed according to flights of thrips or every two weeks.

After planting, the important period of thrips immigration into leek fields occurs usually during the first 3 weeks of August. Therefore, if thrips populations can be controlled by the end of August, there is no need for further treatments (Fig. 7). Our results show that effective crop protection can be achieved with just a few applications of insecticide made when the crop is most at risk. The period of thrips immigration can be forecast from the numbers of day-degrees accumulated above 11.5°C.

Résumé

Activité de vol de *Thrips tabaci* dans les champs de poireaux et les possibilités de prévoir les périodes d'attaques

Des expérimentations ont été réalisées dans plusieurs champs de poireaux sur la côte Ouest du Cotentin. Douze champs ont été suivis en 1993, 13 en 1994 et 10 en 1995. Une

parcelle située dans la station d'expérimentation de la côte Est près du Val de Saire a été étudiée en 1994 et 1995. Dans chaque champ des pièges jaunes englués et des échantillons de plantes ont été utilisés pour enregistrer le nombre de larves et d'adultes de thrips. Un modèle, basé sur les sommes de températures (degrés-jour), était employé pour prédire le moment de l'immigration des thrips dans les cultures de poireaux.

Sur les trois années d'observation, une période de vol importante a lieu à la fin du mois de juillet et le début du mois d'août. Les pièges à glu bleus donnent des informations qui sont reliés aux risques des infestations à l'extérieur des parcelles. Les résultats montrent qu'il y a deux populations à différents stades du cycle biologique (des adultes hivernants et des larves hivernantes) et deux périodes d'émergence des adultes. La première a lieu à la fin du mois de juin et la seconde vers la fin du mois de juillet. la seconde génération qui est constituée de la descendance des adultes hivernant a lieu vers le 15 août. Comme il y a seulement une période d'immigration dans les cultures de poireau, des essais furent faits pour déterminer si les traitements chimiques appliqués seulement pendant cette période pourraient être suffisants. Les résultats préliminaires indiquent que les pulvérisations réalisées à cette période pourraient convenir tout à fait.

Acknowledgements

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Aphid populations and their natural enemies on fresh market tomatoes in central Greece

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Summary

The numbers of aphids and their natural enemies found on fresh market tomatoes were recorded for a growing season in central Greece in 1993. *Macrosiphum euphorbiae* and *Myzus persicae* were the only aphid species found infesting tomatoes. *M. euphorbiae* was present continuously from the end of May until early September but *M. persicae* was not. Both species peaked in August. During the study, the predators *Macrolophus pygmaeus* and *Orius niger* and the parasitoids *Aphelinus* sp. and *Praon* sp. were found. Predators, particularly *M. pygmaeus*, were more numerous than parasitoids. Higher populations of *M. pygmaeus* occurred in August and particularly during September. *M. pygmaeus* was also more numerous than *O. niger*, whereas mummified aphids were found only in very low numbers.

Introduction

Tomatoes can be attacked by pests such as whiteflies, leafminers, aphids, thrips, and larvae of Lepidoptera (Lange & Bronson, 1981). Several species of aphids have been reported colonizing tomatoes. These include *Macrosiphum euphorbiae* (Thomas), *Myzus persicae* (Sulzer), *Aulacorthum solani* (Kaltenbach) and *Aphis* spp. (Blackman & Eastop, 1985). *M. euphorbiae* has developed large infestations on processing tomatoes in Ohio, USA (Walker *et al.*, 1984), and is more abundant than *M. persicae* on processing tomato in central Greece (Lykouressis & Chalkia, 1994).

Aphids can cause direct and/or indirect damage to both fresh market and processing tomatoes. Direct damage results from the aphids sucking out the plant juices, and indirect damage from virus transmission and the presence of sooty moulds which develop on the aphids' honeydew. Indirect damage is particularly important in fresh market tomatoes, as it greatly reduces fruit quality. Therefore, the lower the numbers of aphids found on tomato plants the better the fruit quality.

The aim of this work was to study aphid populations on field tomatoes and how they are affected by natural enemies.

Materials and Methods

The abundance of aphids and their natural enemies on fresh market tomato (cv. Galli) were studied in a fresh market tomato field located in the region of Akraiphnio Co. Boiotia. Samples were taken at weekly intervals from a 0.1 ha experimental plot, within the above

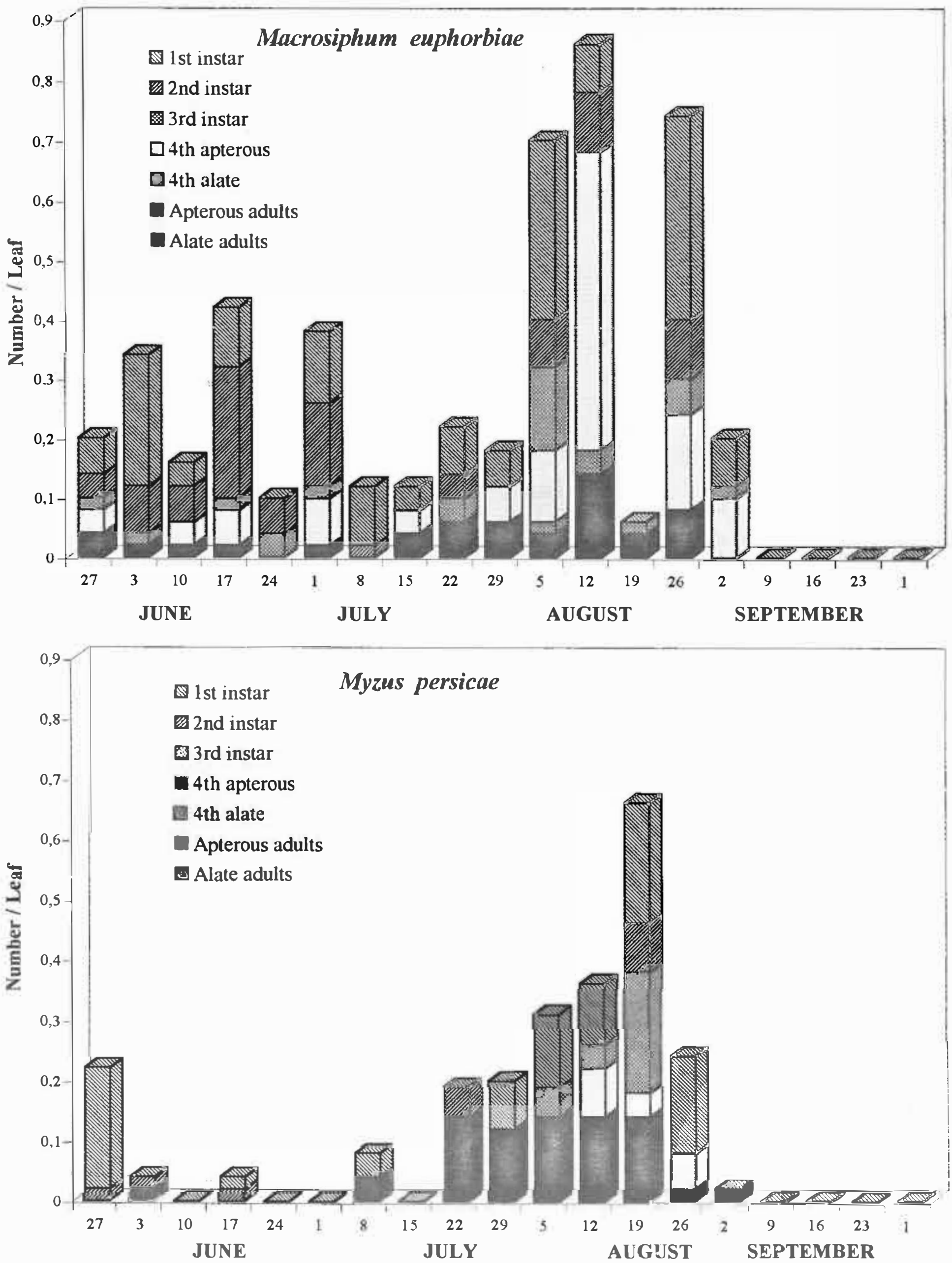

Fig. 1. Mean distribution of instars of *Macrosiphum euphorbiae* and *Myzus persicae* found per leaf (50 - leaf sample) in a fresh market tomato field in Akraiphnio Co. Boiotia from 27 May to 1 October, 1993.

field, from 27 May until 1 October 1993. The sample unit was a fully-grown leaf taken from the upper part of the plant, as this is where most of the aphids were found (Lykouressis & Chalkia, 1994). Fifty leaves were collected on each sampling occasion and were put individually into small plastic bags. The leaves were transferred to the laboratory and examined using a stereomicroscope. The insects found on the samples were preserved in glass tubes that contained storage fluid (2 volumes of ethyl alcohol 90-95% and 1 volume lactic acid 75% w/w) (Eastop & van Emden, 1972).

Aphids and their natural enemies were separated from the other insects. Aphids were identified into species and then separated into instars. Aphid natural enemies were also identified into species by using various keys (Wagner, 1952; Stichel, 1962; Josifov, 1992).

Results

During the growing season, only the two aphid species, *M. euphorbiae* and *M. persicae* produced infestations on tomato plants.

The seasonal fluctuation of *M. euphorbiae* and *M. persicae* are shown in Fig. 1. *M. euphorbiae* was present in much higher numbers than *M. persicae* on most sampling dates. Both species were present from the first sampling date. *M. euphorbiae* was found continuously from the beginning of sampling until early September but *M. persicae* was not. Neither species was recorded after 2 September. The highest populations of both species were found in August.

The natural enemies found during this study were the predators *Macrolophus pygmaeus* Rambur (Hem.: Miridae) and *Orius niger* Wolff. (Hem.: Anthocoridae) and the parasitoids *Aphelinus* sp. (Hym.: Aphelinidae) and *Praon* sp. (Hym.: Aphidiidae).

During the study, very few mummified aphids were found parasitized by *Aphelinus* sp. and *Praon* sp.. In the 12 August sample, a total of 3 third-instar *M. euphorbiae* aphids were found mummified by *Aphelinus* sp. and 2 third-instar larvae by *Praon* sp.

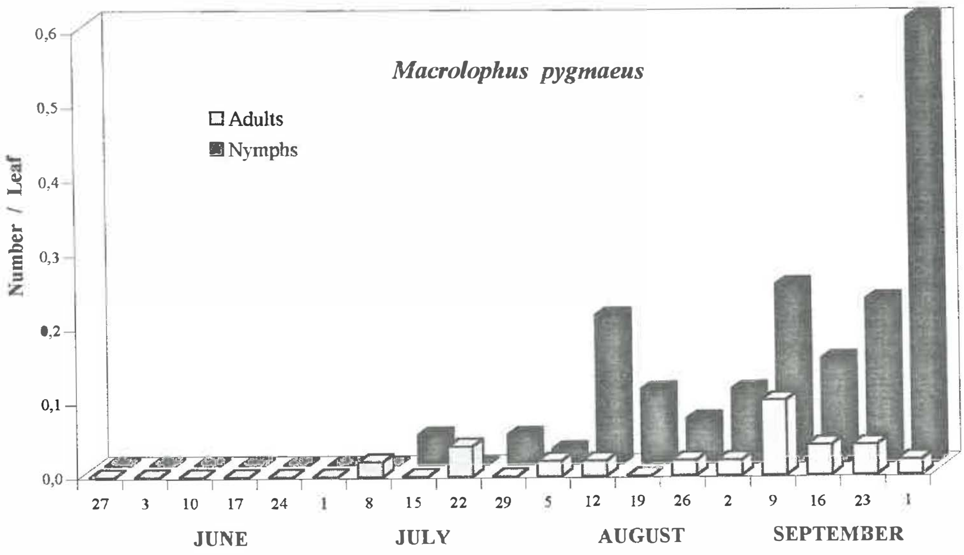

Fig. 2. Mean numbers of adults and nymphs of *Macrolophus pygmaeus* found per leaf (50 - leaf sample) in a fresh market tomato field in Akraiphnio Co. Boiotia from 27 May to 1 October, 1993.

Adults and/or nymphs of *M. pygmaeus* were found on the tomato plants from early in July until the last sampling date, 1 October (Fig. 2). Most adults were found in early September and most nymphs on 1 October. In general, the largest population of *M. pygmaeus* was found in September. This seemed to be a numerical response to the high aphid population present in August, as no other prey was available. In contrast, *O. niger* was present only in very low numbers, one adult being collected on each of 24 June, 15 July and 2 September and three nymphs on 2 September. Hence, occurrence was not associated with aphid abundance.

Discussion and Conclusions

M. euphorbiae was found in higher numbers than *M. persicae* confirming earlier findings (Walker *et al.*, 1984; Lykouressis & Chalkia, 1994) that tomato plants are more suitable for the development and multiplication of *M. euphorbiae* than *M. persicae.*

The parasitoids *Aphelinus* sp. and *Praon* sp. did not reduce the population levels of *M. euphorbiae*, as the number of parasitoid mummies was extremely small.

Among the natural enemies found, *M. pygmaeus* was the most important for suppressing *M. euphorbiae* and *M. persicae* populations. In the study area however, high populations of *M. pygmaeus* developed only towards the end of the season for growing fresh market tomatoes. As the development of sooty moulds is considered most serious at fruit harvest, the presence of higher *M. pygmaeus* number at that time decreased aphid populations and consequently contributed to better fruit quality.

Résumé

Les puçerons et leurs ennemis naturels sur les tomates commercialisées en frais en Grèce

Le nombre de puçerons et leurs ennemis naturels trouvés sur des plants de tomates commercialisés ont été enregistrés pendant la saison de croissance dans le centre de la Grèce en 1993. *Macrosiphum euphorbiae* et *Myzus persicae* sont les seuls puçerons trouvés qui infestent les tomates. *M. euphorbiae* est présent en permanence de la fin mai jusqu'au début de septembre, ce qui n'est pas le cas pour *M. persicae.* Le pic des deux espèces a lieu en août. Au cours de l'étude, les prédateurs *Macrolophus pygmaeus* et *Orius niger* et les parasitoïdes *Aphelinus* sp. et *Praon* sp. ont été trouvés. Les prédateurs, principalement *M. pygmaeus*, étaient plus nombreux que les parasitoïdes. Les populations plus importantes de *M. pygmaeus* sont présentes en août et particulièrement en septembre. *M. pygmaeus* était aussi plus abondant que *O. niger*, tandis que les momies de puçerons ont été trouvées seulement en très petit nombre.

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Aphids on lettuce: the effects of excluding aphid predators

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Summary

The impact of aphid predators on aphid numbers was studied on lettuce (*Lactuca sativa* L.) in southern Germany during 1992 and 1993. Cages to exclude predators were erected on the lettuce after the plants had been colonized by aphids. About two weeks later, aphid numbers in the caged plots started to increase over those in the uncaged plots. At harvest, one week later, these differences increased to 19 (1992) and 10 (1993) times more aphids in the caged, than in the open plots. Aphid numbers in predator-accessible 'open' cages did not differ ($\underline{P}>0.05$) from those in the uncovered plots on any date even though the microclimatic conditions within the open cages were comparable to those in the closed cages. Increases in the numbers of aphid predators (esp. syrphid larvae, coccinellids and chrysopid larvae) coincided with the decline in aphid numbers in the open plots. It is proposed, that predators are the key factor for reducing aphid populations on lettuce one to two weeks before harvest. This natural regulation of aphids is not compatible with the current strategy of making frequent applications of insecticides to control aphids. Owing to the considerable potential of the predators, it is proposed that the use of alternative plant protection strategies should be considered.

Introduction

Studies using exclusion cages have now been done for more than 50 years, and, although this approach has limitations, it is still considered to be the most appropriate way to evaluate the impact of natural enemies (Luck *et al.*, 1988). The importance of predators in regulating aphid populations has been shown using exclusion cages on plants such as cereals (Chambers *et al.*, 1983; Hopper *et al.*, 1995), alfalfa (Frazer *et al.*, 1981) hops (Campbell & Cone, 1994), thistles (Völk, 1988) and spindle trees (Chikh-Khamis & Hurej, 1991). Unlike the above lettuce crops are in the field for a few weeks only. This may not be sufficient time for the numbers of natural enemies to increase sufficiently to give adequate aphid control. Furthermore, head formation in lettuce, which occurs about two weeks before harvest, changes drastically the conditions for any arthropod living on the head. For example, the expected increase in relative humidity could make aphids more vulnerable to fungal diseases (Latgé & Papierok, 1989). In contrast, shelter from the head may protect the aphids from adverse weather conditions, predators and parasitoids. This study uses cages to exclude natural enemies in an attempt to determine the impact of natural enemies on aphids found on lettuce, an ephemeral host plant.

Materials and Methods

The experiment was carried out during 1992 and 1993 near Albershofen, about 20 km east of Würzburg in southern Germany. A randomised complete-block design was used and it involved four replicates of the three treatments which were (1) cages, (2) 'open' cages, and 3) plots without cages. In both years, the experimental block was situated within a larger strip-cropping experiment that involved both lettuce and faba beans. It was installed at the centre of a block of lettuce (1992: 7.5 x 54 m; 1993: 7.5 x 72 m), that was bordered on the two long sides by strips of faba beans (*Vicia faba* L.). The distance between plots was 2 m in 1992 and 3 m in 1993.

The lettuce were planted at the beginning of June (10 June 1992, var. 'Miran'; 8 June 1993, var. 'Soraya'). Gauze-covered cages (0.90 x 0.85 m, 0.6 m high, 7 x 7 mesh cm^2) were placed over 9 lettuce plants/plot to exclude predators once the plants had been colonized by aphids. These cages were erected in 27 June 1992 and 24 June 1993; and on the same days the faba beans alongside the experimental plots were mowed. Plots of the same size without cages were marked as the control plots. 'Open' cages, that were similar in size to the other cages, but did not have gauze over the lower 15cm, were intended to produce comparable climatic conditions, but allow predators to enter. All cultural practices were similar to those done on the surrounding farms. The lettuce plants were spaced 30 cm apart both within and between the rows, the plots were irrigated frequently, and mineral fertiliser was applied at planting (N_{min}=50kg N/ha) and again about 3 weeks after planting (N_{min}=100 kg N/ha). In contrast to standard farm practice, no insecticide or fungicide was applied.

The numbers of aphids and aphid predators were counted each week on all 9 plant plots *in situ* as long as plant development allowed. One week prior to harvest and at harvest time, 4 plants/plot were destructively sampled (at harvest 1992: 5 plants). In 1992, 4 plants were cut from near to the 4 plots without cages on 8 July. Although attempts were not made to separate aphid species or instars, simple observation indicated that *Nasonovia ribis-nigri* (Mosley) was the dominant aphid in both years. The numbers of aphids recorded (x) were transformed to log (x+1), and so geometric means ($\pm$S.D.) are shown in the Figure. The transformed data were analysed by two-way analysis of variance (ANOVA) for each date separately and, if significant, the mean densities were compared by modified (Bonferroni adjusted) LSD tests (SPSS for Windows, V5.0). The rates of increase in aphid numbers were calculated as $r=(\ln(x_2+1)-\ln(x_1+1))/(t_2-t_1)$, with t_2-t_1 being the difference in days between the two sampling dates. They were calculated separately for each replication and analysed subsequently the same way as the mean numbers.

In 1992, meteorological data were collected using sensors for temperature (Li-Cor 1000-16, Li-Cor Inc.), relative humidity (YA-100-Hygromer, Rotronic), photosynthetic active radiation (LI-190 SA, Li-Cor Inc.) and wind speed (A100R, Vector Instruments) coupled to a data-logger (LI-1000-32, Li-Cor Inc.). Data were collected from each of the three 'cage' treatments by the loggers taking records every few seconds and storing the mean values every 15 minutes. The sensors were positioned at a height of 35 cm.

Results

Although the microclimate was changed by the cages, the various parameters were affected similarly in both the closed and the open cages (Table 1). The mean daily wind speed and the daily sum of photosynthetic active radiation were reduced by about 50% and 20%, respectively, in both types of cage. In addition, the mean daily temperature was slightly higher and the mean daily relative humidity was slightly lower inside the cages.

Table 1. Microclimatic conditions recorded in three cage treatments: a closed cage, an 'open' cage and in the open field (no cage) in 1992 (means ± S.D. recorder for 23 days).

Cage	Closed		'Open'		None	
Mean daily temperature (°C)	19	(± 3)	20	(± 3)	19	(± 3)
Max. daily temperature (°C*)	29	(± 6)	29	(± 6)	28	(± 6)
Min. daily temperature (°C*)	11	(± 2)	11	(± 2)	11	(± 2)
Mean daily rel. humidity (%)	73	(± 11)	72	(± 11)	74	(± 11)
Daily sum of photosynthetic active radiation (mol/m^2)	30	(± 13)	29	(± 12)	37	(± 11)
Mean daily wind speed (m/s)	0.3	(± 0.1)	0.3	(± 0.1)	0.6	(± 0.2)
Max. daily wind speed (m/s*)	1.1	(± 0.4)	1.0	(± 0.3)	1.7	(± 0.5)

* Maxima and minima from a 15 min. integrated recording period.

Table 2. 1992: Mean numbers of aphid predators and percentage of alate, mummified and diseased aphids on lettuce in closed cages, 'open' cages and plots without cages (means of 4 replications; E = eggs, L = larvae, P = pupae, A = adults).

Date		8 July 1992			13 July 1992			21 July 1992		
Cage		closed	'open'	none	closed	'open'	none	closed*	'open'	none
Plants/replication		0	0	4	4	4	4	5	5	5
Syrphidae	L	-	-	0.2	0.0	1.4	1.7	1.8	1.9	1.6
	P	-	-	0.0	0.0	0.0	0.0	0.0	0.6	0.4
Coccinellidae	E	-	-	0.0	0.0	1.3	0.8	0.0	0.0	0.0
	L	-	-	0.1	0.0	0.0	0.0	0.6	0.7	1.1
	P	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	A	-	-	0.0	0.0	0.4	0.1	0.2	0.6	0.6
Chrysopidae	E	-	-	0.3	0.0	1.1	0.6	0.0	1.4	0.9
	L	-	-	0.0	0.1	0.2	0.0	0.2	0.7	0.4
	P	-	-	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Sum of active stages of predators		-	-	0.3	0.1	2.0	1.8	2.7	3.9	3.7
% alates		-	-	8.0	9.1	5.0	3.8	3.7	5.4	7.5
% mummified		-	-	4.0	4.1	6.9	7.0	5.3	16.1	18.4
% fungal diseased		-	-	3.2	11.3	19.4	14.7	23.7	59.8	48.6

* In 1992, aphid predators, mostly small larvae, were observed inside the cages at harvest time (Table 2). In 1993, this was minimised (see Table 3) by additional sealing of the edges of the cages.

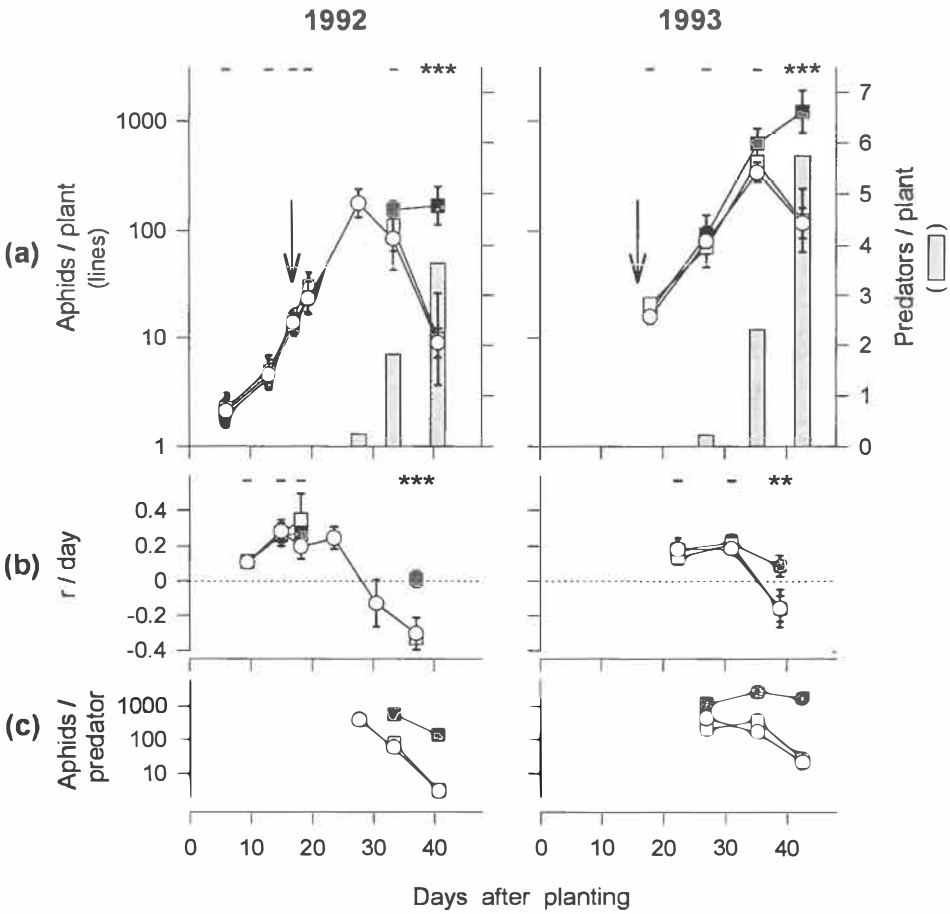

Fig. 1: (a) Mean numbers of aphids (log (x+1)) and (b) their rates of increase (r) and (c) the ratio of the numbers of aphids to the numbers of active stages of aphidophagous predators on lettuce in closed cages (■), in 'open' cages that allowed predators to enter (□) and in open plots without cages (○) (means of 4 replications ± S.D.). Sums of active stages of aphid predators in the plots without cages are given in (a) as bars. Arrows denote dates of caging. Differences between treatments are indicated (ANOVA, df=2, 6, *=p<0.05, **=p<0.01, ***=p<0.001; -=not significant).

In both years, there were no differences in aphid numbers between the three treatments during the first four weeks after planting (Fig. 1; all dates: ANOVA, P>0.05, df=2, 6). One week prior to harvest, more aphids were found in the closed cages than in open plots (modified LSD, P<0.05, n=4). By harvest, the differences had increased to 19 and 10 times more aphids under the cages than in the open plots in 1992 an 1993, respectively (ratios calculated with back-transformed geometric means; both differences significant: modified LSD, $\underline{P}<0.001$, n=4). Throughout the experiment, aphid numbers in the 'open' cages did not differ from those in the plots without cages on any date (either ANOVA $\underline{P}>0.05$, df=2, 6 or modified LSD, $\underline{P}>0.05$, n=4). In the open plots, the numbers of aphids declined about one week earlier in 1992, than in 1993, resulting in much lower aphid numbers being found at harvest in 1992 (Fig. 1).

Table 3. 1993: Mean numbers of aphid predators and percentage of alate, mummified and diseased aphids on lettuce in closed cages, 'open' cages and plots without cages (means of 4 replications; E = eggs, L = larvae, P = pupae, A = adults).

Date		5 July 1993			13 July 1993			21 July 1993		
Cage		closed	'open'	none	closed	'open'	none	closed	'open'	none
Plants/replication		9	9	9	4	4	4	4	4	4
Syrphidae	L	0.0	0.1	0.1	0.0	0.9	1.8	0.3	3.9	4.9
	P	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.4	0.7
Coccinellidae	E	0.0	1.9	0.9	0.0	3.9	2.5	0.9	1.1	3.4
	L	0.0	0.1	0.0	0.0	0.4	0.4	0.2	1.2	0.7
	P	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
	A	0.0	0.2	0.1	0.0	0.2	0.1	0.3	0.0	0.1
Chrysopidae	E	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.7	0.0
	L	0.0	0.1	0.0	0.1	0.3	0.0	0.2	0.4	0.1
	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Sum of active stages of predators		0.0	0.4	0.2	0.1	1.8	2.3	0.9	5.5	5.8
% alates		7.9	6.1	6.6	8.7	4.3	4.3	6.9	4.0	4.1
% mummified		0.3	0.4	0.3	0.1	0.8	0.6	0.4	2.3	3.1
% fungal diseased		0.0	0.0	0.2	0.7	1.7	1.8	4.6	14.5	9.8

Table 4. Total numbers of Coccinellidae observed in all lettuce plots in 1992 and 1993.

Species	1992	1993	Totals	Percentage
Propylea quatuordecimpunctata (L.)	16	9	25	45%
Coccinella septempunctata (L.)	14	5	19	35%
Adalia bipunctata (L.)	3	1	4	7%
Coccinella quinquepunctata (L.)	1	2	3	5%
Tytthaspis sedecimpunctata (L.)*	0	2	2	4%
Hippodamia variegata (Goeze)	1	1	2	4%
Totals	35	20	55	100%

* not aphidophagous, therefore omitted from the rest of the analysis

At the same time that aphid numbers decreased, the numbers of aphid predators increased in the open plots (Fig. 1, bars) and in the open cages (Table 2 and 3). The main predators were syrphid larvae (esp. *Sphaerophoria scripta* L. and *Episyrphus balteatus* De Geer), coccinellid larvae and adults (species composition in Table 4), and larvae of *Chrysoperla* spp. (Tables 2 and 3). The levels of fungal disease and parasitism were higher in 1992 than in 1993. However, the levels indicated are probably an overestimation, as by harvest in 1992 the density of aphids had fallen to less than 10/plant. The percentage of alate aphids never exceeded 10%.

Discussion

During the summer months, aphid numbers decline on most crops and this may be caused by several factors. The importance of individual factors is a matter of controversial discussions (Bombosch, 1963; Carter & Dixon, 1981). Apart from the impact of stenophagous aphid predators (e.g. Bombosch, 1963; Chambers *et al.*, 1983; Hopper *et al.*, 1995), aphid mortality can result also from diseases (Latgé & Papierok, 1988), parasitoids or polyphagous (Wratten and Powell, 1991). Other factors that can account for the decline of aphid numbers in different host-plants are: a combination of high temperature and photoperiod (Bombosch, 1963), a combination of high temperature and declining host-plant quality (Dixon, 1987), and intrinsic factors of aphid biology. The latter include discontinuous colonisation by the aphids or intraspecific competition which increases the percentages of both emigrating alatae and non-reproducing aphid larvae (Bombosch, 1963; Dunn & Kempton, 1971; Carter & Dixon, 1981; Dixon, 1987).

In our experiment, differences between treatments in aphid numbers occurred only near to harvest. Hence, colonisation was assumed to be comparable. The differences in microclimatic conditions were small between the closed and 'open; cages. Therefore the more than 10-fold differences in aphid numbers at harvest between the two types of caged populations in both years cannot be assigned to high temperature, rain or photoperiod. Due to the comparable microclimatic conditions, plant quality can be assumed to be similar in both situations and is also unlikely to account for the differences in aphid numbers. The higher percentage of alatae in the closed cages probably resulted from increased intraspecific competition at the higher population densities in these plots. However, the alate aphids were found mainly inside the heads and emigration from such sites could be difficult when lettuce heads become compact near to harvest. Therefore, neither an obstructed emigration from the closed cages nor a higher rate of emigration from the open cages seems to explain the differences in aphid numbers. The percentages of mummified and of fungal diseased aphids were lower in the closed cages than in the 'open' cages. However, it is difficult to assess the impact of parasitoids and of fungal diseases from simple sampling without additional laboratory studies. The decreasing aphid densities in the open plots and in the 'open' cages presumably lead to overestimations of mortality from parasitism and fungal diseases due to temporal dynamics (Walker *et al.*, 1984) and a relative enrichment of mummies (Kindlmann *et al.*, 1988).

If the reasons listed above do not explain satisfactorily the distinct differences in aphid numbers, do aphidophagous predators give a better explanation? To answer this question, the daily consumption rates for each predator that would be necessary to explain the changes in aphid numbers in the open plots were estimated, ignoring all other possible mortality factors. This was done using projected curves for the increase in the aphid population (slightly modifying the method of Chambers *et al.*, 1983).

Using a linear increase in predator numbers and a constant of 0.25 for the aphids rate of increase (Fig. 1b), the calculation indicates that it would be necessary for each predator to eat ca. 50 and ca. 25 aphids/day at the times aphid numbers fell in 1992 and 1993, respectively. This does not seem to be an unreasonable assumption (see Chambers *et al.*, 1983).

In this study, changes in aphid numbers were measured without any artificial inoculations (as e.g. in Hopper *et al.*, 1995), and so an unnatural aggregative numerical response of natural enemies was avoided. It might be suspected that the proximity of the faba bean strips may have increased the numbers of aphid predators in this experiment. However, on further examination (L.N., in prep.), this effect was shown to be restricted to distinct areas. In the bed of lettuce next to the beans, aphid densities were reduced by about 50% compared to a control field without strips. However, at the site in which the cages were erected, which was three beds away from the strips of faba beans, the aphid density was almost the same as that in the control field.

Other factors, which are unlikely to have caused major differences between the cages, can account (1) for the slowing down of the rate of increase of aphid populations in all plots and (2) for the differences in aphid numbers between the two years. For example, fungal diseases of aphids were more frequent in 1992 than in 1993 and may have resulted in reducing peak aphid numbers to 177 plant in 1992 compared to 339 plant in 1993. Intraspecific competition might also have reduced the rate of increase in aphid numbers under the cages once the population exceeded 600 aphids/plant (see Fig. 1b). However, the carrying capacity of heads of lettuce seems to be higher than this figure, as mean densities of more than 1200 aphids/plant were recorded in our experiment, and Quentin *et al.* (1995) report up to 3200 aphids/plant in controlled-environment.

If aphid densities decrease on lettuce heads one or two weeks before harvest, because of activities of aphid specific predators, it would have implications for aphid control strategies. To maintain predator activity, it is essential to tolerate some aphids on the plants at the stage of head formation. As shown in a study on cereal aphids (Poehling, 1988), spraying with even selective insecticides can result in starvation and reduced oviposition of aphid predators. On lettuce near to harvest the aphid population may recover following repeated applications of the insecticide Pirimicarb and hence, aphid numbers at harvest can be higher on sprayed than on unsprayed plots (L.N., unpubl.). Instead of the current strategy of frequent insecticide applications which prevents natural regulation processes, it would appear more advantageous to try to sustain the enormous potential of natural aphid regulation.

Aphid regulation could be regarded as sufficient in 1992, as there were fewer than 10 aphids/plant at harvest. In 1993, despite the distinct reduction of aphid numbers in the open field, the overall level was too high and resulted in visible debris and more than 100 aphids/plant at harvest, which is certainly not acceptable. However, the present study indicates several ways in which natural control could be made more effective. For example, extending the growing time for about one more week would decrease aphid numbers even further (Fig. 1 and additional data, L.N., unpubl.). At present this approach is not compatible with growing practices. However, applying less fertilizer might be. This would lead not only to reduced nitrate levels of the harvested product, but also to reduced plant growth which presumably would reduce the rate of increase of the aphid populations (Petitt *et al.*, 1994) and also give the predators more time in which to produce their effect. The increase in aphid numbers could be decreased further by using partially resistant varieties and by using lower doses of insecticides both of which allow aphid numbers to remain sufficiently high to attract predators (van Emden, 1988; Poehling, 1988). Several strategies have been proposed for increasing predator densities to an 'unnaturally' high ratio of natural enemies to aphids, particularly early in the season (see van Emden, 1988). These include the creation of habitats that provide feeding and overwintering sites in the field (Nentwig, 1995; Thomas *et al.*, 1992), artificial food sprays (Hagen *et al.*, 1971), intercropping (Andow, 1991) or, on a smaller spatial scale, the cultivation and destruction of faba bean strips that act as a source of aphid predators (L.N., in prep.).

Résumé

Les pucerons de la laitue : effets de l'exclusion des prédateurs de pucerons

L'impact des prédateurs d'aphides sur le nombre de pucerons a été étudié sur la laitue dans le sud de l'Allemagne en 1992 et 1993. Des cages ont été mises en place sur des plantes de laitue qui étaient colonisés par des pucerons afin d'en exclure les prédateurs. Environ deux semaines plus tard, davantage de pucerons ont été comptabilisés dans les parcelles encagées que dans les parcelles sans cage. Au cours des semaines suivantes, immédiatement avant la récolte, ces différences atteignaient 19 (1992) et 10 (1993) fois plus de pucerons dans les cages que dans les parcelles sans cage. Les nombres de pucerons des cages "ouvertes" accessibles aux prédateurs n'étaient pas différents ($\underline{P}>0,05$) de celles des parcelles non couvertes à quelque date que ce soit même si les conditions microclimatiques dans les cages ouvertes étaient comparables à celles des cages fermées. L'augmentation du nombre des prédateurs de pucerons (larves de syrphes, larves et adultes de coccinelles et larves de chrysopes) coïncidait avec la décroissance du nombre de pucerons dans les parcelles ouvertes. Il est proposé que les prédateurs sont le facteur clé de la réduction des populations de pucerons sur la laitue une à deux semaines avant la récolte. Toutefois cette régulation naturelle des pucerons n'est pas compatible avec la technique habituelle, qui est de traiter fréquemment avec des insecticides pour lutter contre les pucerons. En raison du potentiel considérable des prédateurs, il est proposé de prendre en considération l'utilisation de stratégies alternatives de protection des plantes.

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Future studies on the population dynamics of the carrot fly

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Summary

A new three-year project to develop "Pest thresholds for the treatment of carrot fly" will be started in April 1996 and will be co-ordinated by Stan Finch. The main aim of the project will be to relate the numbers of carrot flies (*Psila rosae* Fab.) caught on yellow sticky traps (Finch & Collier, 1989) to the amount of crop damage found at harvest. Extensive work to determine the optimum position and number of traps required per field to obtain robust estimates of fly populations (Collier & Phelps, 1994; 1996) and how best to assess overall crop damage will be done in commercial carrot fields by Rosemary Collier. I will determine how various chemical, biotic and abiotic factors regulate the survival of carrot fly larvae. The work will be done at HRI Wellesbourne mainly in a small field in which blocks of insecticide-free carrots are grown continuously to maintain a high population of flies. Pupae collected from this field will be used to produce the carrot flies needed for much of the experimental work.

The intensive work will involve inoculating groups of carrot plants with carrot fly eggs and then recording the relative rates of survival of the three larval instars following various experimental treatments. Much of this work will be done in large field-cages to prevent the natural population of flies from confounding the results. The larval extractions will be done using a system based on Tullgren funnels, as these enable even 1st-instar larvae to be extracted from soil (Finch & Vincent, 1996). The skill in this approach lies in being able to identify carrot fly larvae, particularly the newly-hatched 0.5mm-long individuals, from all of the other fly larvae found in the soil beneath carrot crops. Being able to extract 1st-instar larvae, means that it is now possible to make a direct assessment of the effects of the treatment on the insect, shortly after the treatment has been applied, rather than having to wait long periods before making an indirect assessment based on root damage. Results obtained in 1994 and 1995 using the Tullgren funnel extractions are shown in Finch & Vincent (1996).

It is hoped that the combined information from the extensive (R. Collier) and intensive (J. Vincent) parts of the study can be incorporated into a model to predict crop damage at harvest, in any area of any commercial carrot crop, from the numbers of flies caught earlier in the season on yellow sticky traps.

Résumé

Etudes envisagées sur la dynamique des populations de mouche de la carotte

Un nouveau projet d'une durée de trois ans débutera en avril 1996 sur les seuils de nuisibilité de la mouche de la carotte et il sera dirigé par Stan Finch. L'objectif principal sera de relier le nombre de mouche de la carotte (*Psila rosae* Fabr.) capturées aux piéges à glu jaunes (Finch & Collier, 1989) à la quantité des attaques trouvées à la récolte. Un travail important est nécessaire pour déterminer la position et le nombre de piéges par parcelle et pour obtenir des données robustes de la population de mouche (Collier & Phelps, 1994, 1996). Pour une meilleure estimation, les attaques de toutes les cultures seront calculées par Rosemary Collier.

Je déterminerai quelle variable chimique, quels facteurs biotiques et abiotiques régulent la survie des larves de mouche de la carotte. Le travail sera réalisé principalement à Wellesbourne au HRI dans de petites parcelles dans lesquelles des blocs de carotte indemnes de traitement insecticide seront semées régulièrement pour maintenir un niveau élévé de population de mouche. Les pupes collectées aux champs seront utilisées pour produire le matériel nécessaire à la plupart des travaux d'expérimentation.

Un travail intensif comprendra des lots de carottes inoculées par des oeufs de mouche de la carotte et on notera les taux relatifs de survie des trois stades larvaires dans les différents traitements. La plupart des expériences seront faites sous de grandes cages à l'extérieur pour éviter les infestations naturelles de mouches qui rendraient les résultats difficilement exploitables. L'extraction des larves sera réalisée au moyen des entonnoirs de Tullgren qui permettent même d'extraire les larves de premier stade (Finch & Vincent, 1996). La facilité de cette approche tient à la capacité d'identifier les larves de mouche de la carotte particulièrement celles qui viennent d'éclore qui ont 0,5 mm de long. La capacité d'extraire les premiers stades larvaire signifie qu'il est maintenant possible de faire des hypothèses sur l'effet des traitements très rapidement après l'application des produits plutôt que d'avoir une longue période avant de faire une estimation indirecte basée sur les dégâts racinaires. Les résultats obtenus en 1994 et 1995 au moyen des entonnoirs de Tulgren sont donnés par Finch et Vincent (1996).

On espère que la confrontation des informations du travail extensif (R. Collier) et intensif (J. Vincent) pourront être incorporés dans un modèle prédictif des dégâts à la récolte pour quelque surface et quelque parcelle commerciale que ce soit à partir du nombre de mouches de la carotte capturées plus tôt dans la saison au moyen des piéges à glu jaunes.

Acknowledgement

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Modelling the phenology of the cabbage root fly and its interactions with cauliflower

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Summary

A simulation model has been developed to describe the phenology of cabbage root fly (*Delia radicum*) and its interactions with cauliflower (*Brassica oleracea* var. *botrytis*). The model is based on the metabolic pool concept that has an age-specific distributed delay procedure to simulate the population dynamics of the pest. Temperature and exchange of energy between different trophic levels are the major driving forces behind the population dynamics. Aspects of how the simulation model can be improved are discussed.

Introduction

The development of a reliable IPM system for use on the cabbage root fly (*Delia radicum*) in cauliflower crops has proven to be an extremely difficult, as both the insect and the crop are affected by many different biotic and abiotic factors. Management strategies for complex biological systems usually requires a large number of field trials, if they are to be useful under different weather and growing conditions. The use of simulation models is one way to provide insight into these complex systems.

Pest forecast models for cabbage root fly activity have been described in recent years by several authors (Johnsen, Gutierrez & Freuler, 1990; Collier, Finch & Phelps, 1991; Hommes, Müller-Pietralla & Gebelein, 1993). As the number of fly generations, the egg-laying intensity and the egg-laying period varies between years, the aim of the models has been to predict the start of egg-laying for any given locality. With such systems, however, egg-laying still has to be assessed in the field.

Even with reliable estimates of the mean number of eggs per plant, the assessment of final crop damage is difficult because the immature stages of the cabbage root fly suffer from high mortality rates during the egg and early larval instars. Early work at Wellesbourne in the 1950s estimated egg mortality due to predators was about 90% when the eggs were placed on the surface of the soil (Hughes & Salter, 1959; Hughes, 1959). Recent research, however, (Finch & Skinner, 1988; Finch & Elliott, 1994) showed, that egg and early larval mortality is closer to 30%. However, considerable mortality may occur in the later larval instars as a result of abiotic rather than biotic factors (Finch & Elliott 1994). In Denmark, egg and larval mortalities due to abiotic factors ranged from 45% to 75% in pot inoculation experiments (Bligaard, unpubl.).

Cauliflower seedlings are highly susceptible to larval damage during the first few weeks after planting (Coaker, 1970). The growth stage at which cauliflower can tolerate larval attack is, however, still uncertain. El Titi (1979) found that cauliflowers were able to withstand more than 60 eggs per plant without yield loss four weeks after transplanting, whereas Maack (1977) found plants had to be more than six weeks old to tolerate such levels of attack. The destruction of the secondary root system of the plants makes air and soil humidity an important factor in plant survival (Maack, 1977; Coaker, 1965). Daily temperatures and solar influx also have a major effect on photosynthate production and plant vigour. Thus, weather is a factor that affects both the plant and the pest.

At present there are no well-documented control thresholds that include all these aspects. As a consequence, cauliflower growers usually carry out routine treatments based on their own personal experiences.

Johnsen (1990) started the work to model the cabbage root fly/cauliflower system, using a model based on the metabolic pool concept (Gutierrez, Baumgärtner & Hagen, 1981). The major part of Johnsens work (1990) was theoretical and was based on extensive data from the cabbage root fly literature, supported by his own studies. However, Johnsen (1990) did not relate the model output to field experiments that had been designed for such purposes.

The present work continued the modelling approach of Johnsen (1990) to obtain some of the critical information needed for improvement and validation of the model.

Material and Methods

Modelling method

The modelling approach adopted here could be considered as three closely-linked individual parts: 1) a model to describe the phenology of the plant; 2) a model to describe the phenology of the insect and 3) a model to describe the interactions between insect and plant. The cauliflower model was adopted from a plant phenology model (Olesen & Grevsen, 1993) modified by Thorup-Kristensen (1995). This model can describe from a given a number of daily weather variables the plant dry matter production and allocation at any time during the growth of the crop.

A modified version (Gutierrez & Baumgärtner, 1984a,b) of the mathematical model proposed by Manetsch (1976) and Vansickle (1977) for modelling distributed delay processes was used to model the phenology of the insect. In the model, some individuals mature faster than others, as this is what happens in nature. Therefore, although the model is deterministic, it simulates stochastic development. Age-specific mortality and fecundity, both of which affect greatly the population dynamics of the pest, can also be included in the model.

The basis of the metabolic pool concept is the exchange of energy, e.g. biological dry matter, that occurs between the different trophic levels. Hence, the linkage between the plant and the insect requires a parallel model for the dry matter flow of the insect, coupled to the population dynamics model. By doing this, it is possible to keep track of both insect dry matter and numbers of insects at any given time.

Food obtained from the plant is digested in the insect gut, a fraction is egested as faeces and the remaining is assimilated into the insects haemolymph. From the haemolymph, assimilated food is allocated firstly to respiration and secondly to larval growth (Fig. 1). The amount of dry matter acquired from the plant depends on the amount of dry matter supplied by the plant and the demand for food. Mathematically this can be expressed by a functional response equation (Gutierrez et al., 1981) modified after Frazer and Gilbert (1976). The instantaneous form gives a food acquisition rate, A: $A = D\,[1 - exp(-a\,S\,/\,D\,)]$, in which D is the insects demand rate for resources, S is the food supplied by the plant, and a is the ability of the insect population to access the food resources.

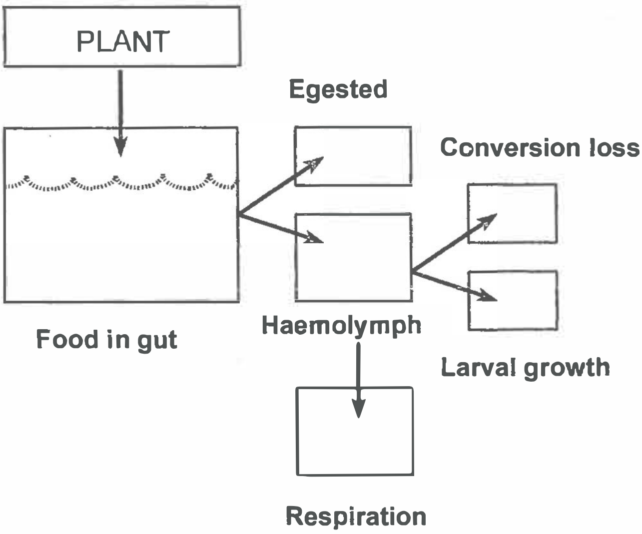

Fig. 1: A conceptual view of the metabolic pool modelling approach. Acquired plant dry matter is either egested as faeces or assimilated into the haemolymph of the larva, from where it is allocated to respiration, growth or to an energy conversion loss.

Respiration cost, R is included in the model as an Arheniuss function of temperature: $R = M\ Z\ 2^{(T/10)}$, where Z is a respiration constant, M is the relative mass of herbivores, and T is the temperature above the developmental threshold for this particular insect stage. Any surplus of food, after the deduction of respiration costs is allocated to larval growth which also includes the costs of converting one type of energy into another.

By running the simulation model loop with very small time steps e.g. daily, it is possible to simulate feed back mechanisms, which predict closely what occurs in the field.

Field experiments

A series of field experiments was set up in 1994 and 1995, but only the 1994 experiments are included here. Emergence of the first generation of flies was recorded by daily counts of newly-emerged flies in four to ten emergence traps in a previous years' cabbage field in Lyngby. For the second and third generation of flies, the traps were placed in crops where egg-laying had taken place during the preceeding generation.

The dynamics of egg-laying by the cabbage root fly was recorded by sampling the soil from around ten plants three to seven times a week from the begining of May until mid-October. Eggs were recovered from the samples by flotation and counted (Hughes & Salter, 1959).

To assess egg predation by predators, soil was sampled at the same time from ten plants each surrounded by a barrier (Diameter = 30 cm; height above ground = 10 cm; depth in the soil = 10 cm). The barriers were used to eliminate egg predation by ground beetles. A pitfall trap (Diameter = 6.5cm) was used inside each barrier to catch any intruding beetles. The relative population size and activity of ground beetles in the crop was recorded by five pitfall traps (Diameter = app. 10 cm), which were emptied also at the time the soil was sampled. Beetles were counted subsequently and identified to genus or species.

Approximately one week prior to the start of egg-laying by the second generation of flies (27 June, 1994), a 200m² area was transplanted with cauliflower (variety: *Plana*). The plants were grown according to normal commercial practices. Ninety-six randomly-chosen control plants were treated with carbofuran granules one week later. Twice a week, 15 plants (4 treated plants and 11 untreated plants) were sampled at random and each was divided into roots, leaves, stem and curd. The plant parts were dried at 60-80°C for one week and weighed. Further, roots were inspected to assess the numbers of larvae and pupae present. All larvae found were measured and then the dry matter of both the larvae and the pupae were assessed.

Throughout the season, daily weather data (maximum-minimum temperatures in air (+150cm) and soil (-10cm), solar radiation and rainfall) were recorded using a Hardi Metpole® sited in the experimental field.

Results

The timing of cabbage root fly emergence and egg-laying were usually related closely to the recorded temperature sums. The daily egg-laying pattern was related also to weather conditions. Egg-laying took place when the daily maximum temperature was above 10-12°C, and increased considerably when the maximum temperatures exceeded 18-20°C (Fig. 2). An inverse relationship was found also between egg-laying and the amount of precipitation in the preceeding period (Fig. 3).

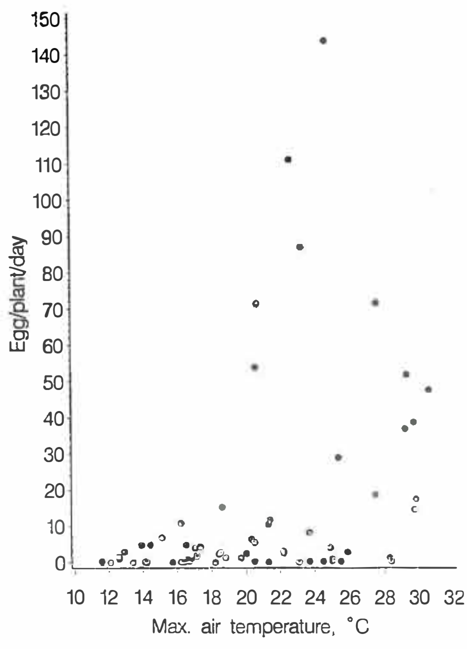

Fig. 2: Relationship between cabbage root fly oviposition (egg/plant/day) and maximum daily temperature (°C).

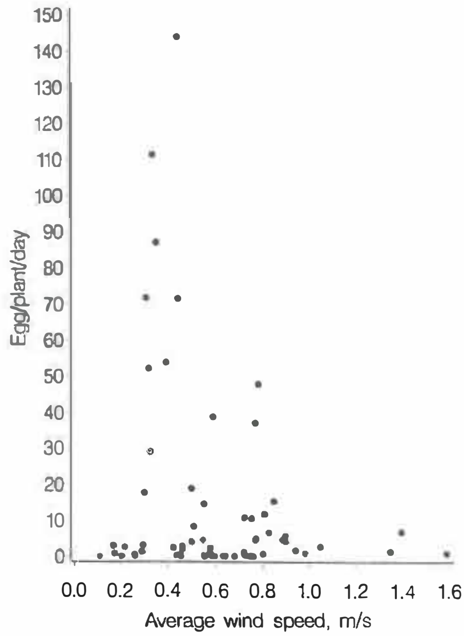

Fig. 3: Relationship between cabbage root fly oviposition (egg/plant/day) and rainfall (mm).

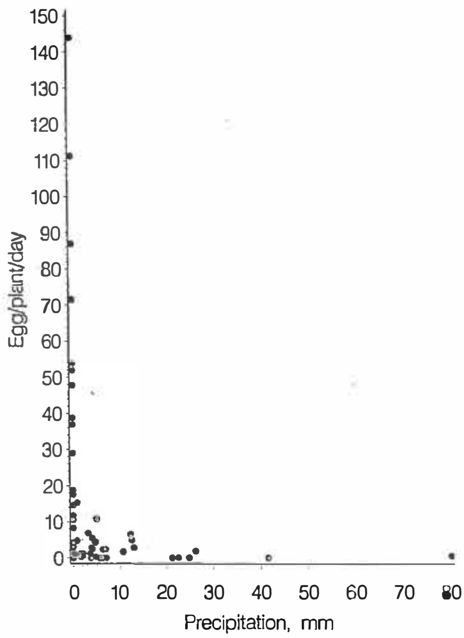

Fig. 4: Relationship between numbers of cabbage root fly eggs recovered from around plants with and without barriers. A line (dashed) with a slope or 1.0 is shown for reference.

An average of approximately five beetles were caught per day in the five pitfalls, or about 800-900 beetles during the entire season. Egg-predation by ground beetles seemed, however, to be of no consequence in the present experiments. No significant differences were found in the numbers of fly eggs collected from around the plants that were, or were not, surrounded by barriers (Fig. 4).

Larvae were found on the roots of both carbofuran-treated and untreated plants. However, the untreated plants had approximately three times as many larvae as the carbofuran-treated plants (Fig. 5). The growth rate of the leaf and curd of untreated plants was reduced severely by the feeding larvae during the later stages of the growing season (Fig. 6). In contrast, the treated plants continued to grow until harvest.

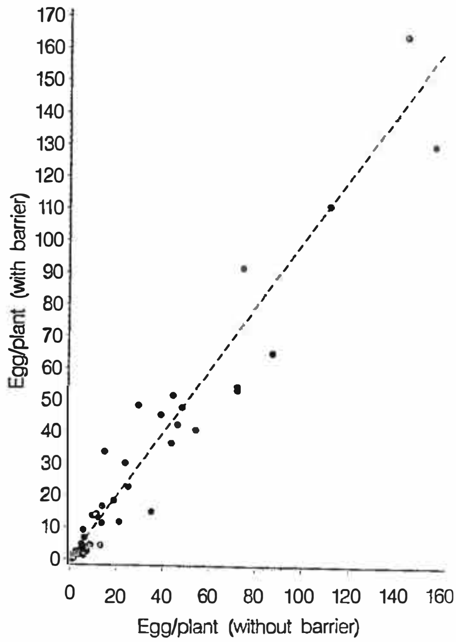

Fig. 5: Numbers of cabbage root fly larvae and pupae found around untreated and treated (carbofuran) cauliflower plants in samples taken during June-September 1994.

Discussion

The present experiments provided information to 'fine-tune' the output of the model by including effects of weather. The results suggested that the prediction of daily egg-laying should be scaled for precipitation and, to some extent, for daily maximum temperatures.

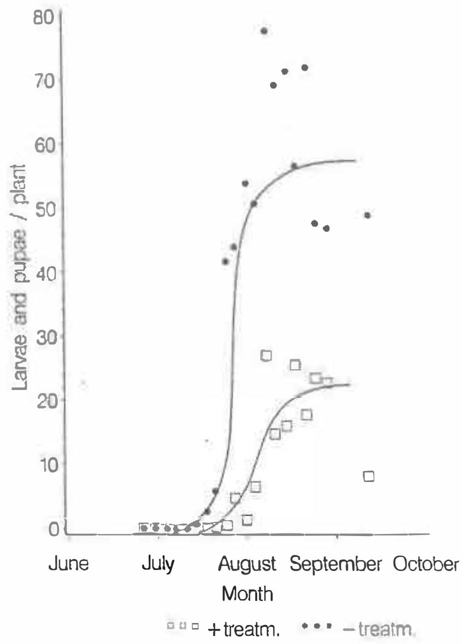

Fig. 6: Cauliflower growth and development: A) dry matter allocation (g) in untreated plants; B) dry matter allocation (g) in carbofuran treated plants.

High rates of egg predation, similar to those recorded at Wellesbourne in the late 1950s and early 1960s, were not recorded in the present experiment. On the contrary, the same numbers of eggs were found around plants with barriers as around plants without barriers, which suggested that egg predation was negligible. The only other reasonable explanation would be, that cabbage root flies did not like to oviposit behind the barrier, and hence, this reduction in egg numbers should be equal to the number of eggs eaten by egg predators outside the barrier. This seems unlikely, however, as on several occasions up to 100-150 eggs were found on individual plants with barriers. The low egg predation by ground beetles is due to the fact, that cabbage root flies lay their eggs in, rather than on, the soil, and this reduces egg predation markedly (Finch & Elliott, 1994).

A basic problem with insect/plant interaction models, is how to describe damage. Johnsen (1990) suggested that direct feeding on phloem fluids and root tissues, in combination with indirect effects that interfere with the uptake of water and nutrients by the plants, should be included in damage. McDonald and Sears (1992) similarly suggested that root damage on canola (*B. campestris*) interferes with the ability of the root to meet the critical water and nutrient demands of developing seeds. The findings of McDonald and Sears (1992) were parallel to the observed growth reduction during curd formation in heavily infested cauliflower. Preliminary simulation runs indicated that indirect effects on water and nutrient uptake, caused by extensive injury to the lateral root system, were apparently the major effects produced by cabbage root fly larvae. For most plants, larval food demand seemed negligible, as they were in milligrams/day, whereas plant net-production was in grams/day.

The use of accurate pest forecasts and simulation models for insect/plant interactions are important steps towards the development of IPM. The next step is to combine simulation models with actual field observations, as most current pest forecasts predict only the timing of egg-laying in the field and not its magnitude. The development of user-friendly methods for obtaining reliable estimates of egg-laying in the field, thus becomes as important as the simulation models themselves.

Résumé

Modélisation de la phénologie de la mouche du chou et de ses interactions avec le chou-fleur

La mouche du chou (*Delia radicum*) est communément le ravageur le plus important sur chou-fleur au Danemark. Deux à trois générations sont observées chaque année avec des pontes plus importantes au cours de la deuxième génération. En raison des difficultés rencontrées pour suivre les pontes et le temps passé, les agriculteurs effectuent des pulvérisations sur les choux-fleurs de façon préventive pendant toute la saison. L'emploi de modèles de la phénologie est une des voies qui permet de minimiser la période ou le suivi des pontes prend beaucoup de temps. Ainsi un modèle de simulation a été développé pour relier la phénologie de la mouche du chou (*D. radicum*) aux interactions avec le chou-fleur (*Brassica oleracea* var. *botrytis*). Le modèle est basé sur le concept d'une base métabolique qui tient compte, à un âge spécifique, des processus pour simuler la dynamique de la population du ravageur. La température et les échanges d'énergie entre les différents niveaux trophiques sont les points principaux qui déterminent la dynamique de la population. Les différents aspects sur la manière dont le modèle de simulation peut être amélioré sont discutés.

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Simulation models for the cabbage root fly and the carrot fly

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Summary

Simulation models based on the extended Leslie model were developed for the two major vegetable root pests in Europe, the cabbage root fly (*Delia radicum* L.) and the carrot fly (*Psila rosae* F.). The models illustrate the dynamics of a simulated pest population for each of the four development stages: adult, egg, larva and pupa. The results of the simulations are presented graphically. The information obtained from the models will be used as a decision tool for the advisory service and for practice. The period for field monitoring could be minimised. An appropriate time could be chosen so that practices such as sowing or planting could be timed to coincide with periods of low infestations. Control methods could be applied at the most effective times.

The current version of both models is based on daily data for air temperature, soil temperature and wind speed. The computer programme is written in C++ and runs on nearly any personal computer with a 286, or higher, processor.

Since 1994, both models were tested in different vegetable growing regions of Germany. Results of the first two years were promising and showed a good correlation between the values calculated by the models and the field observations, obtained from egg traps for the cabbage root fly and from yellow sticky traps for the carrot fly.

Introduction

Progress in computer technology is increasing rapidly and high-performance computers are now available to nearly everyone. As a consequence, computer-based decision tools, like simulation models (Collier *et al.,* 1990; Collier *et al.,* 1991; Johnsen *et al.,* 1990) or expert systems (Johnsen *et al.,* 1995), are now offered frequently for use in plant protection. Models for simulating the risk of disease infestation or the development of insect pest populations can be extremely useful to both the advisory service and farmers for improving plant protection.

Within the framework of a large research project sponsored by the Federal Ministry of Food, Agriculture and Forestry, simulation models were developed for three major vegetable pests in Germany, the cabbage root fly - *Delia radicum* L., the carrot fly - *Psila rosae* F. and the diamond back moth - *Plutella xylostella* L. (Crüger *et al.*, 1993, Hommes, *et al.*, 1994).

Since 1994, both root fly models were tested in a subsequent project within different regions in Germany to show how the models work under different climatic conditions and to introduce the models into practice.

In this paper a simple overview is given of the structure of the models. Results are presented also of the comparison made between predictions from the models and field observations at a site in Braunschweig.

Basis and structure of the models

The mathematical basis of both models is the extended Leslie matrix (after Söndgerath, 1987). This matrix combines several Leslie processes, and so the matrix can be used for describing the dynamic of insect populations with different development stages. Each instar is divided into age classes and the transition probabilities have to be calculated for each age class and for each instar. An age class (AC) is the combination of time and the status of development of the insects.

Diapause and non-diapause pupae are categorised as different instars in the model. Superimposed onto these are functions for the survival distribution and the fecundity of the females. Aestivation during the summer months and flight activity dependent on the wind speed are also considered in the two root fly models (Crüger *et al.*, 1993 & Hommes *et al.*, 1993).

The models require daily inputs of average air (2 m height) and soil temperature (5 cm depth) and, when available, date for wind speed (2 m height). The technical requirements for the computer are extremely low. The simulation programme runs on nearly every standard PC with a 286, or higher, processor and at last 640 KB memory buffer. At the moment, the programme is available in three languages: German, English and French. Expansion into other languages would be simple.

User shell and output of the simulation programme

The actual version of the computer programme is written in the language C++. This allows the build-up of very fast and powerful programmes, which will run on nearly every platform. To increase its acceptance to the user, we orientated the user shell to the Standard Application Architecture (SAA), with so called 'pull down menus', with which most of the common sotfware programmes are equipped today. The first level of the user shell contains eight different menus and is presented in Fig. 1.

The menu (Graphic), in which the simulation results are presented in the form of graphs, will be the most important tool for the users. In this menu, the user can choose between output screens for population dynamics (development of all stages in one figure), AC structure (shows the distribution of biological age classes in bar charts of all instars at one day), egglaying, flight activity, or weather data. From our point of view, the AC structure is the most powerful option, because it provides the maximum information about the development and structure of the fly population on one screen (Fig. 2).

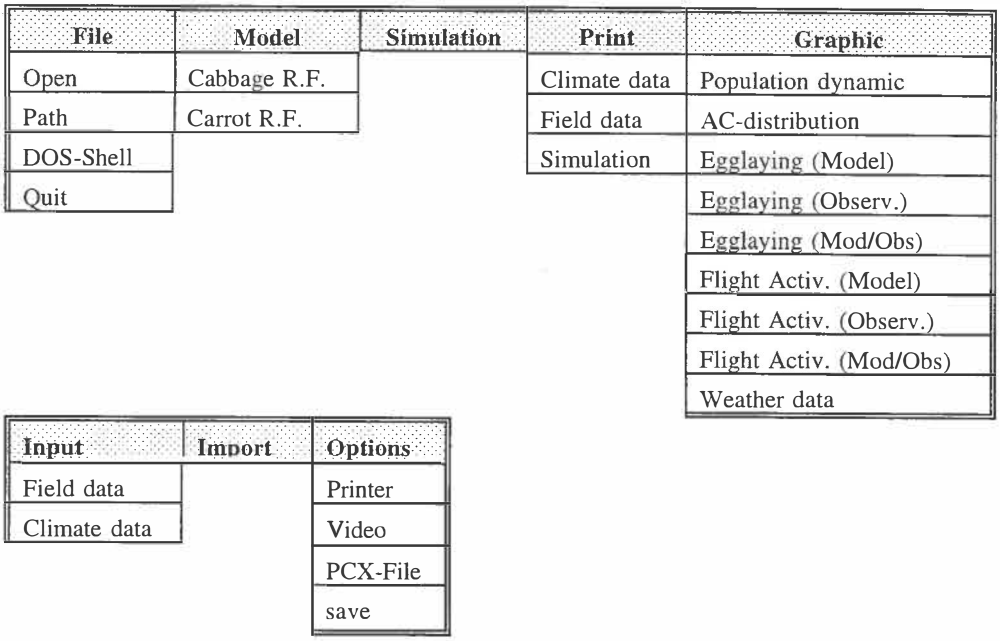

Fig. 1: User shell of the simulation programme (Main menu).

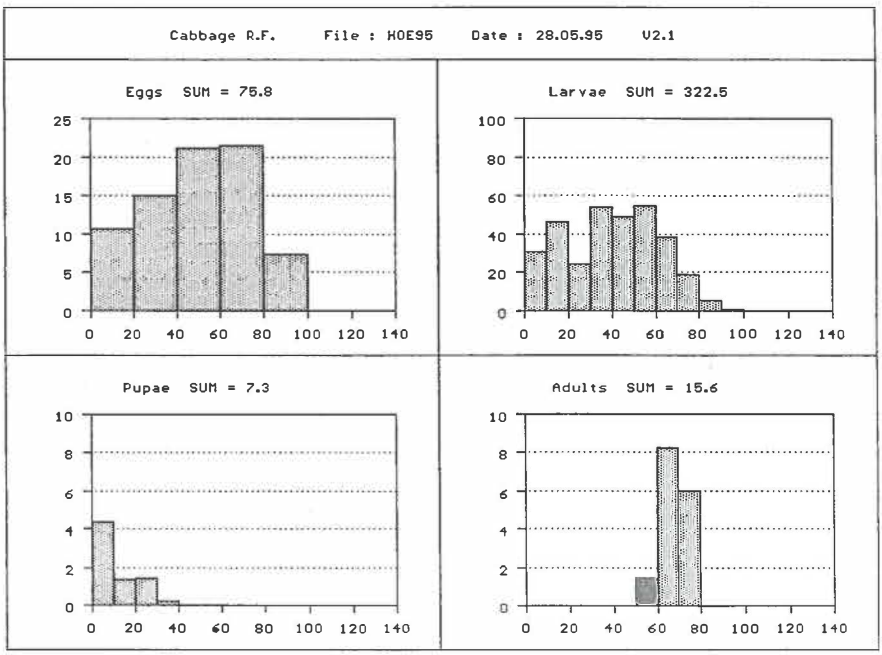

Fig. 2: Example for an output of the age class (AC) distribution.

Validation: comparing the model-generated data with field observations

After building up a prototype computer programme, the simulation models have been tested in different regions of Germany since 1994. The validation of the models was done by collecting samples from untreated cauliflower and carrot fields using egg traps for the cabbage root fly and yellow sticky traps for the carrot fly.

Results

Results for cabbage root fly

The model data obtained for the cabbage root fly fit well to the monitoring data especially for the first generation. The observed differences between the results from the model and the field data can be tolerated (Table 1). The accuracy of the simulations decreased for the later fly generations. During a hot and dry summer, where the pupae could enter aestivation or when the second and third fly generations overlap, the deviations between the expected (model) and the observed values (field monitoring) could increase considerably.

Table 1. Comparison of the expected (model) [E] and observed (field monitoring) [O] start and peak of egg-laying by the first generations of cabbage root fly and carrot fly at Braunschweig during 1990-1995.

	Cabbage root fly		Carrot fly	
	First eggs	Peak eggs	First eggs	Peak eggs
Year	O-E (days)	O-E (days)	O-E (days)	O-E (days)
1990	+2	+2	-4	-3
1991	-11	-8	-22	-23
1992	-1	-3	+5	-5
1993	+6	+3	+3	-1
1994	+4	+7	+3	-6
1995	+4	+13	+3	-5

Results for carrot fly

For the carrot fly, the differences between the field observations and the model are slightly larger than those for the cabbage root fly, but still sufficiently accurate for practical purposes (Table 1). In general, the model predicts activity to be later than it actually is in the field. A likely reason for this is that carrot flies remain in hedges and other sheltered places during the pre-oviposition period and only enter the carrot fields later to lay their eggs. There might also be a larger influence of soil moisture, which could possibly delay eclosion of the adults from the pupae or increase the mortality of eggs and young larvae during dry periods.

Use and prospects of the models

There are several ways in which these simulation models can be used:

Forecasting system. With appropriate weather data the models could be used to forecast the timing of infestations by both root flies.

Minimising the time space for monitoring. With a good forecasting system, the time interval during which fields were monitored could be kept to a minimum.

Hints. The information from the models can identify appropriate times (for example the end of a generation) for cultural practices such as sowing, planting, putting covers onto crops, or removing covers so that crops can be weeded.

Hints for control methods at the most effective time. The models can also help to ensure that control measures are applied at the most effective times. If an insecticide kills only one instar, for example the adults or the larvae, the information on the best timing to apply an insecticide can be obtained from the age class (AC) distribution. The model can also provide the user with the necessary information for releasing natural enemies at the most appropriate times.

Risk analysis for shifts in climate conditions. With the help of the models, it is possible to simulate changes in the global climate (Collier *et al.*, 1990). For example, if the average temperature decreases by two degrees at Braunschweig the cabbage root fly will have only 2 distinct generations per year in comparison to the 3 or 4 experienced at the moment.

Conclusions and future prospects

With appropriate weather data, the models allow growers and advisors to forecast the occurrence of both root flies and minimise the time interval in which fields should be sampled. With the possibility of a simultaneous view into the age structure of the different development stages, decisions can also be given for the timing of control procedure and other cultural practices.

In future it is planned to include soil moisture into the simulation, to improve the accuracy of the model, especially during periods of dry weather when the mortality of eggs, larvae or pupae can be increased or their development delayed.

Résumé

Modèles de simulation pour la Mouche du chou et la Mouche de la carotte

Des modèles de simulation basée sur le modèle étendu de Leslie furent développés pour deux ravageurs majeurs en Europe, la Mouche du chou (*Delia radicum*) et la Mouche de la carotte (*Psila rosae*). Les modèles illustrent la dynamique des populations des ravageurs simulées pour chacun des quatre stades de développement : adulte, oeuf, larve et pupe. Les résultats des simulations sont présentés graphiquement. L'information obtenue de ces simulations sera utilisée comme outil de décision par les services d'avertissement et dans la

pratique. La durée de suivi des cultures pourra être minimisée. Un temps approprié pourrait être choisi soit pour les pratiques soit pour les semis ou la plantation, afin de le faire coïncider avec les périodes de basses infestations. Les méthodes de lutte pourraient être effectuées au moment le plus efficace.

La version courante des deux modèle est basée sur les données journalières de la température de l'air, du sol et la vitesse du vent. Le programme d'ordinateur est écrit en C++ et fonctionne sur n'importe quel ordinateur personnel ayant un processeur de 286 ou plus.

Depuis 1994, les deux modèles ont été testés dans différentes régions de culture légumière d'Allemagne. Les résultats des deux premières années sont prometteuses et montrent une bonne corrélation entre les valeurs calculées par les modèles et les observations obtenues aux champs des pièges à oeufs pour la Mouche du chou et des pièges à glu jaunes pour la Mouche de la carotte.

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Systems for the supervised control of carrot fly (*Psila rosae* F.) in The Netherlands: I Method of sampling flies

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Summary

During the first flight in 1994, a comparison was made between the numbers of carrot flies caught on a pivoting sticky trap and the numbers caught on a non-movable trap (Rebell) with the top pointing towards the east. All the non-movable traps were placed at an angle of 45° towards the crop. The catch on the lower surface of the pivoting trap was more reliable than that from the non-movable trap.

At four sites in 1994, four and six traps were used during the second flight of the carrot fly to determine the timing and number of flies caught at a distance of 0.75m and 5m into a carrot crop. More flies (1.5 to 2.5 times as many) were caught 0.75m into the crop than 5m into the crop. The arrival of carrot flies was also detected earlier at 0.75m. The most appropriate place to site the traps, can be determined initially by placing traps throughout the field.

Introduction

Monitoring carrot fly numbers 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 polythene, 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 effect that appeared to be influenced by the direction of the prevailing wind. A simple construction was made to ensure that the lower surface of the traps always faced away from the wind (leeward side).

During the second flight in 1993, a comparison was made between the numbers of flies caught on a pivoting sticky trap and a non-movable trap whose top pointed towards the east. Differences were not recorded because the wind was always from the west (Schoneveld & Ester, 1994a). Hence, this experiment was repeated during the first flight in 1994.

During the development of a system for supervised control of carrot fly (3 years) the traps were always placed five metres into the carrot field (Schoneveld & Ester, 1994b). Sampling carrots showed that crop damage was much more severe at the edge of the field. The question to be answered is would traps placed 0.75m into a crop give a better estimate of the fly population from traps placed 5m into the crop?

Materials and Methods

Pivoting sticky trap

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 wind vane of galvanised iron bolted to the top. The whole structure pivoted on a pointed bar of mild steel (Schoneveld & Ester, 1994a).

During the first flight in 1994, carrot flies were caught only on the lower surface of both traps. The non-movable trap was angled at 45° with the top pointing towards the east. This experiment was carried out in five carrot fields. For comparative purposes, the traps were placed in pairs, 2 to 3 metres apart.

Numbers of carrot flies caught 0.75m and 5m into fields

During the second flight (week 31 to 40) in 1994 four and six Rebell traps were placed 0.75m and 5m from the edge of three different carrot fields.

Results

Pivoting sticky trap

Table 1. Total number of carrot flies caught per field on the lower side of pivoting (P) and non-movable (NM) traps during the first flight of carrot fly in 1994.

Field no.	Number of weeks	P	NM	% P : NM
310	11	199	140	142
312	11	165	162	102
401	5	20	11	182
201	8	315	275	115
501	11	163	147	111
averages		204 b	170 a	120

Averages followed by the same letter do not differ significantly (Analysis done on data transformed to logarithms).

During the first flight the wind blew from all directions. The average number of carrot flies caught depended on the number of weeks that observations were made in a particular field. Thirty-four more flies (204-170) were caught on the pivoting trap than on the non-movable trap (20% more carrot flies) (Table 1). The numbers of flies caught on the pivoting trap (P) was higher than on the non-movable trap (NM) during weeks 18 to 23 with a maximum of 205% being recorded for week no. 21 (Table 2). After week 25 the pivoting trap caught fewer flies than the non-movable trap, and the results became more variable.

Table 2. Numbers of carrot flies caught per field per week on the lower surfaces of the pivoting (P) and non-movable (NM) trap. Data recorded during the first flight in 1994.

Week no.	Field no.	310		312		501		Average		% P:NM
		P	NM	P	NM	P	NM	P	NM	
18		10	6	2	2	2	1	5	3	157
19		36	24	9	4	14	17	20	15	131
20		33	22	23	12	53	39	36	24	149
21		26	18	39	23	21	19	29	14	205
22		29	21	24	22	16	24	23	22	103
23		16	13	24	20	25	16	22	16	133
24		21	14	25	34	15	14	20	21	98
25		18	10	28	33	9	10	18	18	103
26		8	8	2	10	4	3	5	7	67
27		1	1	0	1	2	3	1	2	59
28		2	2	2	4	3	1	2	2	100
Total		200	139	178	165	164	147	542	451	120

Means followed by the same letter do not differ significantly. (Analysis done on data transformed to logarithms).

Numbers of carrot flies caught at 0.75m and 5m into crops

Table 3. Comparison of the numbers of carrot flies caught per week at distances of 0.75m and 5m from the boundaries of three carrot fields in 1994.

Week no.	Field no. Distance into crop (m)	315[1)]		316[2)]		406[1)]	
		0.75	5	0.75	5	0.75	5
31		-	-	3.5	0.5	0	0.3
32		1.2	0.8	30.2	3.0	2.7	0.5
33		1.7	2.2	23.7	3.8	3.2	1.2
34		8.8	4.5	50.5	13.2	6.0	3.0
35		10.3	2.5	72.3	33.8	0.5	0.8
36		9.8	6.5	9.0	6.3	1.5	0.8
37		5.3	1.7	5.2	4.5	1.7	0.5
38		4.0	0.8	38.7	12.5	0.3	0
39		3.0	1.5	13.0	5.8	0	0
40		1.5	0	10.5	6.2	0	0
Total		46	21	257	90	16	10

Averages followed by the same letter do not differ significantly. (Analysis done on data transformed to logarithms).[1)] 4 replicates [2)] 6 replicates and 3 applications of dimethoate.

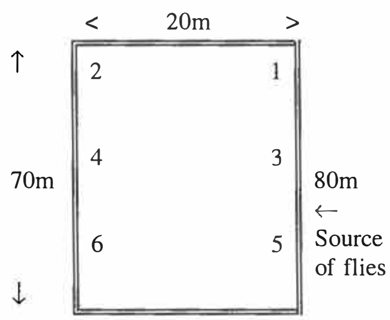
The data from the three fields indicated that 1.5-2.5 times as many flies were caught at 0.75m than at 5m from the crop boundary (Table 3). Field 316 was sprayed three times with dimethoate.

Table 4. Comparison of the numbers of carrot flies caught per trap (6 reps) at a distance 0.75m and 5m in from the boundary of carrot field 316.

Trap position	1		2		3		4		5		6	
week	0.75	5	0.75	5	0.75	5	0.75	5	0.75	5	0.75	5
31	8	0	7	1	1	0	1	1	3	1	1	0
32	73	2	63	3	8	4	3	3	29	2	5	4
33	66	8	42	7	3	2	4	3	20	2	7	1
34	144	29	49	20	40	12	9	9	44	8	17	1
35	141	33	109	50	43	43	37	36	54	26	50	15
36	17	6	16	10	8	4	3	6	4	10	6	2
37	11	5	7	3	6	6	3	2	3	9	1	2
38	72	16	45	14	30	16	16	10	47	11	22	8
39	27	6	17	8	7	6	7	9	16	4	4	2
40	18	7	28	10	2	5	11	8	1	4	3	3
Total	577	112	383	126	148	98	94	87	221	77	116	38
Ratios 0.75:5	5.1		3.0		1.5		1.1		2.9		3.0	

In field 316 the numbers of carrot fly caught varied considerably depending upon where the traps were sited. Most flies were caught on traps 1 and 2 followed by traps 5, 3, 6 and 4 (Table 4). More carrot flies were caught also on traps 5 and 6 than on traps 3 and 4. The largest difference between 0.75m and 5m into the field was recorded on trap 1 followed by trap 2, 5 and 6. Lowest numbers of flies were caught in the centre of the field on traps 3 and 4. Table 4 shows that reasonable numbers of flies were caught 0.75m into the field on traps 1 and 2 during week number 31, whereas similar numbers of flies were caught only two weeks later on the traps 5m into the field.

Siting of traps in field 316



Discussion

Pivoting sticky trap

Differences can be expected between the numbers of carrot flies caught on pivoting traps and non-movable traps. For example, when there is hardly any wind, there is no difference between windward side and the leeward side of the pivoting trap. In addition, it is important to have sufficient wind to move the pivoting trap into the correct alignment, particularly the supporting pole has not been placed exactly vertical. Similarly, largest differences are found between the two traps when the period between the assessments coincides exactly with a changed wind direction.

Even with varying wind directions during the first flight in 1994, the pivoting sticky trap caught more flies that the non-movable trap.

Conclusions

The pivoting sticky trap caught approximately 20% more carrot flies during the first flight in 1994 than the non-movable trap. The pivoting sticky trap was more reliable when the wind direction was variable or from the east.

About 1.5-2.5 times as many carrot flies were caught on traps placed 0.75m into the carrot crop than traps placed 5m into the crop.

The immigration of flies into a crop was recorded earlier by siting traps at 0.75m rather than 5m into the field.

Résumé

Les systèmes de suivies de la lutte contre la mouche de la carotte (*Psila rosae* F.) aux Pays Bas : I Méthode d'échantillonnage des adultes

Lors du premier vol en 1994, une comparaison a été faite entre le nombre de mouches capturées sur un piége pivotant et le nombre de mouches capturées sur un piége rigide (Rebell) dont le sommet était orienté à l'est. Tous les piéges rigides sont placés avec une inclinaison de 45 ° vers la culture. Les captures obtenues sur la face inférieure du piége pivotant sont davantage reliées à celle du piége rigide.

Aux quatre emplacements de 1994, quatre et six piéges ont été utilisés pendant le deuxième vol de mouche de la carotte pour déterminer la durée du vol et le nombre de mouches capturées à une distance de 0,75 m et 5 m dans la culture de carotte. Plus de mouches (1,5 à 2,5 fois plus) ont été capturées à 0,75 m dans la culture que à 5 m. L'endroit le plus approprié pour positionner les piéges peut être déterminé initialement en placant des piéges au travers de la culture.

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Systems for the supervised control of carrot fly (*Psila rosae* F.) in The Netherlands: II Relationship between the number of flies caught on traps and crop damage

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Summary

The relation between the number of carrot flies caught and damage showed considerable variation in the field trials done in 1992, 1993 and 1994. Damage was found only when more than 20 and 8 flies were caught per trap per week, during the first and second flights respectively.

Carrot fly damage decreases with distance into the field. Applying insecticide only to the edge of the field (18-24m) is effective only when the population density remains around the damage threshold.

Introduction

This research was started because the insecticide bromophos was withdrawn by the manufacturer. This insecticide had been used previously to control the second flight of the carrot fly in The Netherlands. However, following its withdrawal, few complaints were received from growers. This was due either to the alternative treatments being effective or because carrot fly numbers were low in certain regions of The Netherlands.

Materials and Methods

Locations

The research was started in 1992 as a combined project between the Plant Protection Service (PD) in the various regions in The Netherlands and the PAGV in Lelystad. Traps were placed in two fields in each region to determine the start of the first flight of the carrot fly, and to gain experience in servicing traps and identifying flies. During the second flight in 1992, and both flights in 1993 and 1994, traps were placed in one field in each region.

The number of flies caught

Three Rebell traps were placed 5 metres apart and 5 metres away from a field boundary. The sites chosen for the traps were, 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 was noted. All traps were placed just above the crop, at an angle of 45° (Finch & Collier, 1989), with the top facing east. Each week the non-movable 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.

Data for the relationship between the numbers of carrot flies caught and crop damage have been included from 1992 and 1993, and from untreated carrot fields in 1994.

Crop damage

On each field, three 20m long plots (A, B and C) were marked out. Each plot was either 18m or 24m wide to accommodate the width of the sprayboom. Plots A and B were used as untreated controls and plot C received the normal insecticide spray treatments.

Eight weeks after the peak of flight activity, three samples were taken from each plot. The samples were taken 5, 10 and 15 metres away from the field edge in plots A and C and 25, 30 and 35 metres away from the field edge in plot B.

A total of 50 large and 100 small carrots were taken at 10 random spots, parallel to the field edge. 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.

Results

Relation between the distance from the edge of the field and crop damage

As the distance from the field edge was increased, crop damage decreased (Fig. 1). At high levels of infestation, crop damage extends further into the field. Only when few flies were present, was spraying the field edge (18-23m) sufficient to prevent damage.

The relationship between percentage damage and distance into the crop has been described by the function and parameters in Table 1. Only for classes 15-40m is the parameter R significantly different from class >40m. Classes 0-5 and 5-15m did not differ with respect to parameter B. All other values of B were different ($P < 0.001$).

Table 1. Parameters of the function $Y = BxR^x$: in which Y is the percentage of attack, B the constant, R the slope and x the distance to the boundary of the field.

Distance of trap from field boundary	B[1)]	(s.e.)	R	(s.e.)
0-5	5 a	(2.0)	0.95 ab	0.038
5-15	10 a	(4.1)	0.97 ab	0.030
15-40	33 b	(4.0)	0.94 a	0.012
>40	73 c	(3.3)	0.97 b	0.003

Estimates followed by the same letter do not differ significantly ($P \leq 0.01$).

Slope (regression line)	Flight no.
0.59 a	1
1.01 b	2
0.38 c	2 + dimethoate

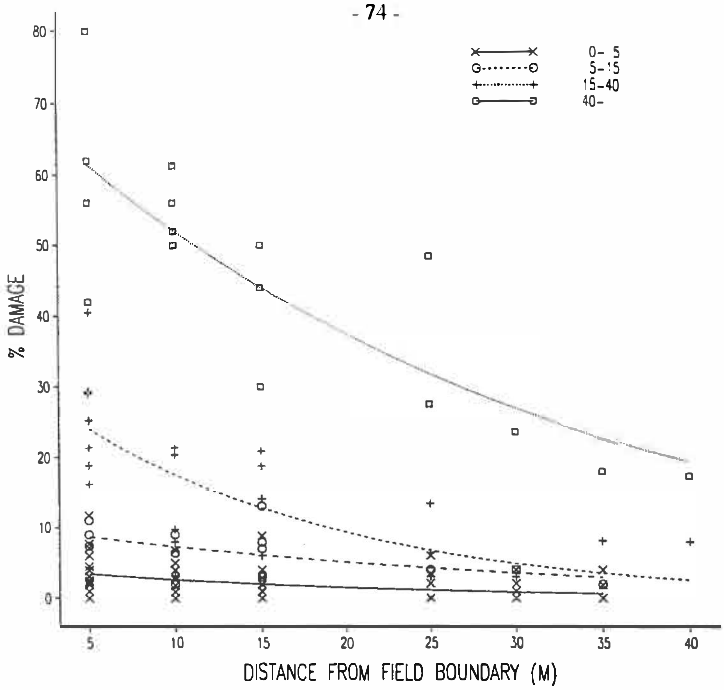

Fig. 1: Correlation between the distance from the boundary of the field and the percentage of damaged carrots.

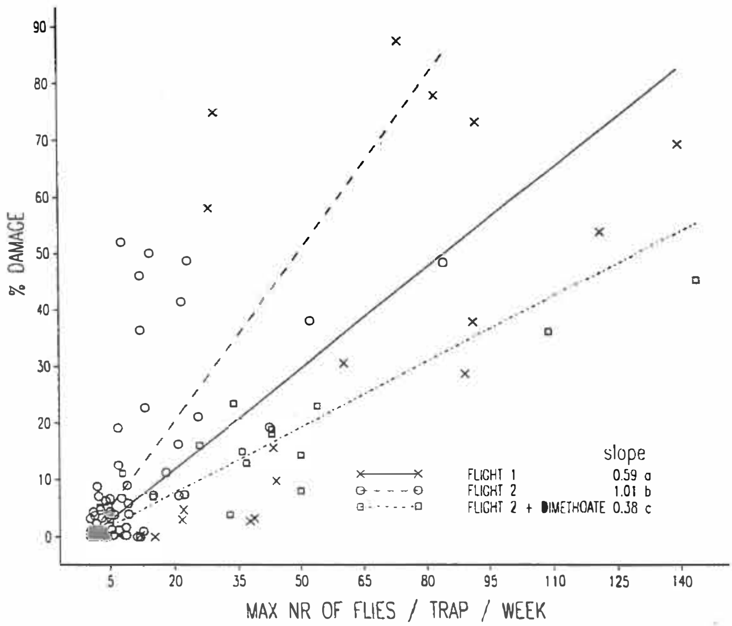

Fig. 2: Correlation between the number of carrot flies caught and the percentage of the carrots damaged. Slopes followed by the same letter do not differ significantly. (Analysis done on data transformed to logarithms).

Relation between number of carrot flies caught and subsequent crop damage

Figure 2 shows the relation between the maximum number of carrot flies caught per week and the percentage of damage during the first and second flight. It also shows data for the second flight when dimethoate was applied to certain fields.

The relationship between the number of carrot flies caught and carrot damage was extremely variable, except when the insecticide dimethoate was applied (Fig. 2). Analysis of the data for the first flight, showed that the regression coefficient for 1994 was significantly lower than that for 1992 and 1993 taking into account the total number of flies caught per flight (Table 2). In all other circumstances, no significant year effect was found. Between the first and second flight there were reliable relationships between the total number of flies caught per flight and the maximum number of flies caught per week. The dimethoate application had a highly significant effect in both cases.

Table 2. Regression coefficient (a) of the relationship between the percentage of damaged carrots and number of carrot flies caught. y = ax.

	1992	1993	1994
First flight total	0.24 b	0.33 b	0.12 a
Max. flies per week	0.50	1.06	0.62
Second flight total	0.32a	0.36a	0.30a
with dimethoate	-	-	0.15
Max. flies per week	0.85	1.24	0.86
with dimethoate	-	-	0.38

Averages followed by the same letter do not differ significantly (P=0.05).

Based on these details a damage threshold can be formulated, which depends on the flight (first or second), position of the trap in the field, and the method of control (Table 3).

Table 3. Damage threshold based on the numbers of carrot flies caught per trap per week.

	First flight		Second flight	
Distance	**flies**	**larvae**	**flies**	**larvae**
0.75m	14	14-21	7	7-14
5m	7	7-10	3.5	3.5-7

1) The lowest threshold can be used to apply sprays of an insecticide against the larvae only around the edges (18-24m wide) of fields.

2) When more than 30 flies are caught/trap/week during the first flight, or 15 flies trap/week during the second flight, insecticide should be applied to control the larvae if the samples are collected 5m from the crop boundary. [When the samples are collected 0.75m from the crop boundary, insecticide as applied only after 60 and 30 flies have been caught from the first and seocnd flights, respectively.]

3) With dry weather and dry soil the damage threshold can be 50% higher.

4) Observations made over periods shorter than one week, damage threshold have to be adapted.

Discussion

These figures show that the spread around the calculated lines was extremely large. This spread was not expected. The large variation between the number of flies caught and the percentage of damaged carrots was not considered too important. More important is the fact that damage was found only when more than 20 flies were caught/trap/week during the first flight. Therefore a spray threshold of 10 flies per trap was considered to be on the safe side.

During the second flight, damage of more than 10% was found when 10 flies were caught/trap/week. Although 10% damage seems high, fields treated with chlorfenvinphos or diazinon can also leave population of carrot flies that result in 2-17% crop damage (Ester & Neuvel, 1990). A damage threshold of 3.5-5 flies/trap/week for the second flight does not cause any serious problems in practice.

After three years (1992-1994) of research and practical experience in the field in The Netherlands, a method of supervised control of the carrot fly is now available. In 1994, the method was used in 252 fields during the first flight, and in 529 fields during the second flight. The 781 fields involved a total area of 2773 hectares. In all cases, the flies were controlled with an average of 0.9 application of the insecticide dimethoate in a year that had a protracted first and second flight. It was necessary to harvest earlier on one field, however, due to the level of damage. On two other fields, although damage was between 3% and 8%, this caused no problem at auction.

In 1995, supervised control of carrot flies was done on 1880 hectares during the first flight and 3000 hectares during the second flight. In total, 7900 hectares of carrots were grown in The Netherlands in 1995. Most of the carrot growers had less than one percent attack. Just five growers had crops that exceeded 1% damage (Everaarts & Loosjes, 1996).

The method of supervised control has to be applied on a field by field basis as the fly population can vary greatly over extremely short distances.

Conclusions

The greater the distance from the boundary of the field, the lower the amount of damage from the carrot fly. There was a positive correlation between the level of damage at the edge of the field and the damage in the field. There was no significant year effect between the numbers of carrot flies caught per trap and subsequent crop damage. Significant differences occurred between the first and second flight, in the total number of carrot flies, per flight, and in the numbers of carrot flies caught per week.

Résumé

Les systèmes de suivi de la lutte contre la mouche de la carotte (*Psila rosae* F.) aux Pays Bas : II Relations entre le nombre de mouches capturées sur les piéges et les dégâts en culture.

La relation entre le nombre de mouches de la carotte capturées et les dégâts montre une variabilité considérable dans les essais aux champs réalisés en 1992, 1993 et 1994. Les dégâts sont observés seulement lorsque plus de 20 et 8 mouches sont capturées par piége et par semaine respectivement pendant le premier et le deuxième vol.

Les dégâts de mouche de la carotte diminuent avec la distance dans le champ. L'application de produit insecticide seulement sur les bords du champ (18 - 24 m) est efficace seulement lorsque la densité de la population reste proche des seuils de dégâts.

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Biological and integrated control of the onion fly and supervised control of the carrot fly carried out commercially by 'de Groen Vlieg'

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Biological and integrated onion fly control

In 1995, 16,000 hectares of onions were grown in The Netherlands. Of these, 2,600 hectares were treated against onion flies using the Sterile Insect Technique (SIT). This successful method has been carried out commercially by one company, 'de Groene Vlieg', since 1981, and the area treated is still increasing.

Almost all clients practice conventional farming. To the farmer, the costs of the SIT are about equal to the costs of applying insecticides to control onion flies. Once the decision is made to use the SIT, the farmer does not apply insecticide when drilling the crop. In most cases, 'de Groene Vlieg' takes sole responsibility for onion fly control. However, in those cultures where onions are sown close together and therefore fly reproduction is high, the SIT is used as part of an integrated control system. In this system, the farmer is advised to spray against the adult flies when fly numbers become too high.

In the rearing unit, onion fly pupae are produced throughout the year. To arrest development, the pupae are stored in a cold chamber until they are needed in the spring and summer. Each week during the growing season, batches of pupae are taken out of storage. After sterilisation and emergence, the flies are released into the contracted onion fields by employees of 'de Groene Vlieg'. These employees also empty the fly traps that are used to monitor the fly populations in each field. The number of flies released in the following week is based on the numbers of wild and marked sterile flies caught in these traps.

Up to the present, the pupae have been sterilized with gamma radiation from a cobalt source in The Netherlands. It is very likely that this facility will be closed in 1996. Therefore 'de Groene Vlieg' is now trying to locate an alternative source of radiation somewhere in Europe.

In 1995, 'de Groene Vlieg' also started field experiments to study the possibility of lowering onion fly infestations by releasing the beetle *Aleochara bilineata*. Releasing this beetle could prove useful in chemical-free farming and/or in combination with the SIT programme.

Supervised carrot fly control

Since 1993, carrot fly control has been supervised commercially by 'de Groene Vlieg'. The monitoring method, which was developed elsewhere, has been adjusted to Dutch conditions at the research station PAGV, Lelystad, The Netherlands (see Ester & Schoneveld - this Bulletin) under the supervision of J. Schoneveld, and refined subsequently by 'de Groene Vlieg'.

In 1995, supervised control was carried out on 2,400 of the 8,100 hectares of carrots grown in The Netherlands. The method involves placing at least one group of four carrot fly traps at the edge of each field. 'De Groene Vlieg' has developed its own trap (Goudval)®, which consists of a yellow holder with a changeable and re-usable transparent sticky plate. The sticky plates are changed weekly by a local employee and sent to a central point where they are checked for carrot flies. If necessary, the farmer is advised to spray against the adult flies.

In 1995, carrot fly damage was well below one percent on nearly all of the fields supervised by 'de Groene Vlieg'. Damage never exceeded the economic threshold of three percent.

Résumé

Lutte biologique et intégrée contre la mouche de l'oignon et suivi de la lutte contre la mouche de la carotte par "de Groene Vlieg"

Lutte biologique et intégrée de la mouche de l'oignon

En 1995, 16000 hectares d'oignons ont été cultivés aux Pays Bas. 2600 hectares ont été traités contre la mouche de l'oignon suivant le principe de la lutte autocide (technique des insectes stérilisés = SIT). Cette méthode est utilisée avec succés et commercialisée par la firme "de Groene Vlieg" depuis 1981, et les surfaces traitées sont encore en augmentation.

Presque tous les clients pratiquent une agriculture conventionnelle. Pour les fermiers, les coûts de la SIT sont presque égaux aux coûts d'une lutte chimique contre la mouche de l'oignon. Une fois la décision prise d'utiliser la SIT, les fermiers n'utilisent plus de produits insecticides en cours de culture. Dans la plupart des cas, "de Groene Vlieg" prend seule la responsabilité de la protection des oignons. Cependant dans quelques cultures où les parcelles d'oignons sont regroupées et où la reproduction de la mouche est élevée, la SIT est employée comme une partie du sytème de lutte intégrée. Dans ce système le fermier est averti afin de pouvoir effectuer un pulvérisation contre les mouches quand leur nombre devient trop élevé.

Dans l'unité d'élevage, les pupes de mouche de l'oignon sont produites tout au long de l'année. Pour bloquer le développement des pupes celles-ci sont stockées en chambre froide jusqu'à leur utilisation au printemps et en été. Chaque semaine pendant la saison de culture des lots de pupes sont prises dans les stocks. Après stérilisation et émergence, les mouches sont lâchées dans les parcelles d'oignons sous contrat par les employés de "de Groene Vlieg". Ces employés relèvent également les piéges à mouche qui sont utilisés pour suivre les populations de mouches dans chaque champ. Le nombre de mouches, lâchées la semaine suivante, est basé sur le nombre de mouches stériles marquées et capturées dans les piéges.

Jusqu'à présent, les pupes ont été stérilisées aux radiations gamma provenant d'une source au cobalt, au Pays Bas. Il est très vraisemblable que cette facilité sera interrompue en 1996. Toutefois "de Groene Vlieg" est en train de rechercher une autre source de radiation quelque part en Europe.

En 1995, "de Groene Vlieg" a commencé des expériences pour étudier la possiblité de baisser les infestations de mouches de l'oignon par des lâchers du staphylin *Aleochara bilineata*. Les lâchers de ce staphylin pourrait trouver leur utilité dans une agriculture sans intrant phytosanitaire et / ou en combinaison avec le programme SIT.

Suivi de la lutte contre la mouche de la carotte

Depuis 1993, la lutte contre la mouche de la carotte a été suivi commercialement par "de Groene Vlieg". La méthode de suivi qui a été développée par ailleurs a été ajustée aux conditions hollandaises à la station de recherche PAGV, Lelystad, Hollande (voir Ester & Schoneveld, 1996) supervisée par J. Schoneveld et affinée par "de Groene Vlieg".

En 1995, le suivi s'est étendue sur 2400 des 8100 hectares de carottes cultivées aux Pays-Bas. La méthode est basée sur la mise en place au moins d'un groupe de quatre pièges mouche de la carotte en bordure de chaque champ. "de Groene Vlieg" a mis au point son propre type de piège (Goudval), qui comporte un support jaune avec une plaque engluée transparente

interchangeable et réutilisable.
Les plaques engluées sont remplacées chaque semaine par un employé du lieu et envoyées dans un site central où les mouches sont comptabilisées. Si nécessaire le fermier est prévenu pour qu'il puisse réaliser une intervention chimique contre les adultes.
En 1995, les dégâts de mouche de la carotte était bien plus basse de un pour cent sur presque toutes les parcelles suivi par 'de Groene Vlieg'. Les dégâts n'ont jamais excédés le seuil économique de trois pour cent.

Managing caterpillar pests of *Brassica* crops

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Summary

In the UK, the five main caterpillar pests of *Brassica* crops are *Plutella xylostella* (diamond-back moth), *Mamestra brassicae* (cabbage moth), *Evergestis forficalis* (garden pebble moth), *Pieris rapae* (small white butterfly) and *Pieris brassicae* (large white butterfly). Although attacks by all five species were sporadic during 1994 and 1995, *P. xylostella* and *P. rapae* were the two most numerous pests.

Forecasts of the timing of activity are being developed for all five species using both published information and data collected from new experimental studies. Little is known about the temperature requirements for development of *E. forficalis* nor is there much information on the requirements for post-winter development for any of the five species.

To provide data to validate the forecasts, pheromone traps and water traps are being used to determine the pattern of adult activity at four locations during 1994-97. Where feasible, weekly counts are being made of the numbers of eggs, larvae and pupae on insecticide-free plots.

To develop a 'user-friendly' sampling system, data on the within-crop distribution of the immature stages of all five species were collected. 'Edge' effects were apparent for some species, but the data need detailed statistical analyses before firm conclusions can be drawn.

Preliminary laboratory bioassays showed that there was considerable variation in the susceptibility of pest species to the *Bacillus thuringiensis* products available in the UK. *M. brassicae* was the least susceptible of the species tested. The potential of a new product, which is based on a different, trans-conjugant, strain of *Bt*, is being assessed.

Introduction

In the UK, edible *Brassica* crops are often sprayed routinely to control foliar pests, such as cabbage aphid and caterpillars (Thomas, Davis & Garthwaite, 1991) often without any regard for the numbers of pest insects present in the crop. However, the multiple retailers are now encouraging growers to adopt systems of Integrated Crop Management so that, whenever feasible, the amounts of insecticide applied to crops can be reduced. In the UK, the key caterpillar pests are: *Plutella xylostella* (diamond-back moth), *Mamestra brassicae* (cabbage moth), *Evergestis forficalis* (garden pebble moth), *Pieris rapae* (small white butterfly) and *Pieris brassicae* (large white butterfly). Although caterpillars are found regularly in *Brassica* crops during the summer, damaging infestations do not occur every year.

In previous studies (Blood Smyth *et al.*, 1992; 1994) systems of 'supervised control', where insecticide was applied only when potentially damaging numbers of caterpillars were present, were compared with systems based on routine sprays. This work showed that it was possible often to reduce the numbers of sprays applied against caterpillars, or not to spray at all, without reducing crop quality at harvest. To date, however, all comparisons have been obtained from plot experiments. Sampling techniques need to be developed that will be acceptable in commercial practice. It is hoped that this can be achieved by reducing the cost of pest monitoring, mainly by targeting crop inspections to coincide with the critical stages in the life-cycles of the various pests.

At present most growers control caterpillars by spraying crops with broad-spectrum pyrethroid insecticides. Therefore, it may be of benefit to use more selective pesticides, such as the insecticide diflubenzuron or the insect pathogenic bacterium *Bacillus thuringiensis* (*Bt*). New developments in selective products have resulted from recent work on *Bt* (Jarrett & Burges, 1986; Carlton, 1993). For example strains that have improved activity against a range of caterpillar pests have been developed using a combination of strain selection and genetic studies. A number of trans-conjugant strains of *Bt* have been produced. The best coded GC91 has been patented by the Agricultural Genetics Company and is now being produced commercially in the USA. The final objective of this project is to assess the potential of these more selective insecticides.

Experimental

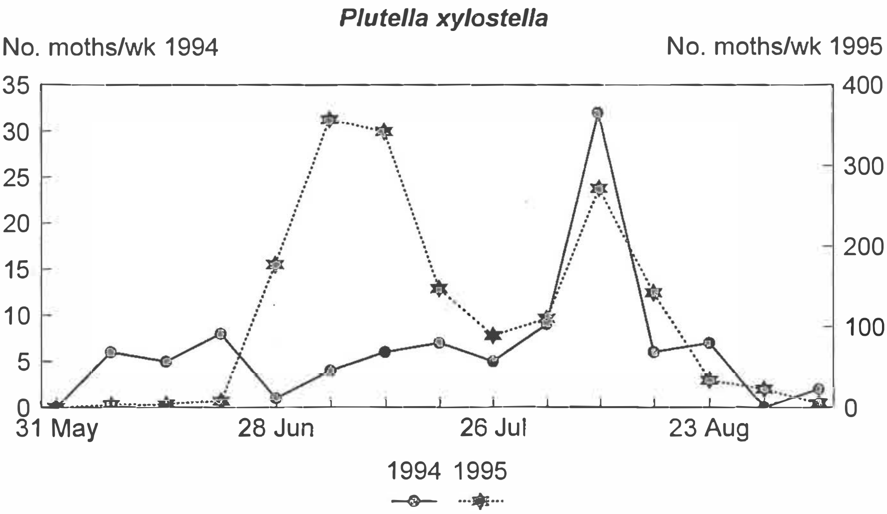
Forecast development and validation

In the UK, the main caterpillar pests of *Brassica* crops complete between two and four generations each year (Table 1). To develop accurate pest forecasts, the relationship between temperature and development must be established for each of the five pest species. Some information has been published already on the development of most of the species. However, although there is much information about *P. xylostella* (e.g Yamada & Kawasaki, 1983) there is no information on *E. forficalis*. Preliminary data for *E. forficalis* have been collected from a culture of this pest reared in the laboratory at Wellesbourne.

Table 1. The five main pest species of caterpillar found in *Brassica* crops in the UK arranged in descending order of importance

	No. generations	Pest status during 1994-95 (1 = most damaging)	Overwintering stage
P. xylostella	3-4	1	Adult?
P. rapae	2-3	2	Pupa
M. brassicae	2	3	Pupa
E. forficalis	2	4	Pre-pupa
P. brassicae	2	5	Pupa

All species, apart from *P. xylostella*, appear to overwinter successfully in the UK, either as pupae or as pre-pupae (Table 1). *P. xylostella* may overwinter as an adult, if temperatures are not too low (Finch & Thompson, 1992), but usually most moths die during the winter and infestations start in the following year only after immigrating moths have arrived from warmer regions. Little is known about the temperature requirements for post-winter development of all five species, so data on this aspect will be collected also during this project.



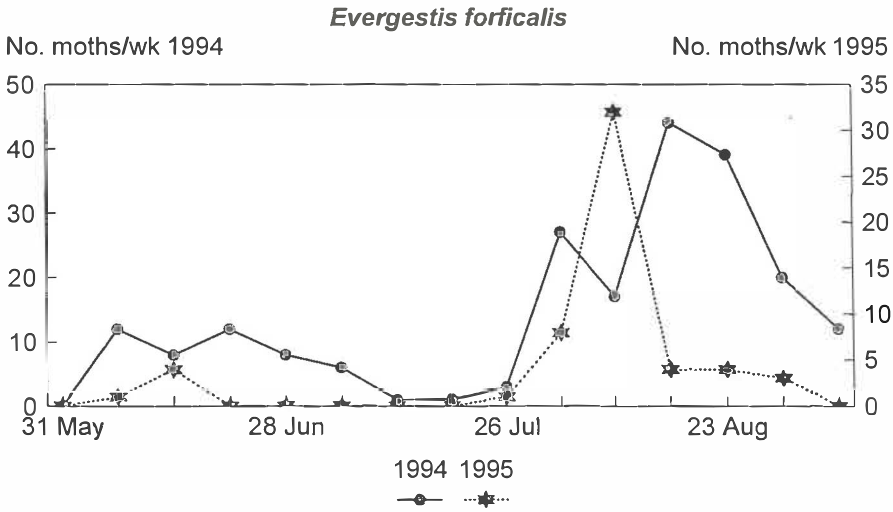


Fig. 1: The activity of adult *P. xylostella* and *E. forficalis* at Wellesbourne in 1994 and 1995.

Detailed monitoring data are required to validate any pest forecast generated during this research. Insect traps are being run at four sites (HRI Kirton, HRI Stockbridge House, HRI Wellesbourne and ADAS Arthur Rickwood) over four years (1994-97) to determine the patterns of adult activity of all five pests. Yellow water traps are being used to capture the two species of butterfly and pheromone traps to capture the three species of moth.

Figure 1 shows the numbers of *P. xylostella* and *E. forficalis* captured at Wellesbourne during 1994 and 1995. Very few adult *M. brassicae* were captured by the pheromone traps. However, in both years, reasonable numbers of caterpillars were observed in insecticide-free crops, particularly at ADAS Arthur Rickwood, indicating that the *M. brassicae* traps do not appear to be very effective. Furthermore, the *M. brassicae* lures were not species-specific, and so large numbers of several other species of moth were also captured in both years.

Although reasonable numbers of *P. rapae* were captured at all sites in both years, few *P. brassicae* were found in the water traps. *P. brassicae* caterpillars were also relatively uncommon, and *P. brassicae* is now rarely an important pest of commercial *Brassica* crops in the UK.

During 1995, the development of caterpillar infestations in untreated plots was recorded at each of the four monitoring sites. One hundred marked plants were inspected each week from around the perimeter of each plot. On each occasion, the numbers of eggs, caterpillars and pupae were recorded on each plant. Figure 2 shows the numbers of immature *P. rapae* (eggs, caterpillars and pupae) recorded at Wellesbourne during 1995.

Of the five species of caterpillar, *P. xylostella* was the most damaging in the two seasons studied, followed by, in decreasing order of importance, *P. rapae*, *M. brassicae*, *E. forficalis* and *P. brassicae*. Attacks by all five species were sporadic and caterpillar damage was not found in every crop, but was more evident in 1995 than in 1994.

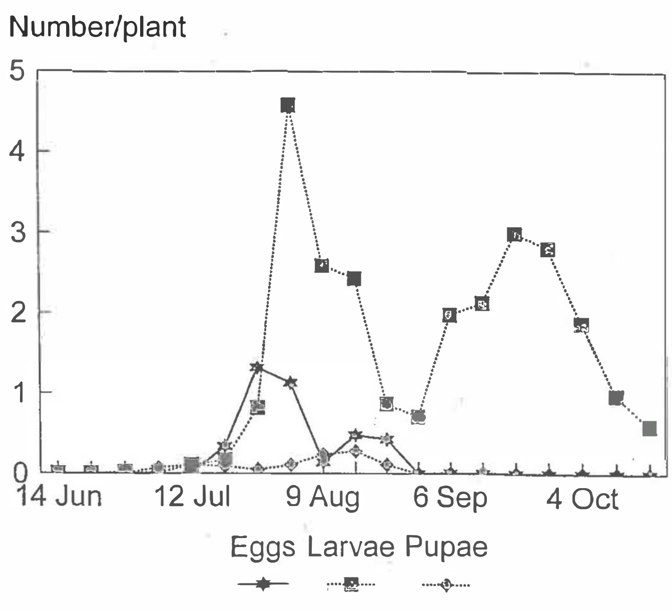
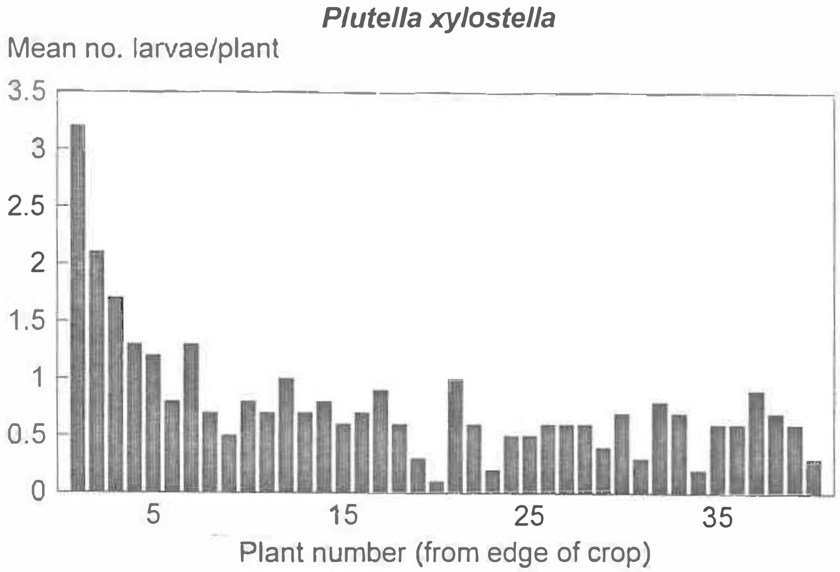


Fig. 2: Immature stages of *P.rapae* in insecticide-free plots at Wellesbourne in 1995.



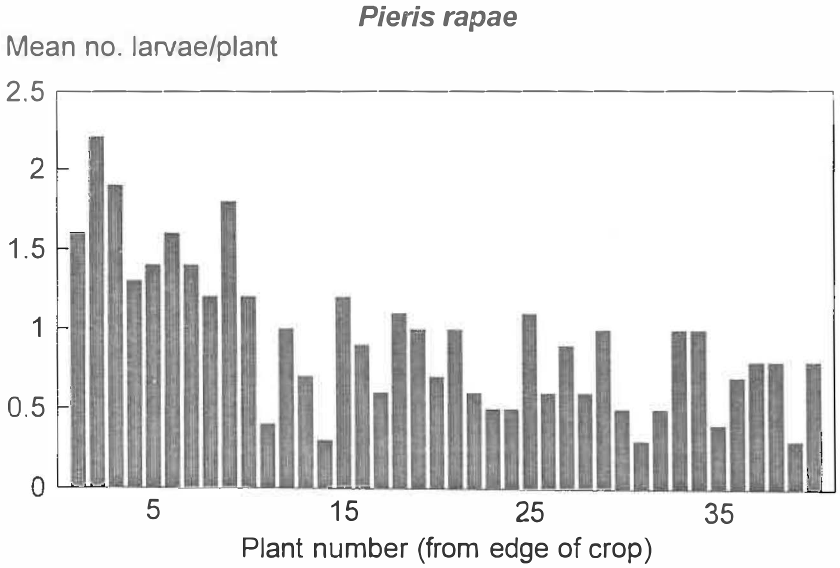


Fig. 3: The distribution of *P. xylostella* and *P. rapae* in insecticide-free plots in 1995.

Development of a 'user-friendly' sampling scheme

The distribution of caterpillars within any particular field is affected not only by the behaviour of the different pest species but also by the physical characteristics of the field and the spatial distribution of the crop plants. All of these factors will need to be considered if the schemes for sampling such pests are to be effective.

Caterpillar populations were sampled in commercial *Brassica* crops to determine the within-crop distribution of each pest species. As pesticide treatments were applied from time to time to these crops, the insects were counted when their numbers were at their highest, that is immediately before a new insecticide treatment was applied. To assess the distribution of the various species, the samples taken in each field consisted either of transects (from the edge of the crop inwards) or samples from within the crop (5 x 5-plant blocks). Approximately 750 plants were examined per crop. Where feasible, the numbers of eggs, caterpillars and pupae of each species were recorded on each plant. The composition of the field boundary (plant species and height) adjacent to each set of samples was recorded in detail.

The distribution of caterpillar pests was also determined in untreated plots of Brussels sprouts (50 x 75 plants) situated at the four monitoring sites (HRI Kirton, HRI Stockbridge House, HRI Wellesbourne and ADAS Arthur Rickwood). These plots were sampled on up to five occasions during the summer to determine the spatial distribution of the species present. The distributions of the various pests were assessed by examining every plant within transects taken across the plots, or from 5 x 5-plant blocks within each plot.

Examples of transects taken from the untreated Brussels sprout plots in 1995 are shown in Fig. 3. Some 'edge' effects were apparent for some species, but the data still need to be analysed in detail before any firm conclusions can be proposed. All data collected from commercial crops and from untreated plots will be analysed together to provide a mathematical description of the within-crop distribution of each species.

Use of selective insecticides

The *Bacillus thuringiensis* products registered currently in the UK (e.g. Dipel, Bactospeine) contain the strain HDI subsp. *kurstaki*. The results of a laboratory bioassay using Dipel are shown in Table 2. In this assay, larvae were allowed to feed on an agar-based artificial diet that contained a serial dilution of the test product. The bioassays were done at 25°C using 5 doses and a minimum of 25 insects per dose. Mortalities were recorded after 6 days. *M. brassicae* was the species least susceptible to Dipel.

Table 2. The activity of Dipel against five species of caterpillar

	LC50 μg *Bt*/g diet
P. xylostella	2.5
M. brassicae	65
E. forficalis	5-10 (estimated)
P. rapae	1.7
P. brassicae	2.1

Agree/Turex (CIBA) is a new *Bt* product based on a transconjugant strain of *Bt* selected from subsp. *aizawai*. This strain produces a different range of toxins to HDI. The five target species are now being treated with Agree in laboratory trials to determine whether it is more effective than Dipel, particularly against *M. brassicae*. The activities of both *Bt* products are being compared under field conditions with the selective insecticide diflubenzuron and the broad-spectrum insecticide deltamethrin.

Discussion

Previous studies have shown that up to 90% of the sprays applied routinely against caterpillar pests of *Brassica* crops may be unnecessary (Blood Smyth *et al.*, 1992; 1994), due mainly to the sporadic nature of caterpillar attacks in the UK. There is considerable scope, therefore, for reducing the amounts of insecticides applied by using sampling and pest forecasting to ensure that treatments are applied only when required. It is also likely that the broad spectrum pyrethroid insecticides that are used currently for controlling caterpillar pests in brassica crops can be replaced with the narrow spectrum *Bt* products. However, the production costs associated with sampling and the purchase of more expensive *Bt* products need to be kept to a minimum as new techniques will not be adopted by growers if the penalty for adopting such techniques is a substantial rise in production costs.

Résumé

Maîtrise des chenilles défoliatrices des cultures de Brassica

En Angleterre, les cinq Lépidoptères ravageurs des cultures de Brassica sont *Plutella xylostella* (la teigne des crucifères), *Mamestra brassicae* (la noctuelle du chou), *Evergestis forficalis* (la pyrale des crucifères), *Pieris rapae* (la piéride de la rave) et *Pieris brassicae* (la piéride du chou). Bien que les attaques de ces cinq espèces aient été sporadiques en 1994 et 1995, *P. xylostella* et *P. rapae* furent les deux ravageurs les plus abondants.
Les prévisions concernant des périodes d'activité ont été développées sur les cinq espèces en utilisant à la fois les informations publiées et les données obtenues de nouvelles expérimentations. On connaît peu de choses sur les besoins en températures nécessaires au développement de *E. forficalis* ainsi que sur les exigences nécessaires au développement post hivernal de chacune des cinq espèces.

Pour obtenir des données qui valident les prévisions, des pièges à phéromones et des pièges à eau ont été utilisés pour définir le modèle d'activité des adultes dans quatre lieux de 1994-95. Il a été réalisé chaque semaine des comptages pour connaître le nombre d'oeufs, de larves et de chrysalides sur des parcelles conduites sans insecticide.

Pour mettre au point un système d'échantillonnage pour les "utilisateurs bénévoles", des données ont été collectées sur la distribution des chenilles des cinq espèces à l'intérieur de la culture. Les effets haies (bordures) sont apparents pour quelques espèces, mais les données nécessitent des analyses statistiques détaillées avant que des conclusions fermes puissent être tirées.

Les bioessais préliminaires conduits en laboratoire montrent qu'il y a des variations considérables dans la sensibilité des ravageurs aux produits à base de *Bacillus thuringiensis* utilisable en Angleterre. *M. brassicae* était la plus sensible des espèces testées. Le potentiel de produit nouveau qui serait basé sur une souche, trans conjuguant, de *Bt* est en cours d'estimation.

Acknowledgements

We thank participating growers for allowing us to sample caterpillars within their crops and the Ministry of Agriculture Fisheries and Food, the Horticultural Development Council, MicroBio Ltd and Oecos for supporting this work. We also thank our colleagues, Wendy Riggall, Julian Davies, Andrew Mead, Jackie Town, Ben Emmett, Sally Minns and Debbie Ellis for their valuable assistance.

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Integrated Crop Management in the production of field vegetable crops in the United Kingdom

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Integrated Crop Management (ICM) is defined by the British Agrochemicals Association as 'a crop husbandry system', which is as profitable as conventional farming, but which places the emphasis on careful control of inputs and aims positively to achieve environmental benefits.

The National Farmers Union (NFU) has entered a partnership with 6 multiple retailers (supermarkets). With the help of grower groups and other organisations, which include the Ministry of Agriculture, ADAS, HRI and private consultants, this partnership has produced protocols for ICM. In essence, each protocol is a set of crop husbandry guidelines for the production of an individual crop. The guidelines include specific techniques for Integrated Pest Management (IPM). Their principal objective is to minimise pesticide usage. The guidelines give scientifically-based 'best agricultural practices' but are not prescriptive. Training and auditing are vital components of the guidelines. One leading supermarket, Tesco is not in this partnership. It has developed its own 'Nature's Choice' and demands much more stringent compliance from its suppliers. Those who grow for Tesco have prescriptive protocols and have to meet audit requirements.

Where is ICM in terms of field vegetable production?

1. More insecticide is applied currently to crops of carrots, brassicas and lettuce than to crops of peas, beans, onions and leeks. There is scope to reduce the amounts of insecticide applied, especially on the major vegetable crops.

2. An average of 4 insecticide spray rounds are applied to carrot and lettuce crops compared with 3 spray rounds to brassica crops and 1 for onions, leeks, peas and beans.

3. There are no standard methods for crop walking or crop sampling.

4. Some monitoring techniques are used (eg insect traps) and a few pest forecasts are followed, but most vegetable growers currently use supervised rather than integrated control. The ICM protocols are an introduction to ICM principles for UK vegetable growers. In apple crops and protected crops, such as tomatoes, ICM principles are practised by many growers. So what is being done to improve this situation in field vegetable crops? In the field of IPM there are two major projects. The first is 'Managing caterpillar pests on brassica crops'. Rosemary Collier is the project leader of this work, which is based largely on pest forecasting and adaptive sampling. Bob Ellis will then outline the second joint project which is concerned with IPM of lettuce aphids. In lettuce crops there is considerable scope to improve the timing of sprays and to rationalise their use.

Conclusions

1. In the UK, Integrated Crop Management is not as advanced in field vegetable crops as it is in protected crops and apple crops.

2. Through a partnership between the National Farmers Union and major retailers, which has involved the introduction of crop protocols, there is a strong commitment to develop Integrated Crop Management in all crops relevant to the food industry.

3. Research and Development is being done concerning both pest and disease problems. Crop protocols will be updated annually and will include validated new improvements.

Résumé

La Conduite intégrée des cultures (ICM) dans la production des cultures légumières de plein champ en Angleterre

1. En Angleterre, la conduite intégrée des cultures (ICM) n'est pas aussi avancée en cultures légumières de plein champ qu'en cultures protégées et en cultures fruitières (pommes).

2. A partir d'un partenariat entre l'Union Nationale des Fermiers et les principaux détaillants, qui ont inclus l'introduction de protocoles de culture, il y a un très fort engagement pour développer la Conduite intégrée des cultures (ICM) dans toutes les parcelles relevant de l'industrie alimentaire.

3. Un programme de Recherche-Développement a été mis au point à la fois pour les problèmes concernant les ravageurs et les maladies. Les protocoles de culture seront mis à jour annuellement et incluront les nouvelles améliorations validées.

Assessment of several components that could be used in an integrated programme for controlling aphids on field crops of lettuce

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Summary

In 1994, experiments were done at different centres to investigate various components of an integrated programme for controlling aphids on field-grown crops of lettuce. The investigations concentrated on the four aphid species which threaten lettuce production in western Europe:- the currant-lettuce aphid, *Nasonovia ribisnigri*, the potato aphid, *Macrosiphum euphorbiae*, the peach-potato aphid, *Myzus persicae*, and the lettuce root aphid, *Pemphigus bursarius.* Aphid numbers were monitored at different sites directly on lettuce plants and indirectly using water traps. The information gathered was used to develop preliminary models to forecast the timings of immigration of the various aphid species and the development of their subsequent populations. The performance of three new insecticides was investigated and all appeared to have considerable potential. The role of host plant resistance and semiochemicals was investigated in field experiments. The resistant varieties performed as predicted but the semio chemical treatments had no effect. The entomopathogenic fungus, *Metarhizium anisopliae*, killed *P. bursarius* in the field. The potential for using the various components as part of an integrated programme for aphid control are discussed.

Introduction

Lettuce aphids threaten the production of iceberg lettuce in the UK and other parts of Europe. Current control of aphids with insecticides is unreliable and spraying lettuce every two or three days in mid-season causes concern amongst growers, supermarkets and consumers. A UK consortium which includes the 1) Horticulture Development Council (HDC), 2) the Ministry of Agriculture, Fisheries and Food (MAFF) and 3) industrial partners is funding a collaborative project to develop a system for aphid control on outdoor lettuce using novel and existing methods. These methods will be targeted at key stages in the aphid life cycle, based on accurate pest forecasts of aphid activity. The project is concentrating on the four most important aphid species identified in collaborative experiments organised under the auspices of the IOBC (Reinink & Dieleman, 1993); the currant-lettuce aphid, *Nasonovia ribisnigri,* the potato aphid, *Macrosiphum euphorbiae,* the peach-potato aphid, *Myzus persicae,* and the lettuce root aphid, *Pemphigus bursarius.* Investigations of the different components of an integrated programme for the control of aphids on field crops of lettuce are described in this paper.

Experiments

Aphid activity

The objective was to predict key events in aphid invasion so that appropriate control measures could be timed accurately. Monitoring data were collected to aid validation of forecasts. Aphid populations were monitored using the following two methods:-

1) Trapping winged aphids

Yellow water traps fitted with vertical yellow baffles were placed in lettuce fields at HRI Wellesbourne, HRI Kirton, Kent and Lancashire. These traps were used from May to October to monitor the numbers of immigrant alate aphids.

2) Sampling `Saladin' lettuce plants

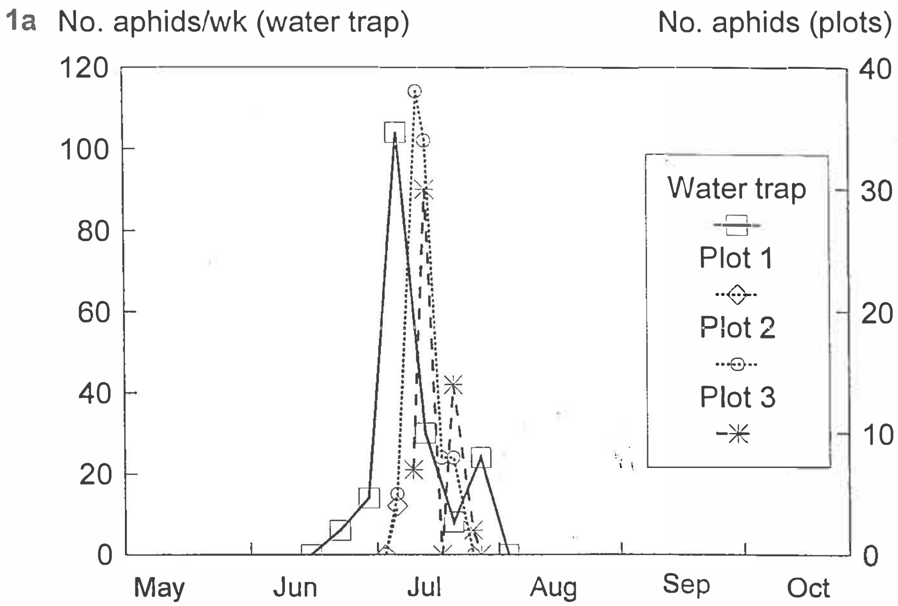
Iceberg lettuce, cv `Saladin', were planted sequentially at three sites, HRI Wellesbourne, HRI Kirton, and in Lancashire. These plants were sampled twice a week throughout the season to monitor the build-up of aphid populations.

Aphids that were collected from both water traps and from 'Saladin' lettuce plants were identified and counted. The roots of the lettuce plants were scored for *P. bursarius* damage. A selection of the results are presented in Figs. 1 and 2 and other results are summarised below.

Alate *Pemphigus bursarius* had a single migration in late June/early July when they flew from their overwintering sites on poplar to colonise lettuce (Fig. 1a). Infestations of *Pemphigus bursarius* were found on lettuce roots between mid-July and early September (Fig. 1b). Alate *Nasonovia ribisnigri* flew from their overwintering sites on *Ribes* species to colonize lettuce crops in May. There was a further migration in September. Alatae recorded during July indicated movement between lettuce crops whereas the peak at the end of the season indicated the timing when the aphids returned to *Ribes* (Fig. 2a). In Europe and parts of the UK, *N. ribisnigri* is the most abundant aphid on lettuce and so it is important to be able to predict accurately its activity. Records of adult apterous *N. ribisnigri* (Fig. 2b) showed that infestations were greatest in July but also extended into August. Although the other two species, *M. euphorbiae* and *M. persicae*, colonised lettuce plants earlier in the season, their numbers crashed in late July at the time when populations of natural enemies increased. These two species are important vectors of virus diseases in lettuce and so it is important that they are controlled effectively.

Novel insecticides

In 1994, field experiments were done on growers holdings in Cambridgeshire and Lancashire to compare three new insecticides with two of the currently-approved products, pirimicarb and demeton-S-methyl (Fig. 3). The first year's results showed that all 3 products had considerable potential.



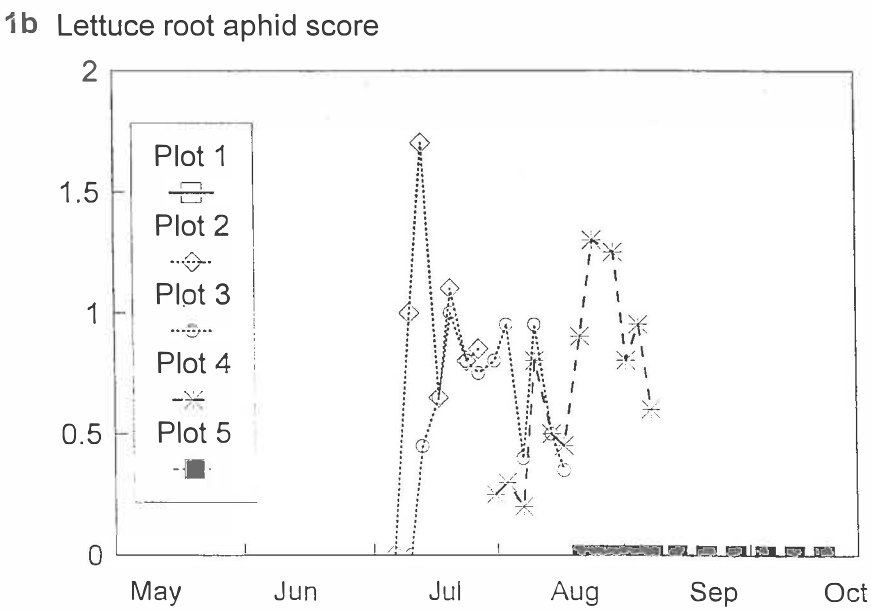
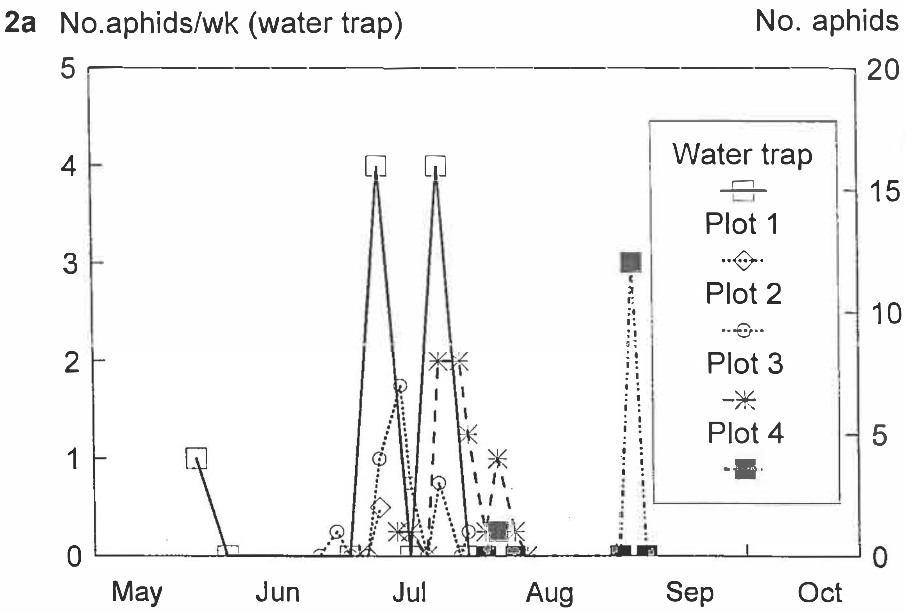


Fig. 1: Numbers of *Pemphigus bursarius* recorded at HRI Wellesbourne in 1994: a) alatae in water trap samples and on plots of lettuce planted sequentially; b) root infestation score from plots of lettuce planted sequentially.
<u>Planting dates:</u> Plot 1, 11 May; Plot 2, 16 June; Plot 3, 7 July; Plot 4, 26 July; Plot 5, 16 August.



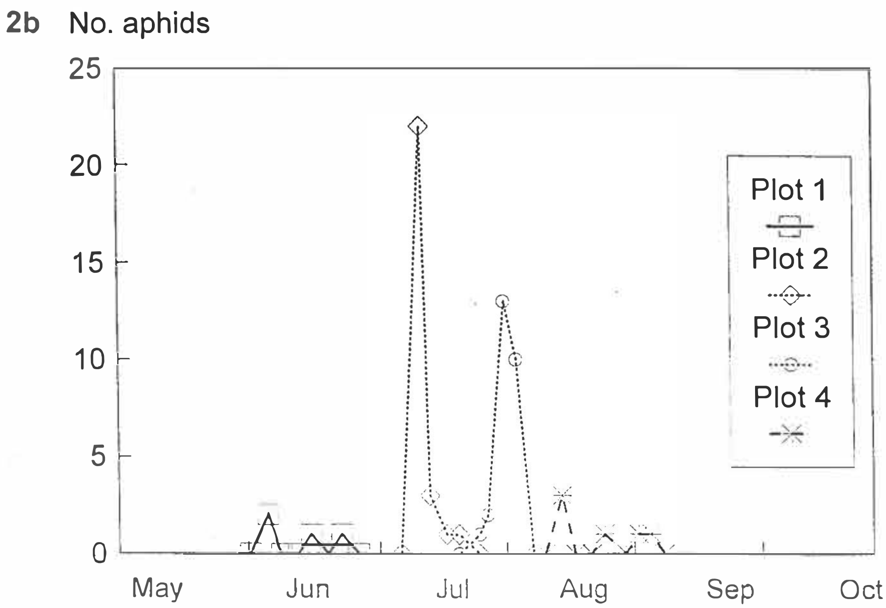


Fig. 2: Numbers of *Nasonovia ribisnigri* recorded at HRI Wellesbourne in 1994: a) alatae in water trap samples and on plots of lettuce planted sequentially; b) adult apterae sampled from plots of lettuce planted sequentially.
<u>Planting dates:</u> Plot 1, 11 May; Plot 2, 16 June; Plot 3, 7 July; Plot 4, 26 July; Plot 5, 16 August.

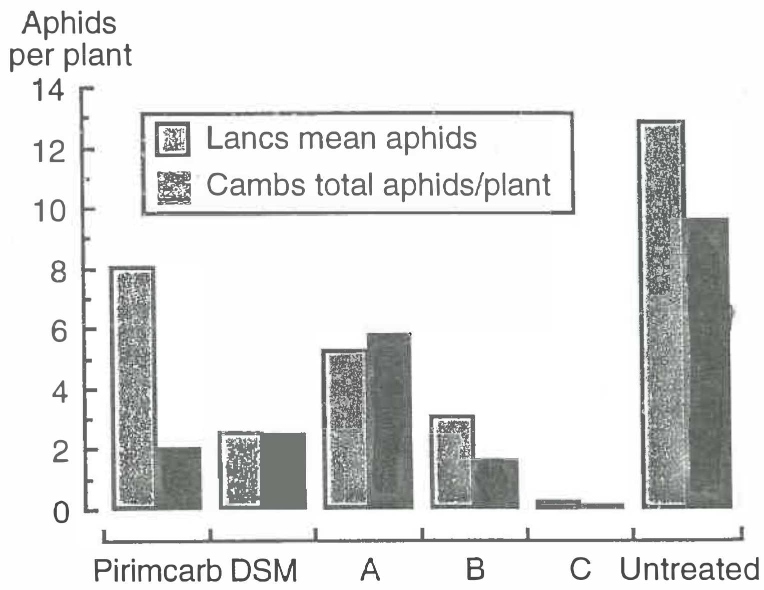


Fig. 3: Performance of three 'new' insecticides tested at Cambridgeshire and Lancashire in 1994. Numbers of aphids found/plant 10 days after applying the insecticides.

Semio-chemicals and resistant varieties

A desirable component of any integrated pest management programme is a cultivar with at least some resistance to one or more of the important aphid pests. However, there is no single variety of lettuce that is resistant to all aphid species. In addition, semiochemicals can modify aphid behaviour and so may be of use in integrated pest management programmes. The role of plant resistance and semiochemicals in limiting colonisation of lettuce plants by aphids was investigated at HRI Wellesbourne in 1994. The performance of two semiochemicals, methyl salicylate (a willow extract) and butyl isothiocyanate (a brassica extract), was compared on four lettuce varieties that had different levels of resistance to aphids. The experiment confirmed the relative susceptibility/resistance of the four lettuce varieties. `Saladin' was highly susceptible to all aphid species whereas `Beatrice' was totally resistant to the root feeding *P. bursarius* but colonised heavily by the foliage aphids. `Great Lakes' was susceptible to *M. euphorbiae*, *M. persicae* and *N. ribisnigri* but partially resistant to *P. bursarius* whilst `Iceberg' possessed high levels of resistance to *P. bursarius* but only partial resistance to the aphid species that colonise the foliage.

There was no decrease in the numbers of aphids found in the plots in which the semiochemicals were released from sachets.

Biological control of aphids

At HRI Wellesbourne a promising isolate of a fungal pathogen of *P. bursarius* has been identified and this was tested in the field in 1994. The isolate of *Metarhizium anisopliae* tested did control *P. bursarius* but the time to death still requires further clarification.

Discussion

Once preliminary models have been developed for the timing of activity by the various aphid species it should be possible to validate them with information collected in subsequent years. The timing of the migration of *P. bursarius* from poplar trees in the spring should be relatively easy to predict and hence enable growers to identify which plantings of lettuce actually require protection. Lettuce varieties possessing high levels of resistance to the lettuce root aphid could be deployed during this period of the growing season for those crops at risk. The life of resistant varieties can be extended by:- deploying a range of varieties possessing different resistant genes or different combinations of resistant genes. The major problem in developing new *P. bursarius*-resistant varieties is to produce lettuce which conforms exactly to the iceberg type. The variety `Beatrice' had a high level of resistance to *P. bursarius* but is not accepted by the leading growers of iceberg lettuce. The experiments with the entomopathogenic fungus, *M. anisopliae,* showed that the fungus can be effective in the field.

N. ribisnigri is a particularly troublesome pest aphid because it colonises the heart of the plant and hence infestations are not immediately apparent unless lettuce plants are cut open. Monitoring this aphid in the middle of the season indicated that it moved both within and between lettuce crops. At HRI Wellesbourne and other sites in the UK, *N. ribisnigri* is the commonest aphid species on iceberg lettuce in late summer and autumn. Lettuce varieties resistant to *N. ribisnigri* are being developed and should represent a valuable component of an integrated control programme.

The other two species of aphids, *M. euphorbiae* and *M. persicae* were particularly numerous on lettuce plants early in the season but their numbers declined rapidly in mid-summer. Although high levels of resistance to *M. euphorbiae* in wild lettuce species have been reported recently (K. Reinink, pers. comm.) it will take many years to develop commercially-acceptable lettuce varieties. Partial resistance to *M. euphorbiae* and to *M. persicae* already exist in varieties such as `Iceberg', which was used in the present experiments. However, additional protection is required to produce control at a level acceptable commercially.

The experiments designed to evaluate the three 'new' insecticides indicated that promising materials now exist. However, these will have to be approved by the appropriate authorities before they can be used on lettuce crops in the UK. If they are approved, they should provide the growers with valuable additions to their current methods of aphid control.

Résumé

Estimation de plusieurs composantes qui pourraient être utilisées dans un programme intégré pour contrôler les pucerons en cultures de laitue en plein champ

En 1994, des expériences ont été réalisées dans plusieurs centres pour examiner les différentes composantes d'un programme de lutte intégrée pour lutter contre les pucerons des cultures de laitues en plein champ. Les recherches sont focalisées sur les quatre espèces de pucerons qui attaquent la production de laitue dans l'ouest de l'Europe : *Nasonovia ribisnigri*, *Macrosiphum euphorbiae* le puceron vert et rose de la pomme de terre, *Myzus persicae* le puceron vert du pêcher et le puceron de la racine *Pemphigus bursarius*. Le nombre des pucerons est suivi directement dans différents sites sur les plants de laitue et indirectement en utilisant des pièges à eau. L'information rassemblée a été utilisée pour mettre au point des modèles de prévision des périodes d'immigration des différentes espèces et du développement de leurs descendances. La performance de certains insecticides nouveaux a été étudiée et des composés prometteurs identifiés. Le rôle de la résistance de la plante hôte et des composés semiochimiques ont été recherchés dans les conditions de champs. Les plantes résistantes agissent conformément aux hypothèses avancées mais les produits sémiochimiques n'ont pas eu d'effet. Le champignon entomopathogène *Metarhizium anisopliae* tue *P. bursarius* au champ. Le potentiel d'utilisation des différents composants comme partie intégrante du programme de lutte contre les pucerons est discuté.

Acknowledgements

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A contribution to the integrated pest management of the aphid *Nasonovia ribisnigri* in salad crops

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Summary

Nasonovia ribisnigri Mosley (Homoptera: Aphidae) is one of the major pests of salad crops (*Lactuca sativa* and *Cichorium endivia* var. *latifolia*) in France and in many other European countries. Poor results following the application of registered insecticides prompted us (a) to investigate whether this aphid was becoming resistant to the commonly used insecticides, and (b) to test the efficacy of a new aphicide that could be applied at sowing to salad plants grown in peat blocks. Our results showed that a population of *N. ribisnigri* from Perpignan had developed resistance to pirimicarb, deltamethrin and endosulfan, and that a single application of imidacloprid (a chloronicotinyle insecticide) prevented aphid infestations establishing on salad crops. Protection with the insecticide lasted from the nursery bed to harvest, which in the current tests spanned a period of 56 days.

Introduction

Salad lettuce (*Lactuca sativa*) and prickly lettuce (*Cichorium endivia* L.) are important crops in southern France. The Languedoc-Roussillon province is the second largest production area in France, and grows salad crops on more that 3000 cultivated hectares, 30% of which produces 2 or 3 crops every year. Extensive sampling of aphids on Iceberg type lettuce, showed that *Nasonovia ribisnigri* is the major pest of outdoor salad crops in France. *N. ribisnigri* is present during most of the year on all salad cultivars, especially on outdoor crops (Aubree, 1991; Forbes, 1982), but sometimes also on greenhouse crops (Labonne, personal communication). Chemical control with the insecticides registered in France is not always effective and this can cause serious problems when the salad is packed, as at this stage live aphids are not tolerated. One possible explanation of chemical failure is that *N. ribisnigri* has developed resistance to the current range of aphicides. Such resistance has been recorded already for aphids such as *Myzus persicae* and *Aphis gossypii* (Delorme, 1993).

The present study was undertaken to test for resistance to insecticides, and to test the new chemical, imidacloprid, for its potential in an integrated pest management (IPM) system aimed at controlling *N. ribisnigri*.

Materials and Methods

Evaluation of resistance

This was done using two laboratory strains of *Nasonovia ribisnigri*. The susceptible strain (HOL) was obtained from the Agronomic Laboratory of Wageningen (Netherlands), and the other strain (ABR) was from a colony collected near Perpignan (France) in 1995. Bioassays were performed using a spraying method adapted from Delorme *et al.* (1990) which was similar to Burjerjon's tower technique. Each bioassay consisted of applying spray, at the rate of 3 mg/cm^2, to batches of 40 non-alate adults. The aphids were presented on 2.7 cm disks of lettuce leaf and were sprayed with one of five different concentrations. Each bioassay was replicated 4 times, one on each of four different days. The numbers of aphids killed were counted 24 hours after application of the test treatment. The insecticide concentrations that induced 50% and 95% mortalities (LC_{50} and LC_{95}) were estimated using the method described by Finney (1971). Three insecticides, pirimicarb (Pirimor), deltamethrin (Decis) and endosulfan (Technufan), were tested.

Efficacy trial

This trial was done with imidacloprid using a Fisher block experimental design that consisted of 4 treatments each replicated four times. Treatment 1 was a conventional spray of pirimicarb (two high volume sprays, at 15 day intervals, of 75g/hl Pirimor containing 75% a.i.). Treatment 2 involved applying imidacloprid to the peat blocks before sowing (70 ml/m^3 peat of Confidor, 200 g/l a.i.). Treatment 3 involved the combination of both pirimicarb and imidacloprid as described for treatments 1 and 2. Treatment 4 was the "control" to which insecticide was not applied. Evaluation of the efficacy of each treatment was made by counting all of the aphids on all the leaves of 25 salad plants and grading them into four classes. The numbers of aphids in each class were: none for Class 0, 1-5 for Class 1, 6-15 for Class 2, and >16 for Class 3.

Results and Discussion

Evaluation of resistance

For the three insecticides tested, both the LC50 and LC95 were higher in the strain collected from Perpignan (ABR) than in the susceptible strain (HOL). The resistance ratio at LC95 were 60, 44 and 151 for pirimicarb, deltamethrin and endosulfan, respectively (Table 1).

Efficacy trial

Large differences were recorded in the numbers of aphids found on the control and treated salad plants when inspected 49 and 56 days after sowing (Fig. 1). The mean infestation class was above 2.5 for the control plants but below, or equal to, 0.5 in the plants treated either with imidacloprid, with pirimicarb, or with a combination of the two insecticides. Therefore, a single treatment with imidacloprid was as effective as two conventional sprays of pirimicarb, and lasted for up to 56 days. In addition, treatment with both imidacloprid and pirimicarb was no more effective than treating the plants with only one of the insecticides.

Despite some resistance (60-fold) to pirimicarb in aphids from Perpignan, pirimicarb was still effective at controlling aphid infestations in the field.

Table 1. Resistance ratio of *Nasonovia ribisnigri* from Perpignan France (ABR strain) compared to a susceptible strain (HOL) of the same aphid.

			Resistance Ratio	
	LC_{50} mg/kg	LC_{95} mg/kg	LC_{50}	LC_{95}
Pirimicarb				
HOL strain	2.8	34.9		
ABR strain	54	2105	19	60
Deltamethrin				
HOL strain	0.06	1		
ABR strain	1.9	43.6	32	44
Endosulfan				
HOL strain	1.3	81.4		
ABR strain	858	12327	660	151

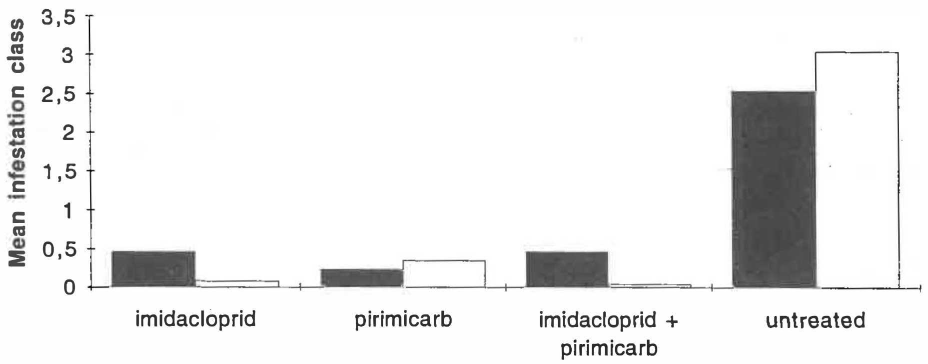

Fig. 1: Mean class of infestation of *Nasonovia ribisnigri* recorded 49 days (solid histogram) and 56 days (open histogram) after the first treatment was applied to salad plants in a field trial in Perpignan.

Conclusions

This preliminary investigation showed that a population of *Nasonovia ribisnigri* from southern France has developed resistance to pirimicarb, deltamethrin and endosulfan. However, despite a 60-fold level of resistance to pirimicarb, this insecticide still controlled aphid infestations in the field.

The new insecticide imidacloprid, showed considerable promise for controlling *N. ribisnigri* infestations when used as a single peat-block application. The effects of this insecticide on beneficial organisms now needs to be studied before its potential for use in IPM systems can be assessed accurately.

Résumé

Une contribution à la lutte intégrée contre le puceron *Nasonovia ribisnigri* en cultures de salades

Nasonovia ribisnigri Mosley (Homoptera : Aphididae) est un des ravageurs principaux des cultures de salade (*Lactuca sativua* et *Cichorium endivia* var. *latifolia*) en France et dans de nombreux pays d'Europe. Le peu de résultats obtenus à la suite d'application insecticide autorisé nous ont amenés 1) à rechercher si le puceron est devenu résistant aux insecticides utilisés couramment, et 2) à tester l'efficacité d'un nouvel insecticide qui pourrait être appliqué au semis des plants de salades en mini-motte de tourbe. Nos résultats montrent que la population de *N. ribisnigri* de Perpignan a développé une résistance au pyrimicarbe, à la deltamethrine et à l'endosulfan, et qu'une simple application d'imidacloprid (un insecticide à base de chloronicotinyle) prévient l'établissement des infestations de pucerons en cultures de salades. La protection avec l'insecticide se maintient de la pépinière jusqu'à la récolte, qui dans les tests utilisés s'étend sur une période de 56 jours.

Acknowledgements

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"Appropriate/inappropriate landings", a mechanism for describing how undersowing with clover affects host-plant selection by pest insects of brassica crops

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Summary

The relative merits of the five mechanisms used currently to describe why fewer pest insect are found on host plants growing in diverse backgrounds are discussed. A mechanism, termed "appropriate/inappropriate landings", is proposed to describe why more pest insects are found on host-plants growing in bare soil than on host-plants undersown with living clover. This mechanism suggests how both chemical and visual stimuli affect the behaviour of the insects during the period prior to accepting a plant as a suitable host. The mechanism proposed, could be appropriate not only for pest insects of brassica crops but for phytophagous insects in general.

Introduction

Five mechanisms have been proposed (see Altieri, 1994) for describing why fewer pest insects are found on host-plants growing amongst other plants than on host-plants growing in bare soil. The mechanisms suggested are that the non-host plants reduce the numbers of insects finding host-plants by 1) physical interference (Perrin, 1977); 2) visual camouflage (Smith, 1976); 3) masking the host plant odours (Tahvanainen & Root, 1972); 4) causing physiological changes in the host-plants that make them less attractive (Theunissen, 1994); or by 5) direct chemical deterrence (Uvah & Coaker, 1984).

This paper reviews briefly each mechanism and discusses their possible contributions to host-plant selection by pest insects of brassica crops. In addition, it proposes a mechanism of host-plant finding that could be appropriate not only for pest insects of brassica crops but also for phytophagous insects in general.

Description and discussion of existing mechanisms

1) Physical interference This applies to situations in which the host plants are in effect hidden physically by using larger or taller non-host plants. For example, Altieri & Doll (1978) used tall maize plants to protect bean plants fom pest infestations. Tall plants are considered to be effective by interfering with the movement of the pest insect within the cropping system (Perrin, 1977).

There is an element of physical interference when crops are undersown with clover, as, to have its maximum impact in "deterring" pest insects, the clover has to be relatively tall and surround much of the host plant (Finch & Edmonds, 1994; Theunissen, 1994). Unfortunately, when clover is used in the field as the undersown crop, there can be several periods when the clover is much shorter than the crop plants. This occurs early in the season, if the clover has not established sufficiently by the time the crop plants are transplanted, and later in the season if the clover begins to senesce or the crop plants become sufficiently large to suppress the clover. During all three periods, the clover may provide the host-plants with relatively little protection against adapted pest insects. This probably helps to explain why the results with *Pieris rapae* in the field have been so variable (see Cromartie, 1991 for references). Another drawback to using clover is that there are times when it becomes too competitive with the main crop, and so has to be mowed. According to Theunissen & Schelling (1996), subterranean clover is usually mowed twice during the growing season of white cabbage crops in The Netherlands. After mowing, and before the clover grows sufficiently tall again, the crop plants will again be open to colonization by adapted pest insects.

2) Visual camouflage Two types of visual stimuli are involved in inducing low-flying insects to land on plants. The first is a directed reaction to the colour of the plant (Moericke, 1952), and the second is an optomotor reaction, in which landing is provoked by plants, "looming up" along the path of the flying insect (Kennedy *et al.*, 1961). Anything that competes with such stimuli, such as other green plants, or raising the height of the overall background with weeds (Smith, 1976), so that the distance over which the host-plant can be separated from the background is foreshortened, helps to camouflage visually the host plants.

In 1976, Smith showed that clean-weeding of Brussels sprouts, the normal agricultural practice, provided ideal conditions for colonization by aphids, whitefly and certain Lepidoptera. This preference for plants which stand out against a background of bare soil was considered to be due partly to the insects' phototactic reaction (Moericke, 1952) but more importantly to the optomotor reaction (Kennedy *et al.*, 1961). Although Smith (1976) showed that background influenced host-plant selection by the cabbage aphid, *Brevicoryne brassicae,* she made no attempt to determine how such a mechanism might operate.

3) Masking of host plant odours The release of odour masking substances into the air by non-host plant species is considered to confer some protection to the associated host-plants. This "associational resistance", as it was termed by Tahvanainen & Root (1972), has been reported also by Buranday & Raros (1975) and Perrin & Phillips (1978).

Although this seems an extremely plausible way in which volatile chemicals emanating from non-host plants could affect the behaviour of pest species, during the last 15 years few data have been collected to support this hypothesis. In contrast, data from detailed wind-tunnel studies showed that brassica plants growing in clover were approached by cabbage root flies as readily as plants grown in bare soil, suggesting that non-host odours did not interfere with this flies' oriented response to host plants (Tukahirwa & Coaker, 1992).

4) Altering the profiles of the host plant odours Many claims are made that African marigolds (*Tagetes* spp.) planted between rows of crop plants reduce pest numbers. Whether this is achieved through a direct effect of the odours of the African marigolds repelling the colonizing insects has not been elucidated. It is well known that species of African marigolds release large amounts of root exudates which can be taken up by adjacent plants (Rovira, 1969). It is possible, therefore, that any host plant growing in an intercrop could be affected directly by chemicals taken up through its roots rather than having its odour masked. This approach is being studied currently by Theunissen (1994).

5) Deterrent chemicals It was suggested that *Plutella xylostella* could be repelled from cabbages intercropped with tomatoes (Buranday & Raros, 1975) or that the highly odorous ragweed (*Ambrosia artemisifolia*) could be used to repel the flea beetle, *Phyllotreta cruciferae*, from collard crops (Tahvanainen & Root, 1972). Such suggestions were made usually during attempts to describe why pest numbers were different in the two situations. They were not based on scientific experimentation. Whether or not true deterrency is a mechanism still needs to be proven. Deterrency usually involves highly aromatic plants that often have to be crushed and tested in small confined spaces in the laboratory to show that they actually are capable of repelling pest insects.

Plants chosen for their odorous nature, such as French marigolds. *Tagetes patula,* were ineffective against the carrot fly, *Psila rosae*, when used as the intercrop in carrots (Uvah & Coaker, 1982). Similarly oviposition by the diamond-back moth ,*Plutella xylostella,* was similar on Brussels sprouts plants intercropped with plants of sage (*Salvia officinalis* L.), thyme (*Thymus vulgaris* L.) or green polythene plant models (Dover, 1986). Extracts of the essential oils of sage and thyme were shown to reduce oviposition by *P. xylostella*, but by contact and not by volatile stimuli (Dover, 1985).

Apart from the volatile chemicals, a wide range of contact chemicals doubtless play a major role during host plant selection, but these come into play only when the insect has landed and so are not included here.

Mechanism considered to operate during host-plant colonization by pest insects of brassica crops

In contrast to the five mechanism described previously, just one mechanism, which I have called "appropriate/inappropriate landings", appears to describe adequately how host-plant selection by pest insects is affected when brassica crops are undersown with clover. In this mechanism, it is the close proximity of the host plants and non-host plants that affects colonization, so that if a pest species lands on a non-host plant it leaves the area sooner than when it lands on a host plant (Tukahirwa & Coaker, 1982; Kostal & Finch, 1993).

Two types of visual stimuli are involved in stimulating low-flying insects to land on plants. The first is a directed reaction to the colour of the plant, or phototaxis (Moericke, 1952) and the second is an optomotor reaction, in which landing is provoked by plants "looming up" along the path of the flying insect (Kennedy *et al.*, 1961). When only these two components are included, however, it is difficult to explain why more pest insects end up on plants growing in bare soil than on plants undersown with clover. The component required to complete the system, is that pest insect of brassica crops rarely land on bare soil (Kostal & Finch, 1993; Finch, 1995). Hence, in addition to the directed response to the colour of a plant there an equally strong avoidance of landing on bare soil.

It is proposed that host-plant selection during colonization by insect species consists of a series of actions in which volatile chemicals emanating from host-plants indicate to the insects that they are flying over suitable host plants. Insects that fly over such plants growing in bare soil will be stimulated to land on the only green objects available to them, host plants, and so most landings will be "appropriate". In contrast, insects flying over undersown crops will land in proportion to the relative areas occupied by the host and non-host plants, as pest species do not discriminate between host and non-host plants when both are green (Moericke, 1952; Prokopy *et al.*, 1983; Kostal & Finch, 1993), and so many of the landings will be "inappropriate". The insects that land on the non-host plants will then fly off again, and depending on the distance flown before another coloured object stimulates them to land, could land eventually on a host-plant. In both situations, however, the host-plant on which the insect first lands may itself not be sufficiently stimulating to arrest the pest insect and hence the overall process will then be repeated. Whether the insects that have made "inappropriate landings" will remain in the locality will depend mainly upon whether the volatile stimuli released by the host plants are sufficiently stimulating to prevent the insects moving elsewhere.

This subject will be reviewed in much greater detail elsewhere. Suffice it to say, that Working Group members should take care to ensure that any conclusions made from field experiments can be justified scientifically. For example, *Pieris rapae* is one species in which some authors have concluded that intercrops have a beneficial effect (Smith, 1976), a neutral effect (Theunissen & Den Ouden,1980) or a detrimental effect (Cromartie, 1975). If comparisons are to be made, it is important to ensure that the conclusions are related unequivocally either to the mechanism of intercropping itself or to attempts to implement a practical system of intercropping under field conditions. For example, as *Pieris rapae* females lay eggs during most of the summer months, mowing the intercrop to lower plant competition will also remove its benefits as a crop protection measure. It is not surprising, therefore, that intercropping may not appear effective against *P. rapae* when crop damage is assessed at harvest, particularly if the crop has in effect been left "unprotected" during critical periods when *P. rapae* populations are high. Intercropping is similar to any other pest control measure, it will only work if it is used correctly.

Résumé

'Attérissage approprié / inapproprié', un méchanisme décrivant comment une culture intercalaire de trèfle agit sur la sélection de la plante hôte par les insectes ravageurs en culture de Brassica

Les mérites relatifs de cinq méchanismes utilisés couramment pour décrire pourquoi on trouve moins d'insectes ravageurs sur les plantes hôtes cultivées sur différents substrats sont discutés. Un méchanisme, appelé 'Attérissage approprié / inapproprié', est proposé pour décrire pourquoi on trouve plus d'insectes ravageurs sur des plantes hôtes cultivées sur sol nu que sur les plantes hôtes associées à une culture intercalaire comme le trèfle. Ce méchanisme suggère comment à la fois les stimuli chimiques et visuels agissent sur le comportement des insectes pendant la période précédant l'acceptation de la plante puis l'utilisation comme hôte. Le méchanisme proposé pourrait être compatible non seulement pour les insectes ravageurs des cultures de Brassica mais aussi pour les insectes phytophages en général.

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Undersowing cabbage and leek plants with clover during 1994 and 1995

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Summary

The clover *Trifolium subterraneum* cv. Geraldton was rapidly overwhelmed and almost totally suppressed by weeds 1) when sown in the spring three weeks before planting white cabbage (cv. Minicole); 2) when sown in the autumn of the year before planting white cabbage (cv. Minicole) in the spring; or 3) when sown in the end of spring one month before planting leek (cv. Axel).

The cabbages and leeks were planted by a machine which disturbed up to 50% of the soil surface. This slowed down the growth of the clover and prevented it from establishing.

Growing the cabbage plants at a higher density and applying the fertilizer as a split dose failed to overcome the competition from the weeds. Hence, final crop yield was poor.

Evaluation at harvest appeared to indicate that the green cover deterred infestation by the cabbage root fly, the cabbage aphid and cabbage caterpillars but encouraged infestation by flea beetles and slugs.

In the leek crop, the clover *Trifolium subterraneum* was almost completely outcompeted by the weed *Portulaca oleracea.* Onion thrips populations were much smaller on the leeks in the green cover plot.

Résumé

Culture intercalaire de trèfle dans une plantation de chou et de poireau en 1994 et 1995

Le trèfle *Trifolium subterraneum* cv. Geraldton a èté rapidement écrasé et presque totalement supprimé par les mauvaises herbes 1) quand il est semé au printemps trois semaines avant la plantation de chou blanc (cv. Minicole); 2) quand il est semé à l'automne de l'année avant la plantation de chou blanc (cv. Minicole) au printemps; ou 3) quand il est semé un mois avant la plantation du poireau (cv. Axel).

Les choux et les poireau sont plantés à la machine qui bouleverse environ 50% de la surface du sol. Cela ralentit la croissance du trèfle et l'empêche de s'établir.

Une culture de chou à densité plus forte et l'application d'un fertilisant à dose fractionnée n'a pas permis de dominer la compétition des mauvaises herbes. Ainsi la récolte en fin de culture était faible.

L'évaluation à la récolte semble indiquer que la couverture verte a un effet de dissuasion sur la mouche du chou, le puçeron cendré du chou et les chenilles du chou mais encourage l'infestation des altises et des limaces.

Dans la culture de poireaux, le trèfle *Trifolium subterraneum* était presque complètement hors compétition vis-à-vis de la mauvaise herbe *Portulacea oleracea.* Les populations de thrips de l'oignon étaient beaucoup plus petites que dans la parcelle ayant une couverture verte.

The effect of undersowing with clover on host-plant selection by pest insects of brassica crops

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Summary

Tests were done to determine how undersowing brassica crops with subterranean clover affected host-plant selection by eight different pest species of insect. The insect species tested were the small white butterfly (*Pieris rapae*), the large white butterfly (*Pieris brassicae*), the cabbage root fly (*Delia radicum*), the mustard beetle (*Phaedon cochleariae*), the diamond-back moth (*Plutella xylostella*), the garden-pebble moth (*Evergestis forficalis*), the cabbage moth (*Mamestra brassicae*) and the cabbage aphid (*Brevicoryne brassicae*). In all cases, 40-90% fewer of the pest insect stage (eggs for all test insects apart from the cabbage aphid) were found on the plants in clover than on those in bare soil. Despite testing insects from a range of orders, the same mechanism appeared responsible for deterring each of the eight pest species from selecting plants undersown with clover.

Introduction

This paper describes experiments to determine how undersowing brassica crops with subterranean clover affects host-plant selection by pest insects and whether any of the proposed four mechanisms governing host plant selection in such cases (see Finch, 1996) applies exclusively to pests from specific insect orders. Originally, attempts were made to study four backgrounds but as this proved too difficult in the time available, the study was restricted simply to comparing host-plant selection in backgrounds of clover and bare soil.

Materials and methods

Insects

The following methods were used for rearing the test insects in a room maintained at 18°C and a L16:D8h photoperiod within the Insect Rearing Unit at HRI Wellesbourne.

Large white butterfly and small white butterfly. Butterflies collected from the field were allowed to lay on brassica plants. The butterfly eggs and plant material were then placed into ventilated plastic boxes (22 cm x 11.5 cm x 8.5 cm high), lined with a few layers of absorbent tissue. Caterpillars were supplied with fresh plant material daily and were cleaned out regularly and moved into a larger number of boxes as the larvae increased in size. This prevented overcrowding and reduced subsequent outbreaks of pathogenic bacteria. The caterpillars pupated on the sides and the lids of the rearing boxes. Such pupae were removed carefully by hand and stored for short periods in a room maintained at 12°C.

About a week before the start of each experiment, the pupae were glued onto 29 cm long and 4 cm wide wooden or plastic labels. The labels with the pupae facing downwards were arranged as tiers about 5 cm apart between two pieces of weld-mesh placed inside a 1 m^3 glass cage. This arrangement allowed the butterflies that emerged to open and dry their wings in an unhindered hanging position. Seven day-old butterflies were used in all tests.

Garden pebble moth and cabbage moth. Both species were reared in the same way as the white butterflies, except that the cabbage moth caterpillars were allowed to pupate in compost and the garden pebble moth in sand. Seven day-old moths were used in all tests.

Diamond-back moth. The adults were housed in a Perspex cage (37 cm x 37 cm x 37 cm) and provided with water and 10% sucrose solution absorbed on cotton wool pads. To maintain the culture, the moths were provided with a brassica plant on which to lay their eggs. This plant was moved three or four days later to another cage to which fresh plants were added regularly as food for the developing caterpillars. Pupae of a similar age were collected from the walls of the larval-development cage and transferred to an emergence cage. Seven day-old moths were used in all of the tests.

Cabbage root fly. These were reared using the method developed by Finch & Coaker (1969). Adult flies were provided with 10% sucrose solution, yeast hydrolysate, powdered brewer's yeast, soya flour and water as food, and a Petri-dish containing sand and a small cube of swede as an oviposition site. The fly larvae were reared on swedes and the resulting pupae were stored in moist vermiculite in a domestic refrigerator (2-3°C) until flies were required. Four to eight day-old flies were used in all experiments.

Mustard beetle. The adults were kept in small ventilated plastic boxes (22 cm x 11.5 cm x 8.5 cm high). Fresh plant material (mainly Chinese cabbage leaves) was supplied twice weekly to the beetles, which not only fed on the leaves but also laid eggs on them. Leaves containing eggs were removed twice weekly to culture boxes, lined with a few layers of absorbent tissue. The newly-hatched larvae were also supplied with fresh plant material twice a week. Prior to pupation, the large larvae were moved to boxes that contained a 2 cm deep layer of compost, in which they pupated. Beetles between two and four weeks old were used for the experiments.

Cabbage aphid. This insect was not reared. Instead, the data were taken from the 1993 IOBC Co-operative trial (see Theunissen *et al.*, 1992) done at HRI Wellesbourne (Finch & Edmonds, 1994). These data were collected from the field using the natural infestation of cabbage aphid.

Plants

The plants used during all experiments were cabbage (*Brassica oleracea* var. *capitata* Alep.), cauliflower (*Brassica oleracea* var. *botrytis* L.), Brussels sprouts (*Brassica oleracea* var. *gemmifera* Zenk.) and Chinese cabbage (*Brassica rapa* var. *pekinensis*). All brassica plants were grown from seed in Hassy 308 plastic plant modular trays (Erin Planter Systems Ltd., Baldock, Herts, England, UK) in a glasshouse. At least one week before being required for experimental purposes, the plants were pulled from the modules and transplanted into 7.5cm diameter pots. The plants were grown in Levington M2 compost (Fisons) except when needed for experiments involving the cabbage root fly. In such cases John Innes loam-based compost was used as it was much easier to extract eggs from this than from the highly-organic Levington compost.

During the experiments, apart from the field cage experiments with the mustard beetle, the brassica plants were not removed from their pots before being placed in the centres of the test backgrounds. To minimise the influence of plant size between the two treatments, brassica plants of the same size were used in all tests.

Subterranean clover (*Trifolium subterraneum* L.) was used not only for the green clover background but also for the brown dead clover background. Both in the glasshouse and in the field the first batch of clover was sown in April 1995 to produce green clover. Some of the early sowings of clover in the plastic seed-trays (36 cm x 21 cm x 5 cm deep) matured rapidly, seeded and died. This was the dead clover, used in the laboratory experiments with the cabbage root fly and the diamond-back moth (see Table 1).

Cages

Laboratory experiments. These were done either in a rotating cage or in Perspex cages. The rotating cage was a wooden-framed test chamber consisting of two equal sized compartments (160 cm x 160 cm x 63 cm high) arranged one above the other. Each compartment contained a 145 cm diameter wooden turntable, which rotated once every four minutes (Ellis & Hardman, 1975). As the insects used in these experiments were positively phototactic and tended to aggregate near to the lights, the rotation ensured that everything placed on the turntables was exposed equally to the insect aggregations.

The Perspex cages (80 cm x 48 cm x 54 cm) were sufficiently large to enable a seed-tray of clover and a seed-tray of soil to be used as the two test backgrounds in each cage.

Field experiments. These were done in large (600 cm x 315 cm x 180 cm high) metal-framed cages, in slightly smaller (433 cm x 218 cm x 195 cm) wooden-framed cages or in small metal framed cages, each measuring 55 cm x 96 cm x 56 cm. All of the cages were covered with 1mm Tygan® netting. The plastic skirtings attached to the bottoms of the cage walls were covered with soil to make the cages insect-proof.

Experimental

In each laboratory test, a brassica plant was inserted into the centre of each seed-tray of clover or bare soil, so that the soil of the potted plant was contiguous with that of the surrounding soil. Two replicates of the clover background and two of the bare soil background were used in the rotating cage but only one of each in the Perspex cages. The soil used as the "bare soil" treatment, came from the field in which all field-cage experiments were done.

In the field, thirty-two brassica plants were arranged in four rows in each of the two larger cages. The plants were spaced 50 cm apart both between and within the rows and the clover backgrounds were alternated with the bare soil backgrounds in a regular pattern. Two seed-trays of clover were transplanted around half of the test plants, so that each clover background was 36 cm x 42 cm, that is twice as large as the backgrounds used in the laboratory tests. Only two brassica plants were used in the small field cages; one half of the cage covered field-grown clover and the other half bare soil. A test plant was planted in the centre of each background.

The numbers of experiments done in the laboratory and field are shown in Table 1. Eight experiments were done in which backgrounds of living and dead clover were tested against bare soil backgrounds. Each experiment was continued for several days to obtain relatively high numbers of replicates. In the field-cage experiments done with the mustard beetle, four cages were used for a week so that 21-28 data sets (replicates in space and time) were available for the analyses. Similarly, sixteen replicates for each of the two test treatments were collected each day an experiment was done in either of the two different types of large (metal- or wooden-framed) field cages. High numbers of replicates were done in the laboratory rotating cages but not in the experiments done in the Perspex cages.

The numbers of insects used in the various tests reflected the numbers available from the various insect cultures.

Egg-sampling

In most experiments, the eggs were sampled each day by taking the test plants out of the experimental cages and replacing them by comparable sets of plants. To reduce bias that arises when certain of the host plants used are highly attractive, plants removed from one background were switched to the opposite background when re-introduced into a test cage. When two or more cages were used simultaneously, plants were switched not only within the same cage but also between cages. Eggs that were laid on leaves and stems of the test plants were removed with a fine paintbrush (diamond-back moth & garden pebble moth eggs) or with forceps (white butterflies, cabbage moth & mustard beetle eggs), placed onto black filter paper and counted. Eggs of cabbage root fly were extracted from the soil using the flotation method described by Hughes & Salter (1959).

Results

The total numbers of eggs laid on the test brassica plants sited at the centres of backgrounds of subterranean clover and bare soil are shown in Table 2. For completeness, data on host-plant selection by the cabbage aphid have been taken from the work published in the last Bulletin by Finch & Edmonds (1994).

The differences between the numbers of eggs laid on the brassica plants in the bare soil and living clover backgrounds were highly significant ($P = 0.001$) for most of the 41 experiments (Table 1) when subjected to Analysis of Deviance. For brevity, however, the data in Table 2 have been presented only as totals, as this is as clear a way as any of expressing values that are so obviously different. The results in Table 2 show clearly that each of the pest species tested "preferred" the brassica plants growing in bare soil to the plants growing in backgrounds of subterraneum clover.

In the least discriminating of the pest insects tested, the diamond-back moth, the reduction in the numbers of eggs laid was only 40% compared to 90% for the two most discriminating species, the cabbage moth and the cabbage aphid.

In the eight experiments involving dead clover (Table 1.), similar numbers of eggs were recovered from brassica plants growing in dead clover as from those growing in bare soil for all three of the pest species tested.

Discussion

The original intention was to test all of the species of smaller insects in the large laboratory rotating cage and the butterflies and moths in the large metal-framed field cages. However, the small numbers of insects available of some species (e.g. the cabbage moth) and the relatively restricted movements of others (e.g. the mustard beetle), meant that some smaller cages had to be used to ensure that the insects were kept near to the host plants for as long as possible to maximize their chances of discriminating between the two treatments.

In the past, some of the results published on how undersowing crops with clover affects host-plant selection by pest insects have not been consistent. Most of the inconsistences have arisen in data collected from the field, primarily because in field experiments it is difficult to ensure that only one factor is varying at any one time. This is particularly true when comparisons are made between crop plants growing in clover and those growing in bare soil because, as soon as plant competition starts to take effect in the clover plots, the crop plants do not grow as well as those in the bare soil. Therefore, differences

Table 1. The number of experiments done in the various types of field and laboratory cages for each of the seven pest species reared in the laboratory at HRI Wellesbourne. * The cabbage aphid data are from the Co-operative IOBC experiment on "Intercropping" carried out at Wellesbourne in 1994. † The values in parenthesis show experiments in which dead rather than living clover was used as the background.

	Laboratory experiments		Field experiments			
	Rotating cages	Perspex cages	Large cages	Wooden cages	Small cages	Open field
Large white butterfly	2	-	3	1(1)†	-	-
Small white butterfly	-	-	5	-	-	-
Garden pebble moth	-	1	-	-	-	-
Cabbage moth	-	2	-	-	-	-
Diamond-back moth	2 (2)†	2	1	-	-	-
Cabbage root fly	6 (5)†	-	-	-	-	-
Mustard beetle	-	3	-	-	5	-
Cabbage aphid*	-	-	-	-	-	1

Table 2. The total numbers of eggs* recovered from *brassica* plants presented to the test insects in backgrounds of bare soil and clover, together with the percentage reduction between the treatments. * The cabbage aphid data are for the numbers of alate aphids settling on crop plants in the spring.

	Background of soil		Background of clover	% Reduction
Diamond-back moth	1258	:	766	40
Small white butterfly	1674	:	846	50
Garden pebble moth Large white butterfly	452 4657	: :	147 1287	70
Cabbage root fly Mustard beetle	1563 3791	: :	309 682	80
Cabbage moth Cabbage aphid*	310 83	: :	31 11	90

in pest insect numbers recorded between undersown and bare soil crops in the field could arise from a direct effect of the clover, from an indirect effect of plant size, or from a combination of the two. To draw meaningful conclusions about how undersowing affects colonization by pest insects in the field, it is important to ensure that only one variable is tested at a time. The best way to do this in the field is to collect data only during the critical immigration periods of the test species and to standardize on plant size by introducing similar-sized potted test plants into both types of background.

Despite reservations about certain field experiments, the current results are in general agreement with the data published already for most of the pest species tested (see Cromartie, 1981; Altieri, 1994). The findings for the mustard beetle are new, as this species has not been tested previously. The only species about which there is still some controversy is the small white butterfly, *P. rapae*. Various authors have concluded from field experiments that weedy backgrounds, as opposed to ones of bare soil, deterred colonization of host plants by the small white butterfly (Smith, 1976), had no effect (Root, 1973), or favoured colonization (Dempster & Coaker, 1974). More recently, backgrounds of clover were shown to reduce the numbers of eggs and subsequent damage by the small white butterfly on some occassions but not on others (Theunissen *et al.*, 1992; Finch & Edmonds, 1994). The variation that occurred in these results was probably related directly to the condition of the clover. In general, the clover has to be growing actively to be effective (Theunissen, 1994; Finch & Edmonds, 1994). However, when the clover becomes too competitive with the main crop, it has to be cut back and at such times its deterrent effect will be reduced greatly. In the system used currently in The Netherlands, the clover is cut about twice during the growth of a white cabbage crop (Theunissen & Schelling, 1996). Similarly, the results with the dead clover indicate that once the clover starts to senesce, which it does in The Netherlands well before the crop is harvested (Theunissen *et al.*, 1992), the crop plants will again be attacked by adapted pest insect species. To make maximum use of the deterrent effects of the clover, the growth periods of the main crop and the clover will need to be scheduled accurately. If this can be achieved, it should be possible to ensure that the pest-deterring effect remains effective against a wide range of pest species over the major part of the season in which a particular crop is grown. For maximum effect, it might be advisable in mainland Europe to overseed the crop at an appropriate time during early summer to ensure a constant supply of green clover. If this is not done, there could be a period, between the senescence of the original clover crop and when it re-seeds itself, when the crop is largely unprotected .

It appears from the current results that just one mechanism could be responsible for deterring all eight pest species from colonizing brassica crops undersown with clover. The most re-assuring finding, however, is that, without exception, fewer insects were found on the plants presented in clover even though the plants in both backgrounds were of a similar size. Therefore, if the agronomy of brassica growing can be changed sufficiently to make the undersown crop plants grow as large as those in the bare soil, this should in no way detract from the crop protection benefits that arise from undersowing.

Résumé

L'effet du trèfle comme plante intercalaire sur la sélection de la plante hôte par les insectes ravageurs de cultures de Brassica

Des tests sont réalisés pour déterminer comment une culture de Brassica associée à du trèfle affecte la sélection de la plante hôte pour huit ravageurs différents. Les insectes testés sont la piéride de la rave (*Pieris rapae*), la piéride du chou (*P. brassicae*), la mouche du chou (*Delia radicum*), la chrysomèle du cresson (*Phaedon cochleariae*), la teigne des

crucifères (*Plutella xylostella*), la pyrale du chou (*Evergestis forficalis*), la noctuelle du chou (*Mamestra brassicae*) et le puçeron cendré du chou (*Brevicoryne brassicae*). Dans tous les cas, on trouve une réduction de 40 à 90 % des jeunes stades des insectes (nombre d'oeufs pour tous les insectes sauf pour les puçerons) sur les plants de choux cultivés avec du trèfle par rapport aux plants cultivés sur sol nu. Quel que soient les insectes dans les différents ordres le même méchanisme semble responsable de l'évitement observé dans le choix des plantes cultivées avec du trèfle par les huit espèces de ravageurs

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Population dynamics of herbivorous and beneficial insects found in plots of white cabbage undersown with clover

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Summary

Plots of white cabbage, cv. Minicole, undersown with clover (*Trifolium subteraneum* cv. Geraldton) were used to test the effects of living mulches on the distribution of pest herbivores and their natural enemies. Undersowing reduced significantly several of the pest species (e.g. the aphids *Brevicoryne brassicae* & *Myzus persicae*; and flea beetles), but had no effect on most lepidopterous species. At the time of aphid colonization most aphids were found on the control plants, whereas by harvest, cabbage aphids were more or less distributed evenly over the whole crop. Fewer cabbage root fly (*Delia radicum*) eggs were recovered from the undersown plots but, at harvest, significantly more heads of cabbage were damaged on the control plots by mining larvae. The numbers of natural enemies, especially Syrphid larvae, and parasitised caterpillars were higher in the undersown plots, but a relationship could not be found between higher predator numbers and low aphid densities. Undersowing reduced significantly the weight of the cabbage plants and this raises several unsolved management problems. The influence of plant appearance and quality during aphid colonisation are discussed.

Introduction

As a consequence of increasing public concern over the excessive application of pesticides and the progressive restriction of their use as a result of new legislation, there is an increasing interest in alternative production systems. This does not apply only to organic systems of field vegetable production but also to highly intensive production systems. The need for an integrated approach to crop production is becoming more crucial as certain pests become resistant to insecticides and as leaching of nitrogen from systems involving high-inputs of fertilizer becomes a huge problem in intensive vegetable production.

The reduction of pathogens, herbivores and beneficial insects in intercropped vegetable crops has been demonstrated many times (see Andow 1991). However, the underlying mechanisms will need to be understood in detail if intercropping is to become a safe and acceptable alternative for commercial growers.

Two of the hypothesis put forward as an explanation for reduced pest populations are the 'resource-concentration hypothesis' and the 'enemies hypothesis' (Root 1973). The first hypothesis argues that mechanical barriers and visual or olfactory cues, that are more diversified in multiple cropping systems, make host-finding and oviposition more difficult for the pest herbivore. The second hypothesis argues that higher numbers of natural enemies, both in space and time, in undersown crops help to suppress pest populations more effectively. However, the two hypotheses could act complementary, antagonistically or independently (Andow 1991).

We used white cabbage, cv. Minicole, undersown with clover (*Trifolium subterraneum* cv. Geraldton) to test the effects of 'intercropping' on the population dynamics of the pest herbivorous insects and their natural enemies found commonly in cabbage crops.

Materials and Methods

The field experiments were done in a rural area near Braunschweig, Lower Saxony, in which cereal crops surrounded the experimental area. Within this area, which belongs to the 'Biologische Bundesanstalt für Land-und Forstwirtschaft', several other field vegetable crops were grown, including cauliflower. Six-week old white cabbage (*Brassica oleracea*), cv. Minicole were planted into the experimental area on 18 May. Four plots of control plants were alternated with four plots of undersown plants. The undersown plots were sown with clover (*Trifolium suberraneum*), cv. Geraldton, at a rate of 20 kg of seed/ha 4 weeks before the cabbages were planted. There were 240 plants (14 x 20) spaced 60 cm apart both within and between the rows in each plot. The two blocks, each of four plots were contiguous (see Figs 1a & b). The complete experimental area was surrounded by two 'guard' rows of cabbage plants from the same sowing. The control plots were hoed to keep them weed-free and the undersown plots were hand-weeded every 4 weeks from the middle of June until August. A NPK-fertilizer was applied at the rate of 30 kg/ha, both at the beginning of the experiment and in July within the control plots. In July, the undersown plots received an additional 60 kg/ha of fertilizer. No insecticide was applied at any time. The plots were irrigated at regular intervals.

Selected plants were inspected visually twice a week from 25 May until harvest at 1 September. In the early assessments, 60 randomized plants were checked per plot for herbivorous insects and their natural enemies. The number of plants sampled/plot was reduced to 34 on July and to 24 on 4 August. This was done to ensure that all of the plants sampled could be inspected within one day. The number of eggs laid by the cabbage root fly were assessed by collecting soil from around the stems of 5 plants within each plot once a week. In the laboratory, the eggs and pupae were floated out of the soil samples, collected, and counted.

Plant growth was monitored twice. On 4 July, 5 plants were sampled at random from each plot, weighed and each leaf area was measured using an automated leaf measurement device (LI-COR, Modell 3100). At harvest on 1 September, thirty-one plants were weighed from each plot. Once this had been done, the number of outer leaves were counted, signs of herbivore feeding on the 5 leaves surrounding the heads were assessed, and the cabbage heads were weighed.

Repeated measurement ANOVA was performed using the MGLH module of SYSTAT (Wilkinson 1992). The contour plots were computed using the contour options of SYSTAT and the Kernel smoothing method.

Results and Discussion

Undersowing white cabbage with clover reduced significantly the numbers of several, though not all herbivorous insect species. *Brevicoryne brassicae*, *Myzus persicae* three

Phyllotreta species and Agromyzid leaf miners (at least two species) were all found in lower numbers (larvae and/or alate, respectively) in the undersown plots (Table 1). These differences were pronounced for the aphid species, which did not manage to colonize the undersown cabbage plants until two weeks prior to harvest.

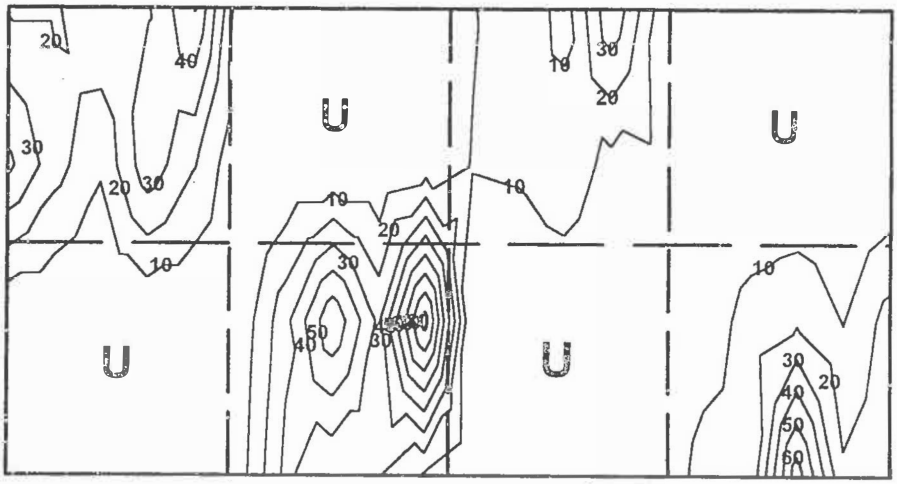
Table 1. Results of repeated measurement ANOVA for herbivorous insects and their natural enemies in control and undersown plots of white cabbage sampled from 9 June-1 September 1994.

Herbivorous species	Insect stage sampled	F-Statistics for RMANOVA	P
Brevicoryne brassicae L.	larvae	9.57	0.021
	alatae	7.51	0.028
Myzus persicae Sulz.	larvae	7.87	0.031
Autographa gamma L.	larvae	7.48	0.034
Mamestra brassicae L.	larvae	4.52	0.078
Pieris rapae L.	larvae	1.03	n.s.
Plutella xylostella L.	larvae	0.13	n.s.
Ceutorhynchus quadridens Panz.	adults	3.91	n.s.
	eggs	0.96	n.s.
Phyllotreta undulata Kutsch.	adults	8.99	0.024
Phyllotreta atra Fbr./*P. nigripes* Fbr.	adults	10.44	0.018
Delia radicum L.	eggs	4.49	0.063
Agromyzidae	larvae	9.58	0.020
Syrphidae	eggs, larvae & pupae	7.17	0.037
Coccinellidae	adults & larvae	1.21	n.s.

Although the overall numbers of *B. brassicae* were low in 1994, there was still a significant preference for the plants on the control plots during the first 8 weeks after planting (Fig. 1a). Higher numbers of cabbage aphids were found on the outer margins of the plots, suggesting that the possible colonizing aphids were arriving from outside the experimental field. By September, the aphids had spread over the whole field and differences between the control and the undersown plots were less pronounced (Fig. 1b). However, most aphids were still found on the plants that were infested with the highest numbers of aphids in July.

The pattern of within field distribution could have resulted from the delay of colonisation of the undersown plots. However, after some aphids had established on the control plots, the possibility that they would colonize neighbouring plots increased, and this led to a more even distribution of aphids later in the season. Dispersal of apterous aphids is common even when colonies are small, as dispersal is not restricted solely to alate aphids (Hodgson 1991). Therefore, physical barriers or the difficulties in finding the cabbage plants within the undersown plots, may be sufficient to explain the lower numbers of aphids found in the undersown plots. The distributional patterns of the colonizing alates indicated that plant-finding appears to be the most crucial factor in undersown plots.

Differences in individual behaviour may also contribute to differences in the population densities of certain other herbivorous insects. For example, flea beetles (*Phyllotreta cruciferae*) tend to fly away more often in mixed cropping systems, and this result in lower populations in such cultures (Garcia & Altieri 1992).



1b

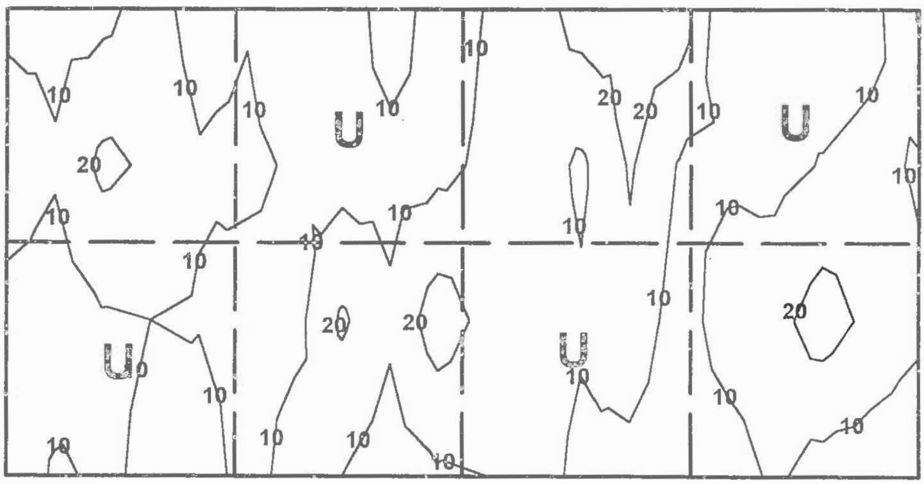


Fig. 1: Contour plots of the distribution of cabbage aphid (*Brevicoryne brassicae*) on white cabbage at the time of peak immigration (a; 15 July 1996) and at harvest time (b; 1 September 1996); U=undersown plots.

The enemies hypothesis predicts higher numbers of predators and parasitoids in more diversified crops, which results in a more effective control of their prey or hosts. Although we found significantly more Syrphid eggs, larvae and pupae on plants in the undersown plots (Table 1; see also Lehmhus *et al.*, 1996), the causal relationship between predator abundance and the suppression of aphid populations was difficult to establish. Predators in cabbage crops tend to concentrate their activity in more diverse habitats despite lower prey densities (Horn 1981, Smith 1976). If natural enemies did contribute to the lower numbers of aphids in the undersown plots in July, when aphid numbers peaked in the control plots, their action should not result in an even distribution later in the season. At harvest time, although the numbers of Syrphids and Coccinellids were still much higher in the undersown plots, but the populations of the aphids approached those in the control plots.

Interpreting the effects of the undersown clover on the lepidopterous pests of cabbage was more difficult. There were no differences in their mean numbers of larvae of the two *Pieris* spp. and *Plutella xylostella* found in the control and the undersown plots. For larvae of *Mamestra brassicae*, a weak trend was found for lower numbers in the undersown plots, whereas for *Autographa gamma* higher numbers of larvae were found in the undersown plots (Table 1). The polyphagous *A. gamma* benefitted from the presence of the clover, as the larvae preferred initially to feed on the clover. Later in the season, however, when the clover had died, the larvae moved onto the cabbage plants. Our results support earlier findings on the effects of intercropping on lepidopterous pests. For example, Andow *et al.* (1986) found first-generation larvae of *Pieris rapae* more common and second-generation larvae less common in undersown cabbage crops. Similarly, Theunissen (1994) and Theunissen *et al.* (1995) found differences in the numbers of larvae or egg-masses of different lepidopterous species in white cabbage undersown with different plant species, but only in instances, and this depended on the plant species used as the intercrop. In field plots, in which the clover was cut regularly, Finch and Edmonds (1994) found no differences in the numbers of the larvae of lepidopterous pest species. Although parasitized larvae were found slightly more often in undersown plots than in control plots, it is questionable whether they imposed a higher mortality on the larvae. Therefore, for lepidopterous pest species the enemies hypothesis could not be supported.

Cabbage root fly egg numbers were affected only slightly by the undersown clover (Table 1), but at harvest significantly more heads of white cabbage were damaged by fly larvae in the control plots (X^2=19.45; P<0.001). Nearly 70% of the cabbage heads harvested in the control plots contained one or more fly larvae that gave rise to a head rot. Such heads were not marketable.

Growth of the cabbage plants in early July was reduced significantly in the undersown plots. The plants in the control plots were nearly twice as heavy as those in the undersown plots (t=23.6; DF=246; P<0.001). The difference in overall leaf area was smaller, but nevertheless significant (t=20.9; DF=246; P<0.001). At harvest, although the differences in plant weight between the two treatments were reduced, they were still significant (t=23.6; DF=246; P<0.001). Thus, our management of the clover/white cabbage crop would be far from acceptable to commercial growers. However, although more of the leaves surrounding the cabbage heads were damaged on the clover plots (t=4.369; DF=241; P<0.001), the overall quality of the heads was better as there was less damage by *Delia brassicae*. Because quality is more important than quantity in vegetable growing (Theunissen *et al.*, 1995), the management of pest insects by undersowing cabbage crops with clover, or other plant species, might still be a viable option. However, larger plants might prove a problem in respect of aphid infestations.

The living mulch had the greatest affect on the aphid. As aphids use visual cues to locate their host plants (Costello, 1995), the probability of colonizing a plant should depend largely on its appearance. The increase in the rate of growth of new leaves of cabbage plants is nearly linear during the first phase of vegetative growth (Krug, 1986). Therefore, the differences between the two treatments tested should have increased considerably during the early weeks of the experiment. This could have effected colonization by the aphids. The natural increase in aphid numbers is either not affected by crop diversification or even enhanced (Costello & Altieri, 1995; Helenius, 1990), which makes it less likely that plant quality is the factor responsible for differences in aphid colonization. Contrary to the resource concentration hypothesis, the size of the host-plant patch and the distance between patches does not affect the numbers of herbivorous insects found on cabbage plants (Grez & González, 1995). However, it has yet to be tested, whether differences in leaf area alone could influence either the rate of colonization or the rate of dispersal by winged aphids.

Résumé

Dynamique des populations d'insectes phytophages et des auxiliaires trouvés dans une parcelle de chou blanc et de trèfle en intercalaire

Des parcelles de chou blanc, cv. Minicole, associé à du trèfle (Trifolium subteraneum cv. Geraldton) ont servi à tester les effets de mulch vivant sur la distribution des ravageurs phytophages et de leurs ennemis naturels. La culture associée réduit significativement plusieurs espèces de ravageurs (par exemple : les pucerons *Brevicorine brassicae* et *Myzus persicae*, et les altises) mais n'a pas d'effet sur plusieurs espèces de Lépidoptères. Au moment de la colonisation des pucerons, on trouve beaucoup de pucerons sur les plantes témoins, alors qu'à la récolte les pucerons des crucifères étaient plus ou moins distribué également sur l'ensemble de la culture. On a observé moins d'œufs de mouche du chou (*Delia radicum*) dans les parcelles où le trèfle était présent mais, à la récolte, il y avait davantage de choux attaqués par des larves sur les parcelles témoins. Le nombre des ennemis naturels, en particulier les larves de syrphe, et les chenilles parasitées, était plus élevés dans la culture associée, mais il n'a pas pu être établi de relations entre le nombre plus élevé de prédateurs et les faibles densités de pucerons. La culture associée réduit significativement le poids des plants de chou et cela soulève plusieurs problèmes d'organisation insolubles. L'influence de l'apparence des plantes et celle de la qualité pendant la colonisation des pucerons sont discutées.

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Undersowing cabbages with clover and its effect on the infestation levels of the cabbage root fly

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Summary

Undersowing cabbages (*Brassica oleracea* var. *capitata*) with subterraneum clover (*Trifolium subterraneum*) reduced oviposition and pupal production by the cabbage root fly (*Delia radicum*), but did not reduce damage to the crop plants. These apparently contradictory results are explained on the basis that the smaller undersown crop plants will be damaged proportionally as much by smaller numbers of root fly larvae as the larger monocropped plants will be by larger numbers of larvae.

Before undersowing can be used as a practical method of pest management in the field, serious husbandry problems, such as the high incidence of weeds and the delayed development of crop plants leading to a yield penalty at harvest, have to be overcome.

Introduction

When two or more plant species are grown together it can be called intercropping (two different types of crop plants), weedy culture (a crop and a weed), cover cropping, undersowing, or using a living mulch, etc (a crop and a beneficial non-crop) (Andow, 1991; McKinlay and McCreath, 1995). Because experimentation with these mixtures of plants is complex and often involves two and even three trophic levels, Trenbath (1993) called for a pooling of resources between individual researchers and research institutions. Such cooperation is occurring under the aegis of the International Organisation for Biological Control (IOBC) Working Group, 'Integrated Control in Field Vegetable Crops' with researchers from several countries within northern Europe exploring how undersowing cabbages (*Brassica oleracea* var *capitata*) with subterraneum clover (*Trifolium subterraneum*) affects the levels of crop infestation by the cabbage root fly (*Delia radicum*) (McKinlay and McCreath, 1995). This paper reports the results of the collaborative field experiment conducted in Scotland during 1994.

Fertiliser was not applied to the experiment (Table 1). The site was considered to be nitrogen-rich, as it had been sown to a grass/clover mixture during the previous year. The percentage ground cover by clover and weeds was measured five times (May 12, June 8, July 6, July 27, August 31) during the season using a 0.25m^2 quadrat at five fixed points in each plot. The weeds in the monocrop treatment were destroyed by regular hoeing. In contrast, the weeds in the cover crop were left unchecked. The incidence of cabbage root fly eggs in the soil around each of 10 plants/plot was assessed weekly from 18 May to 24 August. The numbers of root fly pupae extracted from five soil cores (15cm diameter x 15cm depth) taken from each plot were counted at the end of the first generation on 13 July. The numbers of cabbage plants damaged by root flies in the middle two rows of each plot were also counted at the end of the first fly generation on 14 July. Twenty cabbage plants, chosen at random, were harvested from each plot on 25 August and 5 October.

Materials & Methods

The experimental details are described in Table 1.

Table 1. Details of the field experiment used to assess the effects on the cabbage root fly of undersowing cabbages with clover in Scotland, 1994.

Site details	
Name:	Woodside Farm, Aldroughty Estate, Elgin
British National Grid Reference:	NT175624
Soil Association & Series:	Boyndie Association; Boyndie Series
Soil type:	Fluvioglacial sand; freely drained
Height above sea level:	25m
Aspect:	Flat, sheltered from the North
Rainfall:	730mm/annum
Experimental details:	
Treatments:	Cabbages monocropped
	Cabbages undersown with subterraneum clover
Layout:	Randomised Block, 4 replicates
Crop and cultivar:	Cabbage (*Brassica oleracea* var. *capitata*); cv. Minicole
	Subterraneum clover (*Trifolium subterraneum*); cv. Geraldton
Sowing/transplanting dates:	Clover sown 6 April
	Cabbages transplanted 12 May
Spacing between rows:	70cm
Spacing of cabbages within rows:	50cm
Sowing rate of clover:	20kg/ha
Fertiliser:	none
Plot size:	9.8 x 10m
Harvest dates:	25 August and 5 October

Results

Because of the vigorous vegetative growth of the subterraneum clover, it was mowed eight times during the season to attain an approximate final height of 3cm. The dates of mowing were: 8, 20, 29 June; 6, 13, 27 July; 10, 25 August. The clover was mowed to prevent, as much as possible, plant competition between the cabbages and the clover.

As can be seen from Fig. 1, weeds dominated the clover plots throughout the growing season. In contrast, the weeds in the monocrop treatment were controlled well by hoeing.

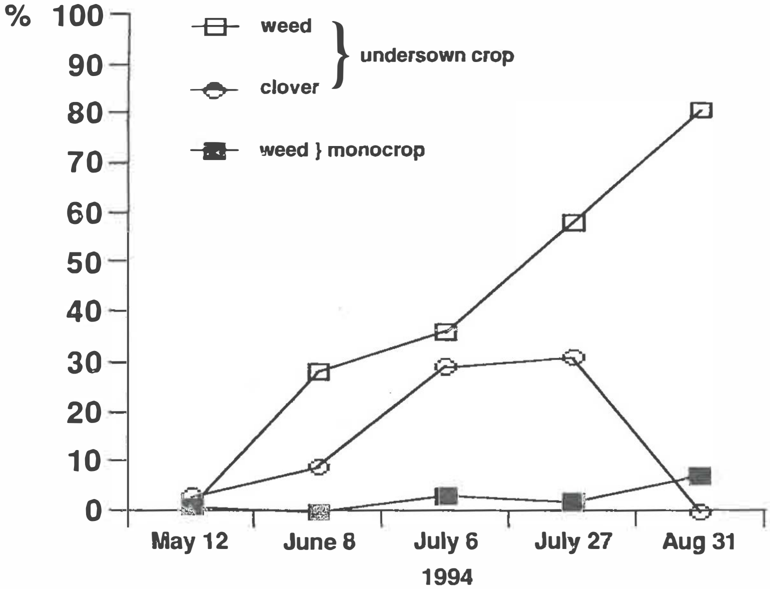

Fig. 1: Percentage ground cover by weeds and subterraneum clover in monocropped and undersown cabbage crops.

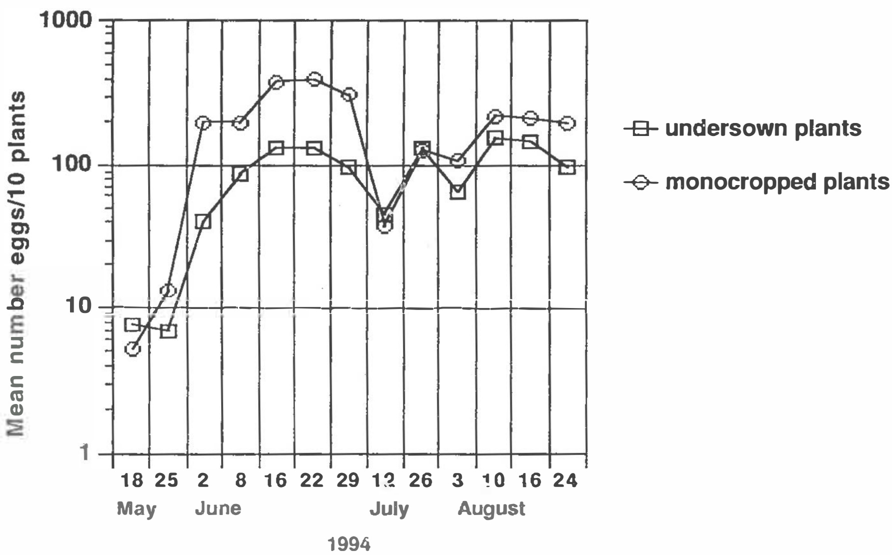

Fig. 2: Mean number of cabbage root fly eggs recovered from around cabbage plants grown as monocrops and undersown with clover.

The principal weeds found in the undersown clover were corn spurrey (*Spergula arvensis*), knotgrass (*Polygonum aviculare*) and chickweed (*Stellaria media*). The clover vegetation began to senesce from the end of July and by the end of August it was effectively dead.

The numbers of cabbage root fly eggs found around the cabbages undersown with clover were much lower than those found around the monocropped cabbages i.e. undersowing reduced oviposition by approximately 63% (Fig. 2). The numbers of root fly eggs in the undersown treatment were significantly (P<0.05) lower than the numbers in the monocrop treatment on 8, 16, 22 & 29 June and, again, on 3 & 24 August. The respective Least Significant Differences (P=0.05; DF=3) for these dates were 66, 220, 96, 182, 24 and 85.

The numbers of cabbage root fly pupae found around the roots of the undersown cabbages were less (P<0.05) than the numbers found around the monocropped cabbages (Table 2) at the end of the first generation on 13 July.

Table 2. Mean number of cabbage root fly pupae per 15cm diameter soil coil taken on 13 July 1994.

Undersown Crop	24
Monocrop	58
LSD (P=0.05)	24

Plant counts in the undersown and monocropped cabbages were not different (P<0.05) at the end of the first generation of the cabbage root fly on 14 July (Table 3).

Table 3. Mean number of plants surviving the cabbage root fly attack from the original 40 transplanted into the middle two rows of each plot. (Counts made on 14 July 1994).

Undersown crop	33
Monocrop	31
LSD (P=0.05)	5

During the first harvest (25 August), although almost all of the monocropped cabbages were harvested as marketable, very few of the undersown cabbages were ready for harvest (Table 4). By the second harvest (5 October), one third only of the undersown plants were able, finally, to be harvested (Table 4). The proportions of plants harvested as marketable from the two treatments thus differed considerably.

Table 4. Percentage of the 20 cabbages harvested/plot that were marketable (>350g)

	Harvest dates 1994	
	25 August	5 October
Undersown crop	1	31
Monocrop	95	-
LSD (P=0.05)	8	

The weights of marketable cabbages at the two harvest dates showed a similar trend. The total weights of harvested cabbages were higher (P<0.05) in the monocrop plants than in the undersown plants (Table 5).

Table 5. Mean weight (kg) of the 20 cabbages harvested/plot.

	Harvest dates 1994	
	25 August	5 October
Undersown crop	0.1	4
Monocrop	23	-
LSD (P=0.05)	6	

Discussion

Theunissen *et al.* (1992) demonstrated that oviposition by the cabbage root fly was reduced on cabbage crops undersown with subterraneum clover. This experiment confirmed the findings of Theunissen *et al.* (1992) and demonstrated also that undersowing reduced the numbers of root fly pupae produced. Plant damage caused by the cabbage root fly was not reduced however by undersowing. These results appear to suggest that smaller numbers of root fly larvae on undersown plants cause as much damage as larger numbers of larvae on monocropped plants. This interpretation would almost certainly be wrong. A more likely explanation is to be found in the different sizes of plants in the two cropping treatments. The smaller crop plants in the undersown plots will presumably be damaged to a similar extent by smaller numbers of larvae as larger numbers of larvae on the larger monocropped plants.

Undersowing requires a high degree of crop management skills. The two most difficult management problems associated with undersowing are the high incidence of weeds and the delayed development of plants leading to reduced yields at harvest. The weeds are likely to cause both immediate problems (more difficult harvesting, contamination of product with soil and weed seeds, etc.) and long term problems (shedding of seeds into the soil seed bank, etc.). Such weed problems may be ameliorated by the judicious use of herbicides. As far as the delayed development of plants and the reduced final yields are concerned, further work is needed to determine the temporal and spatial arrangement of crop and the undersown vegetation to optimise both the pest management benefits and crop yield. The present temporal and spatial plant arrangement is unacceptable in current practice, as subterranean clover is too competitive and growers do not like having to sow the cover crop one month prior to transplanting the main crop. Mathematical modelling and/or computer simulation may assist with the determination of the optimal arrangement of the main crop and the cover crop in space and time.

Résumé

Culture de chou avec du trèfle comme plante intercalaire et mesure des effets sur les niveaux d'infestation de la mouche du chou

Le fait de semer des choux (*Brassica oleracea* var. *capitata*) avec du trèfle (*Trifolium subterraneum*) en intercalaire réduit la ponte et la production de pupes de la mouche du chou (*Delia radicum*), mais ne réduit pas les attaques des plantes cultivées. Ces résultats apparemment contradictoires sont explicables grâce à l'hypothèse qu'un plus petit nombre de plantes en culture intercalaire sera attaqué proportionnellement autant par un plus petit nombre de larve de mouche du chou qu'un plus grand nombre de plante en monoculture sera attaqué par un plus grand nombre de larves.

Avant que des plantes intercalaires ne puissent être utilisées dans la pratique pour gérer les ravageurs dans les champs, on devra résoudre plusieurs problèmes sérieux des pépinières, ainsi que l'incidence élevée des mauvaises herbes, le retard de développement de la culture et de son implantation jusqu'au handicap de la production à la récolte.

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Undersowing crops of white cabbage with strawberry clover and spurrey

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Summary

A field experiment was carried out to compare how two different undersown crops affected pest incidence and crop yields in fresh market white cabbage. The undersown crops used were: Strawberry clover (*Trifolium fragiferum*), cv. Palestine, and spurrey (*Spergula arvensis*). Pest populations were monitored and at harvest time crop yields were assessed in terms of both crop weight and crop quality. No pesticides were used. Populations of *Thrips tabaci* found inside the cabbage heads were much lower in both of the undersown crops. Populations of *Plutella xylostella* caterpillars were not as high as those from the monocropped plots. However, the quality of the cabbages from the undersown plots was much better than from the monocropped plots. Spurrey is scientifically interesting for suppressing pest populations, notably those of *Plutella* caterpillars and thrips, but could be difficult to integrate in existing cropping practices. Strawberry clover has similar effects to other clovers, but could have advantages because it suppresses weeds well, yet does not compete too strongly with the main crop.

Introduction

Undersowing vegetable crops with clovers shows considerable promise for producing good quality crops without using pesticides (Theunissen, 1994a; Theunissen *et al*., 1995). One of the problems that still needs to be solved, however, is the numbers and types of plant species suitable for undersowing. Within the clovers, various species/cultivars can be used to suppress pest populations in crops such as heading cabbage, leek and fennel (Theunissen, 1994b. However, more plant species suitable for undersowing are required to avoid difficulties arising in future from systems based solely on clovers. Previous experience using spurrey (*Spergula arvensis*, Caryophyllaceae) as the undersown crop in Brussels sprouts, indicated that it had good pest suppressing qualities (Theunissen and den Ouden, 1980). Therefore, spurrey was tested in fresh market cabbage and the results compared with those obtained earlier using white clover (*Trifolium repens*) and subterranean clover (*T. subterraneum*) (Theunissen *et al*., 1995). Earlier studies indicated that the advandages of using strawberry clover (*Trifolium fragiferum*) are that it is good at suppressing weeds, because it grows relatively tall (25-30cm), and that it has a relatively low degree of competition with the main crop. In addition, it flowers abundantly and for a long period of time and so is attractive to a large number of insects. It also tolerates being mowed extremely well. This clover was used in the present experiment because of the desirable properties just described. The performance of this clover and spurrey as the undersown crops in plots of white cabbage was tested in the experiment described in this paper.

Materials and Methods

Three 7m x 7m plots of strawberry clover (*Trifolium fragiferum*) cv. Palestine and three similar sized plots of spurrey (*Spergula arvensis*) were sown on April 13 at rates of 15 kg/ha and 10 kg/ha, respectively. A further three plots were left as bare soil. White cabbage, cv. Minicole, were transplanted on 16 May into all 9 plots. The cabbage plants were spaced 70cm apart between the rows and 50cm apart within the rows. The spurrey was mown on 23 June and both the clover and spurrey were mown on 27 June. Fertilizer (NPK) was applied (3.5 kg/plot) on the second week of May and on the second week of June (2.5 kg/plot). No pesticides were applied.

Field observations

Caterpillar and cabbage aphid populations were monitored every two weeks. Two plants were sampled at random from each plot and the eggs, caterpillars and pupae of the various Lepidopterous pest species were counted. At the same time, the cabbage aphid infestation was assessed and cabbage root fly oviposition was determined by sampling the soil from around the base of 5 plants. The numbers of types of natural enemies found were also recorded.

One day prior to harvest, all plants in the fields were assessed in two ways:-

1. Symptoms of caterpillar feeding were recorded on a scale of 1-5, ranging from none (=1), slight (=2), medium (=3), heavy (=4) to very heavy (=5).
2. Symptoms of caterpillar feeding were also divided into two major classes: injury (of no consequence to product quality) and damage (economic-heads unmarketable). In the case of injury only the wrapper leaves showed feeding symptoms, not the heads which are the saleable part of the crop. When the heads had feeding symptoms that would make them unmarketable, the plant was scored as having damage. These observations were done to determine whether field observations could give a reliable estimate of the crop losses expected at harvest.

The amount of ground cover by the intercrops was also registered as % coverage. When both necessary and possible, the intercrops between the cabbage rows were mowed using a Flymow aircushion lawnmower. This was done twice in the clover and 4 times in the spurrey. When the cabbage plants were small mowing reduced the inter-species competition for light and space. When the wrapper leaves were fully unfolded, it was no longer possible to mow.

Harvest

The plots were harvested on 9-14 August. Twenty-five plants were taken from the centre of each plot. These plants were weighed, classified for quality and examined for the possible causes for not being classified (unclassified). The reasons for being graded unclassified were: feeding damage by caterpillars, infestation by cabbage root fly within the cabbage head, presence of cabbage aphids, and symptoms of thrips. During the same period, populations of thrips (*Thrips tabaci*) were assessed by destructively harvesting 5 cabbages taken at random from each plot and counting the numbers of thrips found. Larval and adult thrips were counted on all leaves from each cabbage. The quality classes used were based on the official Dutch standards. Quality 1 is unblemished. In quality 2, very slight symptoms are permitted (still marketable) whereas quality 3 is not marketable because of clear imperfections.

Data analysis

Time series were made from the pest population data. Differences found at the various sampling dates were tested by LSD. Harvest data were tested on replicate and treatment effects using ANOVA. Replicate effects were not found. At low population levels, or low rate of infestation, the overall variability obscured any possible differences.

Results

During the long, dry, and warm summer the main pest was *Plutella xylostella*, followed by *Mamestra brassicae* and *Pieris rapae*. Despite ample evidence of feeding by caterpillars, the actual numbers of caterpillars counted on the sampled plants was low. The caterpillars tended to migrate into the interior of the plants, unlike their behaviour in a "normal", cooler summer. This within-plant migration affected considerably the results of the non-destructive sampling. Infestations of the plants by the cabbage root fly (*Delia radicum*) and by the cabbage aphid (*Brevicoryne brassicae*) were very low, and non existent, respectively. This was attributed to the cold and wet spring and early summer (April, May and first half of June), probably causing a high mortality to the first generation of both pests. A similar situation was found in other vegetable crops. Fleabeetles (*Phyllotreta* spp.) caused injury to the cabbage plants at a young stage. In both undersown crops, fleabeetle numbers and the infestation were very low, but not in the monocrop. The fleabeetles were not counted nor was their feeding activity quantified.

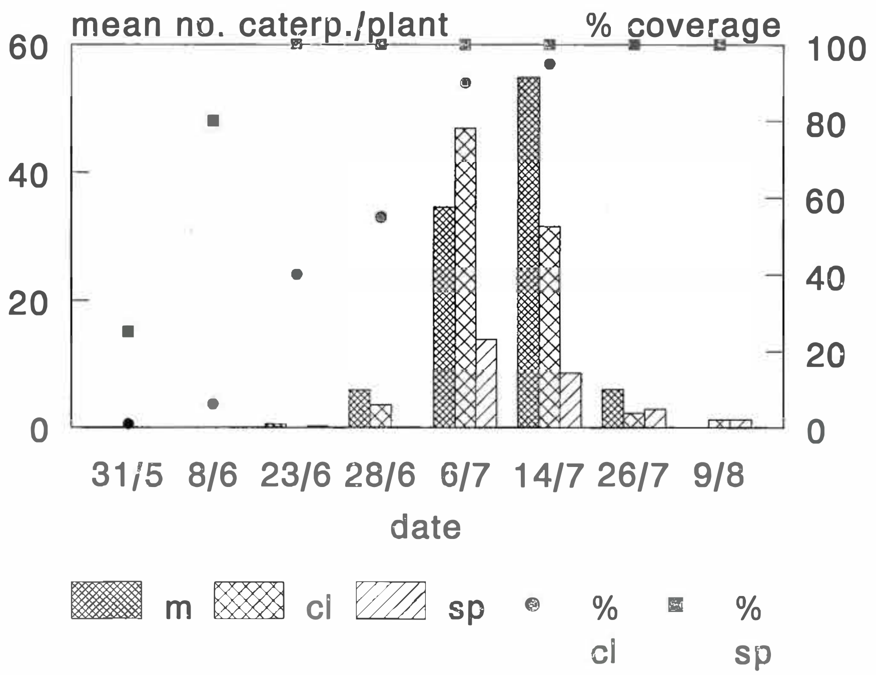

Fig. 1: Population of *Plutella* caterpillars recorded during the growing season for each of the three treatments. The percentage ground coverage, during the experiment by both clover (% cl) and spurrey (%sp) is also indicated.

In agreement with earlier results (Theunissen *et al.*, 1995) the peak numbers of *M. brassicae* larvae in the undersown crops tended to be lower than in the monocrop, although the overall low numbers prevented significant differences being recorded on most observation dates. Few *M. brassicae* larvae were found, particularly on the plants undersown with spurrey. To date, *Plutella xylostella* has not been affected when brassica crops have been undersown with clover. This was also true for the strawberry clover. However, in the plots undersown with spurrey, larval populations of *Plutella* were significantly lower than those in the monocrop (Fig. 1). Differences in *P. xylostella* caterpillar populations were recorded on 28 June, 6 July (both $P<0.1$) and on 14 July ($P<0.01$).

Table 1. Percentage of cabbage plants with economic caterpillar damage, estimated directly before and during harvest. For criteria see the section on 'Field observations'.

	By symptoms		At harvest
Treatment	Damage	Heavy/very heavy	
Monocrop	81	77	79
Undersown with clover	65	19	36
Undersown with spurrey	49	3	20

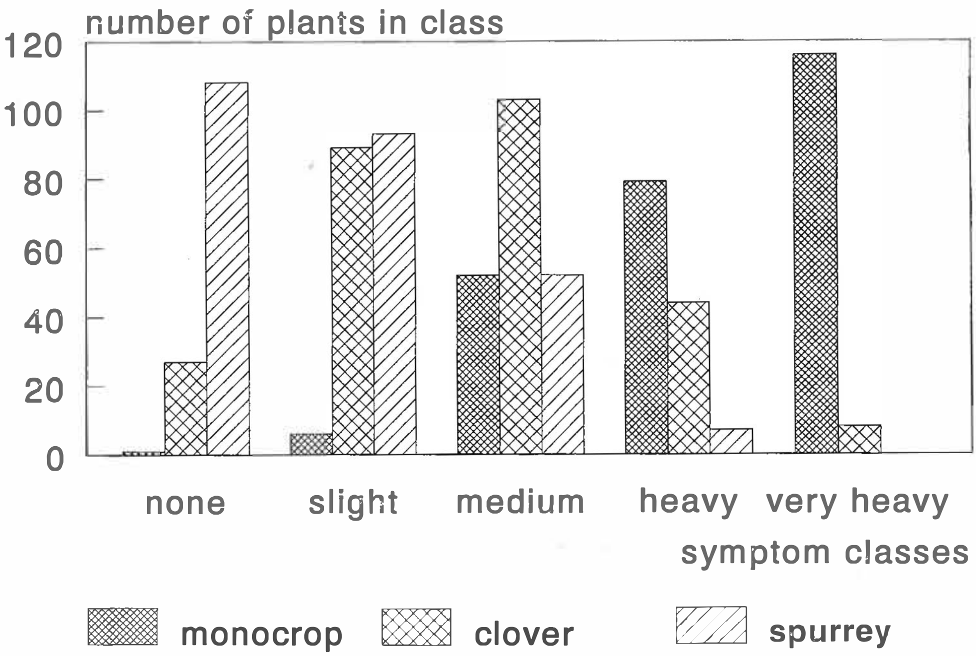

Fig. 2: Frequency distribution of the five classes of caterpillar feeding symptoms found on the plants prior to harvest. Note the skew distributions for the monocrop and for the crop undersown with spurrey.

The pre-harvest field assessment of caterpillar feeding symptoms estimated crop losses correctly only in the monocrop (Table 1). In the undersown plots, 1) damage estimates and 2) classes of feeding symptoms produced overestimates and underestimates, respectively, when compared to the assessments made at harvest. Hence, with the method proposed, a reliable estimate of the expected economic damage is possible only for the monocrop situation. As the method is not suitable for the undersown crops, the feeding behaviour of the caterpillars is probably different in undersown crops (Fig. 2).

The effects of the populations of thrips found in the harvested cabbage samples were not similar. The treatment effects are summarized in Table 2. In the undersown cabbages, thrips penetrated less-deeply into the cabbage heads than they did in the monocrop.

Table 2. Mean number of thrips found per cabbage at harvest. Figures in the same column followed by the same letter do not differ significantly [b]($P<0.05$), [c] ($P<0.01$).

Treatment	Larvae	Adults
Monocrop	77 [a]	28 [a]
Undersown with clover	19 [bc]	10 [c]
Undersown with spurrey	33 [b]	11 [c]

The yield data are summarised in Table 3. The Land Equivalent Ratio (LER) is included to demonstrate the difference between yields in terms of harvested weight and marketable weight. The LER's, are the proportions of area necessary to produce a given quantity of monocrop compared to intercrop (Mead & Willey, 1980). Therefore, the LER is a measure of the production performance of the intercrops.

Table 3. Harvested and marketable weight (expressed as kg/75 cabbages) together with the corresponding LERs. The percentage of marketable plants (MP) is also indicated. Figures in the same column followed by the same letter do not differ significantly.

Treatment	Harvested weight	LER	Marketable weight	LER	% MP
Monocrop	102 [a]		41 [a]		40
Undersown with clover	84 [b]	0.82	77 [a]	1.87	89
Undersown with spurrey	70 [b]	0.69	63 [a]	1.53	88

The symptoms of infestation found of the harvested cabbages are summarised in Table 4. A variety of symptoms may lead to a total, or partial, degrading of the cabbage heads. In the cases of caterpillar and thrips, a distinction was made between light and heavy symptoms on the cabbage heads. Light symptoms lead to declassification to quality class 2, heavy (= not acceptable) symptoms lead to quality class 3 (= not marketable). Infestation of the head by cabbage root fly was classified solely on the presence or absence of the pest.

Table 4. Percentages of cabbages showing symptoms at harvest of infestation by caterpillars, cabbage root fly and thrips. Note that a cabbage can show several symptoms. Figures in the same column followed by the same letter do not differ significantly (*P*=0.05).

	Caterpillars		Cabbage root fly	Thrips	
Treatment	Light	Heavy	Presence only	Light	Heavy
Monocrop	21^{a*}	79^{a}	20^{a}	23^{a}	24^{a}
Undersown with clover	17^{a}	36^{b}	9^{a}	9^{a}	7^{a}
Undersown with spurrey	29^{a}	20^{b}	0^{a}	13^{a}	5a

Discussion

The intention of this experiment was to assess the performance of strawberry clover and spurrey for use as undersown crops in vegetable production. Despite the poor agreement between numbers of caterpillars found and the rate of feeding injury/damage, the relative reduction of caterpillar populations on white cabbages undersown with both plants support earlier findings (Theunissen *et al.*, 1995). A new observation is the reduction of *P. xylostella* populations in cabbage crops undersown with spurrey, which has not been recorded previously in cabbages undersown with clover. This not only indicates differences between various undersown crops in the way they cause population reductions, but it might also indicate a new way to control *P. xylostella*.

Using the criteria proposed in this paper, pre-harvest estimates of economic damage due to caterpillar feeding could be made in monocrops. It is not clear why the estimates made for the undersown cabbages failed to predict the actual harvest losses. The frequency distribution of the symptom classes in the three treatments (Fig. 2) provide a clue to why the harvest losses in the undersown cabbages were underestimated. The observation that the heads of the cabbages in the undersown crop were penetrated less-deeply by the caterpillars, might explain the overestimation of damage when based on the injury/damage symptom criterion.

The reduction in thrip numbers described previously for cabbage crops and fennel (*Foeniculum vulgare*) (Theunissen, 1994b) undersown with subterranean clover, were confirmed here for both strawberry clover and spurrey. A reduction in thrips numbers when cabbage was undersown with spurrey had not been recorded previously.

Crop yields, expressed as harvest weight and marketable weight, are similar to those recorded previously for undersown crops of white cabbage and leek (Theunissen *et al.*, 1995; Theunissen & Schelling, 1996). Reduction in total harvested weight, due to increased plant competition, and a similar, or higher, marketable weight from the undersown crops is the general trend. In term of Land Equivalent Ratios the crops undersown with clover and spurrey score higher because of their better quality. Tables 3 and 4 give a full account of the yields and the factors that influence them.

Agronomically, strawberry clover poses few problems, as it is easy to mow before the crop closes and it does not compete too strongly with the main crop. Spurrey is a much more difficult intercrop. It grows fast and abundantly, and grows over young crop plants if it is not mown in time. The structure and fatty texture of the plant stems makes effective mowing difficult, as the spurrey is often only flattened by "mowing", rather than cut. For many growers, spurrey is considered totally unacceptable, as they fear it will create weed problems for the following year. Although spurrey has an open plant structure it competes quite strongly with the main crop.

In conclusion, strawberry clover seems to have considerable benefits as a crop to be used for undersowing. In contrast, while spurrey has good pest-suppressing qualities, especially with regard to *P. xylostella* and *Thrips tabaci*, it does create agronomic problems. Using spurrey in existing cultural practices is likely to create more problems than using clovers. Scientifically, the pest reduction effects of undersowing with spurrey are very interesting as they are somewhat similar and somewhat different from those produced by clover. Therefore, the question still remains: "what is really going on?".

Résumé

Culture intecallaire de chou blanc avec du trèfle blanc et de la spergule

Un champ expérimental a été utilisé pour comparer l'effet de deux cultures intercalaires sur l'incidence des ravageurs et la récolte de choux blancs vendus en frais. Les deux cultures intercalaires sont le trèfle blanc (*Trifolium fragiferum*) cv. Palestine et la spergule (*Spergula arvensis*). Les populations de ravageurs sont suivies et au moment de la récolte, la production est estimée en poids et en qualité. Aucun produit insecticide n'a été utilisé. Les populations de *Thrips tabaci* trouvées à l'intérieur des têtes de choux sont beaucoup plus basses dans les parcelles comprenant les cultures intercalaires. Les populations de chenilles de *Plutella xylostella* ne sont pas aussi élevées que dans les parcelles conduites en monoculture. Cependant, la qualité des choux des parcelles en intercalaires était bien meilleure que dans les parcelles en monoculture. La spergule est scientifiquement intéressante en raison du fait qu'elle supprime les populations de ravageurs, notamment celles de *Plutella* et de thrips, mais pourrait présenter une difficulté à son intégration aux pratiques de culture existantes. Le trèfle blanc a des effets semblables aux autres trèfles mais pourrait avoir des avantages parce qu'il supprime bien les mauvaises herbes, cependant il ne fait pas trop fortement concurrence à la culture principale.

Acknowledgements

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Carabidae recorded from the same field sown with onions in 1977-1978 and in 1993-1994

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Summary

The aim of this work was to compare the species of *Carabidae* found in a cultivated field, sown with onions, following a period of 15-17 years of standard cultural practices. Twenty pitfall traps were spaced evenly throughout the $800m^2$ sampling area, in each of the four years when beetles were sampled. The beetles were collected from the pitfall traps twice each week. In 1977-1978, 1561 beetles (32 species) were collected, whereas in 1993-1994, 1359 insects (31 species) were collected.

Bembidion lampros was the dominant species in all four years. It made up 28, 43, 55 and 54% of the total beetles collected. During the same period, *Pseudophonus pubescens* increased from about 3 and 5% to 20 and 17%, and *H. froelichii* from 0.0 and 0.5% to 2.7 and 2.2%, respectively. Species that appeared to decrease in numbers were *Bemidion quadrimaculatum*, *B. femoratum* and *Trechus quadristriatus*.

Many years of application of pesticides do not appear to reduce the overall populations of *Carabidae*.

Introduction

The aim of the present study was to show the stability of the complex of *Carabidae* found over a 15 year period in a field included in a normal vegetable crop rotation.

Materials and Methods

In the years 1977-1978 and 1993-1994, carabid beetles were collected from a field sown with onions, that was located alongside a 200 year old park. The agrotechnical data and pesticide treatments used in the field are shown in Table 1.

Over the past 20 years, the onion-based crop rotation included also crops of broad bean, bean, pea, Brussels sprout, cabbage, cauliflower, dill, leek, parsley, carrot, cucumber, garlic and tomato. All of these crops were treated with pesticides against pest and diseases, according to the treatments recommended in Poland. The field was deep ploughed each autumn and mechanically tilled (cultivated, harrowed) each spring. Organic matter was applied every 3 years and mineral fertilizers as, and when, required. The following pesticide treatments were applied to the onion crop; the actual chemicals used are listed in Table 1.

a) seed dressing to control both soil pathogens and the onion fly

b) pre-emergence field sprays to control weeds

c) sprays to control the disease complex found on onion leaves
d) sprays to control both adult onion flies and thrips

Table 1. Pesticides applied during the growing season and the number of treatments applied. (SD) = seed dressing; (S) = spray; (1-3) = no. of sprays. Others = one application.

Specification	1977	1978	1993	1994
Experimental area	800 m^2	800m^2	800 m^2	800m^2
Forecrop	white cabbage	tomato	onion	pea
Date of sowing	April 19	April 14	April 20	April 23
Row distance	35 cm	35 cm	37 cm	37 cm
Chemical applied during the growing season and number of treatments.				
Insecticides	isofenphos (SD)	isofenphos (SD)	isofenphos (SD) cypermethrin (S), 3x	isofenphos (SD) cypermethrin, 2x
Fungicides	thiuram (SD) mancozeb (S), x 1	thiuram (SD) mancozeb (S), 1x	thiuram (SD) chlorothalonil (S) + cymoxanil, 2 maneb, 2x	thiuram (SD) chlorothalonil (S) + cymoxanil, 2x
Herbicides (before emergence)	-	-	pendimethalin, 1x	pendimethalin, 1x
Harvest date	August 9	August 15	August 18	August 16

Shortly after the onion seeds emerged from the soil, 10 pitfall traps were placed within the inter-row spaces and were distributed evenly over the 800m^2 experimental area. Each trap consisted of a plastic cylinder, 10cm in diameter and 14cm high that was buried so that its upper edge was level with the soil surface. Trapped beetles were collected twice each week from May until when the onion crop was harvested.

Results

The results are shown in Table 2. Although there were seasonal changes, the species that dominated in 1977-1978 were also dominant during 1993-1994. Species that were present in high numbers during at least one of the four years were *Bembidion femoratum, B. lampros, Calathus fuscipes, Clivina fossor, Harpalus distinguendus, Nebria brevicollis, Pseudophonus pubescens* and *Pterostichus melanarius.* The total numbers of beetles collected did not differ between the two periods of observations, even though the field was subjected to more intensive chemical treatments during 1993-1994 (Table 1).

At the end of the 15-year period, there was a significant increase in the numbers of *B. lampros* and *P. pubescens*. In contrast, after the 15-year period, fewer specimens were collected of *B. femoratum*, *B. quadrimaculatum*, *N. brevicollis* and *T. quadristriatus*. The dominant species were abundant mainly during June and July.

Table 2. ***Carabidae*** **collected from the same onion field in Skierniewice, Poland during 1977-1978 and 1993-1994.**

No.	Species	1997+ % of participation	1998+ % of participation	1993 % of participation	1994 % of participation
1.	*Acupalpus meridianus* (L.)	-	0.3	-	-
2.	*Agonum dorsale* (Pont.)	0.1	0.2	-	-
3.	*Amara aenea* DeGeer	-	-	1.6	0.3
4.	A. aulica Panz.	0.1	0.2	0.1	0.3
5.	*A. familiaris* Duft.	-	0.3	-	-
6.	*A. fulva* DeGeer	0.6	0.7	0.3	0.1
7.	*A. ovata* F.	-	-	-	0.1
8.	*A. plebeja* Gyll.	-	-	0.1	-
9.	*A. similata* Gyll.	-	-	1.9	0.4
10.	Amara spp.	9.6	7.4	2.6	1.1
11.	*Anisodactylus nemorivagus* (Duft.)	0.6	0.2	-	-
12.	*Badister bipustulatus* (Fabr.)	0.1	-	0.1	-
13.	*Bembidion femoratum* (Strm.)	3.1	17.9	0.1	0.6
14.	*B. lampros* (Herbst)	27.5	42.8	55.3	53.7
15.	*B. quadrimaculatum* (L.)	23.5	1.2	1.8	0.3
16.	*B. ustulatum* (L.)	0.7	-	-	6.7
17.	Bembidion spp.	-	-	0.4	-
18.	*Broscus cephalotes* L.	0.1	-	0.5	2.8
19.	*Calathus ambiguus* (Payk.)	0.1	-	-	-
20.	*C. fuscipes* (Goeze)	7.1	0.5	0.8	1.4
21.	*C. piceus* Mrsh.	-	-	-	0.1
22.	Calathus spp.	-	-	0.4	0.1
23.	*Carabus hortensis* (L.)	0.1	0.2	-	-
24.	*Clivina collaris* (Herbst)	0.3	-	-	-
25.	*C. fossor* (L.)	5.2	0.5	3.3	4.1
26.	Clivina spp.	0.3	0.2	0.4	2.5
27.	*Harpalus aeneus* (F.)	-	-	0.1	-
28.	*H. distinguendus* Dsfch.	3.6	0.2	0.4	2.5
29.	*H. froelichii* Sturm.	-	0.5	2.7	2.2
30.	*H. tardus* Panz.	-	-	0.1	0.1
31.	*H. rufus* Brügg	-	-	0.1	-
32.	Harpalus spp.	3.8	2.2	-	1.3
33.	*Idiochroma dorsalis*	-	-	-	0.3
34.	*Lorocera caerulescens* (L.)	0.2	0.3	-	-
35.	*Metabletus truncatellus* (L.)	-	0.3	-	-
36.	*Nebria brevicollis* (Fabr.)	1.4	4.9	0.5	0.8
37.	Nebria spp.	0.1	0.8	0.1	-
38.	*Notiophilus biguttatus* (Fabr.)	-	0.2	-	-
39.	*Pseudophonus pubescens* Mill.	2.7	4.5	19.5	17.3
40.	*Pterostichus diligens* (Sturm.)	0.1	-	-	-
41.	*P. niger* Schall.	-	-	-	0.1
42.	*P. melanarius* L.	6.9	4.5	1.9	2.0
43.	*Trechus quadristriatus* (Schrank.)		2.1	9.2	0.1 -
	Total number of beetles	963	598	644	715

† Szwejda, 1984

Discussion

Fifteen years after the initial assessment, the population of *Carabidae* found in an onion field did not differ from that found previously. All the species present are found commonly in cultivated soils in Poland (Burakowski, *et al.*, 1973, 1974; Szwejda, 1984).

The dominant species, *B. lampros, B. femoratum, C. fuscipes, C. fossor, H. distinguendus, P. pubescens, P. melanarius* and *T. quadristriatus*, were largely zoophagous and hemizoophagous, but feed also on plant material mainly during periods of drought (Kirchner, 1960; Tischler, 1965; Sunderland, 1975).

According to Tischler (1965), the choice of food depends on weather conditions.

In 1993-1994, repeated applications of insecticide against the second generation of onion fly (*D. antiqua*) did not affect the total number of *Carabidae* caught during the season, although the numbers caught declined considerably immediately after each treatment was applied (Szwejda, 1994).

The present research reflects the stability of the carabid complex within this particular crop production system.

Résumé

Les Carabidae récoltés sur la même parcelle d'oignon en 1977-1978 et en 1993-1994

L'objectif de ce travail était de comparer les espèces de Carabidae trouvés dans une parcelle cultivée en oignon pendant une période de 15-17 ans selon les pratiques culturales classiques. 20 pièges Barber (pitfall trap) furent répartis également au travers d'une zone d'échantillonnage de 8000 m2, au cours des 4 années d'échantillonnage des carabes. Ceux-ci étaient récoltés deux fois par semaine. En 1977-1978, 1561 carabes (32 espèces) furent collectés, contre 1359 (31 espèces) en 1993-1994.

Bembidion lampros a été l'espèce dominante les 4 années de piégeage. Il a représenté 28, 43, 55 et 54 % du total des carabes récoltés. Durant la même période *Pseudophonus pubescens* a augmenté de 3 et 5 % à 20 et 17 %, *H froelichii* de 0,0 et 0,5 à 2,7 et 2,2 % respectivement. Les espèces qui semblent avoir diminuées en nombre sont *Bembidion quadrimaculatum, B. femoratum* et *Trechus quadristriatus.*

L'application de pesticides pendant plusieurs années ne semble pas réduire les populations totales de Carabidae.

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Fauna associated with the cabbage root fly in sequential sowings of turnips

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Summary

The oceanic climate of Brittany is highly favourable to the cabbage root fly, *Delia radicum* L. (Diptera, Anthomiidae), the major pest insect of cruciferous crops in the west of France. Considerable damages occurs each year in the market gardening areas of Finistère, Cotes d'Armor and Ille et Vilaine. Several studies are now being done to find an alternative to insecticidal control. Laboratory studies have shown that *Aleochara bilineata* Gyll. (Coleoptera, Staphlinidae) is an extremely efficient predator and parasitoid of *D. radicum*, but as yet little information is available on the situation in the field. To study the population dynamics of the predators and parasitoids of *D. radicum*, plots of turnips were drilled sequentially over a three month period so that the insects that entered such crops could be trapped and sampled. The results showed that there was a close correlation between the numbers of flies caught and the numbers of fly eggs sampled; and between egg-laying and 1) the stage of host-plant development, and 2) the numbers of *Aleochara bipustulata* and *A. bilineata* adults caught in the crop. An inventory was made of the carabid beetles associated with the cabbage root fly at La Rimbaudais.

Introduction

The cabbage root fly, *Delia radicum* L. (Diptera: Anthomyiidae), is the major pest insect of cruciferous crops in Brittany.

In 1982, Lahmer studied the biology of *D. radicum* and made a list of its natural enemies. Among the most important of its parasitoids were *Trybliographa rapae* West. (Hymenoptera, Cynipoidea, Eucoilidae), *Aleochara bilineata* and *A. bipustulata* (Coleoptera: Staphylinidae).

Laboratory studies have shown that *T. rapae* and *A. bilineata* are effective parasitoids and/or predators of *D. radicum*, but little information is available on the effects of these parasitoids under field conditions. To improve this situation, plots of turnips were drilled every 2-3 weeks during a 3 month period. Insects traps were used and many samples were taken to estimate the numbers of adults and immature stages of insects present in the turnip plots. In 1995, the experiments were done in a large area of cruciferous crops at La Rimbaudais experimental farm in the department of Ille et Vilaine, near Saint Malo.

Materials and Methods

Description of the experimental plots

The trials were done at La Rimbaudais experimental farm, in the middle of the market gardening area of Saint Malo. In this region, cruciferous crops, such as turnips and cabbage, are grown throughout the year. It is an area highly suited to both *D. radicum* and its natural enemies.

Five sequential sowings of turnip were made from April to June (Table 1). Each sowing consisted of 12 rows of turnips drilled to a stand of 50 turnips/metre. Each sowing was 3 m wide and 30 m long and was split into five replicated plots each 6 m long.

Table 1. Date of sequential sowing of turnips.

SOWING	DATE
1	3 - 8 April
2	24 - 30 April
3	5 - 11 June
4	19 - 25 June

Insect traps

These were used to estimate the adult populations of *D. radicum*, *A. bilineata*, *A. bipustulata* and *T. rapae*. The traps used were yellow water-traps (Finch & Skinner, 1974) and pitfall traps.

Water traps

Three yellow water-traps were employed in each sequential sowing. When the sowing was no longer being used, the traps were removed. The traps were placed between the rows of turnips. Each trap was filled with water containing a little liquid soap (Finch & Skinner, 1974) and inspected twice each week. The insects caught were stored in alcohol in small plastic boxes, before being sorted and identified.

Pitfall traps

These were used to sample carabid beetles and specialist parasitoids like *Aleochara* that are active on the surface of the soil. Five pitfall traps were used in each sowing, one in the middle of each 6 m plot.

The traps contained a 1:1000 solution of water and formalin and were inspected twice each week. The insects caught were stored in the same way as those from the water-traps.

Samples of eggs, larvae and pupae of *D. radicum*

The numbers of cabbage root fly eggs in the plots were assessed by taking 6 soil samples from each of the five replicated plots once a week. The soil from 10 cm around each sampled turnip plant was collected down to a depth of 2 cm using a spoon, and placed into numbered small plastic boxes. All the samples were then subjected to Kort filtration which then enabled the *D. radicum* eggs to be counted. To estimate the numbers of fly larvae and pupae present, one 20 cm deep and 20 cm diameter soil sample was taken each week from each replicated plot. Each sample was placed into a number plastic bag. In the laboratory, the soil was sifted carefully and the pupa and numbers of third-instar larvae and pupae found were recorded. Each plant was then dissected carefully to count the numbers of first- and second-instar larvae.

At the end of each crop, the soil was sampled for fly pupae. Fly pupae were picked from three 50 cm lengths of row in each row of turnips. The soil was inspected from 10 cm alongside the rows of turnips and down to a depth of 20 cm. The plants themselves were not included in these samples. The soil collected was placed into numbered plastic bags, and was sifted later to extract the pupae. The pupae collected were separated into *Delia radicum* or *D. platura*. Only the *D. radicum* pupa were retained. They were kept in plastic boxes so that the numbers of adults of *D. radicum* and parasitoids that emerged could be recorded easily.

Results

Figure 1 shows the close relationship between the number of female *D. radicum* caught in yellow traps and the mean number of fly eggs sampled from the plots. This figure shows the results from the first sowing. Similar figures could be produced for the data collected from sowings 2, 3 and 4.

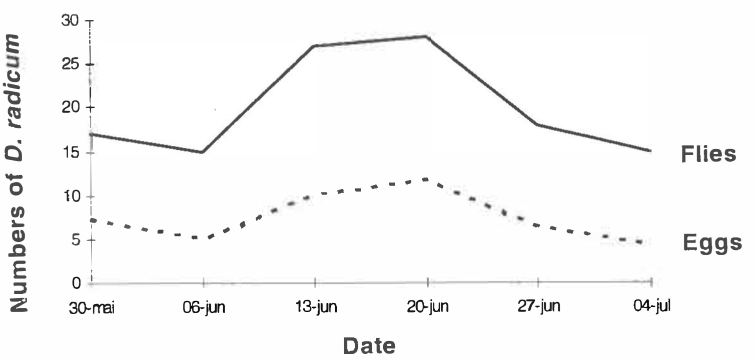

Fig. 1: Mean numbers of female *D. radicum* caught and eggs collected on sowing No. 1 at La Rimbaudais in 1995.

Figure 2 shows that the flies prefer to lay on turnip plants that have 7-8 leaves. Similarly, *A. bilineata* appears to prefer crops when the plants have 6-7 leaves (Fig. 3).

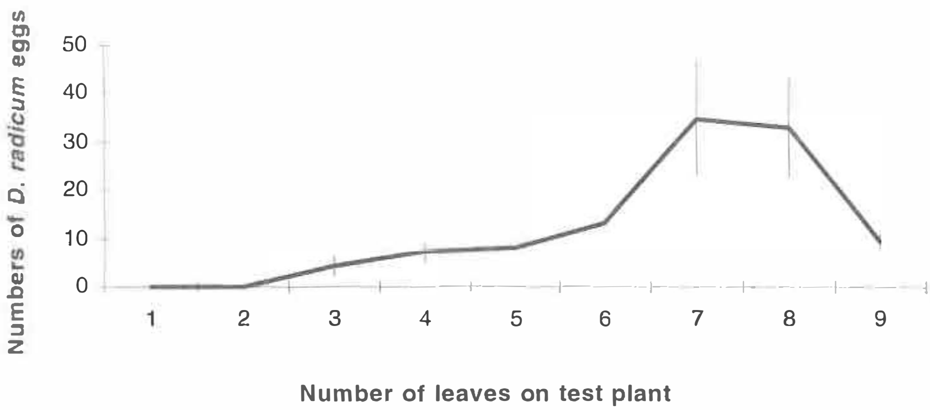

Fig. 2: Relationship between plant development and the mean numbers of fly eggs collected at La Rimbaudais in 1995.

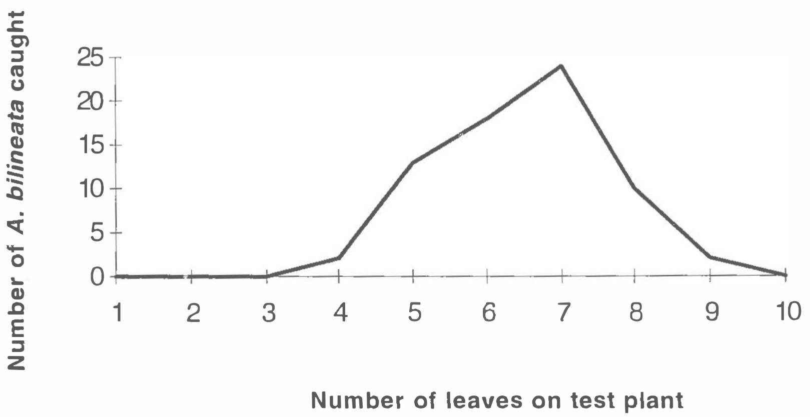

Fig. 3: Relationship between plant development and the numbers of *A. bilineata* adults caught at La Rimbaudais in 1995.

A total of 22 species of beetles were caught in the pitfall traps. The three most abundant species were *Aleochara bipustulata*, *A. bilineata* and *Harpalus rufipes* and these constituted about 37%, 13% and 19% of the total, respectively.

Table 2. List of beetles caught in pitfall traps at La Rimbaudais in 1995.

SPECIES	NUMBERS CAUGHT	%
Aleochara bilineata	91	12.8
Aleochara bipustulata	264	37.1
Agonum muelleri	9	1.3
Agonum dorsale	7	1
Anisodactylus binotatus	3	0.5
Anisodactylus b. b spurca	2	0.3
Bembidion lampros	38	5.3
Bembidion quadrimaculatum	1	0.1
Bembidion ustulatus	1	0.1
Carabus granulatus	1	0.1
Clivina fossor	7	1
Drypta dentata	1	0.1
Harpalus affinis	34	4.8
Harpalus rufipes	135	19
Loricera pilicornis	4	0.6
Megadontus purpurascens	3	0.5
Nebria brevicollis	29	4.1
Pterostichus melanarius	29	4.1
Pterostichus sp2	1	0.1
Pterostichus cupreus	51	7.2
Stapyhlinus olens	3	0.5
Timarcha tenebricosa	1	0.1
TOTAL	**712**	**100%**

Parasitism

The fly pupae collected from the field and placed into plastic boxes, were inspected daily to record the numbers and types of insects that emerged. The percentage of the various insects that emerged are shown in Table 3.

Table 3. The percentages of the four types of insects that emerged from the pupae sampled.

DATE	% *A. bilineata*	% *A. bipustulata*	% *T. rapae*	% *D. radicum*
13 June	11	3	86	
20 June	20	19	0	61
25 June	36	22	2	40
25 July	47	43	1	9
8 August	54	42.6	0	2
22 August	56	44	0	0

Discussion

The first flies were caught in April. At La Rimbaudais, only a few adults of *T. rapae* were caught. Two possible explanations for this are that the traps are not effective against this insect or *T. rapae* do not survive the chemical treatments applied to the fields close to the experimental plots.

A. bilineata and *A. bipustulata* were caught for the first time in the last week of May, one month after the influx of *D. radicum*. This confirms the findings of Bromand (1980). *A. bilineata* and *A. bipustulata* always emerge after *D. radicum* has started to lay (Lahmer, 1981; Finch, 1992).

Figure 1 shows that the mean number of *D. radicum* eggs laid on turnips is proportional to the numbers of flies caught in the area. However, egg-laying seems to be influenced also by the development stage of the host plant, in this case turnips. *D. radicum* females appear to prefer turnips with 6-8 leaves and *A. bilineata* those with 6-7 leaves, when *D. radicum* eggs are present in high numbers. *A. bilineata* adults are arrested within sowings of turnips by the presence of high numbers of fly eggs.

Another aim of this study was to evaluate the number of other insect species associated with *D. radicum*. It is important to have a robust estimate of the populations of carabid beetles in turnips fields, as such beetles are potential predators of the eggs and larval stages of *D. radicum*.

Eighteen species of carabid beetles were caught in the pitfall traps (Table 2). The three beetles caught most frequently were *A. bipustulata* (37% of the total catch), *Harpalus rufipes* (19%) and *A. bilineata* (13%). About half of the beetles caught were *Aleochara*.

The two species of *Aleochara* were caught in the ratio of 1/3. *A. bipustulata* was usually, but not always, the dominant species. A different proportion of parasitism was found in Norway where Jonasson (1994) recorded 66% of *A. bipustulata* and 31% of *A. bilineata*, so that the ratio was only 1/2. It will be interesting to see if the relative proportion of each species is affected by geographic location.

At the end of summer, the genus *Aleochara* was found in about 98% of the overwintering pupa. Under such conditions, availability of host pupae is the factor that limits the two species.

Résumé

La faune associé avec la mouche du chou dans des semis échelonnés de navets

En Bretagne, les conditions océaniques sont reconnues comme étant extrêmement favorable à la multiplication de la mouche du chou *Delia radicum L.* (Diptère : Anthomiidae). *D. radicum* est le principal insecte ravageur des cultures de crucifères en Bretagne et les dégâts causés sont parfois considérables. De nombreuses études sont en court afin de trouver des moyens de lutte alternatifs aux traitements chimiques. En laboratoire, les études menées sur *Aleochara bilineata Gyll.* (Coleoptère : Staphylinidae) montre qu'il est un redoutable prédateur et parasite des stades immatures de *D. radicum.* Mais, jusqu'en 1995 nous n'avions aucune idée de la situation en plein champ dans les principales zones de culture légumière de Bretagne. Une expérimentation sur semis échelonnés de navets a donc été mise en place à la ferme expérimentale de La Rimbaudais (Ille et Vilaine) afin de déterminer les niveau de population et les taux de parasitismes de la mouche du chou et de ses ennemis naturels.

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Co-ordination of the work on biological control of the cabbage root fly in Brittany

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Summary

The timing of the arrival of the beneficial insects associated with the cabbage root fly (*Delia radicum*) is related both to the level of pest infestation and to the growth stage of the plant. This paper describes the underlying principles and the subjects to be studied by the various team members. The team consist of scientists from the University of Rennes 1, scientists from INRA and crop consultants, the latter being represented by researchers from the Plant Protection Service (SPV) and the Vegetable Experimental Stations sited in the West of France. The overall aim is to control the cabbage root fly using methods of biological and integrated control.

Discussion

For many years, people have been trying new methods for controlling *Delia radicum* L. (Diptera: Anthomyiidae), the main pest insect of brassica crops throughout the Palearctic region and north America. More references concerning the various methods that have been tried are described in the paper of Finch (1992) published following the Dipterist Congress held in Bratislava, Slovak Republic.

In France, work has been done also on insect growth inhibitors (Brunel *et al.*, 1991) and on *Bacillus thuringiensis*. The possibility of using genetically-modified brassica plants is also being considered but such plants are unlikely to be available in the foreseeable future. In the meantime, commercial growers continue to apply more and more chemical. We intend to study the possibility of using parasitoids as biological control agents for the cabbage root fly as they have more chance of being used in the near future. Following discussions with partners in Brittany, it was decided to work on *Aleochara bilineata* Gyll. (Staphylinidae). The relationship between the pest and its associated insects is shown in Table 1.

Table 1. The insect fauna associated with the cabbage root fly.

Plant family		*Cruciferae*	
Phytophagous flies		Diptera	*Delia radicum*
Associated insects	Predators	Coleoptera	Carabidae
	Parasitoids	Hymenoptera	*Trybliographa rapae*, *Phygadeon*
	Predators & Parasitoids	Coleoptera	*Aleochara bilineata* *A. bipustulata*

Depending on the weather, beneficial insects may enter brassica crops either too early or too late. Therefore, understanding the interactions between the behaviour of the insects present at different times of year could be important.

Plant-insect relationships

The adult insects find their host-plants using volatile chemicals given off by the plants. Similar chemicals also stimulate oviposition (Städler, 1978). The type and growth stage of the brassica crop affects the numbers of eggs laid by the female flies and also the success of their progeny. The presence of predators (Table 2) has a considerable influence on the population dynamics of the pest.

Host parasitoid relationships

The parasitoid is attracted to damaged plants. The importance of the chemical stimuli on parasitoids needs to be studied to detect whether kairomones are involved and if so whether one crop type is preferred to another. The relationships between pest insect density and plant damage by *D. radicum* are being studied by both Langlet & Brunel (1996), and by a team in Canada.

Competition between predators and parasitoids

The role of predators is quoted often in the literature (Coaker & Williams, 1963; Reader & Jones, 1990; Jones *et al.,* 1993). *Aleochara bilineata* is recorded as being able to out-compete *Trybliographa rapae*. Whether this is true or not will be studied in detail in Brittany. Many aspects of interspecific competition have not yet been studied due largely to the difficulties of including sufficient appropriate environmental variables in the test procedures. Competition between the two *Aleochara* species will also be studied. Information is needed to show why the abundance of the two *Aleochara* species differs from country to country.

A pragmatical approach has been adopted to combine the expertise within INRA, the University, and the Plant Protection Service to develop a system suitable for use in commercial vegetable production. Simultaneously, INRA and the University of Rennes 1 are studying both the biology of the parasitoids and their efficiency of controlling the pest. The Plant Protection Service is developing a system for mass rearing *Aleochara* under the guidance of INRA (Table 3). At the same time, cooperative work has been started with scientists in both Morocco and Canada, who wish also to find new methods for controlling infestations of *D. radicum.* It is hoped that this collaboration can be extended to include all people working on this immense subject (see Table 4).

Table 2. The insects associated with the various stages in the life-cycle of the pest.

Plant	Insect Stage	Beneficial organisms
Healthy	adult flies	
Infested	egg	*Aleochara* (both species) Carabidae
"	larvae	*Trybliographa* & *Phygadeon*
"	pupae	*Aleochara* (both species)
Healthy/ infested	adults	*Empusa muscae* (fungus)

Table 2 shows the sequence of events that occur during a fly generation. Once healthy young host-plants are found by the cabbage root flies, the females lay their eggs in the soil alongside such plants. Generalist and specialist predators enter the crop as soon as the first plants are injured, whereas the parasitoids arrive considerably later.

Table 3. Breakdown of the subjects studied and the French Institutes involved in the project.

Type of studies	Main subjects	Individual topics	Collaborators
Laboratory	Explanatory factors	quantitative studies	1. INRA 2. UNIVERSITY
		percentage parasitism pest density favourable factors	
Interface between lab. & field	Insect rearing	pest flies	3. PLANT PROTECTION SERVICE (SPV)
		insect parasitoids	1. INRA 2. UNIVERSITY
Field	Critical analysis	population dynamics density dependence release rates	1. INRA 3. SPV

Table 4. European and International teams currently studying *Aleochara*

Countries	Scientists	Subjects
DENMARK	Bromand, 1980 Samsoe Petersen, 1987	*Aleochara*: Biology, effects of insecticides
SWEDEN	Ahlstrom-Olsson, 1992; 1994 Ahlstrom-Olsson & Jonasson, 1992	*Aleochara*: Biology, host selection, size of pupae, host niche
ENGLAND	Skilbeck & Anderson, 1994	*Aleochara*: Structure and function of antennal receptors
	Finch, 1995; 1996a, 1996b	*Aleochara* and *Trybliographa*: Intraspecific competition, rates of parasitism, effects of undersowing on levels of parasitization

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Table 4 cont'd.

Countries	Scientists	Subjects
FRANCE	Brunel & Langlet, 1994 Brunel & Fournet, 1996 Langlet & Brunel, 1996 Nenon Neveu *et al* (1996) Kacem *et al* (1996)	*Aleochara*: rearing, rates of parasitoid penetration, fitness of parasitoids, functional response to their hosts *Trybliographa*: rearing, recognition of their hosts
CANADA	Boivin Royer Biron Tomlin *et al* (1992)	*Aleochara*: synchronisation of pest and parasitoid populations, functional response to fly infestations in the field, behavioural response to fly-infested plants
MOROCCO	Lahmer	*Delia radicum*: bioecology

Résumé

La place des différents auxiliaires de la mouche du chou (*Delia radicum*) est donnée en fonction de l'évolution du stade de la plante. Différentes hypothèses de travail sont évoquées et la répartition des taches est précisée dans le cadre d'un travail d'équipe entre l'Université de Rennes 1, l'INRA et les professionnels, représentés par le Service de la Protection des Végétaux et les stations d'expérimentation légumières de l'Ouest de la France. Les résultats présentés par ailleurs sont positionnés dans l'objectif d'une lutte biologique et intégrée contre la mouche du chou.

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Problems associated with controlling the cabbage root fly by inundative releases of the rove beetle, *Aleochara bilineata*

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Summary

Attempts will be made to use the rove beetle *Aleochara bilineata* as a predator for controlling the cabbage root fly. To be successful, the beetles will have to be reared and released into infested crops, as the beetles do not normally emerge sufficiently early in the season to combat the main peaks of fly activity. The literature indicates that batches of beetles will need to be released at intervals of 20m throughout the crops and that a rate of one beetle per plant should be sufficient to control the levels of fly attack experienced normally under UK conditions. Although the work required to rear and release 20,000 beetles per hectare might seem daunting, the costs appear to compare favourably with insecticidal control.

Introduction

During the last 75 years, many authors (see Tomlin *et al.*, 1992) have suggested that it might be possible to control field populations of the cabbage root fly (*Delia radicum* L.) by releasing the parasitoid rove beetle, *Aleochara bilineata*. However, no one has yet used this beetle successfully in the field.

This paper provides a short review of the work published on this subject. A more comprehensive review concerning all three of the major parasitoids of the cabbage root fly can be found in two earlier papers (Finch, 1995; 1996).

Review of existing literature

There are three main parasitoids of the cabbage root fly, the eucoilid *Trybliographa rapae* (Westw.) which has been recorded from 60% of the individuals in some samples of overwintering pupae in Canada (Wishart *et al.*, 1957), and two species of rove beetle, *Aleochara bilineata* (Gyll) and *A. bipustulata* (L), which regularly parasitize 20-30% of cabbage root fly pupae in the UK (Finch & Collier, 1984) and occasionally 60% in Canada (Wishart *et al.*, 1957).

Proposed ways of using *Aleochara bilineata* in the field.

Most researchers (Wadsworth, 1915; Esbjerg & Bromand, 1977; Bromand, 1980; Hertvelt *et al.*, 1984; Tomlin *et al.*, 1992) have concentrated on *A. bilineata* in the belief that it will act both as a predator and a parasitoid provided it can be released into an infested brassica crop sufficiently early in the life-cycle of the pest. It has been suggested, therefore, that *A. bilineata* should be released inundatively at the time the pest fly starts to oviposit, as most early-season brassica crops need to be protected more or less as soon as they are planted. The beetles could then first eat the eggs of the fly, to lower the overall pest infestation, and then lay eggs from which their progeny could parasitize the remaining pest fly pupae.

Rearing sufficient parasitoids

The main difficulty in mass-rearing *A. bilineata* is that an artificial diet has not yet been developed and so the host insect still has to be reared on swedes (*Brassica napus* var. *napobrassica*) which is both labour-intensive and physically-demanding. There is always the possibility of rearing the parasitoids on the closely-related onion fly (*Delia antiqua*), for which there is an artificial diet (Ticheler *et al.*, 1980) but getting the parasitoids to "switch" back to the cabbage root fly might then become a problem. Therefore, it is possible that the beetles may have to be reared solely on the cabbage root fly if this is the species against which they are going to be used in the field.

The cost of production will depend upon the number of staphylinid beetles required. The only two estimates made at present vary between 20,000 (Bromand,1980) and 650,000 (Hertveldt *et al.*, 1984) beetles per hectare. Using the rearing technique described by Whistlecraft *et al.* (1985), 10 hours of labour would be needed to produce 20,000 *A. bilineata*. Although the work required for this approach might seem daunting, the costs appear to compare favourably with insecticidal control. For example to treat 20,000 plants (1ha) with chlorfenvinphos granules requires 11.2kg of product at a cost of £4.63/kg, or about £52/ha. Therefore, providing the hourly wage, plus overheads, of the workers producing the beetles does not exceed £5, the cost of control using these parasitoid beetles could be similar to that of using insecticide. Application costs might vary, but as chlorfenvinphos granules are applied generally as a sub-surface band at a cost of about £30/ha, there appears to be sufficient flexibility to keep within this cost even if the beetles have to be released manually.

Distributing the parasitoids within the crop to be protected

According to Esbjerg & Bromand (1977), *A. bilineata* released into brassica crops disperse at the rate of about 6.5m per day. From studies with beetles marked with radioisotopes, they concluded that for the control of cabbage root fly, batches of several hundred beetles should be placed at each release point, which should be spaced no more than 20m apart to ensure that the beetles spread throughout the crop as quickly as possible. Based on such data, releasing beetles from 16-20 points/ha should not cause any difficulties. To be effective, it is likely that the beetles will have to be distributed in this way, as female cabbage root flies are distributed more or less evenly through brassica crops (Finch & Skinner, 1973).

Discussion

One of the constraints of releasing any biological agent into the field is that it has to compete with the established natural enemies. At worst, the release may simply upset the overall local balance so that the existing predatory ground beetles feed in a density-dependent manner on the released parasitoids until the balance is re-established.

The main drawback with all of the systems used to date to "enhance" the numbers of parasitoids (see Thomas *et al.*, 1991), is that the various treatments have only added to the numbers of parasitoids present rather than "enhancing" their effects as pest control agents.

This raises the question of whether it will ever be possible to improve pest control by making crop boundaries more diverse, as the associations between the numbers of parasitoids and their hosts, is finely balanced in such systems. In general, insects only attain pest status in the types of unbalanced systems that occur in agriculture and, in particular, in large monocultures. Therefore, perhaps the only way to resolve such difficulties will be to treat the unbalanced systems with an unbalanced control measure, such as the release of high numbers of laboratory-reared insects. *A. bilineata* would appear to be an ideal candidate for such an approach, as it is capable of acting both as a predator and as a parasitoid. At present we use specific insecticides to control the cabbage root fly, so by analogy we may also need in future to use specific, rather than general, biological agents for the types of pest control needed in these ephemeral crops.

The final drawback to using *A. bilineata* as a predator, is that it would have to be released at the start of each and every fly generation as, being a pupal parasitoid, its offspring will always emerge 2-3 weeks later than the pest fly.

Résumé

Les problèmes associés au contrôle de la mouche du chou par des lâchers inondatifs de staphylins, *Aleochara bilineata*

Des essais seront fait pour utiliser le staphylin *Aleochara bilineata* comme prédateur afin de lutter contre la mouche du chou. Pour que ce soit une réussite, les staphylins devront être élevés et lâchés dans des parcelles infestées, puisque le staphylin n'émerge pas suffisament tôt en saison pour combattre les principaux pics d'activité de la mouche. La littérature indique que des lots de staphylins seront nécessaires pour être relachés à des intervales de 20 m à travers la culture et que le taux de un staphylin par plante pourrait être suffisant pour contrôler les niveaux d'attaques de mouches rencontrées normallement dans les conditions anglaises. Quoique le travail exigé pour élever et relacher 20 000 staphylins par hectare puisse paraitre décourageant, le coût semble favorable comparé à celui de la lutte chimique.

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Development of *Trybliographa rapae*, a larval parasitoid of the cabbage root fly *Delia radicum*

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Summary

Trybliographa rapae (Hymenoptera: Ecuoilidae) is a larval parasitoid of the cabbage root fly *Delia radicum* (Diptera: Anthomyiidae). A study of the immature stages of this parasitoid was done in the laboratory at 20 ± 1°C, 60 ± 10% RH, and 16L : 8D to determine the duration of each larval instar. Eggs of the parasitoid were laid in the 1st-, 2nd-, and 3rd-instar larvae of the cabbage root fly. The egg of *T. rapae* is ovoid, about 0.8 mm long and possesses a stalk. Embryogenesis took about 5 days. The 1st instar larva is of the eucoiliform type and the subsequent three instars are of the hymenopteryform type. Larval development lasted about 30 to 33 days, and pupal development about 25 days. *T. rapae* adults emerged from parasitized fly pupae after about 61 days.

Introduction

Trybliographa rapae (Hymenoptera; Eucoilidae) is a specialist cynipid parasitoid of several species of *Hylemya* (syn. *Delia*) (Wishart, 1954; Herdvelt, 1970) including the cabbage root fly, *Delia radicum*, a species which is distributed throughout the entire north temperate region of the world. Although *T. rapae* has only two generations a year in southern England (Jones *et al*, 1993), it has a long life-span and hence the adults are able to parasitize all three generations of the cabbage root fly. In northern climes, *T. rapae* also attacks the closely related turnip-root fly *Delia floralis* (Jones *et al.*, 1993). The percentage parasitism of *Delia radicum* by *T. rapae* in Canada varied from 0.4 and 46.3% (Wishart, 1959). The highest level of parasitism was found in pest populations of *H. floralis* sampled in Norway and Finland (Wishart *et al.*, 1957).

Little has been published on the developmental stages of the Eucoilidae since Keilin & la Baume Pluvinel (1913) described the 1st instar larva of *Eucoila keilini* (Kieffer). Other descriptions of the development in eucoilids have been those of James (1928) and Jenni (1951). The present paper provides a brief description of the various larval stages of *Trybliographa rapae* when parasitizing cabbage root fly larvae being reared on turnip.

Materials and Methods

Samples of the parasitoid and their host fly were obtained from the INRA Station at Le Rheu. *T. rapae* were reared using the method described by Neveu *et al.* (1995). The rearing and all experiments were done at 20 ± 1°C, 60 ± 10% RH, and a photoperiod of L:D 16:8. The immature stages of *T. rapae* were obtained by exposing ten newly-emerged 1st-instar larvae to *D. radicum* of individual parasitoid females for 24 h periods.

The different instars of *T. rapae* were recovered from cabbage root fly larvae by first placing the fly larvae into Ringer's solution and then dissecting out the parasitoids under a binocular Stereomicroscope. After being dissected from their hosts, the different instars of *T. rapae* were placed into fine-mesh metallic baskets. The larvae were then dehydrated in baths of alcohol (70%, 80%, 90%, 95%, and 100%) and finally in 100% acetone. Samples were dried to the critical point in Balzers CPDIO apparatus using liquid CO_2, and were then coated with gold using a sputter JEOL JFC 1100.

Samples were observed under a JEOL JSM 6400 Scanning Electron Microscope (SEM).

Results and Discussion

Egg

The egg of *Trybliographa rapae* is ovoid in shape, and possesses the egg stalk that typifies members of the Eucoilidae (Fig. 1.1). The egg is 0.5 mm long, and 0.16 mm wide, whereas the stalk is 0.35 mm long, and possesses a micropyle (Fig. 1.2), which has a role during fertilisation of the egg and may have a respiratory function. Prior to hatching the egg increases in size. It is an hydropic egg and is of the type typically produced by pro-ovigenic parasitoids (Flanders, 1942; Gauld & Bolton, 1988). The embryo develops inside a membrane.

First instar larvae

This is a eucoiliform larvae (Fig. 1.3) of the type described by Keilin and Pluvinel (1913), in their study of *Eucoila keilini* (Kieffer). This larva is about 0.7 mm long and possesses a long cauda which, prior to hatching, is curled towards the head and is armed distally with small setae and three pairs of thoracic appendages. The larvae makes considerable use of these appendages to escape from the egg membrane (James, 1928). There are seven main abdominal segments and two others which form a long cauda. The head is not segmented, but is elongated and possesses a sensory process at its anterior end. On the ventral surface of the head there are two prominent projections that have transparent extremities and which are probably sensory in function. Within the mouth there is a small sclerite.

Second instar larva

This did not differ appreciably from the 1st-instar larva. James (1928) regarded this instar to be a polypodeiform type of larvae. However, the larvae of this instar were much larger and measured about 2.3 mm long and 0.82 mm wide (Fig. 1.4).

In this instar, it was not easy to see the segmentation, the caudal appendage was reduced, and the thoracic appendages were absent. This instar also possessed large mandibles but did not have spiracles.

Third instar larva

This instar was slightly bowed and flattened dorso-ventrally (Fig. 1.5). It was about 3.55 mm long and 0.82 mm wide.

The size of this instar was governed largely by the size of its fly host. This instar possesses 3 thoracic segments and 10 abdominal segments, and its integument is thin and adapted to apneustic respiration (Wishart & Monteith, 1954).

Fourth instar larva

This was characterized by a distinct head capsule, by sclerotized one-toothed mandibles and by a ventral anus (Fig. 1.6). This instar was 4.4 mm long and had no obvious segmentation. It also possessed three thoracic segments, each with dense ventrally-lateral ctenedia, nine abdominal segments and nine pairs of spiracles. This stage was described earlier by James (1928).

Nymph

Although these were not easy to see (Fig. 1.7), the few that were observed could be sexed, as the females possess short antennae and males long antennae.

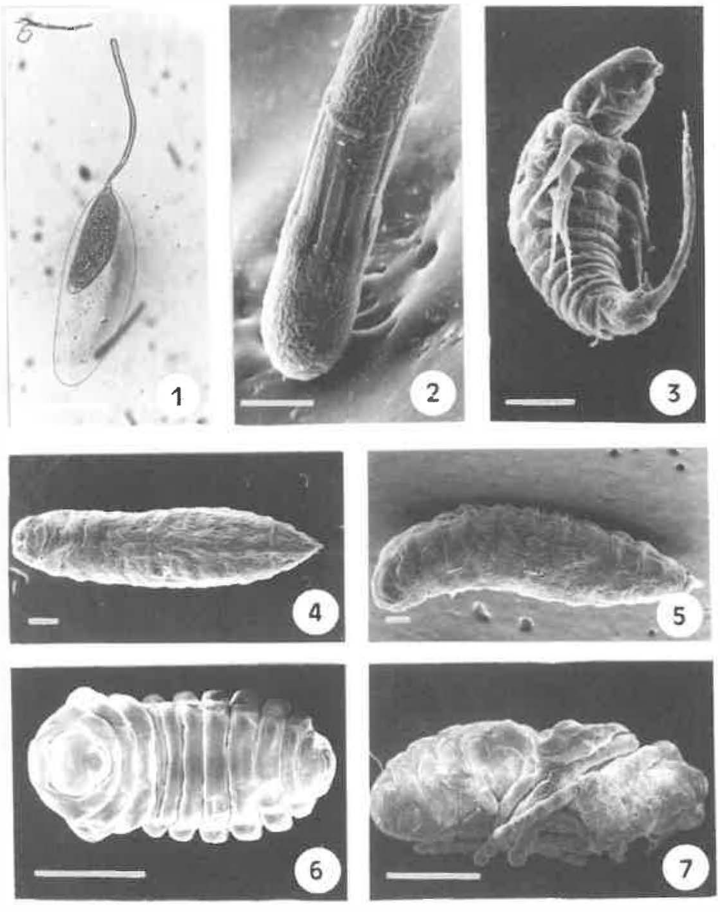

Fig. 1: Immature stages of *T. rapae*

1 = Egg 24 h after oviposition (Scale Bar = 100 µm); 2 = Stalk of the egg (10 µm); 3 = Latero-ventral view of 1st-instar larva (100 µm); 4 = Ventral view of 2nd-instar larva (100 µm); 5 = Lateral view of the 3rd-instar larva (100 µm); 6 = Ventral view of the 4th-instar larva (1 mm); 7 = Nymph of *T. rapae* (1 mm).

Duration of the life cycle

The total duration of development of *T. rapae* ranged from 54 to 61 days when the eggs were laid into 1st-instar cabbage root fly larvae (Fig. 2). In this study, embryogenesis lasted about 5 days and emergence of the 1st instar larvae occurred about 5 to 6 days after the eggs were laid. The parasitoids remained in the 1st-instar for about 15 days. This instar did not develop further until the puparium of the cabbage root fly was formed, at which time the 2nd-instar larvae was formed and lasted about 5 days. The 1st- and the 2nd-instar larvae fed within the host larvae of *D. radicum*, unlike the 3rd-instar fed as an ectoparasitoid (Chrystal, 1930; Jenni, 1951; Wishart & Monteith, 1954; Sychebskya, 1974; Marder & Miller, 1983). The 3rd-instar chews its way out of the pupa of the host fly and then positions itself between the pupa and the puparium when it is effectively eats the pupa from the outside. This instar lasts 3 days, whereas the 4th-instar lasts 13 days. The nymphal stage lasts about 25 days and the adult wasp emerges after a total of about 61 days.

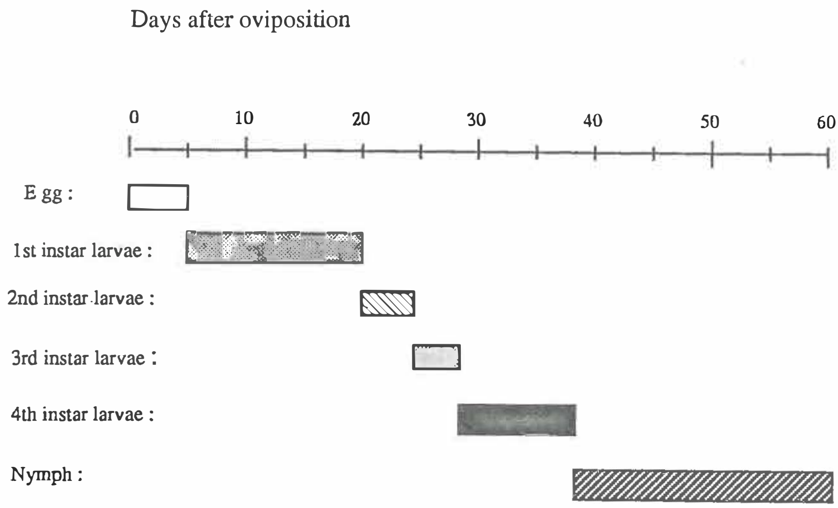

Fig. 2: Mean duration of the immature stages of *Trybliographa rapae*.

Conclusion

Similar studies are now being done in which the *T. rapae* adults are being allowed to oviposit in 2nd- and 3rd-instar larvae of the cabbage root fly. The study will be repeated using Cauliflower as the host-plant and rearing the insects at a range of different temperatures.

Résumé

Développement de *Trybliographa rapae*, endoparasitoïde larvaire de la mouche du chou *Delia radicum*

Trybliographa rapae (Hymenoptèra : Eucoilidae) est une larve parasitoïde de la Mouche du chou *Delia radicum* (Diptera : Anthomyiidae). Une étude des stades immatures de ce parasitoïde a été réalisée en laboratoire à 20 ± 1°C, 60 ± 10% RH, et 16L : 8D pour déterminer la durée de chaque stade larvaire. Les oeufs du parasitoïde sont pondus dans le 1er, le 2ème et le 3ème stades larvaires de la Mouche du chou. L'oeuf de *T. rapae* est ovoïde, environ 0,8 mm et posséde une queue. L'embryogénèse prend environ 5 jours. le premier stade larvaire est de type eucoiliforme et les trois stades suivants sont de type hymenoptéryforme. Le développement larvaire s'achève après 30 à 33 jours, et le développement nymphal demande 25 jours. Les *T. rapae* adultes émergent des pupes de mouches parasitées après environ 61 jours.

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Preliminary results on predation by *Aleochara bilineata* Gyll. (Coleoptera: Staphylinidae)

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Summary

Aleochara bilineata is a predator of the eggs and larvae of certain diptera (e.g. *Delia radicum*, *D. antiqua*, etc) and also parasitizes pupae of the same flies. Earlier results on the levels of predation and the longevity of the adults (Zorin, 1927; Colhoun, 1953; Wishart *et al.*, 1965; Fuldner, 1960; Wright *et al.*, 1960; Coaker, 1965; Bromand, 1980 and Hertveldt *et al.*, 1984). were used to assess the efficiency of predators under controlled laboratory conditions. We studied predation by both male and female *Aleochara* and by pairs of mated beetles. Fecundity and fertility were examined throughout the life of the female. The results obtained were analysed and compared with the earlier data.

Introduction

Few data have been collected recently on predation by *Aleochara bilineata* Gyll. (Coleoptera: Staphylinidae). Earlier authors all agree that this rove beetle consumes various dipterous larvae (Bromand, 1980; Colhoun, 1953). Several authors indicate that *Delia radicum* and *D. antiqua* larvae constitute the main food of *A. bilineata* (Wishart *et al.*, 1956; Coaker, 1965; Wright *et al.*, 1960).

According to Colhoun (1953) this rove beetle eats about 5 fly larvae/day, but he failed to state which larval stage he used in his tests. In contrast, Bromand 1980, indicated that a pair of *A. bilineata* could eat up to 2400 eggs or young larvae, or 350 third-instar larvae during their life. Predation might also have a great impact on the mortality of cabbage root fly eggs under field conditions, but this has not been quantified.

The numbers of eggs laid per female beetle was recorded as 690 (Zorin, 1927), 710 (Colhoun, 1953), 285 to 673 (Fuldner, 1960)., 700 (Bromand, 1980) and 400 eggs (Hertveldt *et al.*, 1984).

This study was done to determine the maximum levels of predation by *A. bilineata* under controlled laboratory conditions.

Materials and Method

The rove beetle emerged from parasitized cabbage root fly pupae. Pairs, or individual male and female *A. bilineata*, were placed into 5 cm diameter Petri dishes. Each day, excess eggs of *D. radicum* were placed into the dishes so that the rove beetle never ran out of food (fly eggs). The numbers and the viability of the eggs laid by *Aleochara* were recorded daily.

The experiments were done in a room maintained at 20°±1 C and 60-70% humidity.

Results

The data collected during 60 days of feeding by male, female and pairs of *Aleochara* are shown in Table 1. Males and females ate 14 and 24 eggs/day, respectively. More eggs (50/day) were eaten by the pairs of beetles than were eaten when the individual male and female data were added together (36 eggs/day) (Table 1).

Table 1. Number of eggs of *Delia radicum* eaten by *Aleochara bilineata*.

		INDIVIDUAL	PAIRS
Fly eggs eaten/male	per day	14	-
	total	815	-
Fly eggs eaten/female	per day	24	-
	total	1356	-
Fly eggs eaten/male + female	per day	36	50
	total	2171	2526
Number of eggs laid by *Aleochara*	per day	6	8
	total	240	409

The daily results are shown in Figs 1, 2 & 3. Fig. 1, the shows the numbers of fly eggs eaten by the pairs of beetles compared to the totals eaten by the males and females when kept individually. Fig. 2 shows the fecundity of the beetles and Fig. 3 viability of the eggs laid by *Aleochara* females kept with either with a male or on their own.

Discussion

Numbers of fly eggs eaten by beetles

During the egg-laying period the female beetles eat more fly eggs than the male beetles. At other times, the two sexes eat similar numbers of eggs. The different levels of predation between the two sexes is probably because the females need to obtain additional food to mature their eggs.

Numbers of fly eggs eaten by pairs (male + female) of beetles

Predation is influenced considerably when the beetles start to lay. The numbers of fly eggs eaten by the pairs is the same as that for the individuals (male and female) during the first 20 days (Fig. 1). After this period, predation decreased gradually for the individual (male + female) beetles. This decrease was reflected by the lower numbers of eggs laid by the isolated females after day 20 (Fig. 2).

Fig. 1: Numbers of *D. radicum* eggs eaten/day by male and female *Aleochara* when kept together or when kept separate.

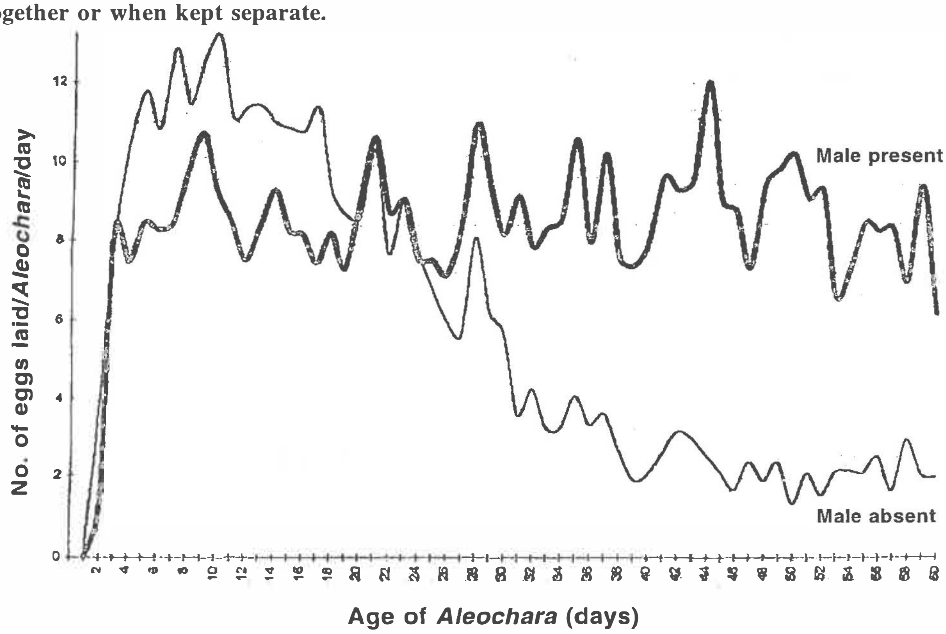

Fig. 2: Number of eggs laid per day by females of *Aleochara* in the presence or absence of a male beetle.

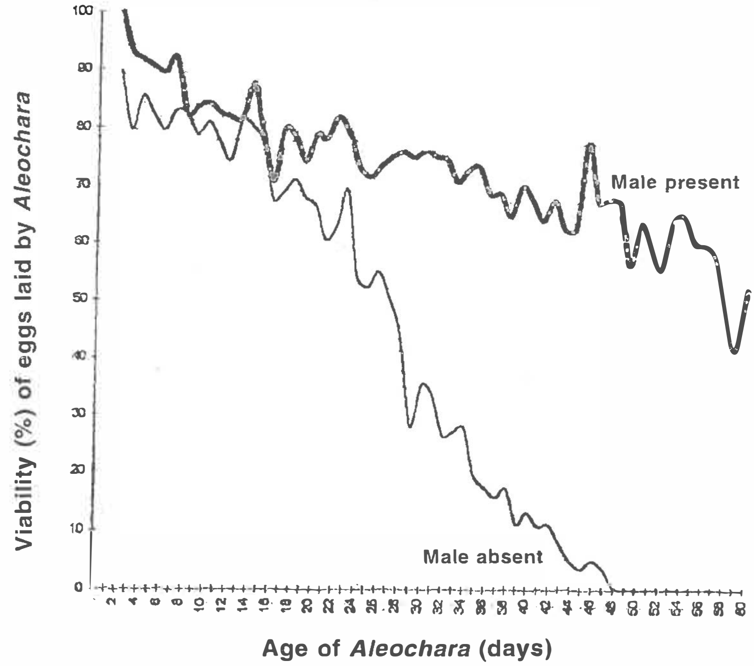

Fig. 3: Viability of the eggs laid by the females of *Aleochara* in the presence or absence of a male beetle.

In addition to fewer eggs being laid, those that were laid were less viable (Fig. 3). It seems that egg-laying is triggered by the stock of spematozoids present within the female, which depend upon whether males are present or not.

This study indicates the potential levels of predation by *A. bilineata*, under laboratory conditions. The levels of predation observed were higher than those recorded by other workers. We think that the experimental conditions used by the earlier authors were more natural, whereas our conditions were selected so that we could record 1) predation of fly eggs, 2) fecundity of the beetles, and 3) viability of the eggs all at the same time. This study is being analysed and published in another paper.

Résumé

Résultats préliminaire sur la prédation par *Aleochara bilineata* Gyll. (Coleoptera: Staphylinidae)

Aleochara bilineata est un prédateur d'oeufs et de larves de nombreux diptères phytophages (*Delia radicum, D. antiqua*, etc). Il vit également en parasite sur ces mêmes insectes. Des résultats obtenus par différents auteurs (Zorin, 1927; Cohloun, 1953; Wishart *et al.*, 1965; Fuldner, 1960; Wright *et al.*, 1960; Coaker, 1965; Bromand, 1980 et Hertveldt *et al.*, 1984) sur la quantité consommée et sur la longévité des adultes nous a amené à examiner la capacité prédatrice maximale en conditions de laboratoire. Nous avons analysé la consommation d'*Aleochara* isolé (mâle et femelle) et en couple. La fécondité et la fertilité-

des oeufs pondus ont été enregistrées tout au long de la vie des femelle. Les résultats sont analysés et comparés aux données de la littérature.

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Preliminary studies on releasing the staphylinid beetle *Aleochara bilineata* Gyll. onto protected cabbage seed beds

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Summary

In France, Brittany is the major region for the production of cauliflowers. In 1995 SRPV Bretagne began experiments to test *Aleochara bilineata* (Coleoptera Staphylinidae) as a possible biological agent for controlling the cabbage root fly *Delia radicum* on field crops of cabbage. *A. bilineata* is both a predator and a parasitoid, and can be reared at Brest (SRPV) on an artificial medium so that large numbers of beetles can be made available for field trials.

The major aim of the study was to evaluate effects of the rove beetle as a predator when released onto seed beds infested by the larvae of *D. radicum*, which caused considerable problems in 1995. On directly seeded beds of cauliflower, a second release of *A. bilineata* under insect-proof cages indicated that the beetles were efficient predators, even when insecticide (carbofuran+isophenphos was also present.

On bulk plants assessment, the efficiency of the beetles was intermediate between the untreated plants and those on which insecticide was applied frequently. A second release of the rove beetle or a higher release rate should increase the effectiveness of *A. bilineata*.

The release of *A. bilineata* adults could help to control cabbage root fly infestation provided the times of fly infestation can be timed accurately. The rove beetle appears to have an effect on regulating fly populations on field cauliflower crops and could be of used in Integrated Production systems.

Introduction

Since the early 1980's, growers have become increasingly interested in the concept of Integrated Pest management (IPM) because of problems associated with control based on the application of insecticides.

Such problems include:-

Insecticide resistance: The main pest of field vegetable crops became relatively more resistant to certain pesticides and as a result growers had to make more frequent applications.

Toxicity problems: Some insecticides are toxic for plants, particularly young plants. Therefore, growers have to take considerable care regarding how frequently to spray; the method use, pesticide persistence and the most appropriate time of day to apply the chemical.

Crops quality and environmental considerations: Consumers have become more aware of crops quality. Biological control and IPM have less pesticides residues in vegetable crops, lower pesticides residues in water and have fewer adverse effects on the environment. For the staff who work in greenhouses and open fields, spraying is difficult, requires considerable time and is often unpleasant.

All of these factors contribute to the current interest in biological control and IPM in field vegetable crops. Therefore, trials were started in 1995 on cabbage crops, which is the main vegetable crop grown outdoors in Brittany. The major aim was to release *Aleochara bilineata* in open fields to determine its effect in controlling *Delia radicum*, cabbage root fly.

Under field conditions, natural enemies help to regulate *D. radicum* population.

The rove beetle *A. bilineata* is an important natural enemy of onion fly, (*Delia antiqua*) cabbage root fly, and many other flies such as *Musca domestica* L., *Pegomyia hyoscyani betae* (Curtis), *Delia platura* (Meig.), *D. floralis* (Fall.), *D. florilega* (Zett.) and *D. planipalpis* (Stein).

The beetles are popyphagous predators that live in and on the soil around cabbage plants, as pupae of flies that live on these plant are hosts for the larvae of the beetle. The adults can live for up to 3 months. The beetles lay their eggs in the soil alongside fly-infested plants, and the newly-hatched larvae then search to find a host pupa. Once a pupa is found, the first-instar larva of the rove beetle gnaws a hole into the pupa enters, and then closes the hole with an intestinal secretion. Development and pupation take place inside the host puparium from which the adult emerges later.

In Brest, *A. bilineata* was reared with *D. antiqua* on an artificial medium (Samsoe-Petersen, 1987). The regular production of rove beetles produces a suitable supply for trials in open fields.

In the first instance, we are interested in protecting seed beds of cauliflower plants, because these beds are of limited area and the adults of *D. radicum* are particularly damaging during May and June when the plants are still in the seed bed.

The protecting effect that we are looking for, is the predatory effect against the eggs and the young larvae stage. Although it is intended to control the pest with inundative releases of beetles, we first need to define an appropriate strategy. If *A. bilineata* is able to breed subsequently in the fields, the benefit will be complete, and we will consider our study as an introductive release.

Experiments in open fields in 1995 on cauliflower (Finistère type)

In 1995, trials were done by releasing *A. bilineata* initially onto cauliflower seed beds. At the same time, water traps were used to capture adults of *D. radicum* (Figure 1).

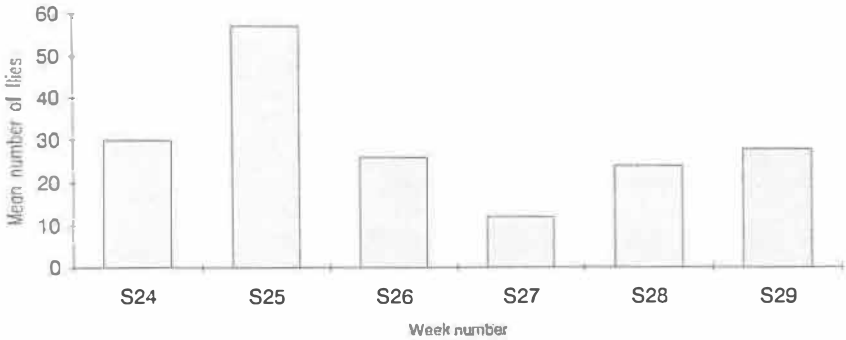

Fig. 1: Numbers of *Delia radicum* adults trapped at Saint Pol de Leon (1995).

1 - Experiments on cauliflower (cv Arcadio) sown directly into the seed bed.

The frames were drilled on 1 June and the subsequent cauliflower plants were destructively harvested on 6 July in the open field and on 20 July in the insect-proof cages.

A total of 12 frames was used so that each of the three treatments could be replicated four times. The three treatments composed were carbofuran and isophenphos (Carma) applied over the seed row (60 g/100 m), adults of *A. bilineata* released at the rate of 2 beetles/m^2 and four frames that were left untreated.

Six insect-proof cages were erected on 15 June, over 2 frames of each treatment repetition. The rove beetle adults were released onto the soil in the '*A. bilineata*' frames.

The first rove beetles were released on 6 June (2 beetles/m^2) and the second batch (16/m^2) on 15 June in one of the two insect-proof cages placed over each treatment.

Assessments were made on 6 June, 35 days after sowing (day + 35) and 20 July, 49 days after sowing (day + 49). In both the open field and the insect-proof cages, the damage on the plant roots was scored into 3 categories: healthy plants, lightly-damaged plants (could be transplanted) and damaged plants (could not be transplanted).

2 - Experiments on broccoli plants grown in peat blocks

The seed was sown on 25 April and the blocks were transplanted on 30 May. The plants were destructively sampled on 6 July, (days + 37). One plot of land was transplanted with blocks that had been treated with chlorfenvinphos (Birland 15 ml/10 l), one plot on which rove beetles were released on 6 June (2 adults/m^2) and a third (control) plot that had neither treatment.

Results

1 - Direct seed bed

The amount of plant damage recorded on the various treatments in the plants sampled on 20 July is shown in Table 1.

Table 1. Percentage of healthy cauliflower seedlings following treatments of the seed bed with either insecticide (Carma) or rove beetles.

	Healthy plants %	Healthy and lightly damaged plants %
Rove beetle (one release)	10	42
Rove beetle (two releases)	20	54
Untreated	10	50
Untreated + rove beetle	26	69
Carma	14	55
Carma + rove beetle	32	76

2 - Block-grown plants

The amount of damage on the block grown plants is shown in Table 2.

Table 2. Comparison of plant damage in block-grown broccoli plants 'protected' by insecticide (Carma) or rove beetles.

	Healthy plants	Lightly damaged plants	Hardly damaged plants	Plantable plants %
Carma	87	12	1	99
Rove beetle	6	43	51	49
Untreated	7	31	62	38

Discussion & Conclusion

As shown in Fig. 1, cabbage root fly was active throughout June and July when these test were done.

In the first experiment on the seed bed, the poor results can be explained because the beetles were released before the plants had emerged from the soil. In the second release made under the insect-proof cage, the beetles had a beneficial effect, even when insecticide was also applied.

On the second block-plant experiment, the amount of damage on the untreated plants confirms how important it is to control *D. radicum* infestation during the summer months in Brittany. The effect of the rove beetle, was intermediate between the untreated and the insecticide-treated plots. Presumably increasing the numbers of *Aleochara* released or making more than one release would increase beneficial effect of releasing the predator.

Adults of *A. bilineata* can assist in the control of *D. radicum.* This rove beetle is an effective predatory when released innundatively. To be effective, however, further information will be needed to define when to release the beetles and how many to release to control the cabbage root fly infestation present in a certain locality or crop.

Résumé

Etudes préliminaires de lâchers de staphylins *Aleochara bilineata* Gyll. en vue de protéger des semis de chou

En France, la Bretagne est la principale région de production de chou-fleur. En 1995 le SRPV Bretagne a commencé des expérimentations pour tester *Aleochara bilineata* (Coleoptera : Staphylinidae) en tant qu'agent biologique afin de contrôler la mouche du chou sur des parcelles de chou en plein air. *A. bilineata* est à la fois prédateur et parasite, et il peut être élevé à Brest (SRPV) sur milieu artificiel en quantité suffisante pour la réalisation des essais de plein champ.

L'objectif principal de l'étude était d'évaluer les effets du staphylin en tant que prédateur quand il est lâché sur une pépinière infestée par les larves de *D. radicum*, insecte qui a provoqué des problèmes considérables en 1995. Sur les semis directs de chou-fleur, un second lâcher réalisé sous cage "insect proof" indique que les staphylins sont efficaces comme prédateurs même lorsqu'un insecticide (carbofuran+isophenphos) est présent.

Sur la répartition des plantes les plus fortes, l'efficacité du staphylin était intermédiaire entre les plants non traités et ceux qui avait reçu un traitement insecticide. Un second lâcher de staphylins ou un lâcher plus important pourrait augmenter l'efficacité de *A. bilineata*.
Le lâcher de *A. bilineata* adultes pourrait aider à contrôler les infestations de mouche du chou à condition de pouvoir connaître précisément les périodes d'infestation des mouches. Le staphylin semble avoir un effet sur la régulation des populations de mouche dans les cultures de chou fleur de plein champ et pourrait être employé dans un système de production intégrée.

Acknowledgements

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A method for rearing *Trybliographa rapae* W. on *Delia radicum* L.

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Summary

In Brittany (France), *Trybliographa rapae* W. (Hymenoptera: Eucolidae) is the main Hymenopteran parasitoid of the cabbage root fly *Delia radicum* L. (Diptera: Anthomyiidae). The parasitoids came from *D. radicum* pupae collected in February 1994 from an infested plot of swedes at Le Rheu. This manuscript describes a method for rearing *T. rapae* on *D. radicum* reared on turnip (*Brassica rapa* L.) in the laboratory. The numbers of *Trybliographa* have increased during the first 20 months of this project and had reached 700 adults/week by October 1995. Laboratory experiments were carried out to determine the time required for *T. rapae* to develop from the egg to the adult stage. The developmental time was shorter when the parasitoid eggs were laid in the 3rd instar (50±1 days) than in the 2nd (55±2 days) or in the 1st instar (62±3 days) larvae of their *D. radicum* host.

Introduction

Cruciferous crops are the major field vegetable crops grown in Brittany. It is common practice to spray cabbage, cauliflower, broccoli and rape crops about eight times between sowing and harvest to control the most important pest, the cabbage root fly *Delia radicum* (L.) (Diptera: Anthomyiidae). As a result, pesticide residues are a problem and hence growers are now becoming aware that some alternative methods, such as biological control, could be desirable.

Trybliographa rapae (Westwood) (Hymenoptera: Eucoilidae) is a parasitoid of several *Hylemya* (=*Delia*) species (Wishart, 1957; Herdvelt, 1970). It attacks mainly the cabbage root fly (Schoene, 1916; Smith, 1927; Wishart & Monteith, 1954) and is the major Hymenopteran parasitoid of *D. radicum* in Brittany (Lahmar, 1982). If *T. rapae* is to be used as a biological control agent against the cabbage root fly, then it is important both to develop a suitable technique for rearing the parasitoid and also to learn more about its biology.

The *T. rapae* reared and used in the current experiments emerged from pupae of *D. radicum* that were collected in February 1994 from an untreated plot of swedes at Le Rheu (Ille et Vilaine, Brittany). Of the 112 pupae collected, about 10% were parasitized by *T. rapae*. The *D. radicum* were donated by E. Brunel (INRA, Le Rheu).

1. Insect rearing

T. rapae was reared on cabbage root fly larvae that were feeding on turnip roots (*Brassica rapa* (L.)) that had been placed into pots and were maintained in the laboratory at 20±1°C, 60±10% r.h. and with 16L:8D photoperiod.

Females of *D. radicum* laid their eggs around half a turnip present in a petri dish. The eggs were collected every two days by floating them in water and picking them off with a fine paint brush. Eggs were then watered onto turnips resting in earthenware pots (20 cm tall and 20 cm diameter) that were filled with damp sifted sand. One fly egg was inoculated for each 2.8 g of turnip, as this is the optimum rate for larvae survival (Coaker and Finch, 1971). Pots containing the eggs were placed immediately into cage (60x60x45 cm) of parasitoids that were provided with acacia honey and water as food. The eggs hatched three to four days later. The female parasitoids oviposited into the fly larvae either by using their long ovipositor through the plant root or by directly entering the tunnels made by the fly larvae. The parasitoids were left to oviposit for 20 days. This period corresponded to the time for the fly required to complete larval development. Ten days later, both parasitized and unparasitized pupae were collected with a sieve (10 mesh/cm^2) and then the pupae were kept in damp sand in small plastic boxes. Adult hosts and parasitoids were collected daily and returned to their respective cage. The numbers of male and female parasitoids that emerged each week are shown in Fig. 1.

2. Developmental times of *T. rapae* under laboratory conditions

The developmental time of *T. rapae* was studied using all three instars of the fly host. The host instars used were 1 day-old (1st instar), 6 days-old (2nd instar) and 14 days old (3rd instar) larvae. One day prior to the start of each experiment, fifteen of 1st, 2nd or 3rd instar fly larvae were placed onto a disc (diameter: 2.5 cm; depth: 1 cm) of turnip. On the same day, pairs of newly-emerged parasitoids (one male, one female) were placed into small plastic boxes (diameter: 7 cm, height: 2 cm) where they had access to acacia honey and water. Females had no previous experience of oviposition but were considered to have mated. Each pair of wasps was kept with the fly larvae for exactly 24 hours. At the end of the experiment, each turnip disc containing the fly larvae was placed onto a whole turnip resting on damp sand in a plastic pot (8 cm in diameter, 7 cm in height). Once the flies pupated, the pupae were kept in damp sand in small bottles. The emergences of parasitoids were recorded daily. The developmental times of *T. rapae* were normally distributed and so the original data could be subjected to analysis of variance without having to be transformed.

Results and Discussion

In 1986, Jones described the unpublished technique that was used by B. Bromand for rearing *T. rapae*. The fluctuations in the numbers of *T. rapae* produced in our laboratory are shown in Fig. 1. Throughout the period of rearing, the numbers of parasitoids gradually increased. Most parasitoids, 700 per week, were produced in October 1995. However, from November 1994 to May 1995 parasitoid numbers were generally lower. This was probably due to the host fly larvae being out-competed by a species of *Drosophila* that all infested the turnips housed in the laboratory. The sex ratio of the parasitoids was at about 50%. This confirmed results from the earlier field and laboratory studies of Jones (1986).

The generations of the parasitoid were relatively synchronous. This could be explained by the low numbers of individuals used to start the colony and by the ability of the females to oviposit more or less as soon as they emerge. According to Jones (1986), the most eggs are laid within the first six days after emergence. Consequently, the generation time of the parasitoid (from adult to adult) can be assumed to be equal to the developmental time (from egg to adult). Under the current conditions, this varied from 42 to 56 days.

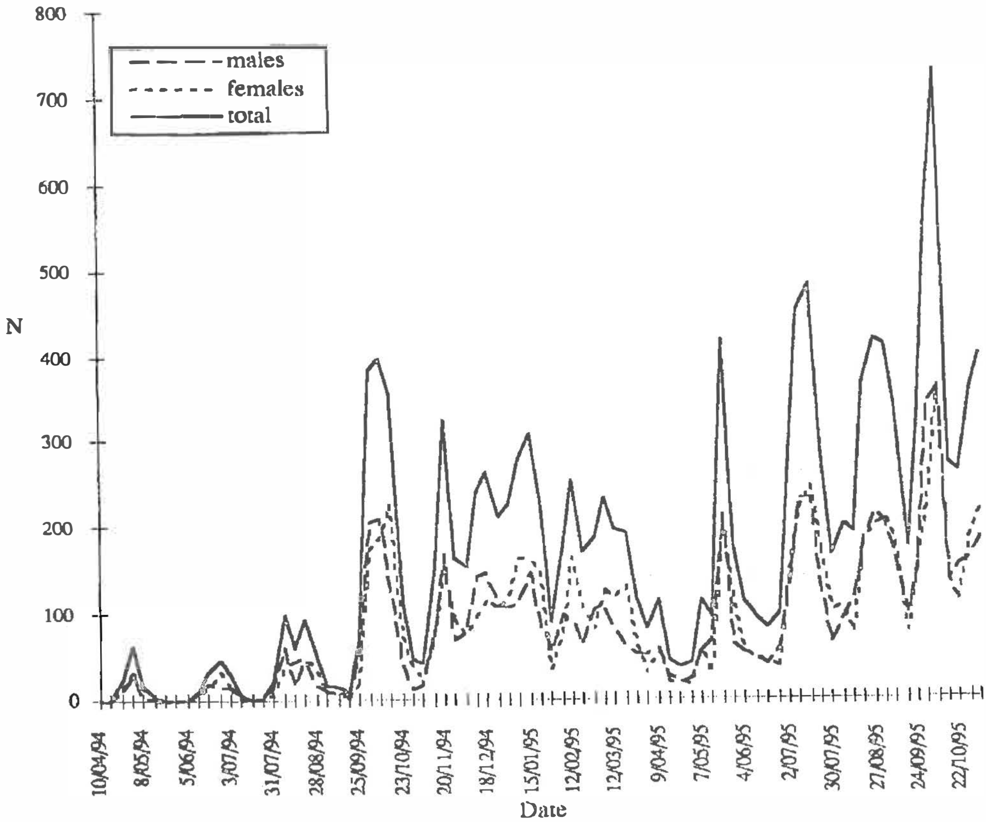

Fig. 1: Fluctuations in the weekly emergences of *T. rapae* reared on *D. radicum* in the laboratory since 1994.

Fig. 2 shows the frequency distribution of the developmental times of *T. rapae* when the eggs were laid in the 1st, 2nd or 3rd instar larvae of the host fly. Female *T. rapae* were able to lay and produce offspring in each of the three larval instars. This has been reported previously by James (1928), Jones (1986) and Tamer (1994). The developmental times of *T. rapae* varied (P=0.05) with the host instar, and lasted 62±3, 55±2 and 50±1 days when the parasitoid laid its eggs in the 1st, 2nd and 3rd instar larvae of the fly host respectively. These results agree with the data from rearing, in which the time for development varied between 42 and 56 days. Hence, in the rearing system, oviposition must occur in all three instars of the fly host. Furthermore, the sooner the oviposition took place in host larvae, the longer the total time required for the parasitoids to develop. This phenomenon is well known in other parasitoid species (Kraaijeveld & Van Alphen, 1986; Löhr *et al.*, 1989).

The current method can provide sufficient parasitoids for biological studies but would not be an economical method for mass rearing the parasitoid. Further experiments will be carried out to develop a shorter procedure. We also need to verify whether parasitism of 3rd instar larvae of the host occurs commonly under field conditions.

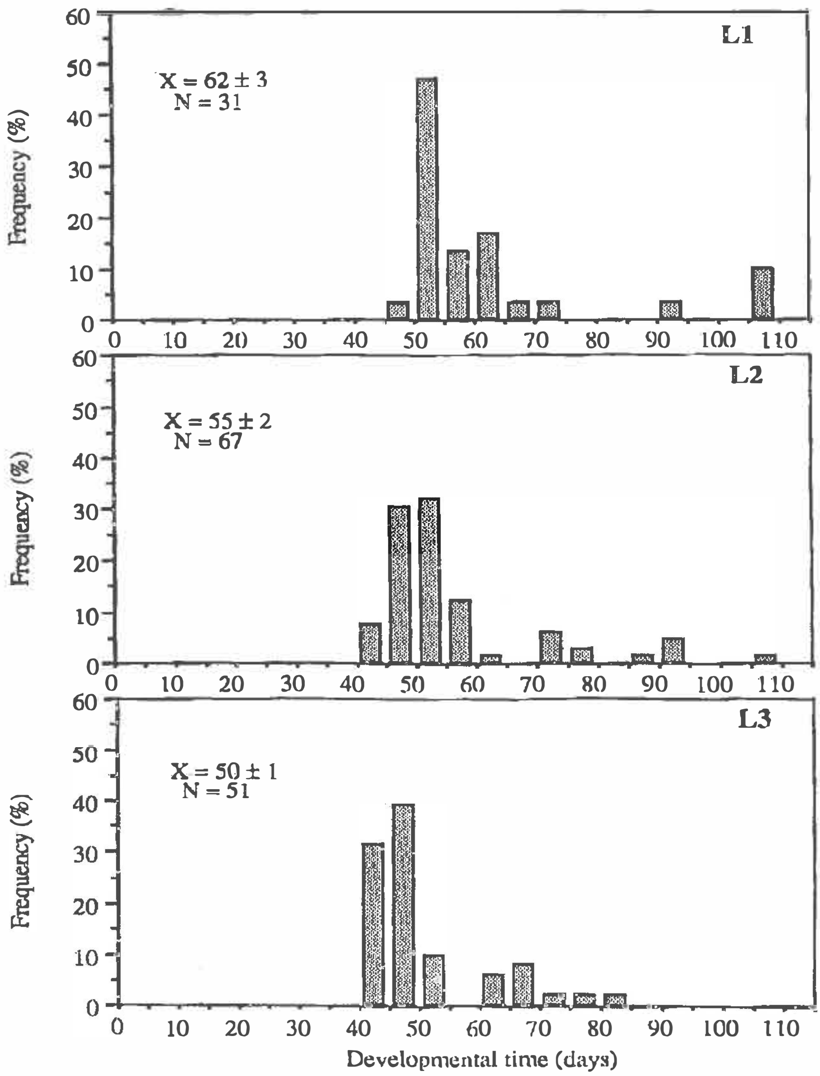

Fig. 2: Frequency distribution of the developmental time of *T. rapae* in each of the three instars of the host *D. radicum* : 1st (L1), 2nd (L2) or 3rd (L3) instar larvae. (X=Mean±s.e.m.)

Résumé

Une méthode d'élevage de *Trybliographa rapae* W. sur *Delia radicum*

En Bretagne (France), *Trybliographa rapae* W. (Hymenoptera : Eucoilidae) est le principal hyménoptère parasitoïde de la mouche du chou *Delia radicum* L. (Diptera : Anthomyiidae). Les parasitoïdes proviennent de pupes de *D. radicum* collectées en février 1994 dans des parcelles de rutabagas infestés à Le Rheu. Cet article décrit une méthode d'élevage de *T. rapae* sur *D. radicum* multiplié sur navet (*Brassica rapa* L.) en laboratoire. Le nombre de *Trybliographa* a augmenté pendant les 20 premiers mois de ce projet et a atteint 700 adultes par semaine en octobre 1995. Des essais en laboratoire furent poursuivis pour déterminer le temps nécessaire au développement de *T. rapae* de l'oeuf à l'adulte. La durée de développement était plus courte lorsque les oeufs du parasitoïde furent pondus dans le troisième stade larvaire (50 ±1 jours) que dans le deuxième stade (55±2 jours) ou dans le premier stade larvaire (62±3 jours) de l'hôte *D. radicum.*

Acknowledgements

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Brassica Lepidoptera and their parasitoids in Brittany

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Summary

Larvae of pest Lepidoptera were collected from brassica crops and reared under laboratory conditions, both to ensure accurate identification and to estimate the rate of parasitism.

The rate of parasitism varied from zero for *Phlogophora meticulosa* to 60 or 90% for the diamond-back moth *Plutella xylostella*. This high level of parasitization was due a to hymenopterous member of the Ichneumonidae, identified by Aubert as *Diadegma semiclausa* (Hellén). This parasitoid is common in many parts of the world but has not been recorded previously from Brittany. The parasitoid is effective in controlling natural populations of *Plutella xylostella*. Consequently, it is worth considering as a commercial biological control agent, particularly as *P. xylostella* frequently develops resistance to chemical and biological products.

Introduction

In Brittany, cauliflowers, *Brassica oleracea*, var. *botytris,* are cultivated widely along the Channel coast and white cabbages, *B. oleracea* var. *capitata* and var. *bullata,* in all urban areas. Two other fodder plants, *B. oleracea* var. *acephala* and *B. napus* var. *oleifera*, are also very common in the rural areas of Brittany. These cultivated and self-seeded cruciferous plants produce a large biomass, and hence support very diversified trophic chains which include many arthropods.

We reared larvae and pupae of pest Lepidoptera collected from these plants. Of the parasitoids that emerged, it appears that one species might be useful in crop protection.

Brassica Lepidoptera and their parasitoids

Field observations in northern Brittany showed that there were two main groups of pest Lepidoptera. One group occurred during the autumn and winter months and included *Phlogophora meticulosa* (L), *Xestia c-nigrum* (L.), *Autographa gamma* (L.) and *Noctua pronuba* (L.). The other group was common in cultivated Brassica crops during the spring and summer months and included *Mamestra brassicae* (L.), *M. oleracea* (L.), *Evergestis forficalis* (L.), *Pieris brassicae* (L.), *P. rapae* (L.) and *Plutella xylostella* (L.), (ex. *maculipennis*). Larvae of *Autographa gamma* were present throughout the year.

The aim of this work was to study the biology of the pest Lepidoptera found in brassica crops to determine whether there were any naturally-occurring parasitoids that might be of use as biological control agents.

Methods

Young brassica plants were sampled from three localities in Brittany : Saint Pol de Léon (Finistère); Pleumeur Gautier (Côtes d'Armor); and Rennes (Ille et Vilaine). At each site, 40 plants were sampled at random twenty rows of plants. These plants were then dissected carefully to ensure that all larvae were collected. These larvae were reared individually on host plant foliage until an adult lepidopteran, or a parasitoid, emerged.

Results

***Evergestis forficalis* L. (garden pebble moth)**

The rate of parasitism of this species never exceeded 4% and was due to two Icheumonidae and one Braconidae, all of which still have to be identified.

***Plutella xylostella* L. (diamond back moth)**

At all locations, the rate of parasitism of this pest was high, and varied from 60 to 90%. Only two specimens of a braconid parasitoid, genus *Apanteles,* were collected during the entire season. The main parasitoid was an ichneumonid, identified by J.F. Aubert as *Diadegma* (=*Angita*) *semiclausa* (Hellén).

This insect is a member of the Campoplegini, subfamily Porizontinae. *Diadegma* is a parasitoid of *Prays olae*, but also occurs throughout Europe in many other insect hosts.

***Pieris brassicae* (cabbage white butterfly)**

At the end of summer, most larvae were killed by *Apanteles glomeratus* (Hymenoptera, Braconidae).

Noctuids

No parasitoids were found in the noctuids, even though samples were collected from a large infestation of *Phlogophora meticulosa.* The only biological mortality we found in the noctuids was caused by the entomopathogenic fungi : *Nomurea rilegi* and *Paelomyces formosa roseus*.

Discussion

Among pest Lepidoptera of brassica crops in west France, only the large cabbage white butterfly and the diamond-back moth are subjected to high levels of parasitism.

At present, the large cabbage white butterfly populations are low even towards the end of the summer when there is a great abundance of suitable brassica foliage. Therefore, crop damage is low and consequently this parasitoid is not of a great interest, despite being present in high numbers.

The situation with the diamond-back moth is different for two reasons:

1) Food consumption by parasitized larvae is lower than that of healthy larvae and so the parasitized larvae cause less crop damage.

2) At the end of its life-cycle, *Diadegma semiclausa* kills the *Plutella xylostella* larva in which it has developed. The high percentage of parasitized larvae (from 60 to 90%) means that this parasitoid reduces the diamond-back moth population prior to winter.

Many published data indicate that different species of *Diadegma* (syn. *Horogenes=Hymenobosmina=Angitia*) attack larvae of *Plutella xylostella.* Hardy (1938) named 40 Ichneumonidae of which 10 were species were from the genus *Diadegma.* Some of these species are reported regularly, particularly *D.* (=*Horogenes*) *fenestralis* and *D. plutella* in North America (Harcourt, 1960), and *D. fenestralis* in both India (Abraham & Padmanaban, 1968) and Poland (Lagowska, 1981).

D. insularis is a highly effective parasitoid of *P. xylostella* in North America (Harcourt, 1960; Putman, 1978; Goodwin, 1979; Nguyen & Workman, 1979 and Riever *et al.*, 1992).

Diadegma semiclausa and other *Diadegma* species have been recorded also in England (Hamilton, 1979).

However a study devoted to *Plutella xylostella* and its parasitoids did not identify the species of *Diadegma* found in New Caledonia (Delobel, 1978). Hortsman (1969 & 1980) worked on this parasitoid and Clausen (1978) reported that *Diadegma* has been introduced as a parasitoid in a biological control programme aimed at controlling *P. xylostella.* In France, Aubert (1960 a, b; 1961; 1962 & 1966) found this Ichneumonidae along the Mediterranean coast, and confirmed its identity in 1983 from a monograph published on Ichneumonidae found in Israel.

In Brittany *P. xylostella* is now an established pest of cultivated brassica crop. In India, Malaysia and other tropical countries, this pest Lepidopteran has become resistant to many synthetic insecticides. Consequently biologically products based on *Bacillus thuringiensis* were introduced but the pest has now developed resistance to them. In contrast, biological control following the release of parasitoids belonging to the genus *Diadegma* was successful in Australia (Wilson, 1960).

Conclusion

The parasitoid *Diadegma semiclausa* had not been recorded previously from Brittany. The present results indicated that this member of the Ichneumonidae was widespread and the commonest natural enemy of *Plutella xylostella.* The high levels of parasitism recorded indicated that *D. semiclausa* is worthy of further study as a biological control agent for use under field conditions.

Résumé

Les Lépidoptères des cultures de crucifères et leurs parasitoïdes en Bretagne

Les chenilles défoliatrices de Lépidoptères ont été récoltées dans les cultures de crucifères et élevées en conditions de laboratoire afin d'assurer à la fois une identification précise et d'estimer le taux de parasitisme.

Le taux de parasitisme variait de 0 % pour *Phlogophora meticulosa* à 60 ou 90 % pour la teigne des crucifères *Plutella xylostella.* Ce haut niveau de parasitisme était dû à un Hyménoptère de la famille des Ichneumonidae, identifié par Aubert comme étant *Diadegma semiclausa* (Hellen). Ce parasite est commun dans la plupart des pays du monde mais n'avait pas été signalé précédemment en Bretagne. Ce parasitoïde est efficace pour le contrôle naturel des populations de *P. xylostella.* En conséquence, il peut être considéré comme un agent utilisable commercialement en lutte biologique, particulièrement contre *P. xylostella* qui développe fréquemment une résistance aux produits insecticides et biologiques.

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The effects of different fertilizer regimes on the populations of earthworms and beneficial arthropods found in a wheat field

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Summary

In 1995, the fauna was studied in a wheat field in which replicated plots had been subjected to various fertilizer treatments. These included plots that were not fertilized (N), fertilized with materials inorganic (I_3), fertilized with compost (C_3) and combinations of inorganic and compost fertilizers (I_1C_2, I_1C_3). Earthworms were hand-sorted from 0.25 m^2 soil samples. Carabid beetles, carabid larvae and spiders (mainly linyphiids) were sampled by pitfall-traps set up within ground photoeclectors.

A total of 958 earthworms were collected. Both in May and in September, highest earthworm densities as well as biomass occurred in the plots fertilized with compost (C_3) followed by combined fertilization. Lowest values were found in the plots (I_3) treated with inorganic fertilizers and the plots (N) that were not fertilized. The differences were significant ($P<0.05$) in September, mainly due to the numbers of juveniles present.

No clear differences were detectable for linyphiids, carabid beetles or carabid larvae, probably because the numbers of samples collected was not sufficiently great.

Introduction

The significance of earthworms in breaking down organic matter and incorporating it into the soil, thereby improving soil structure, aeration and drainage, is well established (Edwards & Bohlen, 1996). Epigeic predatory arthropods, in particular carabids and spiders, are considered to be important predators of pests of field crops (Luff, 1989; Riechert & Lockley, 1984).

Although the effects of different fertilizers on earthworm populations have been described in several studies (see Edwards & Bohlen, 1996, pp. 276-278), no investigations have been done to date concerning how they are affected by composts applied to agricultural soils. In general, little information is available on the impact of fertilizers on carabids and spiders.

The L. Boltzmann-Institute has been doing field plot trials concerning the effects of different fertilizer regimes since 1992. In 1995, it was decided to start sampling earthworm, carabid and spider populations, to study the effects of the fertilizers on the beneficial fauna. The preliminary results of this work are presented in this paper.

Materials and Methods

The research site is situated on an organic farm at the riverside nature reserve Obere Lobau, Vienna (48°10'N and 16°30'E; 152 m above sea level; 9.6°C, 510 mm; greyish alluvial soil, sandy to loamy silt). The trials were done in field plots set up in 1992 to study the effects of 12 different fertilizer treatments. The trial consisted of a latin square randomized block design, involving 10 x 6.5 m plots, each treatment being replicated six times. The fauna was sampled from plots subjected to the following treatments. All amounts of fertilizer/compost are shown as the rates applied per hectare.

N: non-fertilized control
I_3: Inorganic fertilizer (120 kg nitrogen, 40 kg phosphate)
C_3: Compost (60 t compost, produced from organic components of household garbage)
I_1C_2: Combined inorganic fertilizer and compost (60 kg nitrogen, 45 t compost)
I_1C_3: Combined inorganic fertilizer and compost (60 kg nitrogen, 60 t compost) sampled only for earthworms

Inorganic nitrogen was applied as a split dose on 30 March and 10 May 1995. The compost was applied in early September 1994, and the phosphate in late September.

The crop grown in 1994/95 was winter wheat, which followed earlier crops of winter rye (1992/93) and potatoes (1994). The field was ploughed and the seed beds prepared in early autumn 1994. In 1995, the plots were not weeded and wettable sulphur was not applied to control mildew.

Earthworms were sampled in 1995 by hand-sorting 0.5 x 0.5 m units of soil taken down to a depth of 40 cm in 22-24 May, and 25-27 September. One soil sample was taken per plot, that's a total of 30 samples per date. The biomass of the earthworms was calculated by weighing the specimens and using a correction factor derived from Cuendet (1985), to compensate for the weight losses that result from preservation in 4% formaldeyde.

Carabids and spiders were sampled by ground photoeclectors. Each photoeclector consisted of a 0.25 m^2 square metallic frame with a removable, tent-like upper part covered by green raincoat material. To catch the epigeic arthropods, two pitfall traps were placed in opposite corners of each frame. The pitfalls contained 2% formaldehyde that was used to preserve the trapped arthropods. For sampling the flying or climbing insects, a trap that contained 1% formaldehyde and had a transparent lid was fixed to the top of the photoeclector. Once set up, the ground photoeclectors (1 per plot) were left at the same positions throughout the entire sampling period from 23 May to 18 July 1995 (4 trap emptyings, total no. of samples 96). Only the catches from the pitfall trap in the ground are considered in this manuscript. In these samples, the carabid beetles were identified to the species level, the numbers of larvae were expressed as the overall totals, and the spiders were separated into linyphiids and the rest.

The data were subjected to analysis of variance after having satisfied a test for homogeneity of variances. Differences between treatments were identified using Fisher's LSD-Test. For some unknown reason, the 5th and 6th block of replicates contained very few earthworms. Therefore, only the data from the first four blocks were included in the analysis.

Results and Discussion

Earthworms

A total of 958 earthworms were collected. In the samples taken in May, they consisted of 79 adults and 249 juveniles whereas in September 163 adults and 467 juveniles were recovered. The predominant species were *Allolobophora rosea* and *A. caliginosa.*

In both May and September, most earthworms were found in plots C_3, those treated solely with compost, closely followed by plots I_1C_3 and I_1C_2 in which low amounts of inorganic nitrogen had been added to the compost. Fewest earthworms were found in plots I_3 treated with inorganic fertilizer and in the unfertilized plots. These differences were significant (P<0.023) in September (Fig. 1a), due mainly to the juveniles present at this time of year.

The highest biomass of worms was found in plots C_3 (18.3 g/0.25m^2 in September), and the lowest in control plots (6.2 g), followed closely by plots I_3 (8.0 g, Fig. 1b). When the juvenile biomass was analyzed separately, the value from plots C_3 in September was higher P<0.05 than in all other treatments.

Although the variance in earthworm populations was extremely high, probably due to the patchy spatial distribution, the numbers sampled in May and September were closely correlated (P<0.001) indicating that the populations in the various plots persisted over time. The increased ratios of total population from May to September were higher (P<0.05 in all compost treated plots than in the control and the plots treated with inorganic fertilizer.

These results are considered to indicate that the worms are provided with better conditions for reproduction when compost is applied. For *Allolobophora* species, living soil microorganisms are known to be an important source of nutrition (Atlavinyte & Pociene, 1973). In the present trial, they were likely to have been enhanced considerably by the application of compost.

The enhancement of earthworm populations by all kinds of organic fertilizers (except liquid manures) is well-established (see Edwards & Bohlen, 1996, p.276). However, conflicting results have been published concerning the effects of inorganic fertilizers. Edwards & Lofty (1982) showed there was a strong positive correlation between the amounts of inorganic N applied and the size of the earthworm population, which resulted probably from greater amounts of crop residue being returned to the soil (Edwards & Bohlen, 1996, p. 276). Zajonc (1970) and Brinton (1979; cited in Doran & Werner, 1990, p. 213), however, found that earthworm populations decreased with increasing amounts of nitrogen, possibly due to unfavourable changes in the micro habitat caused by the dissolving fertilizer granules (Doran & Werner, 1990, p. 212). Similar decreases, associated with N-fertilizers, were reported for enchytraeid populations (Lagerloef *et al.*, 1989). Our results seem to support the view that the application of pure inorganic nitrogen has an adverse effect on earthworm populations.

The total numbers of carabid beetles, carabid larvae and linyphiid spiders caught under the photoeclectors are shown in Table 1.

A total of 352 adult beetles were caught. *Bembidion lampros* was the most abundant species (33%), followed by *Amara familiaris* (24%), *Syntomus obscuroguttatus* (9%), *Platynus dorsalis* (7%), *Zabrus tenebrioides* (5%) and *Poecilus cupreus* (5%). No differences (P = 0.05) could be found concerning the effects of the fertilizer treatments on beetle numbers, as few beetles were trapped and a correspondingly high variance within the data (Table 1).

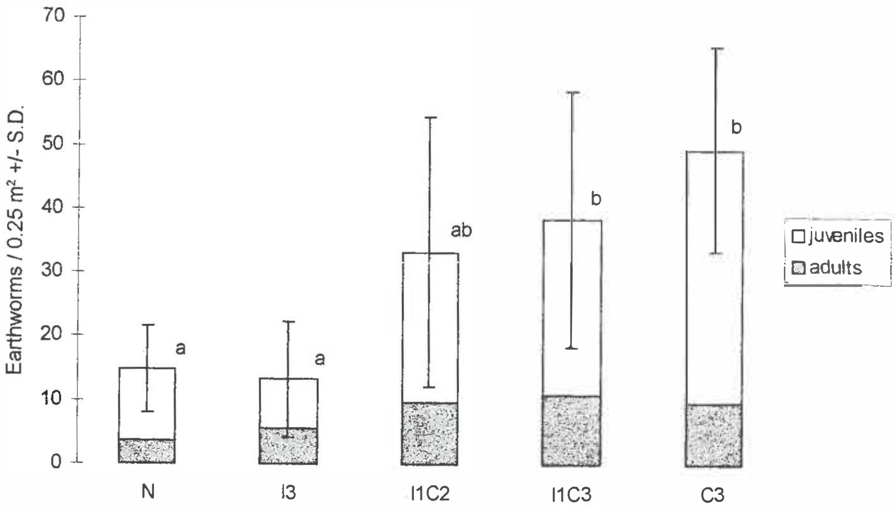

Fig. 1a: Mean numbers of earthworms hand-sorted from the 0.5 x 0.5 x 0.4 deep soil samples collected in September 1995 from plots of wheat subjected to five different fertilizer regimes at Obere Lobau/Vienna. Treatment: N = no fertilizer; I_3 = inorganic fertilizer; C_3 = compost; I_1C_2 = combined inorganic fertilizer + compost; I_1C_3 = combined inorganic fertilizer + greater amounts of compost. Means with the same letter do not differ significantly (P<0.023).

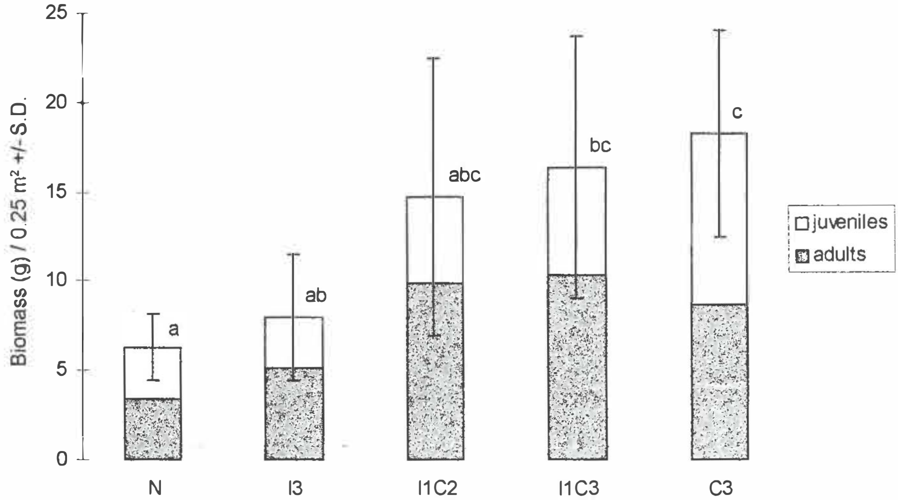

Fig. 1b: Mean earthworm biomass (g freshweight). Treatment: N = no fertilizer; I_3 = inorganic fertilizer; C_3 = compost; I_1C_2 = combined inorganic fertilizer + compost: I_1C_3 = combined inorganic fertilizer + greater amounts of compost. Means with the same letter do not differ significantly (P<0.035).

Carabids and Spiders

Table 1. Mean totals and standard deviations of the numbers of carabid beetles, carabid larvae and adult linyphiid caught 0.25 m^2 under photoeclectors placed onto wheat plots that had been subjected to four different fertilizer treatments at Obere Lobau/Vienna. Treatment: N = no fertilizer; I_3 = inorganic fertilizer; C_3 = compost; I_1C_2 = combined inorganic fertilizer + compost.

Fertilizer treatment	Carabid beetles		Carabid larvae		Linyphiid spiders	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
N	12	15	14	5	24	6
I_3	20	23	12	4	28	6
I_1C_2	11	7	15	6	25	14
C_3	17	12	18	7	23	6

A total of 357 carabid larvae were caught in the pitfall traps inside the ground photoeclectors. The data from the different plots are shown as histograms in Fig. 2. Although fewest larvae appeared to be found in the plots treated with inorganic fertilizer (I_3) the variance in the data was too great for any meaningful analysis to be done.

A total of 601 adult linyphiid spiders were caught together with just 12 specimens from other taxa. No effects could be detected of the different fertilizer treatments on spider numbers (Table 1).

In the few data published on the effects of fertilizer on epigeic arthropods, the numbers of certain carabid species (e.g. *Bembidion lampros*) are reportedly enhanced following the application of farmyard manure (Purvis & Curry, 1984; Hance & Grégoire-Wibo, 1987). Spiders, however, seemed not to be affected by manuring (Pietrasko & De Clercq, 1982). The spider communities found in meadows changed from consisting primarily of the larger-sized, mobile lycosid species towards the small, sedentary linyphiid species (Kajak, 1981), but only after high doses of mineral fertilizer had been applied for several years.

Due to their low capacity for dispersing, carabid larvae are unlikely to be able to move away from adverse conditions in cultivated fields. Therefore, like the earthworm situation, the differences found in carabid larval densities are considered to indicate the effects of the fertilizers on the reproductive conditions for the carabid beetles. Compost possibly enables better recruitment rates of certain carabid species.

We will continue to sample the earthworms and arthropods in the fertilizer plot trial in the hope of finding ways to augment the naturally-occurring beneficials by optimizing the cultivation techniques used in organic agriculture.

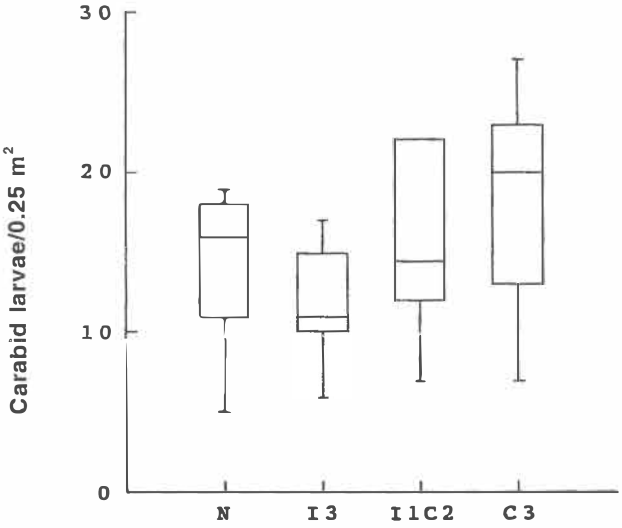

Fig. 2: Total numbers of carabid larvae caught/0.25 m² under photoeclectors placed onto wheat plots that have been subjected to four different fertilizer treatments. Treatment: N = no fertilizer; I_3 = inorganic fertilizer; C_3 = compost; I_1C_2 = combined inorganic fertilizer + compost.

Résumé

Les effets de différents régimes de fertilisation sur les populations de vers de terre et des arthropodes utiles dans un champ de blé

En 1995, la faune a été étudiée dans un champ de blé dans lequel les parcelles élémentaires ont subi différents traitements de fertilisation. Ces parcelles comprenaient une parcelle non fertilisée (N), une fertilisation avec de la matière non organique (I_3), une parcelle avec du compost (C_3) et une avec un mélange de matière non organique et un compost avec fertilisation (I_1C_2, I_1C_3). Les vers de terre ont été extraits à la main dans un échantillon de sol de 0,25 m². Les coléoptères carabidae, les larves de carabes et les araignées (principalement des Linyphiidae) furent échantillonnés avec un piège Barber placés à l'intérieur un photoeclectique de sol.

Un total de 958 vers de terre ont été récoltés. En mai et en septembre, les densités ainsi que la biomasse des vers de terre sont les plus élevées dans les lots ayant reçu du compost (C_3) suivi par les parcelles avec le mélange (I_1C_2, I_1C_3). Les valeurs les plus basses se trouvent dans les lots I_3 avec de la matière inorganique et le témoin sans fertilisation (N). Les différences sont significatives (P<0.05) en septembre, ce qui est du principalement aux nombres de juvéniles présents.

Il n'y a pas de différence claire détectable pour les linyphiides, les carabes ou les larves de carabes, probablement parce que le nombre d'échantillons collectés n'était pas suffisamment important.

Acknowledgements

This investigation was supported by the MA 48 (Department of Refuse Disposal of the City of Vienna). We thank all students and relatives who helped to hand-sort the earthworms.

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Reducing populations of the large white butterfly by applying the foliar fertilizer Ekolist to brassica plants infested with caterpillars

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Summary

Field experiments were carried out at the Research Institute of Vegetable Crops in Skierniewice to control the large white butterfly *Pieris brassicae* by applying the foliar fertilizer Ekolist. The experiments were done in a randomized block design, each treatment being replicated four times.

The Ekolist was applied at the rates of 6 and 12 l/ha. Karate 025, applied at the rate of 0.24 l/ha was used as the 'standard' chemical treatment. Sprays were applied from a knapsack sprayer at the rate of about 600 litres per hectare. To determine the efficiency of Ekolist, the numbers of living caterpillars were recorded on 5 plants on each plot before, and at different times after, the various treatments were applied. The Ekolist killed about 50% of the caterpillars of the large white butterfly. Hence, this foliar fertilizer may be of use in integrated control systems. For home gardens, where the use of synthetic pesticides has to be reduced as much as possible, the use of this fertilizer is especially promising. Ekolist could also be useful in certain commercial systems of vegetable growing.

On the basis of these experiments, Ekolist may allow a reduction in the frequency of pesticide application which could reduce the development of strains resistant to insecticides and cause less contamination of the environment.

Introduction

The large white butterfly, which completes two generations each year in Poland, is the most important pest of late cabbage crops. The second generation is the more harmful, as its caterpillars destroy cabbage as they become ready to harvest towards the end of July and the beginning of August. At present, caterpillars of the large white butterfly are killed by applying pyrethroid, organophosphorus or carbamate insecticides.

Experiments on the performance of foliar fertilizers for controlling certain pests of vegetable crops have been carried out by the following authors: Cook *et al.*, 1995; Narkiewicz-Jodko *et al.*, 1988, 1989, 1993; Oliberius & Veverka, 1985; Veverka & Oliberius, 1985 and Zilka, 1982.

Materials and Methods

Field experiments were done to control caterpillars of the large white butterfly by applying the fertilizer Ekolist. The experiments were done at the Research Institute of Vegetable Crops in Skierniewice in a sandy loamy soil that contained 1-3% organic matter. The chemical composition of Ekolist is shown in Table 1. It also contained some non-harmful additives.

Table 1. Chemical composition of Ekolist (g/l).

N	P	K	Ca	Mg	S	B	Zn	Cu	Mn	Mo	Fe	pH
80	trace	48	5	10	10	5	0.01	5	0.1	0.02	0.2	5-6

Ekolist was used at the rates of 6 and 12 litres per ha. Each treatment was replicated four times. The sprays were applied from a knapsack sprayer at a volume equivalent to 600 litres of liquid per hectare.

To determine the effectiveness of Ekolist in controlling caterpillars of the large white butterfly, the number of living caterpillars were counted on 5 plants before and at different times after spraying each treated experimental plot.

Results

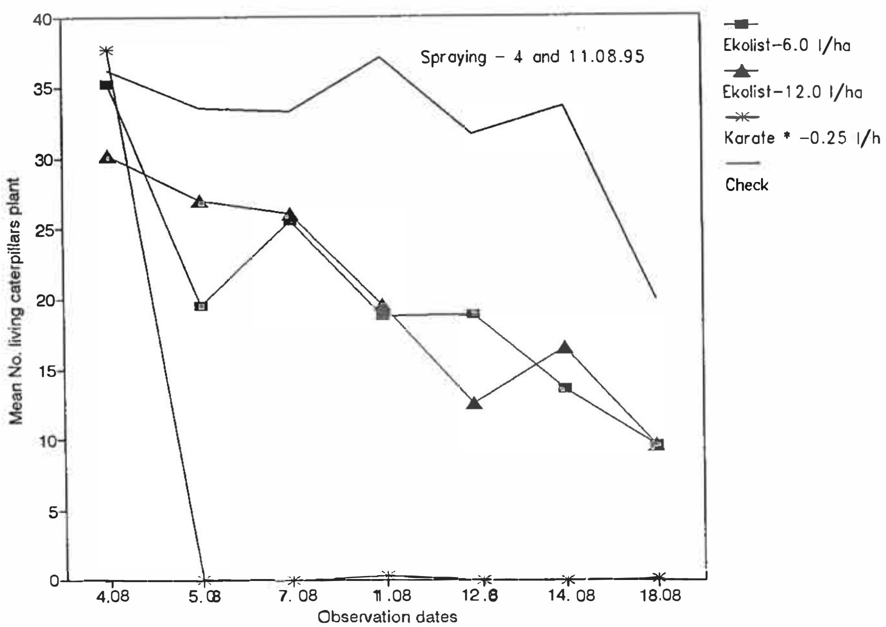

Fig. 1: The relative efficiency of sprays of Ekolist in killing caterpillars of the large white butterfly feeding on cabbage cv. Kamienna glowa [Skierniewice, 1995].

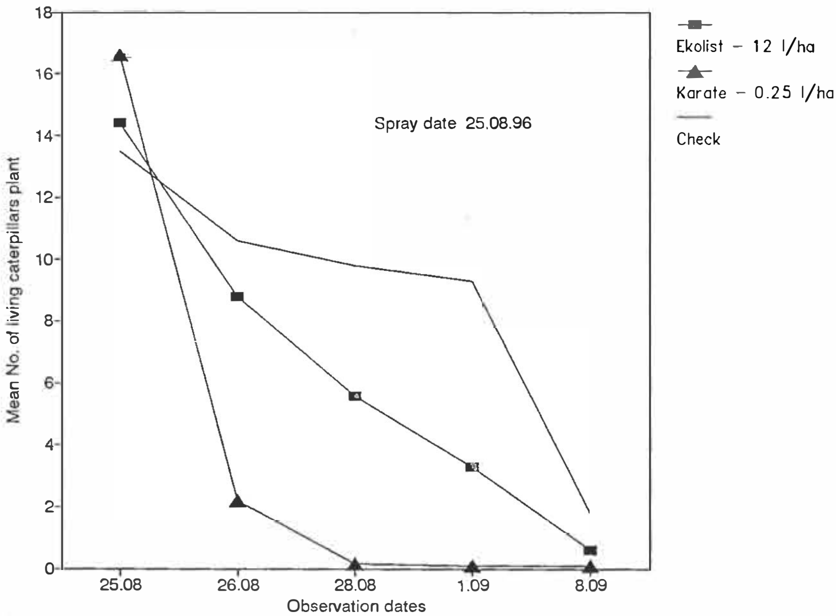

Fig. 2: The relative efficiency of sprays of Ekolist in killing caterpillars of the large white butterfly feeding on cabbage cv. Kamienna glowa [Skierniewice, 1995].

The results are shown in Figs. 1 and 2. Ekolist applied at both 6 and 12 litres per ha showed promise for reducing populations of the large white butterfly. One or two treatments were sufficiently effective to kill about half of the caterpillars (Fig. 1).

The second experiment (Fig. 2) gave similar results to the first.

Discussion

The above experiments show that when Ekolist was sprayed onto infested cabbage plants it killed about half of the caterpillars of the large white butterfly present on the plants. Ekolist could be of use in systems of integrated pest control in brassica crops. Adding a wetting agent such as Sandovit or Citowett improves the efficiency of Ekolist., (Narkiewicz-Jodko *et al.*, 1988, 1989, 1990, 1994). It should be emphasised, that Ekolist cannot be used as a substitute for synthetic insecticides. However, this fertilizer can be used to lower the total number of insecticide application and hence may help both to slow down the development of pest strains resistant to insecticides and to protect the environment.

Résumé

Réduction des populations de Piéride du chou par application foliaire d'un fertilisant Ekolist sur des plants de choux infestés de chenilles

Des expérimentations en champ ont été conduites à l'Institut de Recherche en culture légumière à Skierniewice pour lutter contre la Piéride du chou (*Pieris brassicae*) par

application foliaire d'un produit fertilisant Ekolist. Les essais ont été faits en blocs randomisés, chaque traitement était répété quatre fois.
Ekolist était appliqué à la dose de 6 et 12 l/ha. Karate 025, appliqué à la dose de 0,24 l/ha servait de traitement insecticide de référence. Les pulvérisations furent appliquées au moyen d'un pulvérisateur à dos à la dose d'environ 600 l/ha. Pour déterminer l'efficacité d'Ekolist, le nombre des chenilles vivantes était noté auparavant sur 5 plantes de chaque parcelle élémentaire, puis à différents moments après que les différents traitements aient été effectués. Ekolist tue environ 50 % des chenilles de piéride du chou. Désormais, ce fertilisant foliaire peut être employé dans les systèmes de lutte intégrée. Pour les jardins familiaux, où l'utilisation des insecticides de synthèse a été réduite autant que possible, l'emploi de ce fertilisant est particulièrement prometteur. Ekolist pourrait aussi être utilisé dans certain système de production légumière destiné au commerce.

Sur la base de ces expériences, Ekolist peut permettre une réduction de la fréquence des applications de pesticide ce qui réduirait le développement de souches résistantes aux insecticides et causerait moins de contamination de l'environnement.

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The use of a non-woven polypropylene fleece and polythene nets for protecting cabbage and carrot crop from attacks by pest Diptera

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Summary

In 1995, plant covers were placed over plots of cabbage plants, cabbage seedbeds, and plots of carrots in attempts to reduce damage by the cabbage root fly, *Delia radicum*, and the carrot fly, *Psila rosae*, respectively. The covers used were either non-woven polypropylene fleece or polythene nets with a mesh of 1x1 mm or 1x1.5 mm.

The nets gave good control on all plots. The non-woven fleece gave good control on both the cabbage and carrot plots but not on the seedbeds, mainly because it was difficult to stop the fleece becoming torn.

Introduction

Early cabbage crops, cabbage plants in seedbeds and carrots are damaged regularly in Poland by larvae of pest flies. At present, insecticides are used to prevent heavy losses in cabbage crops by *Delia radicum* and to carrot plants by *Psila rosae*. In certain instances, insecticides have to be applied frequently. This paper describes the possibility of using polythene nets and non-woven polypropylene covers instead of insecticides for controlling both pests.

Materials and Methods

In 1995, experiments were done at Skierniewice to estimate the efficiency of plant covers consisting of non-woven materials and nets in preventing damage by cabbage root fly *Delia radicum* L. on cabbage plants and carrot rust fly *Psila rosae* F. on carrot plants.

Trial 1 - Early cabbage cv. Ditmarska

The following treatments were used:

1. Plants covered with a non-woven polypropylene fleece until 7 days before harvest.
2. Plants covered with polythene net (1x1 mm mesh) until 7 days before harvest.
3. Plants covered with polythene net (1x1.5 mm mesh) until 7 days before harvest.
4. Drench of 0.025 a.i. solution of chlorfenvinphos (50 cc/plant).
5. Drench of 0.015 a.i. solution of teflobenzuron (50 cc/plant).
6. Untreated plants.

The cabbages were transplanted on 10 April 1995 and covered later the same day.

The insecticide treatments were applied on 13 April 1995. To determine the efficiency of the various treatments, all of the plants from each plot were examined carefully. Plants damaged by the cabbage root fly were recorded.

Trial 2 - Cabbage cv. Kamienna glowa, seedbed

The following treatments were used:

1. Seed dressed with carbosulfan at the rate of 12.5 g/kg of a.i. and the plants then covered with non-woven polypropylene fleece until harvest.
2. Seed untreated and the plants then covered with non-woven polypropylene fleece until harvest.
3. Seed untreated and the plants then covered with polythene net (1x1 mm mesh) until harvest.
4. Seeds untreated and the plants then covered with polythene net (1x1.5 mm mesh) until harvest.
5. Seed dressed with carbosulfan at the rate of 12.5 g/kg of a.i.
6. Seed untreated.

Each plot measured 2.0 m x 3.0 m and the six treatments were each replicated four times in a randomised block design. The cabbages were drilled on 18 April 1995 and covered later the same day. To determine the efficiency of the various treatments, all of the plants from each plot were examined carefully. Plants damaged by the cabbage root fly were recorded.

Trial 3 - Carrot cv. Perfekcja

The following treatments were used:

1. Seed not dressed, but plants covered subsequently with non-woven polypropylene fleece.
2. Seed not dressed, but plants covered subsequently with 1x1 mm mesh polythene net.
3. Seed not dressed, plants covered subsequently with 1x1.5 mm mesh polythene net.
4. Seed dressed with teflobenzuron at the rate of 70 ml/kg seeds.
5. Untreated plants.

Each plot measured 2.4 m x 3.0 m and the five treatments were each replicated four times in a replicated plot design. All plots were drilled on 25 April 1995 and the covers were added on 18 April 1995. To determine the efficiency of the various treatments, 200 roots were sampled at random from each plot. The numbers of roots damaged by *Psila rosae* larvae were recorded.

Results

Both types of net (1x1 mm and 1x1.5 mm mesh) gave 100% control of *D. radicum* on the early cabbage plants. The non-woven polypropylene fleece was as effective as the nets. Although the insecticides applied were not as effective as the covers, chlorfenvinphos was more effective than teflobenzuron (Table 1).

In the cabbage seedbed, although the nets of both mesh gave satisfactory control of the cabbage root fly, about five percent of the plants were damaged. However, the non-woven polypropylene fleece was ineffective. The carbosulfan seed dressing was also not effective (Table 2).

Table 1. Effect of crop covers and insecticides in protecting early cabbage from damage by *Delia radicum* L.

Treatment	Mean % of damaged plants	Yield kg/plot
Non-woven polypropylene fleece	1 a	69
Polythene net (1x1.5 mm mesh)	0 a	70
Chlorfenvinphos drench	6 a	70
Teflobenzuron drench	14 c	70
Control - plants not covered	20 d**	54

Means followed by the same letter are not significantly different (P=0.05); ** dead plants.

Table 2. Effect of crop covers and insecticides in protecting cabbage plants in the seedbed from damage by *Delia radicum* L.

Treatment	Damaged
Non-woven polypropylene fleece + seeds dressed with carbosulfan	29 b
Non-woven polypropylene fleece + seeds not dressed	44 c
Plants covered with polythene (1x1 mm mesh) + seeds not dressed	4 a
Plants covered with polythene (1x1.5 mm mesh) + seeds not dressed	6 a
Seeds dressed carbosulfan (50 g/kg)	47 c
Control - seeds not dressed	62 c

Means followed by the same letter are not significantly different (P=0.05).

Table 3. Effect of crop covers and insecticides in protecting carrot plants from damage by larvae of *Psila rosae* F.

Treatment	Mean % of injured plants	Yield kg/plot
Non-woven polypropylene fleece	10 b	72
Polythene (1x1 mm mesh)	7 a	74
Polythene (1x1.5 mm mesh)	6 a	75
Teflobenzuron (70 ml/kg seeds)	11 b	70
Control - plants not covered	25 c	53

Means followed by the same letter are not significantly different (P=0.05).

Plants covered with both type of nets prevented all but about 6-7% of the plants being damaged by *Psila rosae*. Covers of the non-woven polypropylene fleece and seeds dressed with teflobenzuron (70g/kg) ensured that about 90% of the carrot roots remained undamaged (Table 3).

Discussion

Covering cabbage and carrot crops with fleece or nets is a reasonable alternative to insecticides for preventing crop damage by the cabbage root fly and the carrot fly. This confirms the work of Haseli & Konrad (1987), and Ester *et al.* (1994). The disadvantage of most covers is that they are much more expensive than insecticides. Hence, they should be recommended only for growers who wish to adopt systems of integrated production. Antill *et al.* (1990) observed a slight reduction in yield when carrots were grown under covers, but this did not occur in the current experiments.

The non-woven polypropylene fleece, can also prevent damage. However, because this material is very delicate, it can be torn easily and hence sometimes fails to provide adequate protection.

Résumé

Emploi d'un intissé en polypropylène et de filet en plythène pour protéger les parcelles de choux et de carottes des attaques de Diptères

En 1995, la couverture des plantes a été assurée sur des parcelles de choux, des pépinières de choux, et des parcelles de carottes en vue de réduire respectivement les dégâts

de la mouche du chou *Delia radicum* et de la mouche de la carotte *Psila rosae*. La couverture des plantes était assurée par un intissé en polypropylène et un filet de polythène ayant une maille de 1x1 mm ou de 1x1,5 mm.

Les filets assurent une bonne protection dans toutes les parcelles. L'intissé assure une protection sur les choux et sur les carottes mais pas sur les pépinières de choux, principalement car il était difficile d'éviter que l'intissé ne se déchire.

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Controlling cabbage root fly (*Delia radicum*) on outdoor radish in the UK

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Summary

Two soil applied insecticides, two film-coated seed treatments, and two sprayed treatments were evaluated for their efficacy in controlling cabbage root fly on commercial outdoor radish crops in the UK. Pre-drilling soil treatments of chlorfenvinphos or chlorpyrifos, and tefluthrin seed treatment were generally ineffective at preventing damage in organic soils. The most effective treatment was chlorpyrifos used as a film-coated seed treatment. However, even this did not always provide satisfactory control. Experiments were also done to identify the pattern of cabbage root fly egg-laying and subsequent damage on the radish crop. Egg-laying tended to peak during root bulb development, although the pattern of egg-laying was influenced also by the level of fly activity. The interval between egg-laying and the appearance of damage was usually 7 to 10 days. Post-emergence spray programmes of trichlorphon or λ-cyhalothrin, aimed at controlling adult flies, did not improve the level of control given by soil insecticides or seed treatments.

Introduction

Cabbage root fly (*Delia radicum* (L.)) is the most important pest of radish in the UK. The larvae mine in the root bulbs, often causing a severe loss of product quality. Damage levels can vary considerably on different sowings through the season, but even a relatively low level of attack makes it difficult and expensive to grade out the damaged roots.

The currently available chemical control options for cabbage root fly on radish are limited. Only one insecticide, chlorfenvinphos, currently has full label Approval for cabbage root fly control on radish and is applied as a soil treatment pre-drilling. While this treatment is adequate when pest pressure is low, control during peaks of cabbage root fly activity is often poor. Other insecticides which can be used under Specific Off-Label Approvals (SOLA's) are chlorpyrifos (as Dursban 4) and trichlorphon (as Dipterex). Although commonly used, the efficacy of these treatments has never been tested experimentally and experience suggests that their effectiveness is probably limited.

This paper summarises some of the results from a three year project which investigated new approaches to the control of cabbage root fly on radish. The primary objectives were:

1. To investigate the use of seed treatments as an alternative to the standard chlorfenvinphos pre-drilling treatment.
2. To assess the efficacy of the existing SOLA treatments.
3. To investigate the relationship between the pattern of cabbage root fly egg-laying on the radish crop and the subsequent appearance of damage.

Materials and methods

Ten field experiments were done in the period 1993 to 1995, five on mineral soils and five on organic soils. All experiments were done in or alongside commercial radish crops on farms with a history of cabbage root fly damage. Crop husbandry and non-insecticidal crop protection treatments were as per standard farm practice. The same cultivar (cv. Marabelle) was used in all experiments.

Insecticide efficacy experiments

A range of different insecticide treatments were evaluated (Table 1). Only those used on experiments done in Lancashire in 1994 and 1995 (organic soil sites), where cabbage root fly damage was highest, are reported here. These included all the existing on and off-label treatments, plus film-coated seed treatments. Post-drilling supplementary (i.e. in *addition* to a soil treatment at drilling or a seed treatment) programmes of λ-cyhalothrin or trichlorphon were also evaluated. These were aimed at controlling egg-laying adults during the main risk 'window' between crop emergence and the 'last effective egg-lay date' - the cut-off point at which eggs laid on the crop will not hatch in time to produce damaging larvae before the crop is harvested. There is no point in applying treatments after this date. The first supplementary treatments were made as soon as possible after drilling, and repeated at about 5 day intervals until the calculated last-effective egg-lay date.

Table 1. Insecticide treatments used in experiments in Lancashire in 1994 and 1995 (s. t. = seed treatment; * = rate for single application; Y = treatment used, N = treatment not used).

Treatment	g a.i. ha^{-1}	g a.i. 100,000 $seeds^{-1}$	1994	1995
A. No insecticide	-	-	Y	Y
B. chlorfenvinphos (at drilling)	2352	-	Y	Y
C. chlorpyrifos (at drilling)	960	-	Y	Y
D. chlorpyrifos s. t.	-	9.8	Y	Y
E. tefluthrin s. t.	-	40.0	Y	Y
F. chlorfenvinphos + trichlorphon	2352 + 400*	-	Y	N
G. chlorfenvinphos + λ-cyhalothrin	2352 + 7.5*	-	Y	Y
H. chlorpyrifos s.t. + λ-cyhalothrin	s. t. + 7.5*	9.8	N	Y
I. λ-cyhalothrin only	7.5*	-	N	Y

Pattern of egg-laying and damage development

Alongside each insecticide experiment, a complimentary experiment aimed at identifying the relationship between the pattern of egg-laying and the appearance of damage on the crop was also done. The aim of this was to help define the 'risk window' in which post-emergence spray treatments should be most effective. At drilling, a 20 m section of untreated bed was divided into 5 or 6 plots each 4 m long. All plots except one were covered with 17 g/m^2 non-woven fleece. Five days after drilling, three 30 cm length of row were dug up (removing plants and soil to five cm depth in a band three cm wide centered on the plant row) from each of the five plots, minimising the uncovered time as much as possible during the sampling. Dipterous eggs were extracted from the soil samples using standard flotation techniques; cabbage root fly eggs were identified and counted. After each egg-sampling, a further plot (four m of bed) was uncovered. This process was repeated at approximately five day intervals until harvest. Plants retained from the egg-sampling (see above) were assessed for the presence or absence of cabbage root fly damage.

Adult fly activity was also monitored in each experiment using three yellow water traps placed within the experimental area.

Results and Discussion

Insecticide efficacy experiments

The results of the experiments done in Lancashire in 1994 and 1995 are shown in Table 2. Overall, the levels of cabbage root fly damage were lower than expected, but consistent differences between treatments were found. The level of control given by the existing label and off-label recommendations (treatments B & C, Table 2) was generally poor, with reductions in damage being recorded only at the site with the lowest overall level of damage (1994). Of the two seed treatments, tefluthrin also gave inconsistent reductions in damage. Chlorpyrifos seed treatment gave the best level of control in all three experiments, whether used alone or in combination with supplementary post-emergence sprays. Thus, chlorpyrifos seed treatment could be considered a better alternative to the existing recommendations. However, the level of control given by this seed treatment is still likely to be insufficient when high levels of cabbage root fly attack occur.

Table 2. Percentage root damage on treated and untreated plots from the experiments in Lancashire in 1994 and 1995 (for 1995 trials, means are de-transformed from √_transformation. S.E.D. = standard error of the difference between two (transformed) means. Means followed by the same letter are not significantly different at *P* = 0.05, Duncan's Multiple Range Test).

Treatment	1994	1995 (1)	1995 (2)
A. No insecticide	6.6 a	8.8 a	17.8 a
B. chlorfenvinphos (at drilling)	3.4 b	6.3 ab	18.6 a
C. chlorpyrifos (at drilling)	3.5 b	4.9 ab	20.2 a
D. chlorpyrifos s.t.	1.7 c	1.6 c	10.3 bc
E. tefluthrin s. t.	3.5 b	6.0 ab	15.8 ab
F. chlorfenvinphos + trichlorphon	3.1 bc	-	
G. chlorfenvinphos + λ-cyhalothrin	1.7 c	3.3 bc	17.8 a
H. chlorpyrifos s.t. + λ-cyhalothrin	-	1.4 c	8.0 c
I. λ-cyhalothrin only	-	7.5 ab	21.2 a
Error d. f.	29	33	32
S.E.D.	0.66	(0.44)	(0.44)

The supplementary spray programmes did not generally improve the level of control given by the soil-applied treatments or the seed treatments. The only exception was in the 1994 experiment where a λ-cyhalothrin programme following chlorfenvinphos treatment at drilling improved significantly the level of control. However, the results from the 1995 experiments showed clearly that a λ-cyhalothrin programme on its own did not reduce damage. These results suggest that the use of post-emergence treatments aimed at controlling adult flies are unlikely to be cost-effective.

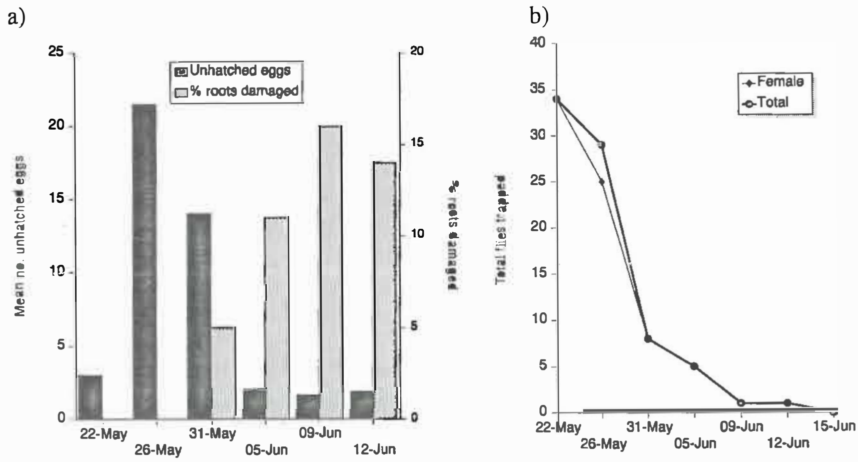

Fig. 1: Experiment 1, Lancashire 1995: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.

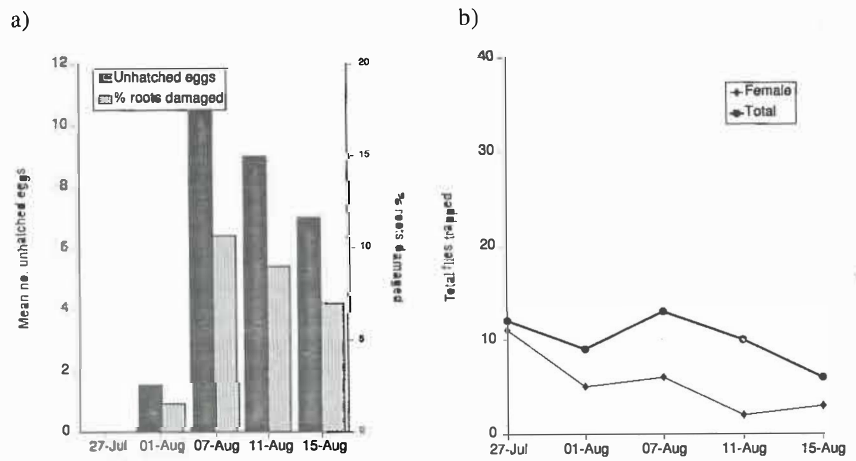

Fig. 2: Experiment 2, Lancashire 1995: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.

Pattern of egg-laying and damage development

Insufficient egg-laying was recorded on the 1994 experiment in Lancashire for valid conclusions to be drawn. In 1995, the levels of adult activity, egg-laying and damage were higher. On the first 1995 experiment, most eggs were found during the first 10 days after crop emergence (Figure 1a), whereas in the second experiment higher egg numbers were found during the latter half of the crop (Figure 2a). Previous work has shown that the attractiveness of radish to egg-laying cabbage root flies varies with plant age (Doane and Chapman, 1962; Ellis *et al.*, 1979). These studies suggested that there is a peak of egg-laying during the time the hypocotyl is swelling (i.e. as the radish bulb approaches marketable size). The results obtained during this project (not all reported here) tended to support this finding (e.g. Figure 2a), provided cabbage root fly activity was constant throughout the life of the crop (Figure 2b). However, the attractiveness of the crop to egg-laying flies may be masked by large changes in fly activity. In the first 1995 experiment, cabbage root fly activity declined dramatically during the course of the experiment, and mirrored closely the intensity of egg-laying (Figure 1).

In most experiments, the period between first recorded eggs and the first appearance of damage was 7 to 10 days (e.g. Figure 1a). Appearance of eggs and damage at the same time (e.g. Figure 2a) was rare. Based on these results, a 'last-effective egg-lay date' of about 7 days before harvest was used to time the end of the supplementary spray programmes in the insecticide efficacy experiments, although this estimate was also backed up by the use of a cabbage root fly simulation model (Collier *et al.*, 1991). However, as supplementary spray treatments are rarely effective (see above), it is likely that this information could best be used to time the removal of crop covers, such as non-woven fleece or nets, to enhance crop earliness and/or to prevent pest damage.

Résumé

Le contrôle de la mouche du chou en culture de radis en plein champ en Angleterre

L'efficacité de deux traitements insecticides du sol, deux traitements par enrobage des graines et deux traitements par pulvérisation a été évaluée pour lutter contre la mouche du chou dans des parcelles de radis conduites en plein champ en Angleterre. L'incorporation dans le sol avant semis de chlorfenvinphos ou de chlorpyrifos, et de tefluthrin en traitement de semences était en général inefficace pour prévenir des attaques dans les sols organiques. Le traitement le plus efficace était du chlorpyrifos utilisé en enrobage de semences ; quoiqu'il en soit, il ne donnait pas entière satisfaction. Des expériences étaient aussi faites pour identifier le modèle de ponte de la mouche du chou et les conséquences sur les dégâts en culture de radis. La ponte s'étend pendant la période de grossissement de la racine, bienque le modèle de ponte soit influencé aussi par le niveau d'activité des mouches. L'intervale entre la ponte et l'apparition des attaques était habituellement de 7 à 10 jours. Les programmes de pulvérisation en post émergence de trichlorphon ou -cyhalothrin, dans le but de lutter contre les adultes, n'ont pas amélioré le niveau de contrôle obtenu au moyen des traitements de sols et les traitements de semences.

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A short review of the resistance found in the two-spotted mite to the acaricide dicofol

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Summary

A sample of the two-spotted spider spider mite was collected from Baliseyh (Ankara). The mites were reared subsequently on bean plants in a room maintained at 27 $\pm$ 1°C and 50-60% RH.

Experiments were done using five doses of dicofol and a slide-dip method. The percentage mortality was calculated and the probit analysis done using the methods described by Finney (1964). The LC_{50} value was compared with that obtained from a susceptible population. The LC_{50} values obtained for the Balişeyh and the susceptible populations occurred at about 18 and 16 ppm, respectively. The resistance factor for the Balişeyh population was estimated to be only 1-1.

Introduction

Resistance problems with phytophagous mites are becoming more serious both with respect to the number of mite species involved and the acaricides used. The rates at which mites develop resistance to various acaricides, and the extent to which the use of one acaricide produces tolerance or resistance to another acaricide, have been recorded only as field observations.

The two-spotted spider mite, *Tetranychus urticae* Koch., is considered to be one of the most important pests of field crops in Turkey. Control of this mite, has deteriorated in recent years because of the development of strains of mites that are resistant to the most commonly used acaricides.

The resistance comprises of both dominant factors and multifactorial epistatic components (McEnroe, 1967). The response of an arrhenotokous population is limited by the response of the haploid males to direct selection (McEnroe & Naegele, 1968). In arrhenotokous species, linked polygenic complexes probably play a more important role, than free genetic diversity, with respect to selection (McEnroe & Harrison, 1968). Previous studies have shown that enforced outcrossing of strains of the two-spotted spider mite results in a rapid response to selection because of the release of cryptic genetic variability. Any outcrossing of mite populations would release genetic variability and the return of such mites could lead to a sudden appearance of resistance (McEnroe & Kot, 1968; McEnroe & Lakocy, 1969).

Several investigators have shown that insecticides can alter the biology of certain mites. In view of the well-known resistance of the two-spotted spider mite to insecticides sprayed onto been crops in Ankara, it was decided to study this subject further. The aim of the present study is to determine the degree of resistance of the two-spotted spider mite to the acaricide dicofol.

Materials and Methods

A population of mites was collected from a bean field in Balişeyh, Ankara. The dosage mortality (DM) was recorded on female mites on the first generation of mites produced on laboratory grown bean plants. A susceptible wild strain of mites was obtained from faba beans growing at the Plant Protection Department at Ankara University.

Mites were reared in a mass-culture room, maintained at 27 ± 1°C, 50-60% RH, and illuminated constantly by fluorescence bulbs of 700 ft. candles intensity. The cages, designed for rearing colonies of mites in the greenhouse, were similar to those described by Andres and Reynolds (1958).

The LC_{50} of dicofol (0.2%) was determined using a 'slide-dip' method (Dittrich, 1962; Anonymous, 1974). Suspensions of the acaricide were prepared by dissolving the test acaricide in acetone. Immediately before use, sufficient water was added to produce a 1 : 1 acetone-water stock suspension. Preliminary tests were done over a wide range of concentrations by diluting serially the stock suspension by one-tenth from one dilution to the next. When the range of partial mortalities was found, dilutions at five concentrations were selected to span the important range.

Adhesive tape was fastened across microscope slides. A fine brush was then used to place 50 mites onto each slide. The backs of the mites were stuck to the tape and young female mites of a standard age were used in all tests. The slides holding the mites were dipped for five seconds into the treatment solution to ensure complete wetting. After treatment, the slides containing the treated mites were allowed to drain for 15 minutes at room temperature. After draining, the slides were placed into a holding chamber for 24 hours at 27°C and 95% RH after which the mites were examined under a stereoscopic microscope. Mites which failed to move their legs after being prodded lightly with a fine brush were counted as dead. The experiments were done using five doses of insecticide.

Percentage mortality, probit analysis and the LC_{50} values were calculated using the methods described by Finney (1964), Ecevit (1977). The mortality figures were then plotted on paper and dose-mortality regression lines fitted by eye. The value of the LC_{50} for the test populations was compared with that from a susceptible population and then the resistance factor was calculated.

Results and Discussion

The mean LC_{50} values of dicofol for two samples of mites are shown in Table 1, which includes also the 95% confidence intervals around the means.

Comparison of LC_{50}'s, indicated that all of the mite colonies tested were resistant to parathion and ethion, while the response to dicofol and aramite varied from colonies that were susceptible to one that had a high level of resistance. The LC_{50} of dicofol to the seven strains of mites varied from 55 ppm to 470 ppm (Kensler & Streu, 1967).

From laboratory studies, the two-spotted spider mite was found to be resistant to dicofol LC_{50} = 0.009537 (active ingredient). Although the two-spotted spider mite seemed to be resistant to dicofol, the resistance was not at the highest level (Ecevit, 1977) as an LD_{50} of 0.29% was recorded by Herne and Chant in 1965 (see Ecevit., 1977).

Atak (1982) reported values of LC_{50} at 0.0010 µl/litre, 0.0035 µl/litre and 0.0023 µl/litre for a susceptible population and two field populations of mites, respectively. He also found resistance factors that were at levels 3.5, 2.3 and 1.8 greater than the susceptible strain. He concluded, however, that, because of the low values recorded, that this was not resistance to dicofol but should be regarded as vigour tolerance.

Table 1. The LC_{50} values, 95% fiducial limits and resistance factors for two populations of the two-spotted spider mite treated with the acaricide dicofol.

Sample	LC_{50} (μikroliter/liter)	95% f.l.	Resistant factor
1. Susceptible strain	0.00160	0.00189 0.00129	1
2. Balişeyh	0.00178	0.00209 0.00147	1.1

Studies in Bulgaria indicated increased tolerance to acaricides based on dicofol and dinobuton (Darakchieva, 1983). Depending upon where the populations were collected in Bulgaria, the populations could be weakly, moderately or highly resistant to dicofol (Darakchieva, 1985).

Laboratory comparison of field-collected susceptible and resistant strains of the two-spotted spider mite showed a 6-fold difference when the slide-dip bioassay was used compared to a 544-fold difference when assessed from a residual bioassay (Dennehy *et al.*, 1984). A strain of *T. urticae* collected from a strawberry garden in New Zealand in 1978 was found to be resistant to dicofol. A resistance factor of 90 was calculated for mites tested from Central Otago population (Baker, 1985). Cross-resistance of the mite strains resistant to dicofol was observed not only to diallylcarbinol acaricides, that resembled dicofol in their structure, but also to organophosphorus insecticides (Kono, 1986).

In tests done using both the 'slide-dip' and 'leaf-dip' techniques, the Keumchun strain of mites was 71 and 74 times, and the Hackyo strain 24 and 23 times, as resistant to dicofol respectively as the Kwangju susceptible strain. Although there was no significant difference between the results obtained using the two methods, the slide-dip method was recommended as the data collected were less variable (Lee *et al.*, 1988).

Conclusions

Resistance to acaricides can develop rapidly in populations of mites. For example, the development of mite populations resistant to organophosphorus acaricides was rapid, reached extremely high levels and strains selected were cross-resistant to most other compounds.

Therefore, the resistance of the mites populations in a region should be assessed before insecticides are applied. The earliest possible warning of incipient resistance is essential if effective and timely alternative measures that do not involve chemicals are to be introduced.

Résumé

Un bref examen de la résistance trouvée chez le tétranyche tisserand (*Tetranychus urticae* Koch.) vis-à-vis de l'acaricide dicofol

Un échantillon de deux populations de tétranyches a été collecté à Baliseyh (Ankara, Turquie). Les acariens ont été élevés par la suite sur des plants de pois en salle maintenue à 27 1°C et 50 - 60 % d'humidité relative.

Les expériences ont été faites en utilisant cinq doses de dicofol par la méthode de trempage. Le pourcentage de mortalité a été calculé et une analyse en probits selon la méthode décrite par Finney (1964) a été effectuée. La valeur de la LC_{50} était comparée à celle obtenue avec une population sensible. Les valeurs de la LC_{50} obtenues pour la souches de Baliseyh et la souche sensible étaient respectivement de 18 et de 16. Le facteur de résistance pour la population de Baliseyh a été estimé de 1.1.

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Control of *Thrips tabaci* Lind in leek crops

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Summary

Attacks by thrips (*Thrips tabaci* Lind.), and to a lesser extent by the leek moth (*Acroleopsis assectella* Z.) cause high losses in both quality and yield in leek (*Allium porrum* L.) crops in Belgium. In practice, leek crops are usually sprayed intensively during the whole season to control thrips and leek moth. However, thrips are particularly difficult to control and, even with intensive sprays of insecticide, the percentage of unmarketable plants is often much too high, especially in summer crops and early-autumn crops.

During 1994, the effectiveness of permethrin was studied in crops sprayed at intervals of one-week, two-weeks and according to a threshold when 25% of the plants were infested by thrips. Thrips control was also tested by covering the leek plants with polythene-net or a non-woven polypropylene fleece. The infestation of thrips was not high and more than 95% of the plants from the treated plots were marketable. Protecting leeks with either net or fleece prevented damage by thrips.

During 1995, the effectiveness of four insecticides (permethrin, endosulfan, parathion, furathiocarb), each applied at two doses, was tested together with sprays applied according to a threshold of 90% of the plants infested with thrips. The best control was obtained with furathiocarb.

Introduction

In Belgium, leek is a major field vegetable crop which is currently sprayed intensively with insecticide from June to October to control infestations of thrips. Methods of supervised control are not used currently in Belgium. However, based on the positive results obtained in Germany (Hommes, 1992; Hommes *et al.*, 1994) a field experiment was done in which sprays were applied 1) according to a threshold; 2) at intervals of one week and 3) at intervals of two weeks. During 1995, a field experiment was carried out to control thrips in a heavily-infested leek crop using three insecticides, each applied at two doses.

Materials and Methods

The experiments were carried out at the Vegetable Research Station at Sint-Katelijne-Waver and at the Provincial Vegetable Research Centre at Kruishoutem in 1995. Cultural and sampling details for the two experiments are shown in Table 1.

Table 1. Cultural and sampling details for the field experiments done in 1994 and 1995.

	1994	1995
Locality	Sint-Katelijne-Waver	Kruishoutem
Date of sowing	30 April	13 March
Date of planting	7 July	8 May
Cultivar	Arkansas	Carolina
No. of plants assessed	60	30
No. of replications	3	3
No. of plants/plot	200	160
Date of final assessment	22 November	9 November

The treatments applied to the field experiments are shown in Table 2.

Table 2. Experimental treatments applied to the field experiments done in 1994 and 1995.

	1994	1995
1	untreated (no insecticide used)	untreated (no insecticide used)
2	permethrin (50 mg a.i./ha) at intervals of one week Applied on 20 & 28 July; 4, 10, 17 & 24 August; 7, 14 & 21 September and on 3 October	endosulfan (700 mg a.i./ha) Applied on 27 July and 8 August
3	permethrin (50 mg a.i./ha) at intervals of two weeks Applied on 20 July; 4 & 17 August; 7 & 27 September and on 3 October	endosulfan (1400 mg a.i./ha) Applied on 27 July and 8 August
4	permethrin (50 mg a.i./ha) according to threshold: Threshold 25% of plants infested by thrips Applied on 28 July; 10 & 24 August and on 14 September	parathion (250 mg a.i./ha) Applied on 27 July and 8 August
5	"Lanet" gauze : polyethylene mesh of 0.17 x 0.37 mm Plots covered directly after transplanting	parathion (500 mg a.i./ha) Applied on 27 July and 8 August
6	"P17" fleece : non-woven polypropylene Plots covered directly after transplanting	furathiocarb (300 mg a.i./ha) Applied on 27 July and 8 August
7		furathiocarb (600 mg a.i./ha) Applied on 27 July and 8 August

In the experiment of 1994, 60 leek plants from each treatment were checked individually for plant damage, plant weight, stem length, stem diameter and marketability. Damage by thrips was graded on a scale of 1 to 9 : in which 1 = clean (no damage, quality extra); 3 = slight (quality A1); 5 = moderate (quality B1); 7 = severe (quality 2) and 9 = very severe. Plants were classified as non-marketable if the damage by thrips was equal to or higher than grade 5. In the 1995 experiment, the insecticides were sprayed on 27 July based on a threshold of 90% plants infested by thrips. Most of these plants were damaged moderately to severely (5-7 on the damage scale). A few days after spraying (31 July), the heart and the leaves of each plant were inspected carefully for living thrips. A second treatment was applied on 8 August, because many living thrips were found in the plants inspected on 31 July particularly in the plots sprayed earlier with endosulfan or parathion.

Results and Discussion

The amounts of damage at harvest and the crop yields from the field experiment in 1994 are shown in Table 3.

Table 3. The grades of damage, mean plant weight (g), length (cm) and diameter (mm), and the percentage of marketable plants recorded from the 1994 field experiment.

Treatment	% plants marketable	No. of plants				Mean plant		
		1	3	5	7	weight	length	diameter
"Lanet" gauze	97	52	6	2		23	20	24
"P17" fleece	100	58	2			212	21	23
Routine (7 days)	95	44	13	1	2	246	21	26
Routine (14 days)	95	32	25	3		252	21	26
Threshold	97	47	11	2		249	21	25
Untreated	75	10	35	12	3	246	21	26

The infestation of thrips was low in 1994. As a consequence, there were no significant effects of the insecticides sprayed to control the thrips, despite 10 sprays of permethrin. At harvest, 75% of the plants were marketable from the untreated plot. In contrast, more than 90% of the plants were marketable from the sprayed plots and from the covered plots. However, crop yields were lower in the covered plots than in the non-covered plots. The efficiency of the various insecticide treatments against thrips and the yields from the field experiment of 1995 are shown in Table 4.

Table 4. The numbers of various stages of thrips found on 3 sampling dates following the application of six insecticide treatments, together with the percentage of plants marketable (% PM) at harvest on 9 November*.

Object	31 July				10 August				16 August				9 Nov *
	No. of plants with				No. of plants with				No. of plants with				% PM
	no thrips	L_1-larvae	L_2-larvae	L_1+L_2 larvae or adults	no thrips	L_1-larvae	L_2-larvae	L_1+L_2 larvae or adults	no thrips	L_1-larvae	L_2-larvae	L_1+L_2 larvae or adults	
untreated		4	1	25				30			2	28	7
endosulfan	12	13	1	4	8	20		2	14		3	13	21
endosulfan	11	14	3	2	14	8	3	5	15	2	8	5	28
parathion	2	7		21	1	3		26	4		1	25	31
parathion	3	12	2	13	4	7	2	17	5		1	24	27
furathiocarb	19	11			27	3			25		3	2	75
furathiocarb	21	9			24	5		1	28		2		81

During July and August of 1995, temperatures were very high and there were long dry periods. As both conditions favour the development and survival of thrips, the infestation was high. By 27 July, more than 90% of the plants had become infested by thrips. The insecticide sprays with furathiocarb were particularly effective. Applications of this insecticide were characterised by a steep decline in the numbers of plants infested by thrips 3 days after treatment with only L_1-larvae being found. In the treatments with endosulfan and parathion more than 15% of the plants still had infestations of L_2-larvae or adults three days after treatment.

Similar results were found two or eight days after the second treatment. A few plants were found with L_1-larvae in the plots treated with furathiocarb. In contrast, many plants had larvae and adults in the plots treated with endosulfan and parathion. The failure to control thrips with parathion is clear from the results shown in Table 4. The data suggest that the thrips population could possibly be resistant to parathion and, to a lesser extent, to permethrin. There were no differences between the two doses applied of each insecticide.

At harvest, only 7% of the plants were marketable in the untreated plots, compared to 75% in the plots sprayed with furathiocarb (Table 4). In contrast, in the plots sprayed with endosulfan and parathion only 21% and 27% of the plants were marketable, respectively.

Resumé

Lutte contre *Thrips tabaci* Lind. en culture de poireau

Les attaques de thrips (*Thrips tabaci* Lind.) et à un moindre degré de la teigne du poireau (*Acroleopsis assectella* Z.) provoquent des pertes élevées en qualité et en récolte dans

les cultures de poireaux (*Allium porrum* L.) en Belgique. Dans la pratique, les cultures de poireaux sont habituellement intensément traitées par des pulvérisations pendant la totalité de la saison pour lutter contre le thrips et la teigne du poireau. Toutefois, les thrips sont particulièrement difficiles à combattre, même avec un calendrier de traitement par pulvérisation intensif, et le pourcentage de plantes non commercialisables est souvent beaucoup trop élevé, particulièrement dans les cultures d'été et les cultures précoces d'automne.

En 1994, l'efficacité de la permethrin a été étudiée dans des cultures pulvérisées avec un intervale de une, deux semaines et cela à partir d'un seuil qui est de 25 % de plantes infestées par les thrips. La protection contre les thrips comprenait aussi des essais de couverture de la planche de poireaux avec un filet de polyéthylène ou un intissé de polypropylène. L' infestation de thrips était peu élevée et plus de 95 % des plantes des parcelles traitées étaient commercialisables. Une protection des poireaux au moyen d'un filet ou d'un intissé prévient les attaques de thrips.

En 1995, l'efficacité de quatre insecticides (permethrin, endosulfan, parathion, furathiocarb), chacun utilisé à deux doses, était testée au moyen de pulvérisations appliquées lorsque le seuil de 90 % des plantes étaient attaquées par les thrips. La meilleure protection a été obtenue avec du furathiocarb.

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