Union Internationale des Sciences Biologiques

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE ET INTEGREE CONTRE LES ANIMAUX ET LES PLANTES NUISIBLES

SECTION REGIONALE OUEST PALEARCTIQUE

ISBN 92-9067-011-8

WORKING GROUP "INTEGRATED CONTROL IN FIELD VEGETABLE CROPS"

GROUPE DE TRAVAIL "LUTTE INTEGREE EN CULTURE DE LEGUMES"

edited by:T.H.COAKER
éditée par:S. FINCH

TUNE(DENMARK)
21-23.09.87

BULLETIN SROP
WPRS BULLETIN

1988/XI/1

International Union of Biological Sciences

INTERNATIONAL ORGANIZATION FOR BIOLOGICAL AND INTEGRATED CONTROL OF NOXIOUS ANIMALS AND PLANTS

WEST PALAEARCTIC REGIONAL SECTION

ORGANISATION INTERNATIONALE DE LUTTE BIOLOGIQUE CONTRE
LES ANIMAUX ET LES PLANTES NUISIBLES

INTERNATIONAL ORGANISATION FOR BIOLOGICAL CONTROL OF
NOXIOUS ANIMALS AND PLANTS

LUTTE INTEGREE EN CULTURE DE LEGUMES
INTEGRATED CONTROL IN FIELD VEGETABLE CROPS

TUNE, DENMARK 21-23 SEPTEMBER, 1987

EDITED BY: T.H. COAKER
EDITEE PAR: S. FINCH

BULLETIN SROP
WPRS BULLETIN

PREFACE

In 1983, the 'Working Group on Integrated Control in Brassicas' extended its range of activities to include carrot and Allium crops, and changed its title to the 'Working Group in Field Vegetables'. In addition, the Group incorporated representatives from the 'Working Group on Breeding for Resistance to Insects and Mites' to provide a closer cooperation on topics of common interest.

The main objectives of the Group remain unchanged, these are to develop pest management systems that encourage the rational and effective use of pesticides while recognising the demand for high quality vegetable crops. Such objectives have been pursued by both individual and collaborative projects, the latter being particularly successful irrespective of the obvious problems that arise in maintaining continuity of involvement by members of the Group who are also busy with their own research programmes. These achievements have been stimulated by the regular biennial meetings of the Group since the early 1970's and the cooperation that has built up between its members.

Since the previous Bulletin (1980/III/I) was published, collaborative projects now incorporate, in addition to the establishment of pest and damage thresholds, methods for monitoring vegetable pests and the development of their use in commercial crops. From these activities supervised control techniques are now in use by advisors and growers in a number of member countries, for the control of caterpillars, aphids and root fly on brassicas, and for carrot fly on carrots. These techniques enable growers to use less insecticide to obtain the same results as from programmed treatments. Non-insecticidal methods of control, such as partial resistant varieties and cultural control have also been made available for use in pest management systems. Accounts of these activities are presented in this Bulletin.

T.H. COAKER
(Group convenor)

List of participants

Bromand, B.	Research Centre for Plant Protection Institute of Pesticides, Lottenborgvej 2, DK-2800 Lyngby, DENMARK
Brunel, E.	Station de Zoologie - INRA, Centre de Recherches de Rennes, Domaine de la Motte au Vicomte, BP 29, F-35650, Le Rheu, FRANCE
Coaker, T.H.	Department of Applied Biology, Pembroke Street, Cambridge, CB2 3DX, UK
Collier, Rosemary H.	Institute of Horticultural Research, Wellesbourne, Warwick CV35 9EF, UK
Eilenberg, E.	Dept. of Zoology, Royal Veterinary & Agricultural University, Bulowsvej 13, DK-1870 Frederiksberg Copenhagen, DENMARK
Ellis, P.R.	Institute of Horticultural Research, Wellesbourne, Warwick CV35 9EF, UK
Esbjerg, P.	Research Centre for Plant Protection Zoological Department, Lottenborgvej 2, DK-2800 Lyngby, DENMARK
Finch, S.	Institute of Horticultural Research, Wellesbourne, Warwick CV35 9EF, UK
Freuler, J.	Station Fédérale de Recherches Agronomiques de Changins, CH-1260 Nyon, SWITZERLAND
Hawkes, C.	Department of Biological Sciences, Plymouth Polytechnic, Drake Circus, Plymouth PL4 8AA, Devon, UK
Hommes, M.	Federal Biological Research Centre for Agriculture & Forestry, Institute for Plant Protection in Horticultural Crops, Messeweg 11/12, D-3300 Braunschweig, FDR
Koch, W.	Station Federale de Recherches Agronomiques de Changins, CH-1260 Nyon, SWITZERLAND
Langer, Vibeke	Institute Y. Aalborg University, Fibigerstraede 11, DK-9220, Aalborg O, DENMARK
Percy-Smith, A.	Research Centre for Plant Protection, Institute of Pesticides, Lottenborgvej 2, DK-2800 Lyngby, DENMARK
Philipsen, H.	Department of Zoology, Royal Veterinary & Agricultural University, Bulowsvej 13, DK-1870 Frederiksberg, Copenhagen, DENMARK
Steene, F. van de	Centrum voor Onderzoek op Groentegewassen - IWONL Faculteit van de Landbouwwetenschappen, Coupure Links 653, B-9000 Gent, BELGIUM
Theunissen, J.	Research Institute for Plant Protection P.O. Box 9060, Binnenhaven 12, 6700 GW Wageningen, NETHERLANDS
Tornéus, C.	Swedish Agricultural University Box 44, S-23053 Alnarp, SWEDEN

CONTENTS

DEVELOPMENT OF TRAPS FOR MONITORING POPULATIONS OF THE CARROT FLY

By STAN FINCH AND ROSEMARY H. COLLIER

AFRC Institute of Horticultural Research, Wellesbourne,

Warwick CV35 9EF, U.K.

SUMMARY

The numbers of carrot flies caught in water traps indicated two distinct generations of this pest in the Fens, the major carrot growing area in the United Kingdom. Each generation occurred about two weeks later than the comparable generation at Wellesbourne. Water traps were most effective when placed 20-25m into the crop and when painted either orange-red or yellow-green rather than the yellow-orange colours now used commonly in Europe. More flies were caught on vertical sticky traps placed within the canopy of the crop, or just above, than on traps sited over bare soil. The effectiveness of systems currently used in Europe for monitoring populations of the carrot fly are discussed.

INTRODUCTION

Several studies are currently being carried out at Wellesbourne to reduce the amounts of insecticide applied to protect crops against the carrot fly, Psila rosae Fab., without reducing crop quality.

One effective strategy is to use partially resistant cultivars in conjunction with reduced doses of insecticide (Thompson et al., 1980). Others depend on more effective placement of the insecticide in the soil. For example, deep distribution of a granular insecticide, using a Matco Verba (R) vertical band applicator during drilling, protected long carrots more effectively than a conventional, shallow "bow-wave" application (Thompson et al., 1986).

Other research is concentrating on improving the timing of mid-season sprays applied routinely against this pest (Finch & Collier, 1988). This paper describes initial efforts to develop a practical system for monitoring field populations of the carrot fly in the United Kingdom. For about 30 years, carrot fly activity was monitored by counting the numbers of flies swept from sheltered hedgerows alongside the previous year's infested fields (Petherbridge et al., 1942; Coppock, 1974). This method was superseded by one based on large yellow cylindrical sticky traps (Oakley, 1979) which, unfortunately, are difficult to handle. They are also particularly difficult for growers to send by mail to their regional ADAS officers for verification of their catch. Therefore, the small sticky petri-dish traps proposed by Dutch entomologists (Ouden & Theunissen, 1988) are now being tested by ADAS entomologists in Cambridge and Lancashire as an alternative to the large sticky cylinders. On mainland Europe, two systems are currently used, one based on sticky traps developed in Switzerland (Freuler et al., 1982) and the other on water traps developed in France (Brunel et al., 1970). This paper describes some of the problems to be overcome before any of these monitoring schemes can be used to forecast reliably the times and severity of attacks by this pest.

EXPERIMENTAL

Numbers of carrot fly generations each year

The numbers of carrot flies caught in water traps during the last five years (Skinner & Finch, 1988) have confirmed that there are two discrete generations of this pest at Wellesbourne (Fig. 1). Flies of the second generation start to emerge in late July and within two days begin to lay eggs in the soil alongside the stems of carrot plants.

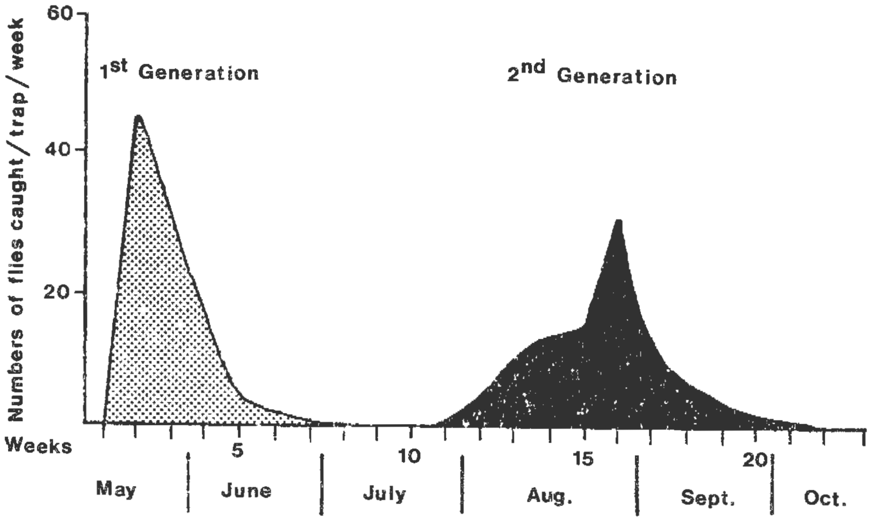


Fig. 1. Mean numbers of carrot flies caught per yellow water trap per week at Wellesbourne during 1982-1986.

To determine whether fly populations in the Fens also have two well-defined generations, water traps were used in twenty carrot fields to monitor fly activity from July to October 1987. The Fens are about 150km due east of Wellesbourne and comprise a region of highly-organic soils in which about 75% of the U.K. carrot crop is currently produced. The 20 carrot fields sampled were widely-separated over an area stretching about 30km N-S and 10km E-W. Six traps were used at each site; three placed alongside the crop boundary and the other three placed 5m into the crop. All traps were spaced 10m apart.

At all sites in the Fens, the patterns of distribution of the flies caught indicated two discrete generations that occurred about two weeks later than the comparable generations at Wellesbourne (Fig. 1).

Trap Development

The systems used currently for monitoring carrot fly populations are based on either yellow or orange traps placed about 5m into the crop and generally supported at crop height. Effects of trap colour, height, and position on the numbers of carrot flies caught were evaluated in the field in 1987.

Trap colour - Six different colours were selected to cover the yellow to orange range. The colours selected were classified in terms of hue, using the Royal Horticultural Society (RHS) standard colour cards used to describe accurately the colours of new cultivars of ornamental plants. The colours of the traps tested and their RHS Classifications are given in Table 1. Coloured water-traps were tested in the Fens and the same colours, except for colour 5, which could not be supplied, were tested in sticky traps in Denmark. Each water trap consisted of a 16cm diameter plastic dish filled 4cm deep with a solution of 20ml soap solution/litre (Finch & Skinner, 1974). Each sticky trap consisted of a two-sided, 12.5 x 20cm rigid plastic sheet painted the appropriate colour and overlaid with a sheet of acetate, coated in advance with Tangletrap (R) (The Tangle Co., Grand Rapids, Michigan 49504, USA). All traps were placed at crop height and were spaced 10m apart along the edge of crops in the Fens and in a 5x5 latin square close to the edge of a carrot crop in Denmark.

Table 1. The numbers of carrot flies caught in coloured water-traps in England and in similar-coloured sticky traps in Denmark.

Colour No	Trap colour	RHS Classification	Water traps		Sticky traps	
			Total flies (27 Aug) - 16 Sept)	Mean rank over reps	Total flies (10 Sept -25 Sept)	Mean rank over reps
1	Yellow-green	Yellow 2B	52	2.7	122	1.5
2	Bright yellow	Yellow 5A	37	3.3	121	1.5
3	Dull yellow	Yellow 9C	40	3.6	91	4
4	Pale orange	Yellow-orange 24B	29	4.7	100	4
5	Orange	Orange 25A	16	4.9	-	-
6	Orange-red	Orange-red 30B	87	1.7	96	4

The orange-red (6) and yellow-green (1) water traps were the most effective and colour 5 caught fewest flies in these experiments. In contrast, although more flies were caught in the sticky trap experiment in Denmark than in the water trap experiment in England, similar numbers were caught by each colour tested in Denmark. The least effective colour for the water traps in this experiment, colour 5, is the "standard" colour now used by the French for their water traps. Similarly the hue of the traps now used regularly in Switzerland/Denmark is, according to the RHS classification, yellow-orange 17A, a hue about mid-way between colours 3 and 4 (Table 1). Hence this colour also would have a high mean rank and catch few carrot flies in the Fens.

Trap height - To determine the most effective height for sticky traps, 10 x 20cm sticky orange (Colour 5 - Table 1) boards were placed with their long axes vertical at five different positions in a carrot crop (Fig. 2). The bottom edge of the traps were placed just above the soil, between and within beds of carrots, level with the top of the carrot crop or at 2 and 4 times the height of the carrot crop (Fig. 2). The experiment was carried out between 19 August and 16 September to correspond with peak fly activity of the second generation of flies.

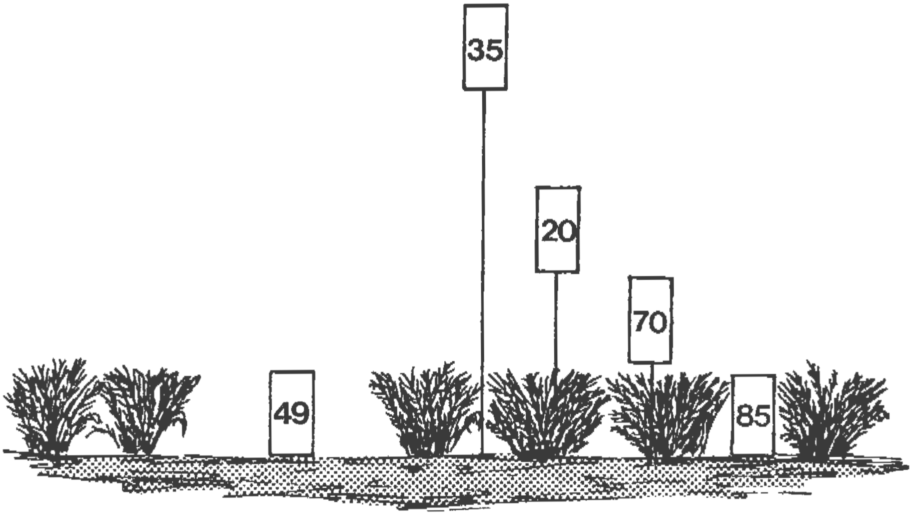


Fig. 2. Mean numbers of carrot flies caught per week on orange sticky traps positioned at various heights above the ground.

More carrot flies were caught on traps sited above or amongst carrot foliage than on those sited over bare soil. Traps with the base at ground level, or level with the crop canopy, were most effective (Fig. 2).

Trap position - A critical question to be answered in any pest monitoring system is "where should the traps be sited to be most representative of the fly population within the field?" To study this aspect, sticky traps were spaced at 5m intervals from the hedgerow to 50m into a carrot crop. The experiment was carried out from 3-30 September using double-sided, 12.5 x 20 cm sticky traps painted pale orange (Colour 4 - Table 1).

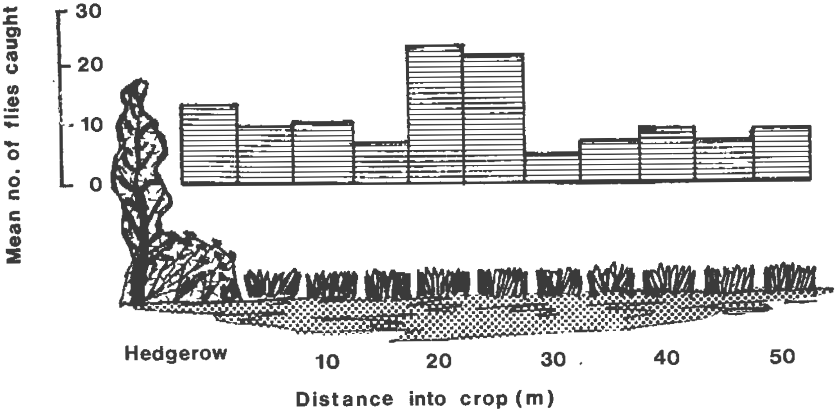


Fig. 3. Mean numbers of carrot flies caught per week in pale orange sticky traps placed at various distances into a carrot crop

The numbers of flies caught varied considerably from one 5m to the next but most flies were trapped 20-25m from the hedgerow (Fig.3).

DISCUSSION

The type of trap used as the "standard" for monitoring carrot fly populations in Switzerland and Denmark is largely a consequence of the commercial availability of appropriate cheap materials. Initially, several yellow traps were tested under field conditions in Switzerland. During 1976 at Changins, 51 flies were caught on "Plexiglas"(R) (Jauslin SA, CH-1032 Romanel, Switzerland) 229 sticky traps compared to 30 flies on "Plexiglas"(R) 374 sticly traps and so colour 229 was chosen in preference to colour 374 (Stadler et al., 1978). Although in 1977 at Wadenswil, 36 and 58 flies were caught on sticky traps made from Plexiglas(R) 229 and 374, 229 was retained because it caught fewer bees and syrphids. As yellow "Plexiglas"(R) was too expensive for disposable traps, three different colour variations (No. 9944, 9946 & 9949) of a thin polystyrol material "with an orange hue" were tested as replacements for Plexiglas(R). In a field trial from 28 July to 21 August 1981, 5 traps of polystyrol 9946 and Plexiglas(R) 229 caught totals of 29 and 30 flies respectively. Although the new orange polystyrol was then adopted as the standard material for sticky traps (Freuler et al., 1982; Philipsen, 1983; Stadler et al.,1988), the results from the Fens (Table 1) suggest that the current trap may not be the most attractive colour.

The numbers of carrot flies caught in variously-coloured yellowish-green /yellow /orange and red water traps (Bohlen, 1967) and sticky traps (Danish data - Table 1) are sometimes remarkably similar, but the relative numbers caught by coloured traps depend on trap spacing (Bohlen, 1967). Thus in cage experiments with traps spaced 10 cm apart, totals of 121 and 55 flies were caught in yellow and orange traps, respectively. However, proportionally more flies were caught in orange traps, sometimes more than in yellow traps, when traps were spaced more than 30cm apart. Traps tested to select the most attractive colour in the field should be placed sufficiently close to ensure they all compete for the same population of flies.

The monitoring system used in France is based on water traps instead of sticky traps. The traps are made from 10-12cm diameter plastic dishes (Missonier & Boulle, 1964) and were originally painted buttercup-yellow (jaune bouton d'or). In trials this colour was about twice as attractive as the best other colours tested, namely lemon-yellow and orange (Brunel et al., 1970; Brunel & Rabasse, 1975). Although buttercup-yellow, the most attractive colour tested, reflected considerable amounts of light at 560nm in the yellow wave band, this was not the critical factor, as cream-yellow and lemon-yellow reflected much more light at 560nm. The critical factor was the ratio of the light reflected at 560nm to that reflected at 460nm (in the blue band), a factor approximating to 13:1 and 8:1 for the buttercup-yellow and lemon-yellow respectively. Effects of these traps on the numbers of beneficial insects were not reported. Brunel (personal communication) has now replaced the original buttercup yellow of his traps by an orange colour of similar hue to colour 5 (Table 1).

The recent discovery that screens of Netlon(R) mesh placed around traps sieve out the larger beneficial insects without reducing the numbers of carrot flies caught (Philipsen, 1988), will enable some of the more attractive yellow colours to be used as the basis for carrot fly traps. However, factors other than the numbers of flies caught make certain colours unsuitable and require consideration. For example, carrot flies stuck onto traps painted with colours from the orange-red end of the spectrum are more difficult to identify and count (A. Percy-Smith - personal communication).

The data collected throughout Europe on the relative attractiveness of traps painted various hues of orange/yellow are extremely variable and may indicate that carrot flies from different countries do not behave similarly with respect to "colour preference". However, such differences could be environmental rather than genetic and arise largely from the different qualities and quantities of the light falling on the variously-coloured traps at the times the flies are most active in the fields in the various countries. Experiments similar to those used for cabbage root fly (*Delia radicum*) (Finch *et al.*, 1988) are needed to determine whether carrot fly populations from different countries do behave differently and if so whether the differences are regulated by environmental or genetic factors.

Agreement has been reached that the most effective place for carrot fly traps is at about crop height (Wainhouse, 1975; Freuler *et al.*, 1982; Ouden & Theunissen, 1988; Finch & Collier -this paper) but it is not clear how many traps should be used in each field and where they should be placed to ensure that data collected are representative of the infestation as a whole.

We thank Miss Marian S Elliott and Dr Hefin T Jones for invaluable technical assistance.

REFERENCES

BOHLEN, E. (1967). Untersuchungen zum Verhalten der Mohrenfliege, *Psila rosae* Fab. (*Dipt. Psilidae*) in Eiablagefunktionskreis. *Zeitschrift fur Angewandte Entomologie* 59, 325-360

BRUNEL, E. & RABASSE, J.M. (1975). Influence de la form et de la dimension de piéges à eau colorés en jaune sur les captures d'insectes dans une culture de carotte. Cas particulier des Diptères. *Annals de Zoologie* - *Ecologie Animale* 7, 345-364.

BRUNEL, E., LANGOUET, L. & MISSONIER, J. (1970). Influence de caractéristiques optiques du milieu sur les adultes de *Psila rosae* Fab. (Diptères: Psilides): attractivité de surface colourées, rythme journalier d'activité. *Comptes Rendue des Séances de la Société de Biologie* 164, 1638-1644.

COPPOCK, L.J. (1974). Notes on the biology of carrot fly in Eastern England. *Plant Pathology* 23, 93-100.

FINCH, S. & COLLIER, ROSEMARY H. (1988). Monitoring and forecasting attacks of cabbage root fly and carrot fly in vegetable crops. *Proceedings of the International Symposium on Diptera Pests in Vegetable Crops*. Skierniwice - Poland (In press).

FINCH, S. & SKINNER, G. (1974). Some factors affecting the efficiency of water-traps for capturing cabbage root flies. *Annals of Applied Biology* 77, 213-226.

FINCH, S. & BROMAND, B., BRUNEL, E., BUES, M., COLLIER, R.H., DUNNE, R., FOSTER, G., FREULER, J., HOMMES, M., VAN KEYMEULEN, M., MOWAT, D.J., PELERENTS, C., SKINNER, G., STADLER, E. & THEUNISSEN, J. (1988). Emergence of cabbage root fly from puparia collected throughout Northern Europe. In: *Progress on Pest Management in Field Vegetables*. Eds. R. Cavalloro and C. Pelerents. P.P. Rotondo - D.G. XIII - Luxembourg No. EUR 10514 (In Press).

FREULER, J., FISCHER, S. & BERTUCHOZ, P. (1982). La mouche de la carotte, *Psila rosae* Fab. (Diptera: Psilidae). II Mise au point d'un piége. *Revue Suisse de Viticulture, Arboriculture and Horticulture* 14, 137-142.

MISSONIER, J. & BOULLE, MALLE N. (1964). Remarques sur la biologie de la mouche de la carotte. *Phytoma - Defense de Culture* 156, 31-33.

OAKLEY, J.N. (1979). Carrot pest monitoring in S W Lancashire. *Report to Umbelliferous Pests Working Party*. MAFF/ADAS. 3pp.

OUDEN, H. den & THEUNISSEN, J. (1988). Monitoring of the carrot rust fly, *Psila rosae*, for supervised control. (Present Bulletin).

PETHERBRIDGE, F.R., WRIGHT, D.W. & DAVIES, P.G. (1942). Investigations on the biology and control of the carrot fly (*Psila rosae* F.). *Annals of Applied Biology* 29, 380-392.

PHILIPSEN, H. (1983). Brug af gule limplader til vurdering af risiko for angreb af gulerodsfluen (*Psila rosae* F.). *Tidsskrift for Planteavl* 87, 389-397.

PHILIPSEN, H. (1988). Monitoring techniques for the carrot fly *Psila rosae* (F.). (Present Bulletin).

SKINNER, G. & FINCH, S. (1988). Field and laboratory studies on the behaviour of the carrot fly, *Psila rosae*. In: *Progress on Pest Management in Field Vegetables*. Eds. R. Cavalloro and C. Pelerents. P.P. Rotondo-D.G. XIII - Luxembourg N. EUR 10514. (In press).

STADLER, E., GFELLER, F. & FREULER, J. (1978). Monitoring the carrot rust fly with visual traps. *Report to IOBC Group Meeting*. 4pp.

STADLER, E., GFELLER, F., KELLER, K. & PHILIPSEN, H. (1988). Toward an effective and economic carrot fly trap: progress report 1981-1985. In: *Progress on Pest Management in Field Vegetables.* Eds. R. Cavalloro and C. Pelerents P.P. Rotondo - D.G. XIII - Luxembourg N. EUR 10514. (In press).

THOMPSON, A.R., ELLIS, P.R., PERCIVALL, A.L. & HARDMAN, J.A. (1980). Carrot fly. Integrated control using insecticides with carrot cultivars of differing susceptibilities. *Report of the National Vegetable Research Station for* 1979, p. 30.

THOMPSON, A.R., PERCIVALL, A.L. SUETT, D.L. & EDMONDS, G.H. (1986). Effects of depth of placement of granules at drilling on the performance of insecticides against cabbage root fly (*Delia radicum*) and carrot fly (*Psila rosae*) on root vegetables. In: *Aspects of Applied Biology* 12, 247-257.

WAINHOUSE, D. (1975). *The Ecology and Behaviour of the carrot fly*, Psila rosae (*F*). Ph.D. Thesis: University of Cambridge. 284pp.

MONITORING TECHNIQUES FOR THE CARROT FLY

(Psila rosae F.)

HOLGER PHILIPSEN

Royal Veterinary and Agricultural University,
Department of Zoology, Bülowsvej 13,
1870 Frederiksberg C, (Copenhagen), Denmark.

SUMMARY

The experiments reported in this paper show, that attempts to develop a more selective yellow sticky trap have been successful. The data shows, that adult carrot fly catch is not negatively influenced by protecting the traps with "Netlon". Furthermore, catches of a range of other insects are negatively influenced. This can not be fully appreciated from the data alone, as the effect is more tangible, for the people who service the traps.

INTRODUCTION

Yellow sticky traps and water traps are accepted as useful tools for monitoring adult carrot flies (Psila rosae), but they do have some shortcomings. One is that the catch level is very low, another is that they catch many other insect species and therefore servicing is laborious. For use in practical situations, where agricultural advisers have responsibilities for several crops, it is necessary to ensure, that monitoring tools are quick and easy to use. For yellow sticky traps this means modification of the trap in such a way, that they catch either more carrot flies or fewer other insects or both.

It has been shown earlier, that placing the traps close to a "Netlon" cylinder creates a situation, where carrot flies are attracted to the trap and net as they are to other obstacles such as trees, bolters or tall weeds (Philipsen,in press). To establish information on the significance of "Netlon" on the catch of carrot fly and other insects, trials were carried out, where net-protected traps were compared to unprotected traps.

MATERIALS AND METHODS.

Yellow sticky traps were arranged in carrot fields with unprotected traps alternating with net-protected ones along a row 10 to 12 m from the edge of the field and 5 to 7 m apart. At each end of the row an extra trap was placed as a " guardtrap". Five traps of each type were used. The protection consisted of a net hood, 50 cm high x 65 cm long, made from "Netlon" plastic netting with a mesh of 1.2 cm square. The net was placed over the trap in such a way that it could be seen from all directions since the bottom opening is oval, appr. 55 cm long and appr.30 cm wide.

Disposable orange plastic traps, 15 x 21 cm, (Rebell, E.F.A., CH-8820 Wadenswill, Switzerland) were clamped to iron stakes, just above the foliage and the net-hood hung over the trap and stake. Traps were normally serviced once a week, but during some periods more often.

Throughout the season, numbers of female and male flies were recorded together with the numbers of other insects in selected weeks. These insects were divided into groups, with emphasis being placed on the insects which, from experience,under Danish trapping conditions, interfere with ease of counting the catch of carrot flies.

Syrphids and other large Diptera are a nuisance due to their size and to their occasional occurrence in great numbers. During peak periods of flight, Syrphids can almost cover the traps. Furthermore, an individual specimen can cover a carrot fly caught on the trap. Smaller Diptera and Hymenoptera can also be a problem due to some resemblance to carrot flies.

During periods when Meligethes spp., are on flight, these species can cause difficulties for a number of reasons. The pollen beetles resemble the abdomen of carrot flies hereby confusing identification when servicing the traps. Within a few days or even hours, the traps can be covered with pollen beetles. Lepidoptera are also caught on the traps but not usually in great numbers. Nevertheless, the nets also seem to keep catches of butterflies at a lower level.

Trap orientation was investigated between 28/8 - 24/9, 1984. Three different arrangements were used; traps placed vertically and facing N-S and E-W, and laid horizontally. The numbers of flies in the hedge were assessed by trapping at an elevated point in the hedge near the carrot field, the main aim being to register trends in population changes.

RESULTS

Net protection

Trapping data from one site where the traps were situated in 1986 and 1987 are shown in Table 1. It can be seen that catches of carrot flies were as large on the net protected traps as on the unprotected traps during the main part of the growing season. Towards the end of the season there was a shift towards larger catches on unprotected traps especially in 1986, and further experiments are needed to validate this finding.

Table 2. also show selected catches of other insects from two sites ower different periods in the two years investigated. The numbers can only represent examples of the influence of the net protection. The actual influence depended on, what insect groups and species were active at any one time of the year. Nevertheless, the general trend is, that the catch of many insect groups was diminished, while catch of carrot flies during the main part of the second flight period was not negatively affected.

Trap orientation

Catches from traps in the orientation experiment show, that horizontally orientated traps caught fewer flies over the whole period, than the vertically placed ones, and can therefore be disregarded for practical purposes. Results from the period 28/8-3/9 are shown in fig. 1. Despite possible differences between N-S and E-W orientated traps during short periods, these are not of an order, that may influence the practical use of the traps.

Late in the year the traps were moistened by morningdew, which influenced their efficiency. Traps facing the sun dried up faster and therefore become more efficient a little earlier in the day than traps not facing the sun. A similar situation occurred throughout the season, when traps placed horizontally remained wet longer after rain than vertical traps.

Trapping in the canopy of a hedge gave very high catches, over some periods 10 - 20 times more carrot flies were caught on a single trap high in the hedge, than on 5 traps in the field 10 - 12 m from the hedge.

DISCUSSION

The experiments reported here illustrate the possibility of improving yellow sticky traps by making them more selective. The numbers of carrot flies trapped was not reduced by net protection, although the numbers of other insects trapped were reduced. The overall effect of using net-protected traps is best expressed by the experience of people using traps. They now regard yellow sticky traps as being more acceptable as a monitoring method following the introduction of net protection as a part of the standard trapping equipment used in Denmark (Esbjerg,Philipsen & Percy-Smith, 1987).

The choice of "Netlon" with mesh size 1.2 x 1.2 cm was a consequence of earlier tests, where it was found, that carrot flies were attracted to net cylinders with a mesh of 0.5 x 0.5 cm, but were caught in lower numbers inside the net than outside it (Philipsen, in press). By changing the net cylinders to ones with a mesh of 1.2 - 1.2 cm this difference in catch was eliminated (Philipsen, unpublished).

Orientation experiments did not show any immediate solutions in respect of making yellow sticky traps more efficient - except that the large catches high in the hedge could possibly be used to detect carrot flies at the beginning of their flight on localities with a low population level.

It is possible, that further selectivity can be achieved by changing the "environment" around traps. Different shapes and colours of netting and other mesh seizes could possibly give better results, but so far the results obtained have been good enough to be able to put the trap into practical use.

REFERENCES

Esbjerg,P., Philipsen,H.& Percy-Smith,A. (198x) The significance of carrot fly (Psila rosae) monitoring in Denmark. SROP/WPRS Bull. xxxxxxxxxxxxxxxxxxxxx

Philipsen, H. Integrated pest management in Danish carrot fields: Monitoring carrot fly (Psila rosae F.) by means of yellow sticky traps. In "Progress on Pest Management in Field Vegetables" EUR 10514; Ed: Cavalloro R. and Pelerents, C.; in press.

Table 1. Catches of carrot flies on yellow sticky traps during two seasons.

DATE	FREELY EXPOSED TRAPS 5 TRAPS	NET PROTECTED TRAPS 5 TRAPS	-N/N *
Strandholm 1986			
9/6-16/6	372	377	1
16/6-23/6	184	177	1
23/6-30/6	91	115	0.8
30/6- 7/7	46	83	0.6
7/7-14/7	23	21	1.1
14/7-21/7	18	19	0.9
21/7-28/7	7	8	0.9
28/7- 4/8	37	53	0.7
4/8-11/8	352	582	0.6
11/8-18/8	213	304	0.7
18/8-25/8	461	387	1.2
25/8- 1/9	561	516	1.1
1/9- 8/9	110	39	2.8
8/9-15/9	56	23	2.4
Strandholm 1987			
27/5- 1/6	32	30	1.1
1/6- 3/6	19	24	0.8
3/6- 9/6	92	87	1.1
9/6-11/6	39	45	0.9
11/6-17/6	18	20	0.9
17/6-22/6	9	12	0.8
22/6-29/6	23	34	0.7
29/6- 6/7	49	61	0.8
6/7-14/7	36	56	0.6
14/7-21/7	8	16	0.5
21/7-28/7	21	31	0.7
28/7-17/8 »	3	5	- -
17/8-31/8 »	3	12	- -
31/8-14/9 »	5	11	- -
14/9-21/9	26	20	1.3
21/9-28/9	56	53	1.1
28/9-7/10	1	1	- -

*) -N/N = fraction of insects on freely exposed traps in relation to insects on net protected traps.

») weekly catches from periods with low catches have been summarized.

Table 2. Examples of catches of insects on yellow sticky traps from two localities

	3 FREELY EXPOSED TRAPS			3 NET PROTECTED TRAPS			-N/N *
STRANDHOLM **N-W ZEALAND** **7-11/8 1986**							
Psila rosae	46	42	45	74	36	106	0.6
Syrphidae	50	54	65	6	9	12	6.3
Diptera › P.rosae	57	60	70	23	22	14	3.2
Diptera ‹ P.rosae	39	38	46	13	26	16	2.2
Meligethes spp	169	201	360	27	33	38	7.4
Hymenoptera parasitica › P.rosae	15	11	7	9	16	13	0.9
STRANDBY **South FUNEN** **2-9/9 1987**							
Psila rosae	2	0	1	1	0	2	1.0
Syrphidae	215	245	230	15	12	12	17.7
Diptera › P.rosae	51	29	39	35	22	20	1.5
Diptera ‹ P.rosae	850	750	550	110	120	160	5.5
Meligethes spp.	250	220	125	14	20	21	10.8
Hymenoptera parasitica ‹ P.rosae	15	11	19	15	37	27	0.6
STRANDBY **South FUNEN** **9-16/9 1987**							
Psila rosae	0	0	1	1	0	0	- -
Syrphidae	110	79	63	6	2	10	14.0
Diptera › P.rosae	53	38	42	15	9	21	3.0
Diptera ‹ P.rosae	250	260	370	100	75	110	3.1
Meligethes spp.	20	18	17	8	6	3	3.2
Hymenoptera parasitica › P.rosae	13	13	14	15	6	6	1.5

* -N/N = fraction of insects on freely exposed traps in relation to insects on net protected traps.

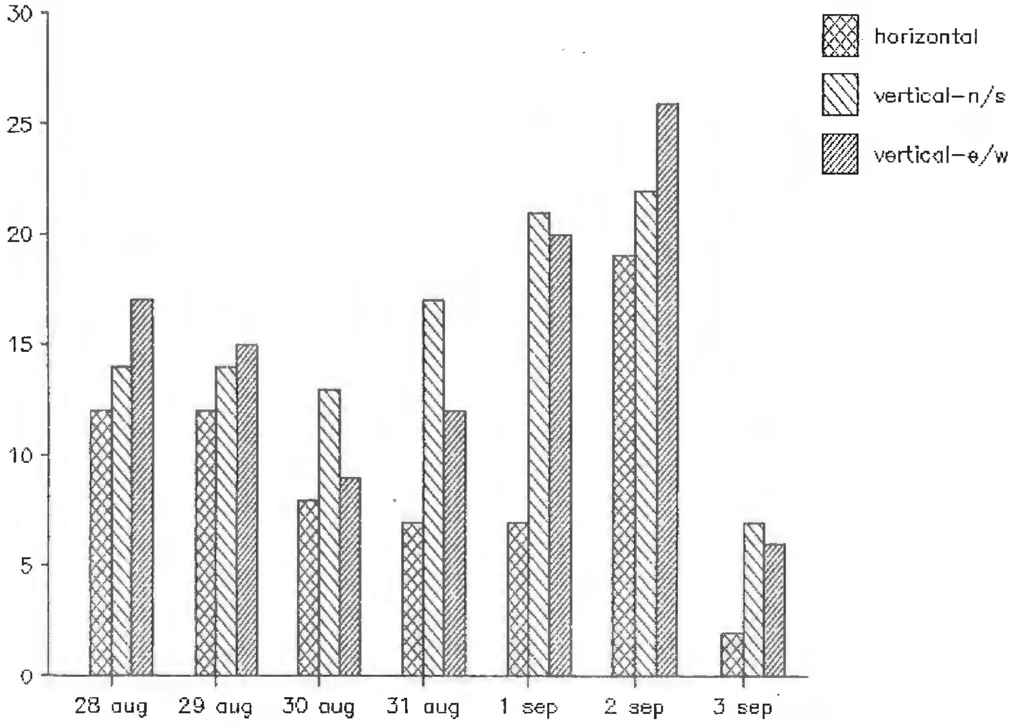


fig.1. Catches of carrot flies on traps orientated horizontally and vertically. Strandholm 1984. Each bar is the summarized daily catch from 6 traps.

THE SIGNIFICANCE OF CARROT FLY (PSILA ROSAE) MONITORING IN DENMARK

P. Esbjerg(1), H. Philipsen(2) and A. Percy-Smith(1)

1): The Research Centre for Plant Protection, Lottenborgvej 2,
DK-1800 Lyngby, Denmark

2): The Royal Veterinary and Agricultural University,
Bülowsvej 13, DK-1870 Frederiksberg C, Denmark

INTRODUCTION

The carrot fly (*Psila rosae*) is a regular pest of carrots in Denmark. Consequently, growers have for many years carried out treatments on a routine basis. Carrot fly used to be controlled by chlorinated hydrocarbons, especially Aldrin, until these were banned in 1963. Since then, organophosphorous compounds have been used. Diazinon (Basudin 40 W.P.) was approved for use in 1967, but until 1980, the most frequently used chemical was ethylparathion. Both chemicals gave varying results (Nøddegaard et al., 1968, 1969 and 1972), but, in general, those from Diazinon were the least variable. Considerable variations in performance had already been noted from using chlorinated hydrocarbons (Jørgensen, 1968). Parathion treatments were carried out throughout the season and were not based on any kind of field inspection or monitoring, but followed a fixed time schedule. The topic of discussion 10 years ago was whether treatments should be carried out at intervals of 8 or of 10 days. This often led to 8-10 (and in a few cases up to 16) parathion applications per crop, while a minority used 4 applications of diazinon. The treatments were applied as foliar spray, and, in the case of Diazinon, often with large quantities of water (800-2000 litres per ha) in order to get the chemical down to the roots of the carrot crop.

Despite the numerous treatments against the carrot fly, losses due to larval damage was still frequent. Taking the biology of the carrot fly into consideration the frequency of the chemical applications was clearly too high, in particular during mid-season between the two generations of adults. The farmers, however, responded to their fear of yield losses and carried out insurance applications obtaining better yields from this kind of chemical control than without it.

These details were important factors when planning the project "Integrated control of insect pests" (Esbjerg et al., 1983) using carrot flies *(Psila rosae)* and cutworms *(Agrotis segetum)* on carrots as a model. This project was carried out (1979-82) collaboratively by the Zoology Departments of the Royal Veterinary and Agricultural University (Agric. Univ.) and the Research Centre for Plant Protection (C. f. Plant Prot.). The project included development of monitoring methods, which was considered an important part of the effort to reduce the frequency of chemical treatments. It was obvious that organized monitoring could give information on population development and thus lead to an economically advantageous reduction in the frequency of treatments. According to the principles of Integrated Pest Management it was also considered desirable to minimize the side effects on the beneficial fauna.

As a part of the project, the monitoring of adult carrot flies by means of yellow sticky traps was started experimentally. During the following years the collaboration has been continued. However, the work at the Agric. Univ. was concentrated on further improvement of the trap (Philipsen, in press). The C. f. Plant Prot. took over the monitoring system from 1984, and since then monitoring has been handled on a contract basis between the C. f. Plant Prot. and farmers. An increasing number of the farmers regard monitoring as economically advantageous and environmentally necessary. The importance of this monitoring has been accentuated by the fact that according to a parliamentary decree from 1986 the general consumption of pesticides in Danish agriculture must be reduced by 25% over the next 4 years.

It is hoped that the following description may give a valuable account of the economic and environmental results which have been achieved by the carrot fly monitoring and warning system based on trial and error.

THE DANISH CARROT FLY MONITORING AND WARNING SYSTEM

During the experimental phase the traps used were mostly 20 x 20 cm yellow acrylic glass plates. During 1984-87, all the traps used were of the disposable 15 x 21 cm orange plastic type (Rebell, E.F.A., CH-8820 Wädenswill, Switzerland). At each locality to be monitored, 5 of these traps were placed in a line 10-12 m into the field and parallel with the edge and 5-7 m apart. Choosing a site for the traps can be difficult, but, as a rule, the traps were situated in a part of the field regarded as a high-risk area, normally the most sheltered part of the field. The traps were purchased by the farmers from the C. f. Plant Prot. at a price (1987) of 600 Dkr. (+ VAT) for 1 set of 50 (= 5 for each of 10 weeks). This number of traps was designed for monitoring the 2nd generation as few growers monitor the 1st generation. The farmers' payment include instructions, registration forms, assessment of catch results and advice. At present, an extension officer or other skilled staff service the traps once a week and send results to the C. f. Plant Prot. A recent improvement of the traps has been made by enclosing them within a green netlon, which prevents catching a lot of other insects (Philipsen, 1987). This resulted in a considerable reduction in the time necessary for counting carrot flies in 1987. Thus the servicing of some 50 localities has been carried out by one of the authors (Alex. Percy-Smith), temporarily employed by two companies who process carrots. This provided the opportunity of gathering valuable information for further development of the system. The servicing of so many trap sites by one person has been made possible by the use of green nets. Use of sticky traps is only part of the evaluation of each locality. Servicing by Alex. Percy-Smith has made possible more detailed observations and thus contributed to a better interpretation of catch in relation to each locality.

The catch results from each single farmer are used in conjunction with a set of farm data (soil type, rotation, crop variety, wind exposure, etc.) sent in to the C. f. Plant Prot. at the start of the season. With this background advice is given to him. A more general warning, for farmers who do not participate in the monitoring system, based on analysis of the results from the individual farms, can also be given. These are issued as Plant Protection Bulletins ("Planteværnsmeddelelser").

During the last 4 years a preliminary set of guidelines has been worked out based on **weekly catches in 5 traps**. The catch levels are expressed as numbers of **flies/trap/day** (Table 1):

Table 1:
Guidelines used as the basis for advice on carrot fly control based on monitoring with orange sticky traps. The catch levels are expressed as numbers of flies/trap/day.

Catch levels:	
A) Lower than 0.3	No need for control (except under exceptional conditions)
B) 0.3-0.5	Normally no need for control except under special conditions
C) 0.5-1.0	Control may be necessary
D) Above 1.0	Control is required

For the final decision making, other factors are also taken into consideration. If there is a history of severe damage, or if the locality is suitable for the carrot fly because of shelter, treatment may be recommended at the lower catch level. In addition, there has been a degree of uncertainty as to the significance of the cumulative effect of continuous catches just below the threshold. In these cases, a recommendation for treatment was made.

When a farmer is advised to carry out treatment, temperature is taken into account when determining the timing of the treatment.

RESULTS OF THE DANISH CARROT FLY MONITORING AND WARNING SYSTEM

Only 14 farmers participated in the monitoring scheme when it started in 1984, but since then the number has increased (Table 2). The considerable increase from 1986 to 1987 is due to the collective participation of nearly 50 farmers in two carrot growing areas which are coordinated by two processing factories.

Table 2:

Danish carrot fly monitoring and warning system:

	Active participants	Spraying recommended	% Not spraying at all
1984	14	5	64%
1985	24	10	58%
1986	33	10	70%
1987	96	24 (+7)	68%

As was found during the initial project period (Philipsen, 1983), monitoring has also revealed important local differences both in the size of catch and the time of peak catch within a single year (Fig. 1). In addition, the time of peak catch varied considerably and from year to year (Fig. 2). In some years, e.g. 1984, the peaks generally occurred early in the year, and in others, e.g. 1987, they occurred later (Fig. 2).

The year-to-year variation is also reflected in the proportion of localities with continuously low catches (Fig. 3). The weeks with low catches occurred during the period between the 1st and the 2nd generation flights. At a few localities almost continuous flight was recorded (Fig. 1 - Samsø), and in these localities the number of flies caught was exceptionally high.

On the basis of catches, advice was given that only a limited proportion of the farmers should treat their carrots (Table 2). Harvest results are not yet available for the 1987 crop. Questionnaires sent to farmers in 1984, 1985 and 1986 revealed only three cases of attacks against which control measures should have been taken. These three cases should be compared to the total of 46 growers who were advised not to treat and 25 farmers who should treat (Table 2).

COST-BENEFIT ANALYSIS OF THE CARROT FLY MONITORING

The value of the monitoring may be illustrated by the following example of a cost-benefit analysis based on an average field size of 6 ha:

Cost of monitoring per site:

Traps, nets etc.	600 kr.
Servicing of traps	1400 -
	2000 kr.

Cost of treatment with Diazinon = 500 kr./ha

Example 1:

Cost of 1 treatment (6 ha)	3000 kr.
Cost of monitoring	2000 -
Benefit due to reduction of 1 treatment	1000 -

Example 2:

Cost of 3 treatments (6 ha)	9000 kr.
Cost of monitoring	2000 -
Benefit due to reduction of 3 treatments	7000 -

If the farmer avoids a 10% yield loss by carrying out one well-timed treatment, the gain will be as follows:

Mean yield of carrots (according to the statistics of the Danish Growers' Cooperative Marketing Organization, GASA)	50 tons/ha

Producer's price:
A) 0.50 kr./kg for processing carrots
B) 1.50 kr./kg for fresh market carrots

A) 6 ha x 50 tons/ha x 0.50 kr/kg x 10%	15,000 kr.
- Monitoring costs	2,000 -
- Spraying costs	3,000 -
Net gain	10,000 kr.

The corresponding net gain for fresh market carrots would be 40,000 kr.

To each of these net gains should be added 9,000 kr. saved by omitting 3 treatments. Thus the total gains are 19,000 kr. and 49,900 kr., for processing and market carrots respectively.

It should be noted that damage has often been seen in spite of 4 routine treatments of Diazinon per crop.

Four routine treatments per crop may also be used as a basis for estimating the environmental benefit (Table 3) where 1987 is used as an example, and all the fields are assumed to be of equal size.

Table 3

Environmental benefit by reduction of treatments in 1987 among 96 active participants in the carrot fly monitoring and warning system.

Treatments in case of routine spraying:
96 (growers) x 4 (treatments) = 384 (= 100%)

Number of treatments applied	by number of growers	Reduction (4 - No. of treatments x growers)
0	55	55 x 4 = 220
1	32	32 x 3 = 96
2	6	6 x 2 = 12
3	1	1 x 1 = 1
4	2	-
	Total	329

$$\frac{329 \quad x \quad 100}{384} = 86\%,$$ which constitutes the reduction.

DISCUSSION

From a scientific point of view the monitoring and warning system described has several shortcomings. It is difficult to standardize the catching procedure, which in principle should take place in the most open and uniform centre of a field, according to the distribution found by (Wright and Ashby, 1946). The difference between the windward and leeward side of a shelter belt has been described in connection with the Danish project on carrot pests (Philipsen, 1983). In practice it is desirable to place traps for monitoring on the leeward side of shelters to obtain the highest possible catch. Because of the generally low catches on traps in the crop, interpretation may be difficult, as was discussed by Münster-Swendsen (1983), who stressed the importance of increasing trapping efficiency to obtain a better basis for decision making for carrot fly control. An obvious way of improving the catch might have been the use of more or larger traps. However, this possibility may be ruled out as it would make the monitoring unacceptable to the farmers. Farmers and extension officers have, nevertheless, accepted Philipsen's (1987) green netlon-protected traps which reduce the catch of other insects. Thus it may be concluded that the Danish carrot fly monitoring and warning system is, in many respects, a compromise between scientific and practical considerations.

For instance, preliminary thresholds based on limited examinations of the relationship between the total catch and the damage level (Philipsen, 1983) are used for making decisions about control measures. They should, therefore, be regarded as guidelines rather than thresholds, their practical value being assessed in a large-scale trial and error experiment carried out over a number of years with the aim of creating a more solid basis for the warnings. In order not to lose the farmers' confidence, and so create difficulties for the monitoring system in general, an important principle for both of the collaborating institutions has been to consult each other before taking any decisions but also to recommend treatment if there was any doubt about the necessity of control.

As the system is more likely to result in too many treatments rather than too few, the results shown in Table 2 are surprising because 60-70% of fields monitored over 4 years needed no treatment. This leads to the conclusion that 3-4 treatments are only necessary at a few localities and that 1-2 treatments are necessary in a limited number of fields. Of course, the situation could change if the 4 years had included one or two years with generally high population levels of carrot flies. However, such years are unusual, and it may be concluded that, when a period of many years is considered, the monitoring and warning system may also contribute to improvements in farming economy and decreased environmental stress. The principles of the system may also be of value in other countries, and should be promoted through joint projects under the auspices of the IOBC.

LITERATURE

Esbjerg, P., Jørgensen, J., Nielsen, J. K., Philipsen, H., Zethner, O. & Øgaard, L. (1983): Integreret bekæmpelse af skadedyr. Tidsskr. Planteavl 87: 303-355.

Jørgensen, J. & Thygesen, Th. (1968): Gulerodsfluen, *Psila rosae* F. Tidsskr. Planteavl 72, 1-25.

Münster-Swendsen, M. (1983): Sampling pest insects. Design and evaluation in connection with integrated pest management. Tidsskr. Planteavl 87: 365-369.

Nøddegaard, E., Hansen, T. & Rasmussen, A. Nøhr (1968): Afprøvning af plantebeskyttelsesmidler 1967. Tidsskr. Planteavl 72: 273-321.

Nøddegaard, E. Hansen, T. & Rasmussen, A. Nøhr (1969): Afprøvning af plantebeskyttelsesmidler 1968. Tidsskr. Planteavl 73: 488-548.

Nøddegaard, E. & Hansen, K. E. (1972): Forsøg med plantebeskyttelsesmidler i landbrugs- og specialafgrøder 1971. Tidsskr. Planteavl 76: 658-681.

Philipsen, H. (1983): Brug af gule limplader til vurdering af risiko for angreb af gulerodsfluen. Tidsskr. Planteavl 87: 389-397.

Philipsen, H. (in press): Integrated pest management in Danish carrot fields: Monitoring carrot fly (*Psila rosae* F.) by means of yellow sticky traps. Paper presented at the EEC/IOBC meeting on Integrated Pest Protection in field vegetables, Rennes, France, 20-22 November 1985.

Philipsen, H. (1987): Monitoring techniques for the carrot fly (*Psila rosae* F.). IOBC/WPRS Bulletin.

Wright, D. W. & Ashby, D. G. (1946): Bionomics of the carrot fly (*Psila rosae* F.). I. The infestation and sampling of carrot crops. Ann. appl. Biol. 33: 69-77.

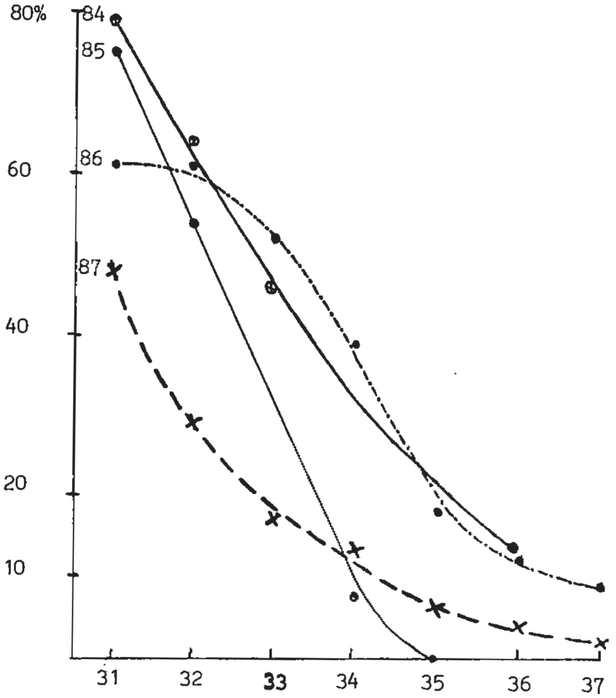


Fig. 3: Annual variation in carrot fly catch on orange sticky traps illustrated by the weekly percentages which have not caught fly since the first generation (curves fitted by eye). In week No. 31, 1985, the catch was zero at 75% of the trapping localities while in week No. 35 it was 0 when fly were caught in all other trapping localities.

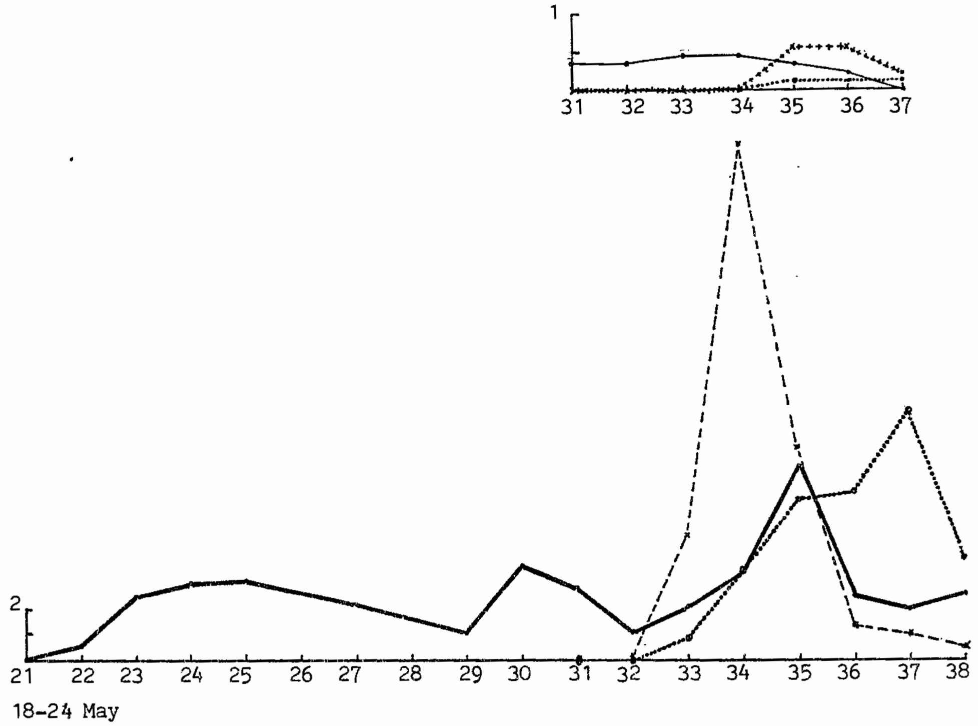


Fig. 1: Geographical variation in carrot fly catches on orange sticky traps at 6 Danish localities in 1987.
The upper curves show low catches while the lower show high catches. At one locality, Samsø (lower curves: Solid line) there was a continuous high catch throughout the season.
Abscissa: Week numbers.
Ordinate: Flies per trap per day.

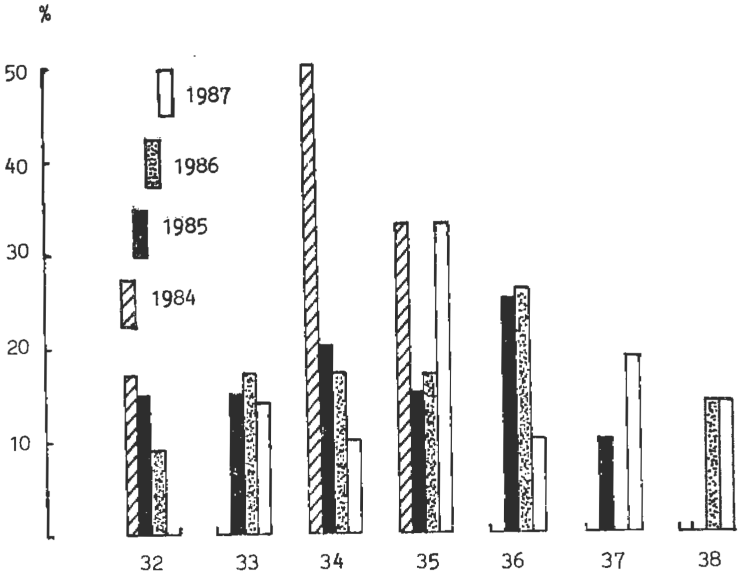


Fig. 2: Annual variation in the occurrence of peak catch of carrot flies on orange sticky traps. Only localities with a clearly defined peaks are included (1984: n = 6, 1985: n = 20, 1987: n = 21). Each column shows the percentage of localities with peak catch in the particular week. E.g. 50% of clearly defined peaks in 1984 occurred in week number 34.

MONITORING POPULATIONS OF THE CARROT RUST FLY, PSILA ROSAE, FOR SUPERVISED CONTROL

H. DEN OUDEN AND J. THEUNISSEN
Research Institute for Plant Protection (IPO)
Wageningen, the Netherlands

SUMMARY

Monitoring the carrot rust fly Psila rosea (L.) in open polder areas has been used to develop a supervised control system for use in carrot crops. Using this approach, the application of insecticides can be avoided on a considerable part of the carrot acreage. Catches of Psila rosae were correlated with distances from shelter barriers and with percentage of infested carrots.

INTRODUCTION

The severity of attacks by the carrot rust fly, Psila rosae, varies considerably with weather conditions and with the position of shelter barriers. When the population density is high, soil treatment with insecticides at sowing time and/or spraying of the crop rarely reduces damage to a satisfactorily low level.

The low numbers of flies of the first generation of P. rosae compared to the often high numbers during late summer and autumn raise doubts about the necessity of the soil treatment in the spring. This treatment has consequences for the economics of producing the crop and for the population level of the natural enemies of the fly.

The value of spraying in late summer is affected both by the safety of the insecticide applied and by the market price of the carrots. Being able to monitor the size of P. rosae populations and hence predict the degree of damage likely are both important decisions in crop protection.

Finally, the threat of the fly developing resistance to currently-applied insecticides or the selection of bacteria that quickly can break down soil insecticides need to be considered carefully when applying insecticides to control this pest.

MATERIALS AND METHODS

Monitoring carrot rust fly can be carried out either by a depot system or by trapping flies in the field. Although the former gives good information about the time of emergence, the physiological conditions of the population in the depot is rarely the same as that in the field (van 't Sant, 1961). Trapping by sticky traps Freuler et al. (1982) is more promising, but is expensive on a field scale.

In our experiments we used an adapted version of the yellow sticky trap of Berlinger (1980), which consisted originally of the lid of a polymer Petridish painted yellow into which the sticky bottom of the dish was inserted. For our tests these dishes were fixed in varying numbers onto a 16 mm diam. polyvinylchloride (PVC) pipe, using aluminum rods forced into narrow holes in the pipe (Fig. 1).

The materials are very cheap. The polymer pipe with rods and yellow dish lids can be used for many years and the sticky bottoms can either be inspected easily and quickly in the field, or sent to an inspector's address after covering them with lids. After inspection they are discarded. The application of glue to bottoms and lids is also easy to carry out and cheap.

The traps were placed in the carrot fields with the sticky plates just above the foliage of the crop. When the plants grew higher, the length of the pipe was increased by an additional piece of PVC-pipe (25 cm).

To investigate the influence of barriers on the presence and flight activities of P. rosae, the traps were placed in varying numbers (10-20) in rows parallel to hedgerows or groups of trees etc. and in a row perpendicular to these shelter barriers. Traps were spaced 3 m apart and each supported two sticky dishes. In this way, a reasonable area of sticky surface was presented in the field and hence the increase and decrease in the numbers of flies per trap between sites could easily be observed in the perpendicular rows. A more representative sample might have been obtained with a grid of traps, but the amount of work required per field would have been unacceptable, particularly in the open polder areas, where carrot fust fly is often present in only extremely low numbers.

OBSERVATIONS

In the years 1983-1987 observations were made in open polders and in more sheltered areas. In these years, particularly in early summer, the flights of P. rosae were poor. More flies were caught generally at the times of the second and/or third generations. Experiments in the polders and in open areas where rows of traps were placed perpendicular to each other provided information about the occurrence of adults P. rosae at different sites in the field. Fig. 2 shows the results of these experiments. The catches in the series parallel to the shelters have been averaged and so the few records on distance zero (actually about
1 m into the carrot field) have a weight that is 10-15 times higher than that of the records from the single catches in the other traps. A negative correlation is shown between the distance of the traps from the trees or shrubs and the numbers of flies caught.

Table 1 shows the results of individual experiments during 1983-1987. A decrease in the numbers of flies caught within the first 20 m of the crop is evident and there is a good correlation between the percentages of infested carrots in the crops and the numbers of flies caught. In 1987 relatively high numbers of flies occurred in the polder experiment. These flies crossed the 20 m area alongside the shaggy ditch, but as in earlier seasons, the infestation further into the field was relatively low.

A separate experiment was carried out in a sheltered area using three double dishes alternately directed North-South or East-West. The numbers of flies caught averaged 3.1/trap in week 25. These traps were 2.5 m apart in two rows parallel to two hedgerows perpendicular to each other at a distance of 40 m, forming a rectangle with them. There was an even distribution of the flies in this experiment.

In week 25 + 26, twice as many flies were caught on the lowest of the three dishes ($P=0.05$). In September (weeks 34 + 35) when the foliage was fully grown, similar numbers of flies were caught on all dishes.

Table 1. Numbers of carrot flies caught on yellow sticky traps at different distances from shelter barriers sited in a polder area together with the percentage of infested carrots.

Average distance from object (m)	Week	Flies caught per trap per week	Percentage infested carrots	Date of sampling	Composition of shelter barrier
5	36-37 1983	0.8	16	8 Oct.	Trees and shrubs
10		0.5	11		
30		0	2		
50		0	-		
5	35-38 1984	0.23	10	10 Oct.	~~Trees~~ and shrubs
15		0.1	6		
20		0.05	4		
30		0	3		
5	35-39 1985	0.5	24	30 Sept.	Trees and shrubs
15		0.36	4		
30		0.2	3		
5	35-39 1985	0.56	45	30 Sept.	Road and ditch
15		-	16		
5	35-39 1985	0	0	30 Sept.	Wheat
3	33-38 1987	0.8	47	30 Sept.	Road and ditch
6		0.3	17		
15		0.4	9		
24		0.3	4		
36		0.3	6		
45		0.4	5		
54		0.3	1		

DISCUSSION

With the few figures available concerning the percentage of carrots infested, a curve has been fitted to the data (Fig. 3). It might be necessary to modify this curve when more data become available.

The data of this figure have been collected during late August and early September. At this time growers are faced with a choice either to harvest the crop within two weeks or to spray it and wait a further two months when it will be sufficiently free of insecticide residues to make it suitable for harvest.

Catches early in the season were generally low. Therefore the value in economic terms of a soil-applied treatment, particularly in the cold polder areas, is questionable and can only be considered a safeguard in those years when a high number of flies occurs during the first generation.

A promising approach would to be sow late to avoid the first generation and the corresponding late harvest then makes it easier to spray the crop two months before harvest. The 7% infested carrots that cannot be exceeded if crop quality is to be retained occurs at an average figure lower than 3 flies per ten traps per week.

According to Figure 3, therefore, a minimum of ten traps should be placed in the field at spots where the risk of carrot rust fly attack is high. The yellow traps should be placed close to the top of the foliage, a result confirming the earlier findings of Freuler et al. (1982). More information should be obtained about the influence not only of hedgerows but of all other habitats bordering carrot fields. The shelter effect from maize fields, a fodder crop increasing in importance in the Netherlands, and often remaining in the field well into the autumn, will represent a threat as serious for supervised control as hedgerows and other barriers already mentioned.

Generally, sprays should be restricted to a 20 meter's zone (representing one machine run) alongside such barriers but only when the rest of the field is in an exposed windy site and when there is no serious carrot fly infestation in the immediate vicinity.

The trapping system described can be used either invidually by well-trained farmers or by teams establishing scouting systems e.g. similar to those being developed in Switzerland. In both situations the time required for manufacturing and placing the traps, walking the crop and collecting the catches will determine the costs.

ACKNOWLEDGEMENTS

Thanks are due to Dr. C.H. Booij for mathematical treatment of the data mentioned in Fig. 2 and Fig. 3.

REFERENCES

BERLINGER, M.J., 1980. A yellow sticky trap for white flies, Trialeurodes vaporariorum and Bemisia tabaci (Aleurodidae). Entomologia Experimentalis & Applicata 27(1980): 98-102.

ESBJERG, P. JORGENSEN, J. NIELSEN, J.K., PHILIPSEN, H., ZETHNER, O., og OGAARD, L., 1983. Integreret bekaempelse af skadedyr. Tidsskrift før Planteavl 87: 303-355.

FREULER, J., FISCHER, S. and BERTUCHOZ, P., 1982. La mouche de la carotte, Psila rosae Fab. (Diptera, Psilidae) II Mise au point d'un piege. III Avertissment et seuil de tolerance. Revue Suisse Viticulture Arboriculture Horticulture 14: 137-142, 275-279.

SANT, E. VAN 'T, 1961. Levenswijze en bestrijding van de wortelvlieg (Psila rosae F.) in Nederland. Verslagen Landbouwkundig Onderzoek nr. 67.1, Wageningen 1961, pp. 131.

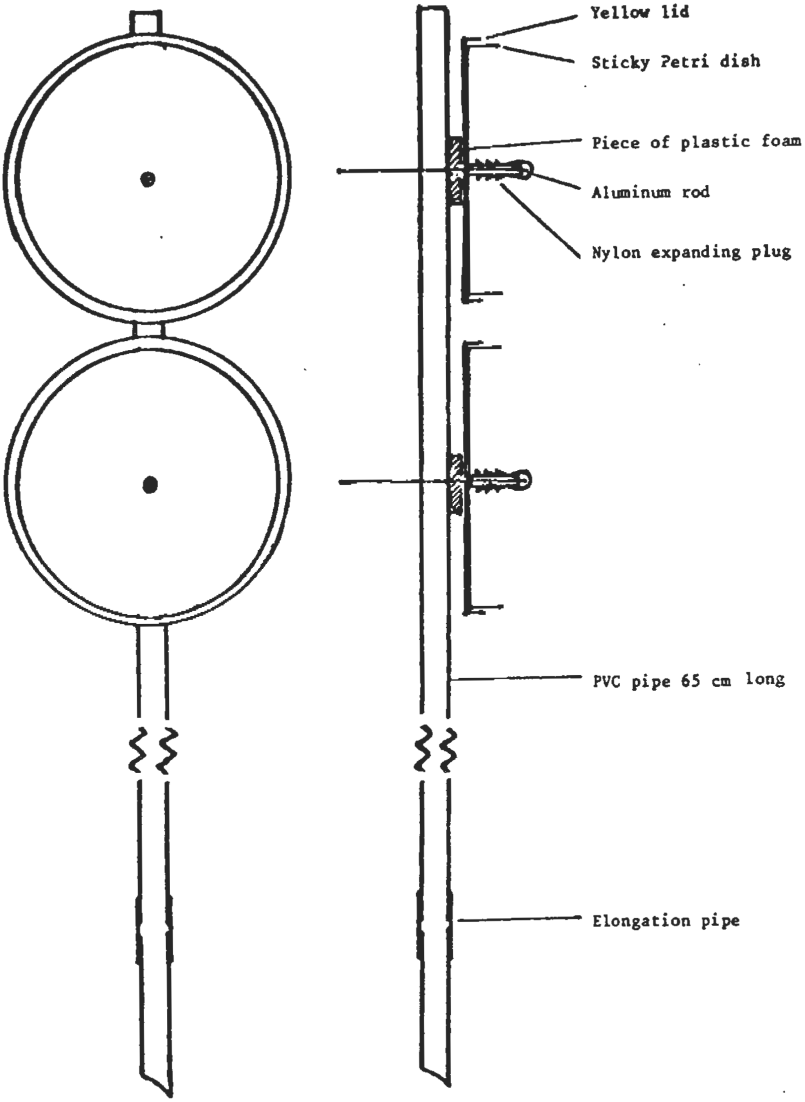


Fig. 1: Scheme of modified Berlinger trap to a Scale of 1 to 2.

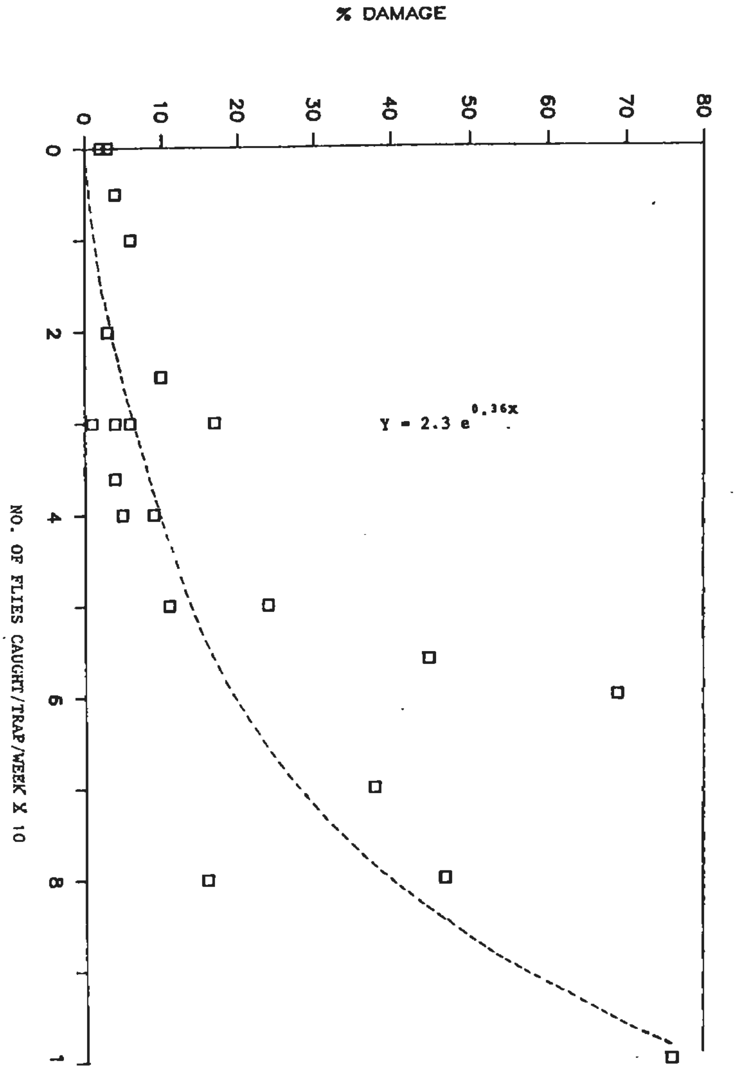


Fig. 3: Relationship between the numbers of <u>Psila rosae</u> caught on yellow sticky traps and the percentage of infested carrots.

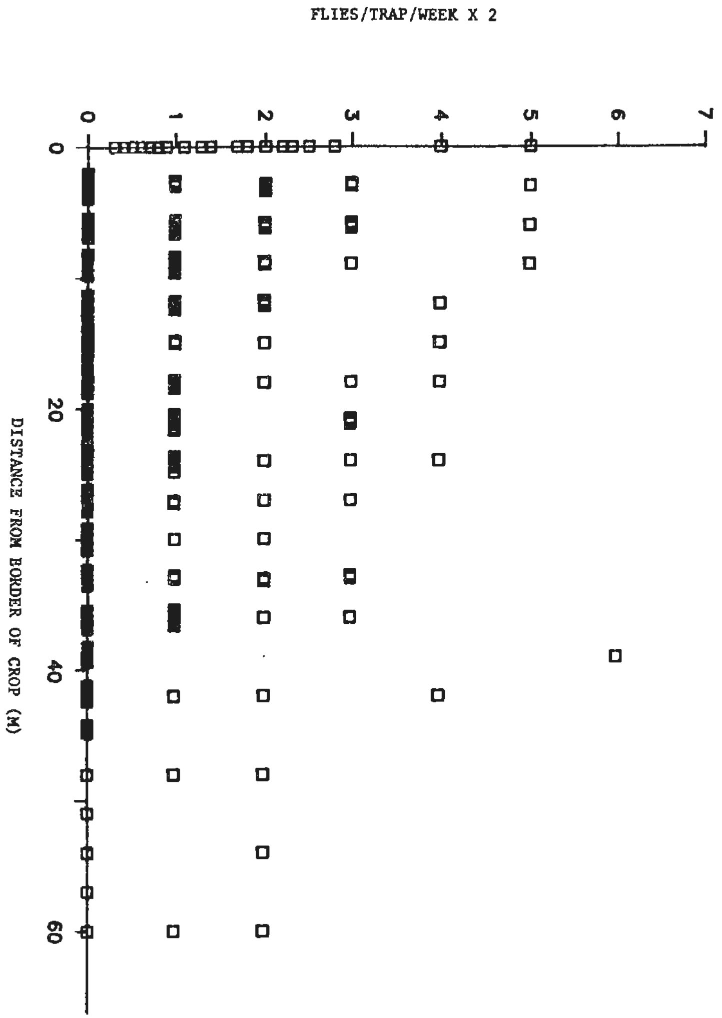


Fig. 2: The relation between the numbers of P. rosae caught and the distance of the traps from shelter barriers in a polder area. Catches at zero distance are averages of 12-15 trappings.

NON-INSECTICIDAL CONTRIBUTIONS TO AN INTEGRATED PROGRAMME FOR THE PROTECTION OF CARROTS AGAINST CARROT FLY

BY P.R. Ellis and J.A. Hardman

AFRC Institute of Horticultural Research, Wellesbourne,

Warwick, CV35 9EF, Great Britain

SUMMARY

Several alternative methods are being investigated at Wellesbourne to reduce the use of insecticides for the protection of carrots against carrot fly. Carrot cultivars with resistance to carrot fly offer an environmentally-acceptable method of reducing the growers' dependence on insecticides. Several sources of resistance have been identified in commercially-acceptable cultivars and in wild relatives of carrot and are being exploited in collaborative programmes with seed companies. The resistance complements cultural and insecticidal control methods currently used against this pest.

Benefits of the careful choice of sowing and harvesting dates have been demonstrated. Crops sown to avoid first generation attack suffered little damage. Delaying sowing by 2-3 weeks reduced pupal production 20-fold on a susceptible cultivar. The combination of a partially-resistant carrot cultivar and a 2-3 week delay in sowing resulted in a 100-fold reduction in pupae.

Plastic film covers over a carrot crop reduced first generation carrot fly damage. A crop covered for four weeks during late May and early June suffered little carrot fly damage and produced roots twice as heavy as an unprotected crop. The integration of non-chemical methods into a programme of carrot fly control is discussed.

INTRODUCTION

As pressures increase to reduce the amounts of insecticide applied to crops, more effort is being directed towards alternative measures to supplement or replace insecticides. For the carrot fly, Psila rosae (F.), a wide range of alternative measures is being explored at Wellesbourne. These include the re-evaluation of some practices, outlined by Whitcomb (1938) fifty years ago, as well as the development of new approaches. These approaches need to be tested under present-day commercial conditions, particularly as crop husbandry has changed considerably over the years. For example, in the UK there has been a tendency for the mid- and late-maturing Chantenay and Autumn King types to be replaced by either Berlicum or Nantes type carrots which may be sown at more or less any time of the year. Thus, carrots at a suitable stage of growth may be available to carrot fly in all months the pest is active.

This paper describes three non-insecticidal aspects of protecting carrots against carrot fly investigated at Wellesbourne - plant resistance, choice of cropping schedules and plastic film mulches - and discusses their role in an integrated plant protection programme.

EXPERIMENTS

Resistance in carrots and related species to carrot fly attack

1. Resistance in carrot cultivars and breeding lines

Using techniques devised at Wellesbourne (Ellis, Wheatley & Hardman, 1978; Ellis, Freeman, Dowker, Hardman & Kingswell, 1987), 238 carrot cultivars and breeding lines were screened for resistance (Table 1).

Table 1: Screening of 238 carrot cultivars for resistance to carrot fly at Wellesbourne

Group	No. of cultivars	Group	No. of cultivars
Amsterdam	5	Forage	15
Nantes	49	Japanese	21
Chantenay	40	Indian	5
Autumn King	30	Guerande	4
Danvers	6	Middle Eastern	14
Berlicum	9	F_1 hybrids	17
Imperator	3	Miscellaneous	16
Long Orange	4		

Fifteen of these possessed some resistance (Ellis, Hardman, Jackson & Dowker, 1980; Ellis, Hardman & Dowker, 1982a & b) and certain of these partially-resistant cultivars performed consistently when tested at 12 sites in Europe (Ellis & Hardman, 1981)and during five seasons at Wellesbourne (Ellis, Freeman & Hardman, 1984). This partial resistance is believed to be due mainly to antibiosis (Guerin, Gfeller & Stadler, 1981; Ellis, Freeman & Hardman, 1984) and can contribute to carrot protection by enabling the dose of insecticides required to be reduced (Thompson, Ellis, Percivall & Hardman, 1980). Attempts to increase resistance in the cultivar 'Long Chantenay', by recurrent selection were not successful (Ellis, Dowker, Freeman & Hardman, 1985). However, a slight response to selection in the partially-resistant Nantes cultivar 'Sytan' has been demonstrated at both Wellesbourne and in the Netherlands. The most promising selections were multiplied and are being evaluated at several sites in 1987.

The cultivar 'Sytan' was also used in a single seed descent programme to produce a range of carrot inbreds. Following four generations of inbreeding in the glasshouse the first inbreds were screened for carrot fly resistance in the field at Wellesbourne in 1987. Twenty-four of these lines were significantly less damaged than the partially-resistant cv. 'Sytan'.

To exploit these new lines, a joint breeding programme has recently been set up between four British seed companies and the IHR, Wellesbourne.

2.Resistance in umbelliferous species

More than 100 umbelliferous species were tested at Wellesbourne to identify potential sources of resistance to the pest. The plant species were collected from all over the world and a special effort was made to obtain Daucus species since, in breeding programmes, these offer the only chance at present of hybridisation with the cultivated carrot Daucus carota L.. Of the umbelliferous species tested, fifteen failed to support the pest while others were better hosts than cultivated carrot (Hardman & Ellis, 1982).

Three Daucus species, D. capillifolius Gilli, D. glochidiatus (Labill.) Fisch. Mey et Ave-Lall and D. pusillus Mich. supported few carrot flies. Daucus capillifolius has been the focus of breeding work. Crosses have been made between D.capillifolius x D.carota and progenies with carrot-like roots screened for resistance to carrot fly in the field. The least damaged progenies have been seeded. These procedures of screening, selection and seeding have been conducted over several generations and the lines produced shown to possess a higher level of resistance than that which exists in any partially-resistant commercial carrot cultivar (Ellis, Hardman, Dowker, Cole, Horobin, Mayne, Rollason and Jukes, 1987) The other two resistant species, D. glochidiatus and D. pusillus do not cross with cultivated carrot by known conventional means.

Combination of partial resistance and cropping schedules

In certain insect/crop situations, careful choice of sowing and harvest dates can reduce pest damage to a minimum (Metcalf & Flint, 1939). It has been known for 175 years that carrot fly damage from the first generation can be reduced considerably by choosing an appropriate sowing date. This type of cultural control was first discovered by Henderson (1814) in 1807 and has been recommended for the last 80 years by the Ministry of Agriculture, Fisheries and Food in Britain (Anon., 1905).

In 1983 and 1984/85 experiments were done at Wellesbourne to use a partially-resistant cultivar in combination with specific sowing and harvesting dates. A combination of five sowing dates and seven harvest dates were compared using the partially-resistant cultivar 'Sytan' in plots alongside the highly susceptible carrot 'Danvers Half Long 126'. Only four sowings produced carrots of a marketable size, the fifth was drilled too late (10 August) in the season. Production of carrot fly pupae was consistently lower on 'Sytan' than 'Danvers' (Table 2).

Table 2: Carrot fly pupal production on carrots grown at Wellesbourne in 1984/85. Assessments made in March 1985

Sowing date	Numbers of pupae/row*		Mean numbers of pupae per 100 g root*	
	'Sytan'	'Danvers'	'Sytan'	'Danvers'
9 April	12	95	0.3	5.8
9 May	40	215	0.8	4.4
12 June	2	6	0.2	0.5
9 July	14	26	0.5	0.7
10 August	4	9	1.1	2.9
L.S.R. (P = 0.05)	3.8		4.84	

* Values back-transformed from log-transformed data

Sowing the crop in June to avoid first generation attack decreased the number of pupae produced on 'Danvers' by about 10-fold when compared with earlier sowings (Table 2). On all assessment dates, the partially-resistant cv. 'Sytan' was less damaged than the susceptible 'Danvers'. The reduction of carrot fly larvae on 'Sytan' compared with 'Danvers' ranged from 33 to 95%. Nine combinations of sowing and lifting dates provided more than 80% marketable roots of 'Sytan' compared with only three for 'Danvers' (Table 3).

Table 3. The combination of partial resistance and choice of cropping schedules in the reduction of carrot fly damage. Percentage marketable roots of cvs 'Sytan' (S) and 'Danvers Half Long 126' (D). Values < 80% have been omitted for clarity.

Sowing date	Harvest date									
	16 Aug		18 Sept		15 Oct		8-14 Nov		10-17 Dec	
	S	D	S	D	S	D	S	D	S	D
9 April	100	100	94	-	87	-	-	-	-	-
9 May	-	-	84	-	-	-	-	-	-	-
12 June	-	-	-	-	95	97	97	81	91	-
9 July	-	-	-	-	-	-	89	-	-	-
10 Aug	-	-	-	-	-	-	-	-	78	-

More than 90% of 'Sytan' roots grown from a June sowing were marketable in December and fewer insects were produced at the end of the season on these roots than on those sown earlier (Table 2). The combination of partial resistance with specific sowing and harvest dates offers some potential for the production of marketable roots even in areas where carrot fly is a severe problem.

The use of plastic film covers to reduce carrot fly damage

In 1894, Slingerland stated that the protection of brassicas and radish from cabbage root fly attack with cheese-cloth screens or fine netting was a 'sure preventive but must be applied early before the flies emerge and be kept on during nearly the whole season'. However, this method was only practicable for small areas or for protecting a few selected plants. In recent years in the UK there has been an increase in the area of vegetable crops grown under plastic covers. Such covers are used to extend the cropping season to reduce imports and also to produce early crops which command high prices (Anon., 1984a). Systems developed for growing early carrots under plastic film covers (Anon., 1984b) have proved profitable. The areas of carrots grown in this way increased from zero in the late 1970's to more than 2000 ha in 1986.

At Wellesbourne we have investigated the use of plastic film covers in protecting carrots from carrot fly attack. Cv. 'Sytan', a partially-resistant carrot, was sown in 4-row beds on 25 April 1986 and treated with a pre-emergence spray of herbicide. On 12 May the beds were either covered with a perforated plastic film or left uncovered. On 12 June the film was removed from the beds and the plots were hand-weeded. Carrots were lifted on four occasions between July and November to assess carrot fly damage. Carrot fly activity was also monitored throughout the season using water traps.

The trapping indicated that > 95% of the first generation carrot flies were caught during the last ten days of May and the first two weeks of June, the period when the plastic film covered the treated plots. By the time the first carrots were of marketable size in August, those grown under plastic film weighed almost twice as much as those grown in the open (Table 4). In addition, a reduction in carrot fly damage, resulting from protection from attack with the plastic film, was maintained over the four harvesting occasions even though the benefits provided by the plastic film covers diminished as the season progressed (Table 4). This experiment indicated the potential of the covers for protecting carrot crops from early carrot fly attack.

Table 4. Plant weight and carrot fly damage levels on carrots grown under plastic film covers at Wellesbourne in 1986

Harvest date	Plant root weight		% undamaged roots	
	Protected	Unprotected	Protected	Unprotected
16 July	17	7	98	72
20 August	46	26	72	44
8 October	71	55	53	33
17 November	96	67	39	11

DISCUSSION

It has been possible in field experiments to demonstrate the value of non-insecticidal methods in reducing carrot fly damage. To apply these methods on a commercial scale may not be so straightforward. Present markets require high standards of crop protection and alternatives to insecticides must offer equally high standards or complement reduced doses of insecticide to produce the desired result.

Although resistant cultivars could be the easiest of the alternative measures to include in an integrated crop protection programme there are several problems. Growers expect new cultivars to be immune from attack and it has been difficult to convince them of the potential value of partial resistance. The resistance should, ideally, be available in a wide range of cultivars and therefore it will be advantageous to produce many different hybrids. There is always the possibility of new races of carrot fly developing that could overcome the resistance of carrot cultivars - a situation that needs to be monitored closely.

Modifications to cropping schedules may not be accepted by growers whose strict timetables are governed largely by the markets, crop rotations and the weather. However with careful monitoring of fly activity the alterations to sowing dates may be slight and even a ten-day delay could have significant benefits. Harvesting earlier would also have a significant effect in reducing damage. Unfortunately, most British growers store their maincrop carrots in the ground and carrot fly damage increases during the autumn and winter. If crops were lifted before carrot fly larvae entered the roots [early in October] and the carrots stored elsewhere, damage could be reduced considerably. Systems for storage have been developed and are used in several European countries. To make this a practicable proposition the economics of storage in Britain will need to be re-examined.

Avoiding carrot fly attacks may be more effective than trying to control existing infestations. Covering a crop with a physical barrier has additional expenses and problems, in particular weed control. The present cost of the plastic sheets will certainly come down and techniques for applying the sheets will improve.

Current carrot protection measures are based on a relatively small number of insecticides. Therefore the industry is vulnerable to the loss of insecticides for whatever reason. At present there are mounting problems of enhanced degradation which could make certain pesticides less effective. Thus, it seems probable that alternative control measures will play an ever increasing role in controlling the carrot fly. Progressive growers are prepared to try new techniques and fully appreciate the potential of 'new market' crops including those which have received minimal insecticides. Some changes will therefore come about by growers actively seeking alternative measures while others could be imposed on the industry by stricter legislation. Components of an integrated programme of crop protection for carrot fly need to be developed quickly to support the carrot industry.

We should like to thank Mr B D Dowker for valuable discussions and Mrs P L Jukes for technical assistance.

REFERENCES

ANON., (1905). The carrot fly (Psila rosae F.). Leaflet of the Board of Agriculture and Fisheries, No. 38, 4pp.

ANON., (1984a). Plastic film covers for vegetable production. Booklet of the Ministry of Agriculture, Fisheries and Food, No. 2434, 40pp.

ANON., (1984b). Early carrot production under plastic film covers. Leaflet of the Ministry of Agriculture, Fisheries and Food, No. 888, 5pp.

ELLIS, P.R., DOWKER, B.D., FREEMAN, G.H. & HARDMAN, J.A. (1985). Problems in field selection for resistance to carrot fly (Psila rosae) in carrot cv. Long Chantenay. Annals of Applied Biology 106, 349-356.

ELLIS, P.R, FREEMAN, G.H., DOWKER, B.D., HARDMAN, J.A & KINGSWELL, G. (1987). The influence of plant density and position in field trials designed to evaluate the resistance of carrots to carrot fly (Psila rosae) attack. Annals of Applied Biology 111, 21-31.

ELLIS, P.R., FREEMAN, G.H. & HARDMAN, J.A. (1984). Differences in the relative resistance of two carrot cultivars to carrot fly attack over five seasons. Annals of Applied Biology 105, 557-564.

ELLIS, P.R. & HARDMAN, J.A. (1981). The consistency of the resistance of eight carrot cultivars to carrot fly attack at several centres in Europe. Annals of Applied Biology 98, 491-497.

ELLIS, P.R., HARDMAN, J.A. & DOWKER, B.D. (1982a). Screening of Japanese carrot cultivars for their susceptibility to carrot fly. Tests of Agrochemicals and Cultivars (Annals of Applied Biology 101 Supplement), No. 3, 94-95.

ELLIS, P.R., HARDMAN, J.A. & DOWKER, B.D. (1982b). Screening of carrot cultivars for their susceptibility to carrot fly 1976-1980. Tests of Agrochemicals and Cultivars (Annals of Applied Biology 101 Supplement), No. 3, 96-97.

ELLIS, P.R., HARDMAN, J.A., DOWKER, B.D., COLE, R.A., HOROBIN, J.F., MAYNE, H.J., ROLLASON, S.A. & JUKES, P.L. (1987). Resistance of vegetables to insect pests. Carrots. 37th Annual Report of the National Vegetable Research Station for 1986/87, 29-30.

ELLIS, P.R., HARDMAN, J.A., JACKSON, J.C. & DOWKER, B.D. (1980). Screening of carrots for their susceptibility to carrot fly attack. Journal of the National Institute of Agricultural Botany 15, 294-302.

ELLIS, P.R., WHEATLEY, G.A. & HARDMAN, J.A. (1978). Preliminary studies of carrot susceptibility to carrot fly attack. Annals of Applied Biology 88, 159-170.

GUERIN, P.M., GFELLER, F. & STADLER, E. (1981). Carrot resistance to the carrot fly - contributing factors. Breeding for Resistance to Insects and Mites. Report of the Second Eucarpia/IOBC Working Group. WPBS Bulletin IV, I, 63-65.

HARDMAN, J.A. & ELLIS, P.R. (1982). An investigation of the host range of carrot fly. Annals of Applied Biology 100, 1-9.

HENDERSON, W. (1814). A preventive against the worms infesting the roots of carrots in light early soils. Memoirs of the Caledonian Horticultural Society 1, 200-201

METCALF, C.L. & FLINT, W.P. (1939). Hessian fly. In: Destructive and Useful Insects. Their Habits and Control. New York: McGraw-Hill, pp. 401-405.

SLINGERLAND, M.V. (1894). The cabbage root maggot with notes on the onion maggots and allied insects. Cornell University Agricultural Experiment Station Bulletin, No. 78, 481-577.

THOMPSON, A.R., ELLIS, P.R., PERCIVALL, A.L. & HARDMAN, J.A. (1980). Carrot fly. Integrated control using insecticides with carrot cultivars of differing susceptibilities. Report of the National Vegetable Research Station for 1979, p. 30.

WHITCOMB, W.D. (1938). The carrot rust fly. Bulletin of the Massachusetts Agricultural Experiment Station, No. 352, 36pp.

PEST MANAGEMENT OF PSILA ROSAE ON CARROT CROPS IN THE EASTERN REGION OF ENGLAND

T.H. COAKER and D.R. HARTLEY
Department of Applied Biology, University of Cambridge

Summary

Carrot fly is a major pest of carrot crops in the eastern region of England. Damage is frequently greatest in crop margins and emphasis has been placed on the role of the vegetation in the field surrounds on the biology of the adult fly. In particular, the numbers of adults have been shown to be affected by the composition of the herbaceous vegetation and by the trees in the field boundaries.

Experimental work on the removal of the herbaceous vegetation and on the presence of trees on the distribution of adult flies, and of the damage to carrots, showed that trees were of overriding importance.

Farm records of damage to carrot crops were also examined which enabled the role of trees, carrot crops and herbaceous vegetation to be described more accurately to provide a better understanding of *P. rosae* biology.

Damage levels in commercial carrot crops were related to times of sowing and harvesting, degree of shelter in the carrot field and distance from old carrot fields. This information was codified to form a "planning aid" intended for grower use.

Introduction

Early studies on carrot fly, *Psila rosae*, showed that large numbers of flies in non-crop habitats around carrot fields resulted in high levels of larval damage to adjacent carrots (Baker et al, 1942; Barnes, 1942; Petherbridge & Wright, 1945). Cultural recommendations were made (Petherbridge et al, 1945; Wright & Ashby, 1946) but, as far as it is known, were never practiced on a commercial scale and became unnecessary when organochlorine insecticides were introduced. Control is currently achieved with organophosphorus compounds but their performance is inadequate on crops left overwinter in the soil (Wright & Coaker, 1968).

The importance of non-crop habitats was re-examined by Wainhouse & Coaker (1981) to determine the effect of the floral content of field surrounds on the distribution of carrot flies in a commercial carrot growing area of East Anglia. They concluded that the composition of the herbaceous layer provided the most important physical shelter for the flies and proposed an alternative strategy to simplify the field boundaries since the absence of shelter sites can reduce attack by *P. rosae* (van't Sant & Brader, 1972; Dabrowski & Legutouska, 1976).

Windbreaks of trees could not be removed from fenland farms since they reduce wind erosion of soil and the consequent need to resow crops. The removal of the herbaceous layer on the other hand could have a significant effect on the distribution of the flies.

This paper describes the effect of crop and field factors on the abundance of P. rosae and consequent crop damage, and proposes a "planning aid" for the improvement of carrot fly control.

The study site and description of field boundaries

In the study area, on a large estate covering 2400 ha at Feltwell Fen, Norfolk, carrots occupied about 15% of the arable land. All of the carrot crops studied were treated with phorate at sowing (for control of the 1st generation) and triazophos or chlorfenvinphos as mid-season sprays (for control of the second generation). The carrot crops were sown in late-April to early May and harvested between September and March of the following year. The 6-9 ha fields were divided by non-crop habitats consisting of ditches and/or windbreaks or woodland strips. The ditches were about 2 m deep and 5 m wide and were covered by diverse herbs on their sides and verges. The windbreaks alone or with ditches, consisted of a single or multiple rows of poplar, mostly Populus nigra italica with an understorey of bushes. The woodland strips, 20-40 m wide, consisted mostly of P. canadensis, Salix spp, Alnus glutinosa and various smaller trees and bushes. Beneath the trees was a herb layer often extending several metres from the edge.

Manipulation of field boundaries and sampling methods

The total herb layer was removed mechanically and/or with herbicides from selected boundaries surrounding carrot crops in early May before the flight of the first generation flies (mid-May to mid-June) and again in late July before the flight of the second generation flies (August to late-September). The carrot crops were treated with insecticides except for 15 m wide strips across the fields. Adult flies were monitored during both generations using yellow water traps (Wainhouse & Coaker, 1981) and/or sticky traps (Uvah & Coaker, 1984) sited in the herb layer along the field boundaries, in the trees and in the crop. Larval damage was assessed on root samples collected from four 1 m lengths of row taken along rows across the centre of the field.

Herbage clearance

Two experiments were conducted to examine the effect of herbage clearance on the distribution of adult P. rosae and crop damage. The plans of the two sites are shown in Fig. 1. At Site 1, flies were caught in paired yellow water traps, 25 m apart, placed under the trees, along the ditches and at 7.5 m intervals from the boundary to 22.5 m into the crop. At Site 2, six yellow stickytraps were placed 4 m high and 25 m apart in the windbreak and paired water traps as at Site 1 extended 37.5 m into the crop. In both sites the trap layout was repeated in both the cleared and intact areas. Root samples were taken in December for damage assessment at both sites.

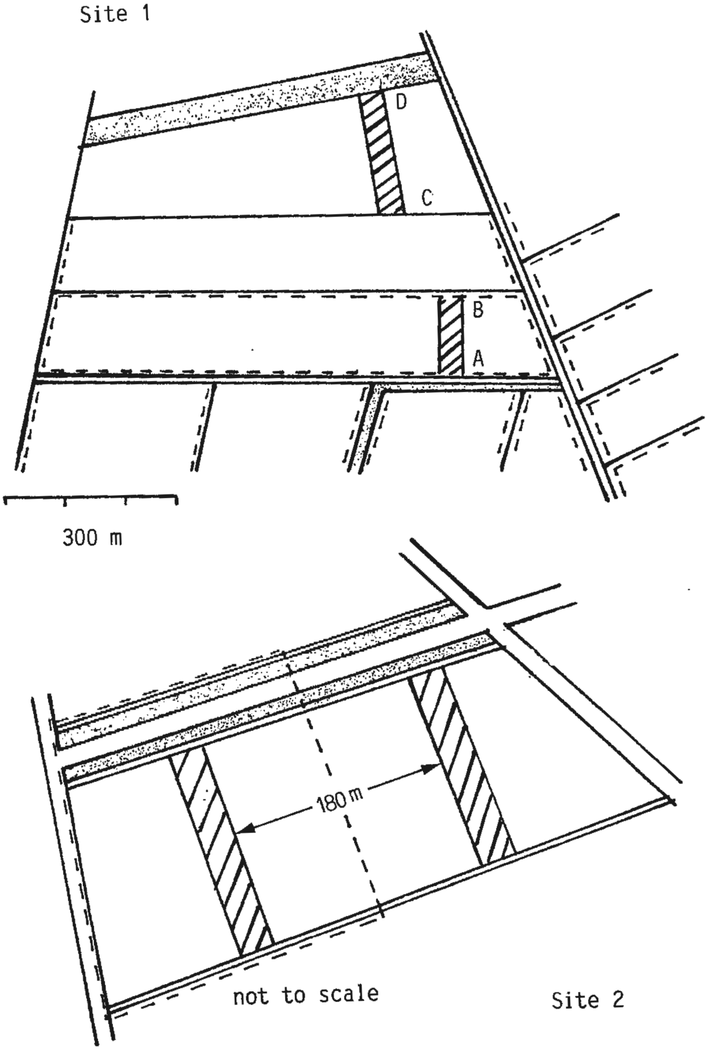


Fig. 1. Plan of sites showing cleared (- - -) and intact (▬) boundaries, trees (▩), ditches (═) and untreated strips across the carrot fields (▨).

On both sites (Table 1), fewer flies were caught in the crop and along the ditches (B and C) than under the trees (A and D) ($p<0.05$). The effect of herbage removal at Site 1 was to reduce the number of flies caught along the ditches although catches in the crop were unaffected as similar numbers were trapped at A and B as at C and D, where the herbage remained intact. The higher catches overall at A (trees and ditch), where the herbage had been removed from beneath the trees and along the ditch, is indicative of other factors also affecting the distribution of the flies, such as dispersal from neighbouring crops or from the same field into the trees. On Site 2, fewer flies were again caught by the crop traps particularly during the first generation, but during the second generation twice as many flies were caught in the crop in the intact area than in the cleared area. These numbers trapped reflected the numbers trapped in the trees where almost three times as many males were caught in the intact area than in the cleared area during the second generation.

Table 1. Mean catch of adult *P. rosae* per trap at different sites within the cleared and intact areas.

SITE 1

		Cleared				Intact			
		A		B		C		D	
	Generation	♂	♀	♂	♀	♂	♀	♂	♀
Crop	1	3	7	3	1	4	2	2	3
	2	6	2	5	4	6	3	6	4
Ditch	1	1	3	2	1	5	1	5	6
	2	2	2	2	2	6	2	6	4
Trees	1	15	11	-	-	-	-	11	3
	2	25	27	-	-	-	-	22	4

SITE 2

		♂	♀	♂	♀
Crop	1	7	4	11	6
	2	9	2	18	10
Trees	1	14	2	20	4
	2	38	2	105	3

The relative numbers of adult *P. rosae* caught in the traps along the various boundaries was not adequate to explain the damage levels in the adjacent carrot crops (Table 2). In particular at Site 1, the high level of damage at D could not have been predicted from the trap catches. The highest levels of damage at A and D were correlated with the presence of trees irrespective of the presence/absence of herbage in the field surround. In the absence of trees at B and C, levels of damage were much lower. At the intact boundaries incorporating C and D, the gradient of root damage was steeper than at boundaries, A and B where the herbage had been removed by mowing (Fig. 2). At Site 1 the percentage of roots damaged from the pesticide treated crop was marginally lower than that from the untreated strips ($p>0.05$). At Site 2, the level of damage was low and no differences between the cleared and intact areas and insecticide treatments could be discerned.

Table 2. Percentage damaged carrots in December, from insecticide treated (+I) and untreated (-I) crops within the cleared and intact areas.

	Cleared		Intact	
	A	B	C	D
SITE 1				
+I	27	6	5	29
-I	36	16	6	35
SITE 2				
+I	3		4	
-I	4		5	

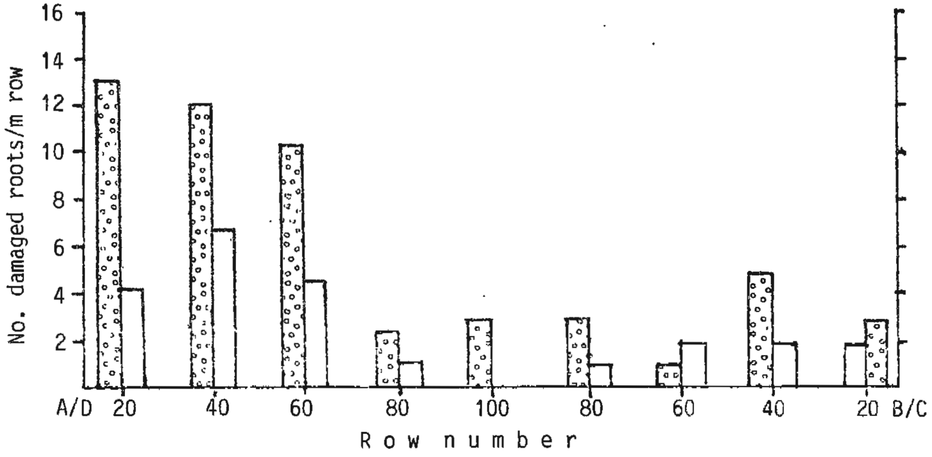


Fig. 2. Carrot damage across untreated strips in cleared (A-B, ☐.) and intact (C-D, ▨) areas on Site 1 in December.

Comparison of shelter sites in tree boundaries

The abundance of adult P. rosae in windbreaks and woodland strips forming part of the boundary of carrot fields was compared using yellow sticky traps placed in sets of 6 per site and positioned 2.5-4 m high on the trunks and branches of trees. Each site selected was adjacent to an old or new carrot crop. The traps were positioned in pairs 8-12 m apart, with one trap facing the crop and the other facing in the opposite direction. Six sets of traps were placed in windbreaks and 6 sets in woodland strips. The positions of the traps in the trees fell into three categories:

1. Visible from the field (sited in an exposed position in the windbreak).
2. Partially visible from the field (sited in a sheltered position on the edge of, or set back into a woodland strip).
3. Not visible from the field (sited on the edge of, or set back into a woodland strip).

Sticky traps were also sited in the crop, four along each of the rows, 10, 25 and 50 m from the boundaries. Four, 1 m lengths of row of roots were sampled along the same rows as the traps were sited, in December for damage assessment.

Males predominated the trap catches and more were caught on the traps placed in the denser foliage of the woodland strips (Category 3) and fewest on the traps in the windbreaks (Category 1) (Table 3). More flies were also caught in the first generation, possibly because more second generation flies sheltered in the crop in which they emerged.

Table 3. Mean catch of adult <u>P. rosae</u> per sticky trap in each trap category. 1, visible; 2, partially visible; 3, not visible (see text for details)

Trap category		1	2	3
Generation				
1	♂	77	358	614
	♀	5	23	28
2	♂	24	95	141
	♀	3	7	6

The effect of trap aspect failed to show consistent differences over the second generation (♀, 22 v 29; ♂, 391 v 343) but in the first generation about twice as many flies, particularly males (♀, 64 v 107; ♂, 312 v 693), were caught on the side of the trees opposite to the crop, possibly reflecting their preferred shelter sites.

The relationship between the numbers of flies caught in the trees and adjacent crop (Fig. 3) shows that about 20 times as many males and twice as many females were caught in the trees than in the crop. In consequence a better correlation was obtained between crop damage and the number of females caught in the trees rather than in the crop (Fig. 4).

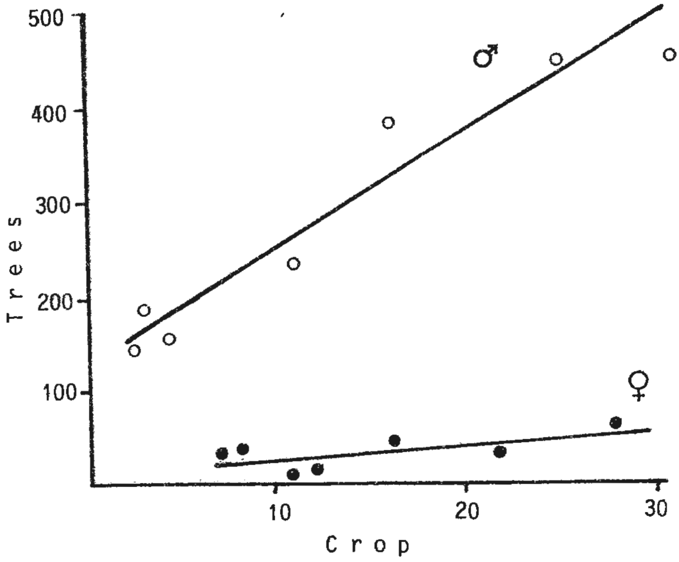


Fig. 3. Mean catch of adult <u>P. rosae</u> per trap in the trees and adjacent crop.

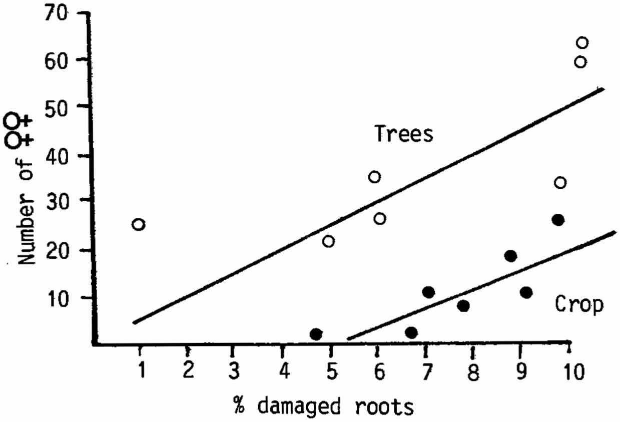


Fig. 4. Mean number of *P. rosae* per trap in trees and crop against % damage carrots.

Survey of crops

The estate conducted its own quality scheme at harvest by removing, a 3 kg sample of roots from each lorry load of carrots that entered the washing station. After washing these roots were examined and classified as marketable or unmarketable. Carrots were placed in the unmarketable category when they showed signs of pest damage, disease, mechanical injury, poor shape and "green top" (an excess of green stem left on the root). When the harvest of each field had been completed, the average percentage damaged roots due to *P. rosae* was calculated from the individual loads. An attempt was made to identify any association between crop/field factors and the damage level recorded for each crop.

From a survey of the fields on the estate, each field was classified according to the field surrounds. Fields classified as "Sheltered" had a woodland strip along one side or tree boundaries, of any description, along two or more sides. "Intermediate" fields had a windbreak along one side whereas "Open" fields were surrounded solely by ditches. Fields were also classified according to their proximity to fields that had previously contained carrot crops. "Adjacent" fields had a common boundary with an old carrot field. "Near" fields were less than 250 m from an old field. "Remote" fields were not closer than 250 m from an old field. Other factors such as field size, were not included in the analysis in order to retain a sufficiently small number of categories so that any contrasts could be substantiated by as many records as possible.

Effects of crop factors on damage

Time of harvest: Little root damage was recorded on crops harvested before the end of September (Fig. 5a). It is not until the end of September that the well developed second generation larvae attack the main root (Petherbridge & Wright, 1943; Overbeck, 1978).

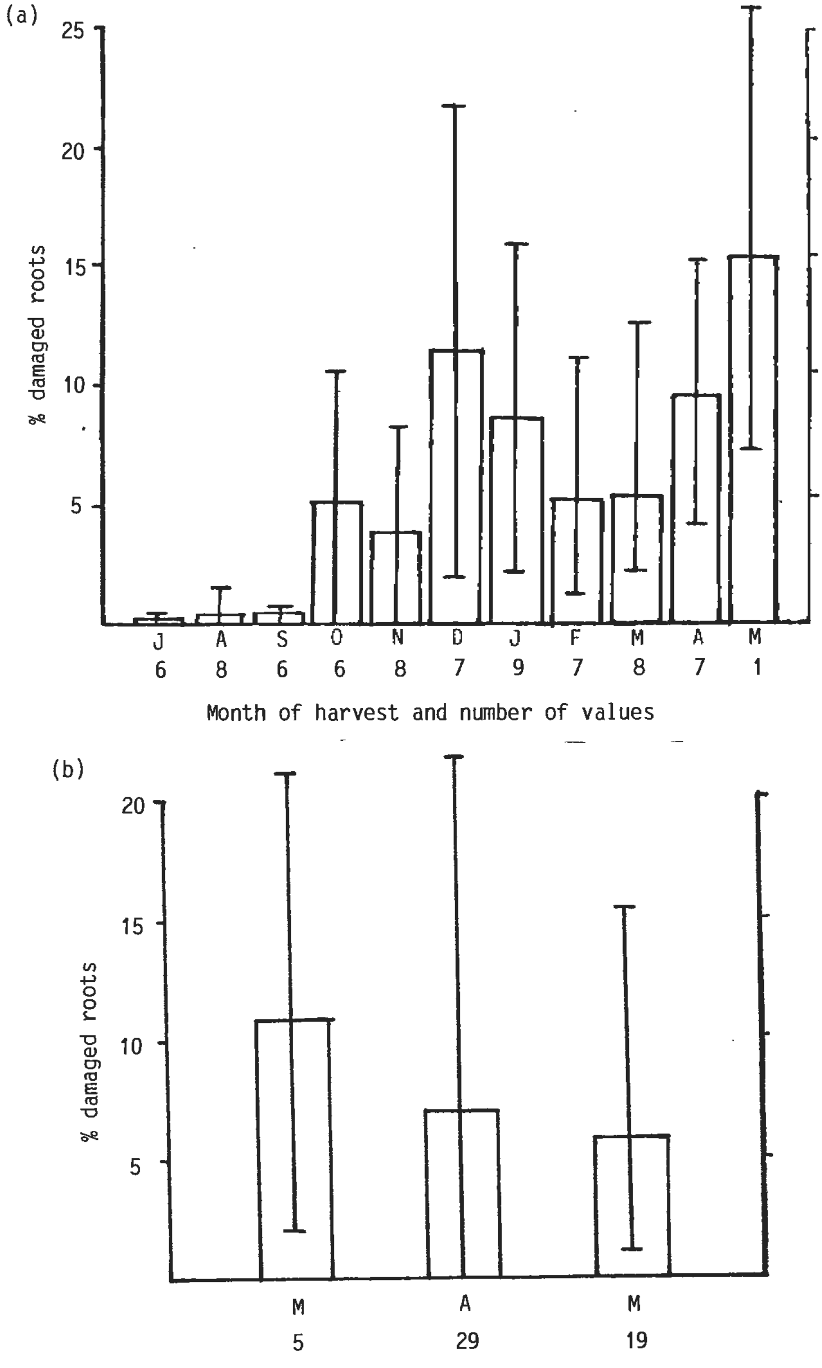


Fig. 5. Mean percentage and range of P. rosae damaged carrots from crop with different (a) harvest and (b) sowing dates.

Time of sowing: Early sowing in March coupled with harvesting after September resulted in high levels of damage (Fig. 5b). Early sown crops became attractive to the first generation adults earlier in the season and had larger roots to support larval development. Earlier sowing also affected the level of second generation larval damage, since the adults emerging from the first generation generally remain in the vicinity of the crop. In one year a March sown crop sustained over 20% damage whereas a May sown crop 100-200 m away sustained less than 5% damage at harvest in April of the following year. Late sown crops can, therefore, largely avoid attack by first generation larvae and in consequence an early attack by second generation larvae and the rapid appearance of damage in early autumn.

Varietal and seasonal variation: No differences in susceptibility were detected between the three principal cultivars grown for late harvest, namely Benjo, Cylinder and Vita Longa.

Although a greater range of percentage damaged roots occurred between the three years that crops were surveyed, possibly due to the effects of weather on dispersal, mating, oviposition and survival of P. rosae, there was no difference in overall damage.

Effect of field factors on damage

Shelter and proximity to sources: Despite the variability and small amount of data collected, especially for "Remote" fields, distance from sources of P. rosae to target crops appeared to affect damage levels (Table 4). This suggests that the flies did not travel far from the site of emergence, possibly because adjacent trees and new crops arrested the dispersing flies. Hence, where carrots are less intensively grown, increased distances between source fields and new crops could contribute to reduced levels of damage. Damage levels on "Sheltered" fields were approximately twice those on "Open" fields.

Table 4. Effect of shelter in field boundaries and proximity of the crop to previous host crops on the mean percentage roots damaged by P. rosae on carrot crops harvested from October to March. Number of values in brackets.

	Adjacent	Near	Remote	Mean
Sheltered	11.6 (6)	9.9 (4)	3.3 (1)	10.2 (11)
Intermediate	6.5 (9)	21.2 (1)	- (0)	8.0 (10)
Open	4.9 (16)	6.8 (13)	3.4 (3)	5.5 (32)
Mean	6.7 (31)	8.3 (18)	3.4 (4)	7.0 (53)

Synthesis

The biology of adult P. rosae (see Dufault & Coaker, 1987) may be summarized diagrammatically as shown in Fig. 6.

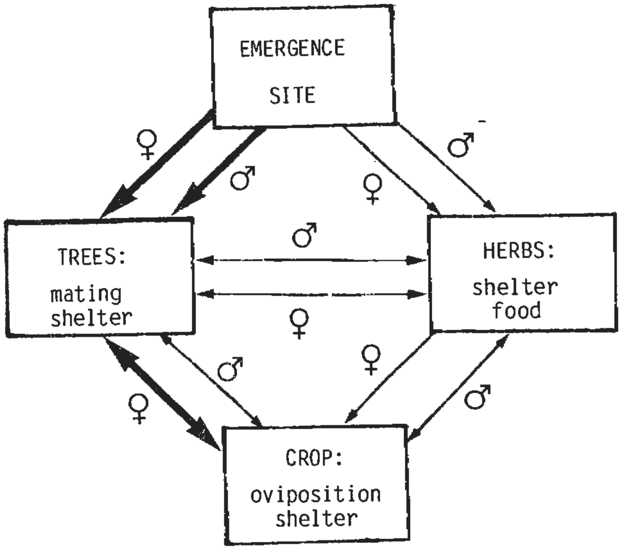


Fig. 6. The environment and biology of adult P. rosae

Two major resources are utilized by the flies, trees for aggregation, mating and shelter, and host crops for oviposition. The trees are actively sought by hypsotaxis and the host plants by orientation to characteristic odours. On emergence, flies of both sexes are attracted to trees and disperse away from carrot fields (Stadler, 1972; Brunel, 1977). Redistribution then occurs, particularly for males, as a consequence of arrestant stimuli provided by the microenvironment of the tree boundaries (Wakerley, 1964). Small populations of adult flies are also found in the herbaceous vegetation of field boundaries not containing trees. Their attraction to herbaceous vegetation to utilize food resources, such as the nectar in flowers (Wainhouse & Coaker, 1981), does not appear to be important.

Distances over which flies disperse are probably determined by features of the landscape and the vicinity of the subsequent crop. Crops at a distance greater than 250 m from the source field had less damage. This may be a direct consequence of trees close to the original source "trapping out" the dispersing flies. Dispersal beyond the confines of the boundaries of the source fields, which might be wind assisted, allows the longer distance type of dispersal as described by earlier Dutch, Swiss and British workers (van't Sant, 1961; Stadler, 1972; Wainhouse, 1977).

Female flies were less influenced than males by the arrestant qualities of the trapping sites. Males preferred to remain in sheltered environments whereas females were more mobile and wide ranging. The field boundary must, however, exert an important influence on gravid females, since the existence of gradients of damage at the margins of crops and the association of high damage levels in the presence of trees, are now well established (Petherbridge, Wright & Davies, 1942; Coppock, 1974). The relationship between damage levels and the presence of trees is clear, since gravid females probably mate in the zones favoured by the males and the subsequent search for host plants will take place from these foci.

Environmental manipulation

The simplest form of enviromental manipulation, i.e., the removal of herbage, led to appreciable reduction in damage in certain circumstances. Where the boundary consisted solely of a ditch, levels of damage were low and the effect of herbage removal was minimal. Where trees were present along the boundary the risk of high levels of damage in the adjacent crop was much greater and the effect of herbage removal might be beneficial. In practice the removal of herbage is subject to severe restrictions though it is regular practice to mow along ditches. The removal of herbage from the base of windbreaks and woodland strips is much more difficult, unless selective herbicides are used.

Manipulation of the cropping plan

The associations between increasing distance from source fields and lower levels of damage, and between field boundaries containing trees and high levels of damage illustrate the importance of the biology of adult *P. rosae* in determining the differences in crop damage recorded from different fields. In addition, the time the crop is sown and harvested is also important (see also Ellis et al, 1987). The possibility exists, therefore, for assessing the risk of damage to any crop by considering the four major factors outlined in this paper. The grower can consider these factors before deciding in which field to grow his carrots. The field factors i.e., degree of shelter and proximity to sources affect his choice of field in which to grow carrots and the crop factors i.e., sowing and harvesting date affect the timing of his crop operation. Using the "planning aid" (Fig. 8) the grower can see that irrespective of field factors, crops harvested before the end of September have a low risk of damage (<1%) whereas crops drilled before April for harvest after September run a high risk (>12%) of unacceptable levels of damage. Also fields further than 250 m from source fields have a low risk of damage (<5%). "Open" fields also have a low to moderate risk (6-15%), but the potential benefit deriving from a choice of open fields for the siting of crops for late harvest is apparent. Conversely, where the use of a sheltered field for carrots is unavoidable, the "planning aid" indicates that an early harvest is advisable.

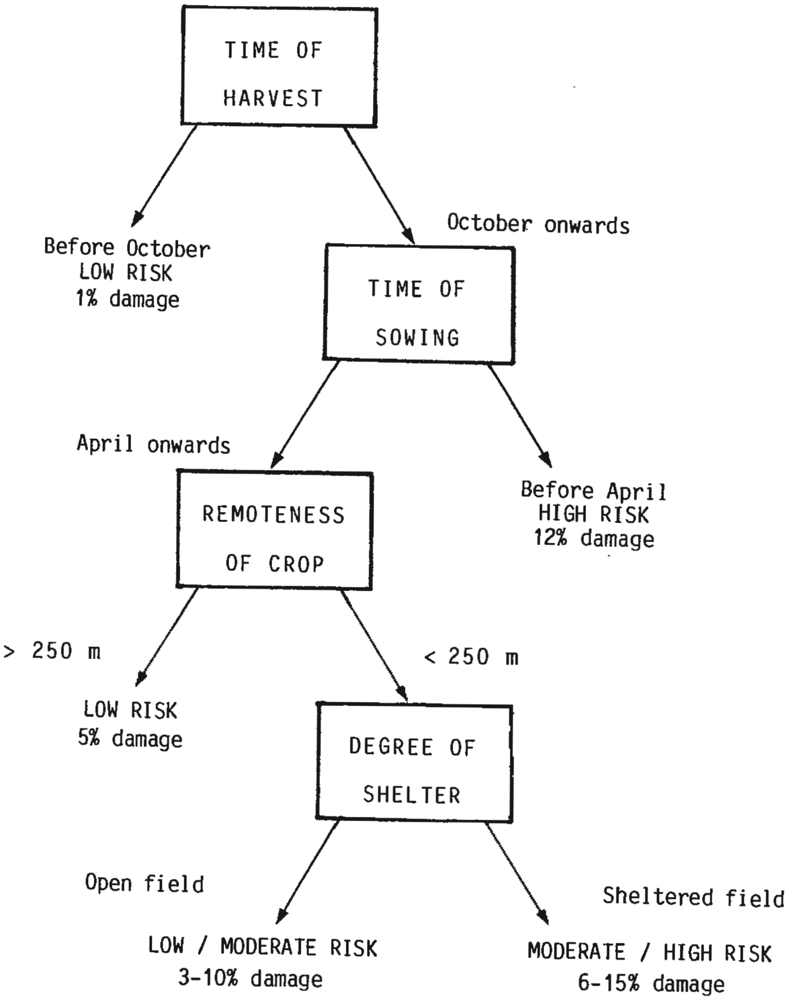


Fig. 7. The "Planning Aid". The percentage risk of damage applies to crops treated with insecticides at drilling and as mid-season sprays

References

BAKER, F.T., KETTERINGHAM, I.E., BRAY, S.P.V. & WHITE, J.H. (1942). Observations on the biology of the carrot fly (*Psila rosae* Fab.): assembling and oviposition. Annals of Applied *Biology, 29*, 115-125.

BARNES, H.F. (1942). Studies of fluctuations in insect populations. IX. The carrot-fly (*Psila rosae*) in 1936-41. Journal of Animal Ecology, 11, 69-81.

BRUNEL, E. (1977). Étude de l'attraction périodique de femelles de *Psila rosae* Fabr. par la plant-hote et influence de la végétation environnante. Colloques Internationaux du Centre National de la Recherche Scientifique, No. 265, Comportement des Insectes et Milieu Trophique, pp. 373-389.

COPPOCK, L.J. (1974). Notes on the biology of carrot fly in Eastern England. Plant Pathology, 23, 93-100.

DABROWSKI, Z.T. & LEGUTOWSKA, H. (1977). Three years experiment on the damage of some carrot cultivars made by *Psila rosae*. Annual Plant Resistance to Insects Newsletter, 3, p. 69. Purdue University, West Lafayette.

DUFAULT, C.P. & COAKER, T.H. (1987). Biology and control of the carrot fly, *Psila rosae* (F.). Agricultural Zoology Reviews Vol. 2, 97-133.

ELLIS, P.R., HARDMAN, J.A., COLE, R.A. & PHELPS, K. (1987). The complimentary effects of plant resistance and the choice of sowing and harvest times in reducing carrot fly (*Psila rosae*) damage to carrots. Annals of Applied Biology. (In press.)

PETHERBRIDGE, F.R. & WRIGHT, D.W. (1943). Further investigations on the biology and control of the carrot fly (*Psila rosae* F.). Annals of Applied Biology, 30, 348-358.

PETHERBRIDGE, F.R., WRIGHT, D.W. & ASHBY, D.G. (1945). The biology and control of the carrot fly. Annals of Applied Biology, 32, 262-264.

PETHERBRIDGE, F.R., WRIGHT, D.W. & DAVIES, P.G. (1942). Investigations on the biology and control of the carrot fly (*Psila rosae* F.). Annals of Applied Biology, 29, 380-392.

SANT, L.E. van't (1961). Levenswijze en bestrijding van de wortelvlieg (*Psila rosae* F.) in Nederland. Mededelingen Instituut voor Plantenziektenkundig Onderzoek, No. 240. H. Veenman en Zouen NV, Wageningen.

SANT, L.E. van't & BRADER, L. (1972). Oekologische waarnemingen als hulpmiddel bij de bescherming van wortelen tegen de aantasting door de wortelvlieg *Psila rosae*. Entomologische Berichten, 32, 187-188.

STÄDLER, E. (1972). Über die Orientierung und das Wirtswahlverhalten der Möhrenfliege, *Psila rosae* F. II. Imagines. Zeitschrift für angewandte Entomologie, 70, 29-61.

UVAH, I.I.I. & COAKER, T.H. (1984). Effect of mixed cropping on some insect pests of carrots and onions. Entomologia Experimentalis et Applicata, 36, 159-167.

WAINHOUSE, D. (1975). The Ecology and Behaviour of the Carrot Fly, *Psila rosae* (F.). Ph.D. Thesis, University of Cambridge, UK.

WAINHOUSE, D. & COAKER, T.H. (1981). The distribution of carrot fly (*Psila rosae*) in relation to the flora of field boundaries. In Pests, Pathogens and Vegetation, (J.M. Thresh Ed.) pp. 263-272.

WAKERLEY, S.B. (1964). The sensory behaviour of carrot fly (*Psila rosae* Fab.). Entomologia Experimentalis et Applicata, 7, 167-178.

WRIGHT, D.W. & ASHBY, D.G. (1946). Bionomics of the carrot fly (*Psila rosae* F.). I. The infestation and sampling of carrot crops. Annals of Applied Biology, 33, 69-77.

WRIGHT, D.W. & COAKER, T.H. (1968). Development of dieldrin resistance in carrot fly in England. Plant Pathology, 17, 178-181.

OCCURRENCE OF FUNGI FROM ENTOMOPHTHORALES IN A POPULATION OF CARROT FLIES (PSILA ROSAE F.) 1985 AND 1986.

Jørgen Eilenberg

Department of Zoology, Royal Veterinary and Agricultural University, Bülowsvej 13, DK-1870, Frb.C. (Copenhagen), Denmark.

SUMMARY

The occurrence of fungi from Entomophthorales on adult carrot flies (Psila rosae) was investigated in a Danish carrot field during 1985 and 1986. Three species were present: Entomophthora muscae, Conidiobolus apiculatus and Erynia sp. E.muscae was the most common, but one epidemic also included C.apiculatus. Both species are thus able to establish natural epidemics and should be considered for biological control.

INTRODUCTION

The carrot fly (Psila rosae) is a serious pest of carrots in temperate areas, including Denmark. Monitoring systems in different countries are under development and some recent improvements are described by Esbjerg et al. (1988) and Philipsen (1988).

Detailed knowledge of the natural enemies of carrot flies is important for a full understanding of the flies population development together with a precise interpretation of catches on yellow sticky traps (Philipsen & Eilenberg, 1988). For the biological control of carrot flies with natural enemies, detailed knowledge of their natural occurrence in the field is a necessary prerequisite.

Fungal pathogens found attacking adult carrot flies have been described from parts of the 1982 season, and for the complete 1983 and 1984 seasons (Eilenberg, 1983, Eilenberg & Philipsen, 1988). Three species from Entomophthorales were found: Entomophthora muscae (C.) Fres., Conidiobolus apiculatus (Thaxt.) Remaud. & Keller and Erynia sp. The most common species and the only one which caused epidemics in the carrot fly population was E.muscae and this fungus pathogen is therefore probably the most important pathogen affecting the population development of carrot flies.

The present paper describes the field occurrence of fungi on adult carrot flies in a Danish field in 1985 and 1986.

MATERIALS & METHODS

The field was situated at Lammefjorden, NW-Zealand, Denmark. and was the same locality used the previous years. Adult flies were sampled with sweep-net and incubated in the laboratory separately in cups, as previously outlined (Eilenberg & Philipsen, 1988). Sampling took place in the hedge around the field and in the field 10-30 m from the hedge.

The flight activity of the adult flies was monitored with yellow sticky traps which were changed weekly. Fungal pathogens that developed on the incubated flies were identified by their external features and spore morphology. Both sticky trap catches and swept flies were sexed.

RESULTS

Table 1 shows the occurrence of the three species of fungi on adult carrot flies. For comparison, the data from 1983 and 1984 are also included and it can be seen that in three of the four years, E.muscae was the only fungus of importance. However, for the first time in 1985, C.apiculatus was involved in an epidemic in August. As a result of this, 33 % of the infected flies from 1985 were infected with C.apiculatus (in August 1985,81 % of the infected carrot flies were infected with C.apiculatus).

Seasonal trends are shown in Figs. 1 & 2. In both years, the incidence of fungal diseases in the first generation of adult carrot flies was very low during late May and early June after which an epidemic developed reaching a peak at the beginning of July.

In August, fungal pathogens were more common, and in 1985, this epidemic consisted mainly of C.apiculatus. The second generation of flies reached the maximum in September, and in both years moderate to high infection levels occurred throughout this period.

There tended to be a lower infection level amongst flies caught in the field compared to flies caught in the hedge in both years. Unfortunately in both years it was not possible to catch flies in the field during the first generation, but in 1983 and 1984, the differences in infection levels tended to be the same for the first and the second generation.

DISCUSSION

The occurrence of fungal pathogens on adult carrot flies is of general importance, since epidemics develop every year, one during the first generation and one or two during the second generation. Results so far allow comparison to be made of the fungal species involved.

E.muscae can cause epidemics under various conditions during the summer months and as late as mid-October. This fungus can suppres carrot fly populations as it has been shown that females, when infected, do not lay eggs or oviposit normally. They fail to recognize their host plant (Eilenberg, 1987).

C.apiculatus was restricted to moist and humid periods, thus being most common in August. It is not known, if *C.apiculatus* has the same effect on egg-laying behaviour as *E.muscae*.

Erynia sp. was uncommon throughout four years and therefore had an insignificant influence on carrot fly population development.

For a future biological control of carrot flies, *E.muscae* should be regarded as the most promising agent. The species is involved in epidemics several time per year, its virulence against carrot fly seems to be high and spores can be produced *in vitro* (Eilenberg et al., unpubl.).

The development of a product based on one or several strains of *E.muscae* could have a greater potential market than just for carrot fly alone, since the target organisms of the fungus include several species of agricultural importance eg.: Cabbage root fly (*Delia radicum*), Onion fly (*D.antiqua*). Other species or strains of *E.muscae*-complex do occur naturally on these flies.

More intensive and extensive studies are required to obtain a greater knowledge of the influence of these fungi on flies in agriculture. A population of carrot flies in one field should be intensively studied over a number of years in order to obtain data for developing a model which describes the influence of these fungi on the population development. An extensive survey on the occurrence of Entomophthoralean fungi on carrot flies in different habitats should also be done. In 1987, E.muscae was found on carrot flies in the United Kingdom (Eilenberg & Wilding, unpubl.), but carrot flies should be sampled in other countries as well together with other flies of agricultural importance.

REFERENCES

EILENBERG, J. 1983.
Entomophthora-svampe på gulerodsflues (Psila rosae F.). Muligheder for anvendelse af Entomophthora-svampe til biologisk bekæmpelse.
Tidsskrift for Planteavl, 87, 399-406.

EILENBERG, J. 1987.
Abnormal egg-laying behaviour of female carrot flies (Psila rosae F.) induced by the fungus Entomophthora muscae.
Entomologia Experimentalis et Applicata, 43, 61-65.

EILENBERG, J. & PHILIPSEN, H. 1988.
The occurrence of Entomophthorales on the carrot fly (Psila rosae F.) in the field during two successive seasons.
Entomophaga (in press).

ESBJERG, P., PHILIPSEN, H. & PERCY-SMITH, A. 1988.
The significance of carrot fly (Psila rosae) monitoring in Denmark.
Bulletin SROP/WPRS Bulletin (in press).

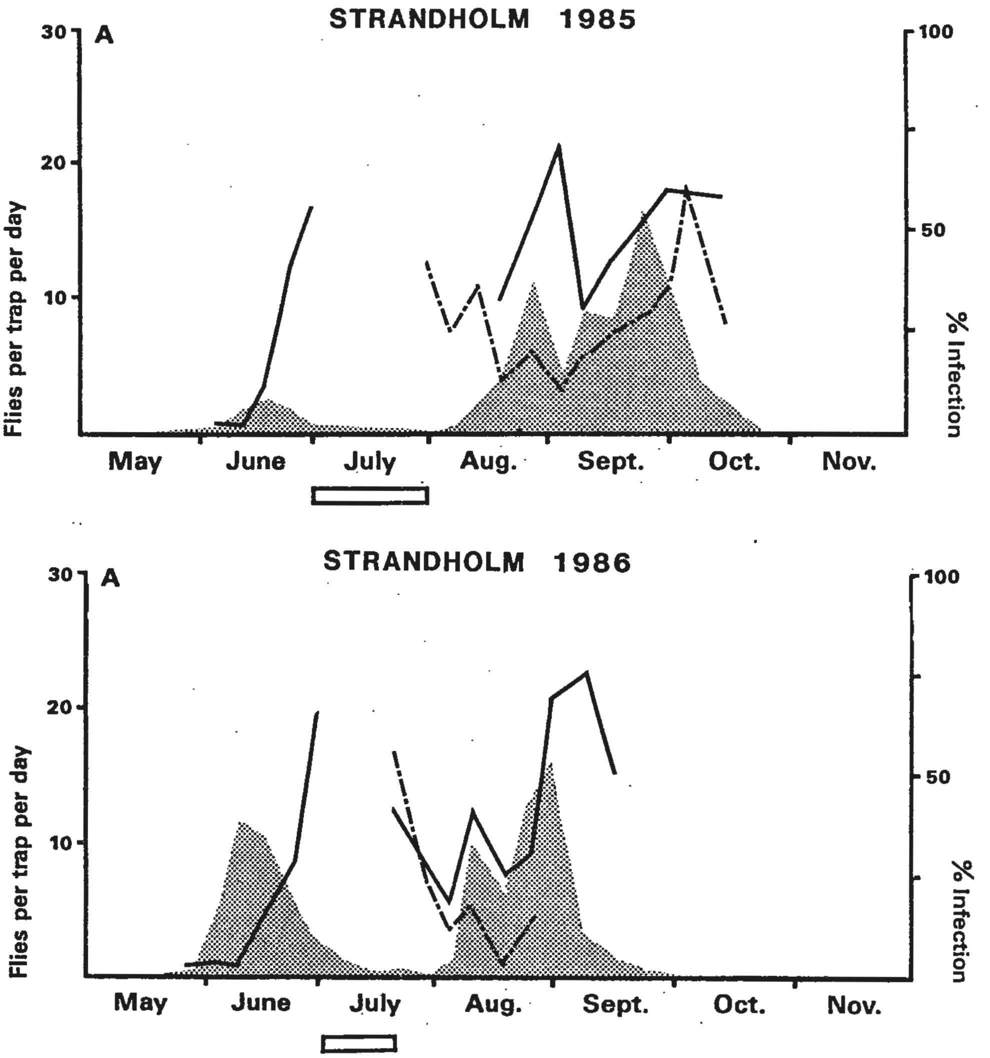
PHILIPSEN, H. 1988.
Monitoring techniques for the carrot fly (Psila rosae F.).
Bulletin SROP/WPRS Bulletin (in press).

PHILIPSEN, H. & EILENBERG, J. 1988.
Some factors influencing the measured population size of carrot flies (Psila rosae F.).
Acta Horticultura (in press).

Table 1.

Frequency of fungal pathogens on adult carrot flies (Psila rosae) during four seasons.

Year	Number of fungus-infected carrot flies	Frequency (%) of the species of fungi		
		Entomophthora muscae	Conidiobolus apiculatus	Erynia sp.
1983	770	99.5	0.4	0.1
1984	778	96.6	3.0	0.4
1985	870	66.4	33.0	0.6
1986	548	95.4	4.6	0.0



Figs. 1 & 2.

Occurrence of fungal diseases from Entomophhtorales in carrot flies (<u>Psila rosae</u> F.) caught at Strandholm 1985 (fig. 1) and 1986 (fig. 2).

—— = % Infection of flies caught in the hedge

–·–·– = % Infection of flies caught in the field

▨ = Sticky trap captures of carrot flies

▭ = Period with carrot fly activity too low for sampling

EFFICACY AND ACCEPTANCE OF THE CABBAGE ROOT FLY EGG TRAP

J. FREULER
Federal Agricultural Research Station of Changins, CH-1260 Nyon.

From a cooperative examination of the egg trap in several countries in the W.P.R.S., further data has provided valuable information on how it can be used. The participants in these trials are listed in Table 1.

Table 1. List of participants in the collaborative trials.

COUNTRY	RESEARCH CENTRE	COLLABORATORS
Denmark	Research Centre for Plant Protection, Lyngby	B. Bromand
England	National Vegetable Research Station, Wellesbourne	S. Finch G. Skinner
France	Chambre d'Agriculture, Chambéry	S. Fort J.M. Navarro
Ireland	Kensealy Research Centre, Dublin	D. Dunne
The Netherlands	Research Institute for Plant Protection, Wageningen	H. den Ouden
Switzerland	Federal Agricultural Research Station of Changins, Nyon	J. Freuler
	Station cantonale de protection des plantes, Châteauneuf	C. Terrettaz

The first question to be answered was whether or not the number of eggs laid in the traps was comparable to numbers laid around host plants. FREULER and FISCHER (1982) showed a similarity in the numbers of eggs laid in traps and around cauliflowers in a commercial crop except on two occasions on 21 and 28 May (Table 2) when on one date the total numbers were higher around the plants and on the other date higher in the trap. This suggests that such variation could be reduced if more plants were sampled by both methods.

Another comparison was done at Wellesbourne in 1984, on two cauliflower crops, each of 70 x 70 plants, and present in the ground from 7 May to 30 July and 1 August to 28 September, respectively. Eggs were sampled from the soil around four groups of five plants and by 10 traps per plot. The results from the Mann Whitney test applied to the data after the number of eggs recovered on two successive dates were combined, making 8 groups of 5 plants for eggs around plants and 4 groups of 5 plants for traps, are shown in Table 3. When the two-tailed critical value $\alpha = 0.05$ was used, no difference was found between the two sampling methods in the early crop, and only on two periods in the late crop, when more eggs were found in the traps. When the critical value was raised to $\alpha = 0.2$ more occasions arose in both the early and late crops when one or the other method sampled more eggs. These results suggest that with the increased number of plants sampled in this comparison than in the previous one, variation in the number of eggs laid may have been influenced by soil moisture conditions which might also have provided better or worse conditions for egg laying in the trap. Similar observations were made in Denmark. It was also shown in the Wellesbourne experiment that the plant growth stage may have a minor influence on the difference between natural egglaying and eggtrapping.

Table 2. Comparison of two egg sampling methods for cabbage root fly on cauliflower.

Date	Method	Nb. of checked plants	Nb. of plants with eggs	Total nb. of eggs
14.5.1980	Egg trap Natural egg laying	10 10	6 8	17 15
21.5	Egg trap Natural egg laying	10 10	5 10	10 81
28.5	Egg trap Natural egg laying	10 10	10 10	166 82
4.6	Egg trap Natural egg laying	10 10	8 6	40 12
11.6	Egg trap Natural egg laying	10 10	7 9	54 58
18.6	Egg trap Natural egg laying	10 9	7 9	89 94
25.6	Egg trap Natural egg laying	10 10	7 8	57 31
2.7	Egg trap Natural egg laying	10 10	7 10	42 144

(After FREULER & FISCHER,1982)

Table 3. Comparison of two egg sampling methods for cabbage root fly on two cauliflower crops.

<table>
<tr><th rowspan="3">Date</th><th colspan="4">MANN-WHITNEY TEST</th></tr>
<tr><th colspan="2">$\alpha = 0,05$</th><th colspan="2">$\alpha = 0,2$</th></tr>
<tr><th>Natural egglaying</th><th>Egg trap</th><th>Natural egglaying</th><th>Egg trap</th></tr>
<tr><td>7. / 9.5.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>11. / 14.5.</td><td colspan="2">=</td><td>></td><td></td></tr>
<tr><td>16. / 18.5.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>21. / 23.5.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>25.5 / 28.5.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>30.5 / 1.6.</td><td colspan="2">=</td><td>></td><td></td></tr>
<tr><td>4. / 6.6.</td><td colspan="2">=</td><td></td><td><</td></tr>
<tr><td>8. / 11.6.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>13. / 15.6.</td><td colspan="2">=</td><td>></td><td></td></tr>
<tr><td>18. / 20.6.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>22. / 25.6.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>27. / 29.6.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>2. / 4.7.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>6. / 9.7.</td><td colspan="2">=</td><td>></td><td></td></tr>
<tr><td>11. / 13.7.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>16. / 18.7.</td><td colspan="2">=</td><td></td><td><</td></tr>
<tr><td>20. / 23.7.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>25./27/ 30.7.</td><td colspan="2">=</td><td></td><td><</td></tr>
<tr><td>1. / 3.8.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>6. / 8.8.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>10. / 13.8.</td><td></td><td><</td><td></td><td><</td></tr>
<tr><td>15. / 17.8.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>20. / 22.8.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>24. / 27.8.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>29. / 31.8.</td><td></td><td><</td><td></td><td><</td></tr>
<tr><td>3. / 5.9.</td><td colspan="2">=</td><td>></td><td></td></tr>
<tr><td>7. / 10.9.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>12. / 14.9.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>17. / 19.9.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
<tr><td>21.9. / 24.9.</td><td colspan="2">=</td><td>></td><td></td></tr>
<tr><td>26.9. / 28.9.</td><td colspan="2">=</td><td colspan="2">=</td></tr>
</table>

Table 4. Comparison of two egg sampling methods for cabbage root fly on swede

Date	Soil sample Mean number of eggs per 30 cm of row	Egg trap Mean number of eggs per 5 plants
21.5.1986	110	196
28.5.	78	55
3.6.	65	44
10.6.	51	30

In the Netherlands in 1984, a field of 196 cauliflower plants was sampled. More eggs were found around plants than in traps. There were also more traps without eggs than plants.

In an experiment started in Switzerland in 1986 on a commercial swede crop, cv. Blanc de Croissy, the number of eggs from eight soil samples along 30 cm of row were compared with those from eight groups of five egg traps (Table 4). The Mann Whitney test revealed no significant differences between the sampling methods.

At present there is more interest in obtaining qualitative information from cabbage rootfly monitoring to provide knowledge of the beginning of egg laying so that advice can be given on the best time to apply chemical control measures. This can be achieved by placing 10 traps along a randomly selected row of plants so that they can be easily inspected at regular intervals. Usually this is weekly but was done twice a week in Denmark and three times a week in England. Most countries counted the number of eggs in the traps, but in France the percentage of traps with eggs was used.

Fig. 1 shows the number of eggs recovered from traps in Denmark, Fig. 2 in England, Fig. 3 in Ireland and from two sites in Switzerland (Figs. 4 and 5). In the latter country farmers are advised not to treat early cauliflower crops between 6-8 weeks old and up to 3 weeks before harvest after egg-laying has started.

Most of the results obtained indicate that the egg trap monitors egg laying activity quite well, although in England eggs were found in traps 2-3 days later than they were recovered from around plants. In north Jutland, Delia floralis has two generations a year, the eggs of the first generation being laid at the time when D. radicum egg laying is at a minimum. Where this occurs, brassica crops are exposed to attack throughout the whole season.

In the Netherlands, the egg traps were tested in a non-preference situation. All the plants (7 x 7) in a small field plot had traps attached to

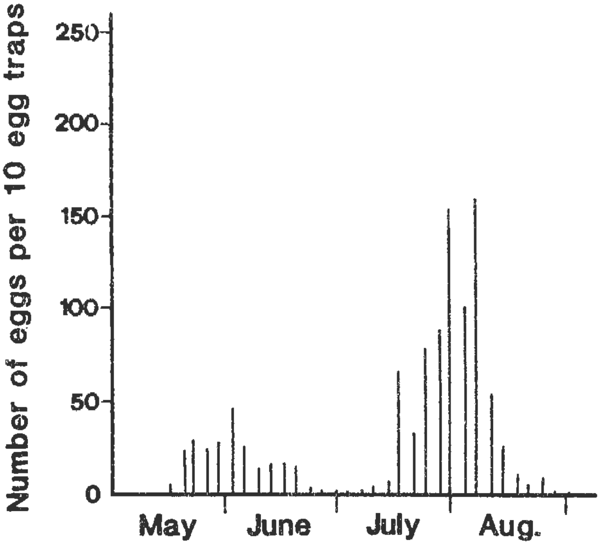


Fig. 1. Monitoring of cabbage root fly egg laying by the egg trap on cabbage in Denmark in 1986. Average of 22 fields.

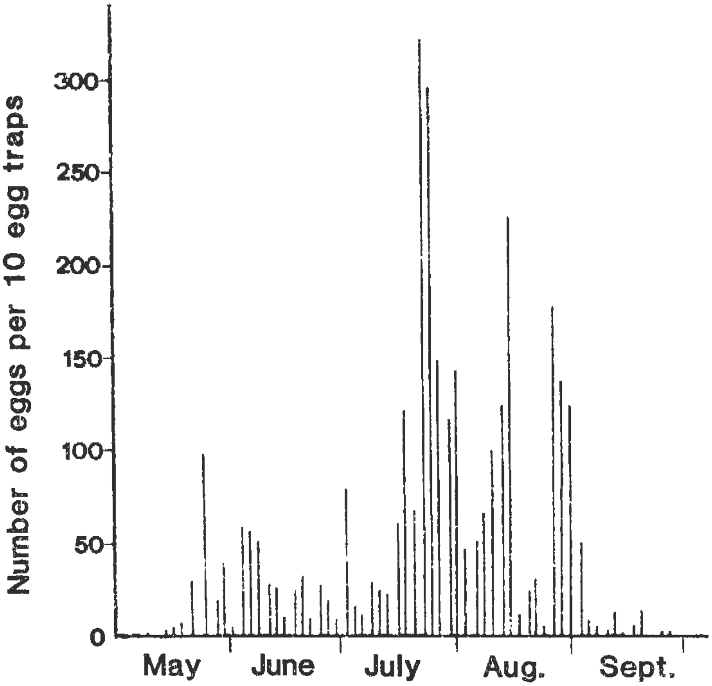


Fig. 2. Monitoring of cabbage root fly egg laying by the egg trap on cauliflower in England in 1984.

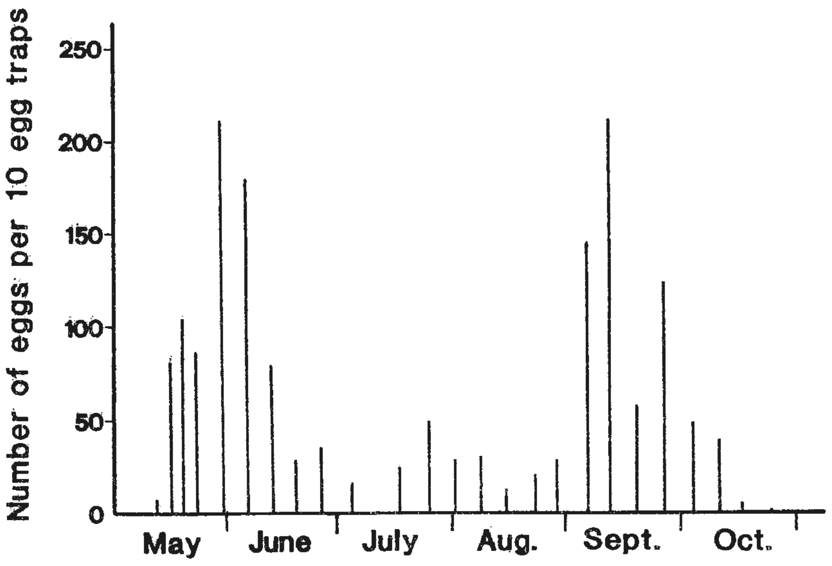


Fig. 3. Monitoring of cabbage root fly egg laying by the egg trap on cabbage/Brussels sprouts in Ireland in 1986.

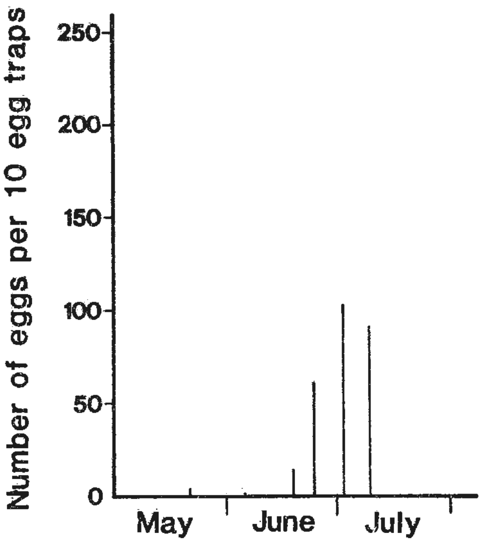


Fig. 4. Monitoring of cabbage root fly egg laying by the egg trap on early cauliflower in Saillon (Switzerland) in 1986

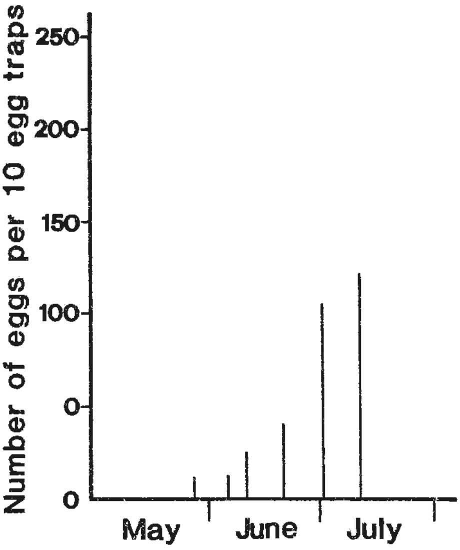


Fig. 5. Monitoring of cabbage root fly egg laying by the egg trap on early cauliflower in Les Epines (Switzerland) in 1986.

them. This encouraged a large number of eggs to be laid in them which facilitated decision making.

It has been found that if a 30% deviation from the mean number of eggs laid in traps is acceptable then 50 traps/field are sufficient to indicate treatment time. If on the other hand more than 20 eggs per week are recovered from each trap only 25 traps need to be employed. This would be the case later in the oviposition cycle. A sequential sampling scheme for traps should, therefore, be developed and tested as a means of measuring the egg thresholds established earlier by the Working Group (EL TITI, 1980).

How the trap has been accepted by farmers and extension services differs in different countries. In Denmark there has been good collaboration with farmers who now count the eggs in the traps themselves. In France, traps are used by the extension service or with student help and in the Netherlands, the extension service is interested in the traps for qualitative monitoring. Counting the eggs in 49 traps in a non-preference situation, as described above, would be too time consuming unless it could be demonstrated that data from a single field can be extrapolated to the neighbouring cauliflower growing district. Until more information is available, the use of traps must at present be restricted to monitoring cabbage rootfly in single fields. In Switzerland, the trap is accepted by the extension service of the Valais but is not used in other cantons of western Switzerland.

Table 5 shows the various organisations that purchased the trap in 1986 and 1987. So far most have been utilized by official institutions rather than individual growers.

Table 5. Organisations that purchased egg traps in 1986 and 1987.

Country	University Agricultural Research Station	Extension service Agricultural School	Private
Austria	1		
Denmark	1		
Finland	1		
France	1	9	1
Germany	1	4	2
Netherlands	3	1	
Norway		4	
Spain			1
Sweden		1	
Switzerland		6	1
U.K.	3	5	
Total	11	30	5

The trap has also been used in France for monitoring D. radicum attacking oil seed rape. Some practical difficulties have been experienced in this high density crop which might be overcome by planting brassicas nearby and monitoring egg laying on them. (E. BRUNEL pers. comm.).

References

FREULER, J. & FISCHER, S. (1982). Description d'un piège à oeufs pour la mouche du chou, Delia brassicae Wiedemann. Mitteilungen Schweizerische Entomologische Gesellschaft 55 : 77-85.

EL TITI, A. (1980). A contribution towards the "economic threshold" of Hylemyia brassicae. IOBC/WPRS bulletin 1980 III/1: 35-41.

COMPARISON OF TRAPS FOR MONITORING POPULATIONS OF THE CABBAGE ROOT FLY

BY STAN FINCH

AFRC Institute of Horticultural Research, Wellesbourne,
Warwick CV35 9EF, UK

SUMMARY

Seven different traps were compared for capturing cabbage root flies. Cone traps caught few flies and should not be used for monitoring populations of this pest. When expressed on a trap by trap basis, the large 1800 cm Canadian traps caught most flies. When expressed as the numbers of flies caught per unit area of trap, the Wellesbourne water trap caught most flies. The attractive visual area of this trap is equivalent to 400 cm, not just the 200 cm^2 area of the water surface. More flies were caught in the water traps than the sticky traps because the flies preferred to land on horizontal surfaces. Details are given of how to convert water-trap data to sticky-trap equivalents, and vice versa.

INTRODUCTION

Many types of traps are used to monitor populations of the cabbage root fly (*Delia radicum* (L.)) to improve the timing, and thus the effectiveness, of insecticides applied against this pest (Finch & Collier, 1986).

In this study the effectiveness of the traps currently used was investigated to determine why different traps catch different numbers of flies. Such information should enable the numbers of flies caught in the different types of traps to be compared with validity. If an "action threshold" were to be produced to indicate that crops should be sprayed when a certain number of flies are caught, conversion of data from sticky traps into water trap equivalents, and vice versa, would be useful.

EXPERIMENTAL WORK

Relative effectiveness of various traps

The traps tested included the 1m diam. x 1m high "cone" trap (Fig. 1A) that is used regularly in North America (Eckenrode & Chapman, 1972) and the standard Wellesbourne fluorescent-yellow water trap (Fig. 1B) (Finch & Skinner, 1974).

All of the other traps tested were sticky. They included: one type in which a transparent Perspex^R acrylic sheet(VT Plastics Ltd, Birmingham, UK) disc coated with Tangletrap^R (The Tangle Co., Grand Rapids, Michigan 49504, USA) replaced the water in Wellesbourne traps (Fig. 1C); the Single- (Fig. 1D) and Double-Rebell (Fig. 1E) traps developed in Switzerland for monitoring populations of the carrot fly (*Psila rosae* Fab.) (Stadler, 1969; Freuler, Fischer & Bertuchoz, 1982); and the Canadian trap developed primarily for monitoring onion fly (*Delia antiqua* Meig.) (Madder & McEwen, 1982) but also used for cabbage root fly (Sears, 1984). Each Canadian trap consisted of three 1-litre milk cartons sited 0.5m apart and painted either fluorescent-yellow (Fig. 1F) or marigold yellow (Fig. 1G). To enable the numbers of cabbage root flies caught by the different types of trap to be compared, all traps except

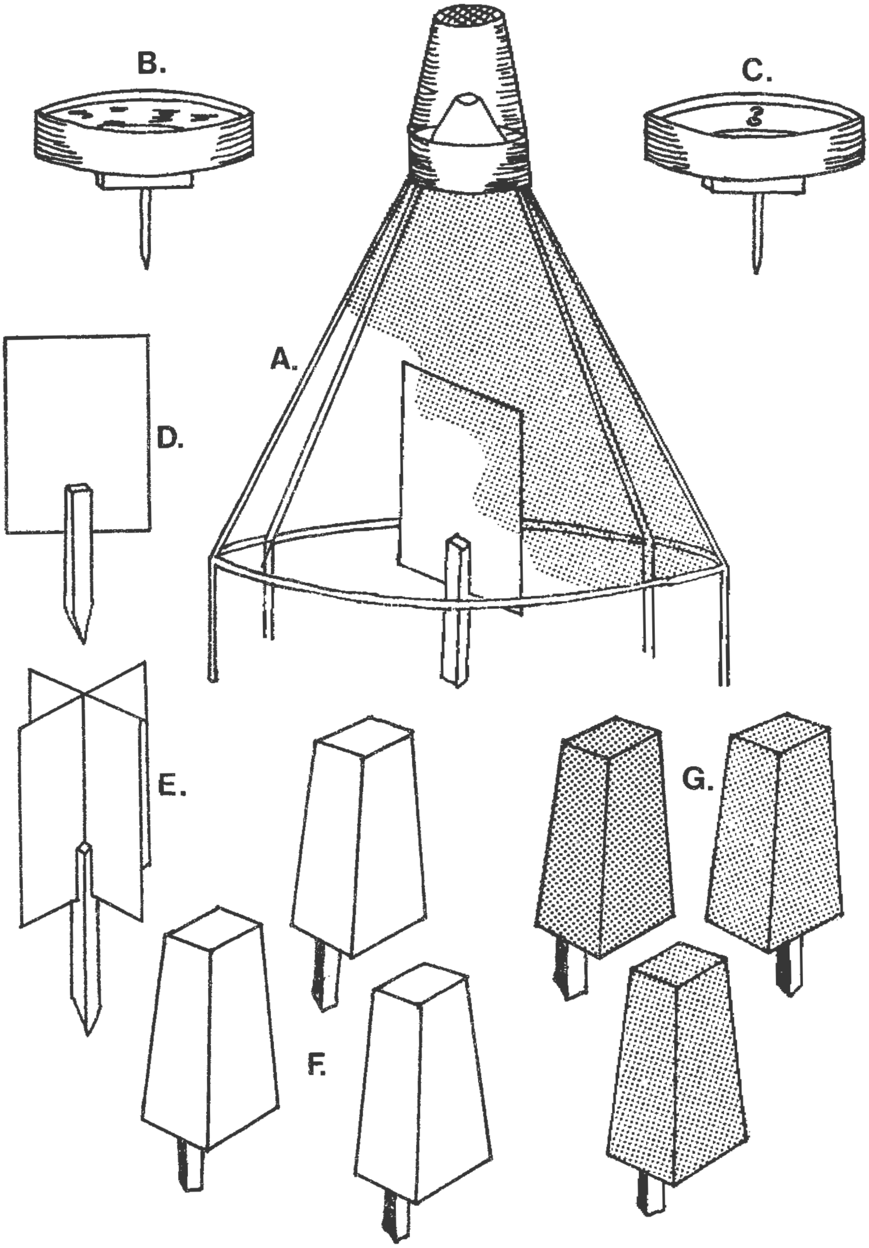


Fig. 1. Types (A-G) of traps used for capturing female cabbage root flies.

the cone trap and the marigold Canadian trap were painted fluorescent-yellow. The trapping surface of the yellow board placed beneath the cone trap was 600 cm^2 and the trapping surfaces of traps B to G were 200, 200, 600, 1200, 1800 and 1800 cm^2, respectively.

Six traps of each type were placed at random 5m from the edge of a crop of swedes (*Brassica napus* var. *napobrassica*) and 10m apart within the rows. This distance was sufficient to prevent the traps from interfering with each other's catch (Finch & Skinner, 1974).

A total of 14,822 female cabbage root flies were caught during the 10 days of this experiment in September 1985. When catches per trap were compared, most flies were caught on the Canadian traps (Fig. 2i), painted marigold-yellow.

Direct comparison is not the most appropriate way to compare trap catches, however, as the different types of traps have very different trapping areas. To overcome this, the numbers of insects caught may be expressed on a trap area basis. When the results were expressed as the number of females caught per 200cm^2 of trap, the surface area of the water in the water trap, 3-5 times more were caught in the water trap than in any other trap tested (Fig. 2i). It is interesting to note that, all the types of sticky trap painted fluorescent-yellow caught within 10% of the same numbers of flies per unit area. More female flies per unit area were caught in the Wellesbourne-type trap with the water replaced by the sticky disc, largely because the flies prefer to land on horizontal rather than on vertical surfaces (see later).

Major disadvantages of using sticky traps and water traps

The main disadvantage of using sticky traps was that they were not easy to service, particularly during windy weather. In addition, the trapped insects often took many days to die and, during this period, a high proportion of the larger insects, particularly the syrphids, escaped and contaminated the vegetation in the immediate vicinity. This made trap servicing unpleasant. In wet periods the Tangletrap^R became denatured and lost its sticky properties. It also often emulsified and masked the attractive colour of the trap. Finally, sticky traps were not suitable in areas where two closely-related species, for example *D. radicum*/*D. floralis*, occurred together as the two species could not be separated readily when the small diagnostic hairs became covered in Tangletrap^R.

A disadvantage of water traps was that the insects began to rot if the traps were not serviced regularly.

Rotting could be prevented by adding two sodium metabisulphite Campden tablets to the water in each trap. Without tablets, flies rotted within 8 days (Table 1). With tablets, the flies remained in perfect condition and could be identified after 16 days.

Table 1. Numbers of female cabbage root flies caught in traps with and without sodium metabisulphite Campden tablets added to the water to reduce microbial breakdown of the trapped insects. Total females trapped = 31,832.

	Frequency of clearing the traps (days)						
	1	2	4	8	12	16	L.S.D. (*P*=0.05)
	Mean numbers of females caught per trap per day						
Without tablets	42	33	32	28	*	*	5
With tablets	40	28	31	29	31	29	

* Most insects too badly decomposed for accurate identification.

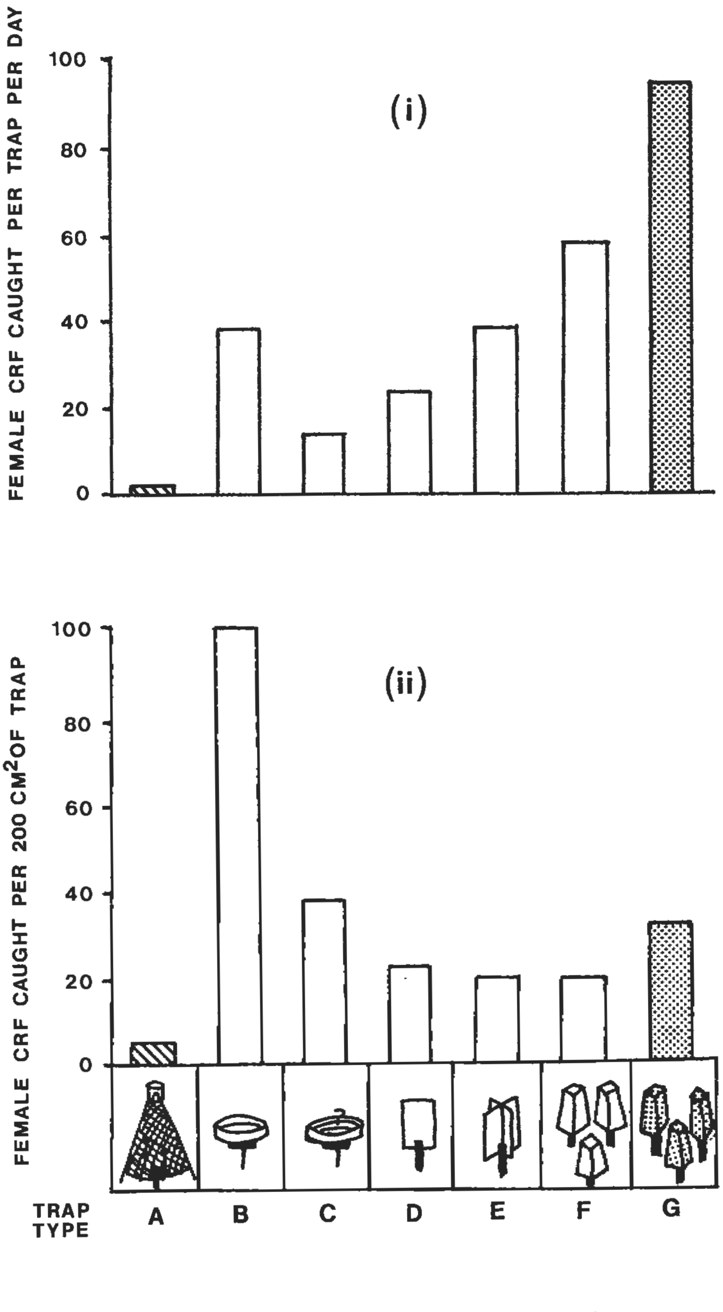


Fig. 2. Numbers of female cabbage root flies caught in trap types A-G. (Total females caught = 14,238).

In addition, the water traps often caught relatively high numbers of benificial Syrphidae. This problem was not easy to solve, largely because cabbage root flies and syrphids preferred to alight on horizontal rather than vertical surfaces. This was discovered by aligning yellow sticky traps at 8 different angles of an octagon (Fig. 3) so that the centre of each trap was the same height above the crop (Fig. 3 -lower diagram) to prevent differences in catch due to trap height (Finch & Skinner, 1974). Figure 3 (upper diagram) shows the strong preference syrphids had for landing on horizontal surfaces and helps to explain why so many syrphids were caught in the water traps.

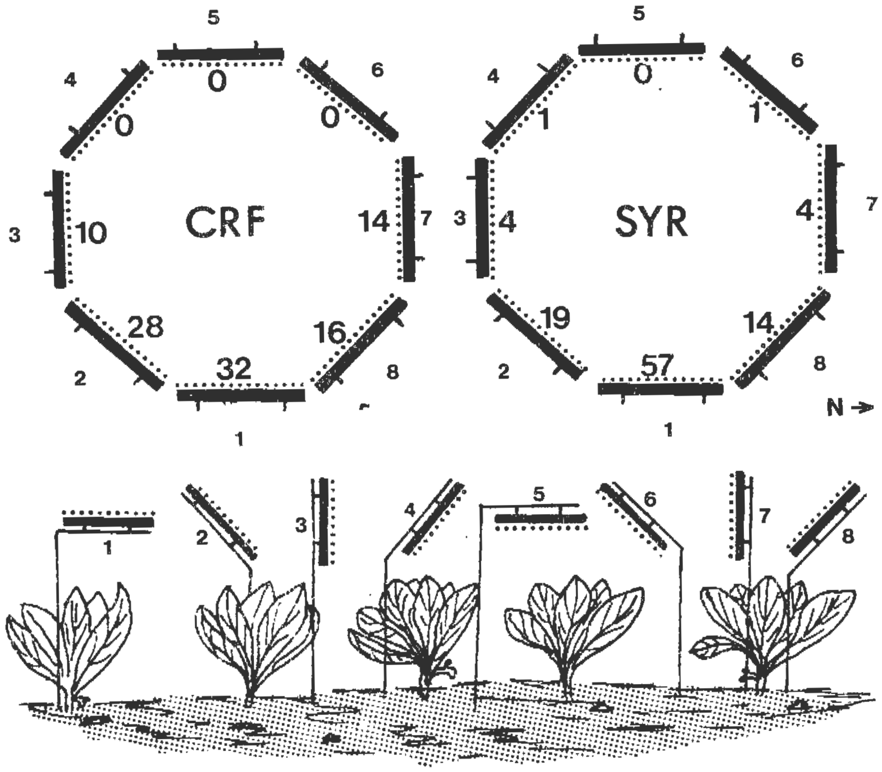


Fig. 3 Percentage of female cabbage root flies (CRF) and syrphids (SYR) caught on 10 x 20 cm yellow sticky traps aligned at eight different angles.

The total numbers of syrphids trapped are unlikely to have any appreciable effect on the overall syrphid population. However, they might be unacceptable to conservationists, particularly if water-traps are used widely for monitoring pest insects in brassica crops. The numbers of trapped syrphids were halved approximately, without reducing the numbers of cabbage root flies caught, by substituting white traps for yellow traps (Table 2) and by painting the inside wall of the standard yellow fluorescent trap black (Table 2).

Table 2. Numbers of cabbage root fly females and syrphids caught in the three experiments aimed at reducing the numbers of syrphids caught. This involved A. changing the colour of the trap, B. painting the inside wall of the trap black and C. covering traps with 12 mm mesh to prevent the larger flies from entering.

	Mean numbers of flies per trap per day	
	Cabbage root flies	Syrphids
A. Yellow:white traps	33:30	11:5
B. Yellow:yellow/black trap	41:49	103:42
C. Uncovered:netted traps	44:14	20:3

Using the technique developed in Denmark for carrot fly traps (see Philipsen in this Bulletin), in which cylinders of 12 mm mesh are placed over the traps to "sieve" out the large insects, the numbers of syrphids caught were reduced. However, the numbers of root flies caught were also reduced (Table 2).

Attractive area of a water trap

In an earlier comparison of the effectiveness of traps, the numbers of insects caught were expressed per 200 cm^2 of trap, an area equivalent to the surface area of the water in the Wellesbourne trap. However, whereas all surfaces of sticky traps can catch flies that alight, the vertical surfaces of water traps can attract but cannot trap flies. Thus, although the trapping area of a water trap may be 200 cm^2, the attractive visual image of these traps is much larger.

To determine how the various parts of a water trap contribute to the trap's overall attractiveness, different parts of yellow traps were painted black, a pigment shown previously to be non-attractive to cabbage root fly adults (Finch & Skinner, 1982). Nine combinations of yellow/black traps were used in the experiment (Fig. 4). All traps were spaced 6 m apart within and between rows of swedes and six traps of each type were used. The total number of female cabbage root flies caught during the 8 days of this experiment was 5,174.

The numbers of flies caught, expressed as percentages of those caught in the standard all yellow Wellesbourne trap, are shown in Fig. 4. For maximum catch, the bottom of the inside and at least the inner or outer wall of the trap had to be yellow (Fig. 4a-c). When only the bottom of the trap was yellow (Fig. 4d), an area equivalent to a 200 cm^2 disc, about half as many females were caught. Similarly, about one quarter of the numbers of females were caught when one wall of the trap was yellow (Fig. 4 g-h). No flies were caught in the all-black traps (Fig. 4f), confirming that black is an unattractive pigment (Finch & Skinner, 1982) and also emphasizing that female cabbage root flies do not enter water traps by chance.

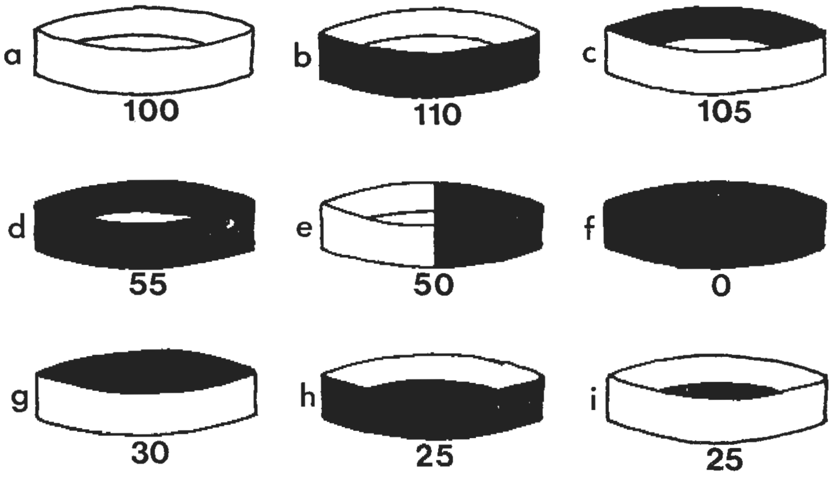


Fig. 4 Relative numbers of female cabbage root flies caught in fluorescent yellow water traps in which various parts of the dish of the trap had been painted black.

DISCUSSION

The reasons for selecting a particular trap are not always based on scientific studies. In many instances, the trap used is a modified version of a freely-available trap developed previously for another pest. Systems using such traps that enable the timing of cabbage root fly attacks to be forecast are unlikely to be changed by outside influences. In addition, the choice of trap is often influenced by personal and national interests when several types are available. For these reasons, this study has concentrated on finding ways of comparing results obtained with different traps, rather than on attempting to recommend that all workers should use the same type trap. However, it would be wise to standardize, on the colour of traps as small differences can have large effects on the numbers of flies trapped. Fluorescent yellow is one of the few pigments supplied as only one type of paint. In contrast, the variations of yellow and white gloss paints available are enormous and, as a result, standardization for these colours would be very difficult.

The first criterion for a monitoring system is that the trap should catch large numbers of the species being studied. As this criterion was not fulfilled by the cone trap (Fig. 2) in this study, nor previously (Finch, Freuler & Stadler, 1980; Sears, 1984), such traps should not be used for the cabbage root fly if either water traps or sticky traps are available.

Similar numbers of female cabbage root flies were caught on each of the three milk cartons comprising a Canadian trap. As comparable estimates of fly populations could be obtained using only one of each group of three cartons, the work involved could be reduced by 67% or two of the cartons could be deployed elsewhere in the field being monitored to obtain a more robust estimate of the local fly population.

Catches of female cabbage root flies in the yellow/black traps indicated that about 25% of the females entering a Wellesbourne water trap are attracted by either its inside or outside wall (Fig. 4 - bottom row) and that about 50% of the flies trapped are attracted by the bottom of the trap (Fig. 4 - middle row). To obtain the full synergistic effect of a 100% catch (Fig. 4 - top line), parts of both the horizontal and vertical surfaces of the trap must be yellow (Fig. 4 - top row). Furthermore, since the trap in which only the bottom was yellow (Fig. 4d) and the trap that was only half yellow (Fig. 4e) caught about half as many females as the all-yellow trap, the attractive area of the Wellesbourne water trap should be considered to be twice that of the surface area of the water i.e., 400 cm^2 rather than 200 cm^2.

The data presented in this paper explain why the Wellesbourne water trap catches 5 times more female cabbage root flies than a 200 cm^2 fluorescent-yellow sticky trap. There are two major factors responsible for the difference. Firstly, the "attractive area" of a water trap is about twice the size of its trapping surface. Secondly, as more cabbage root flies land on horizontal than vertical surfaces, greater numbers are caught in horizontal water traps than on vertical sticky traps.

If a Wellesbourne water trap with an attractive area of 400 cm^2 catches 100 flies, a sticky trap of 200 cm^2 would be expected to catch 50 flies. However, as 2.6 times as many female cabbage root flies alight on an horizontal as on a vertical surface (12:32 CRF - Fig. 3), 50/2.6 = c. 19 flies (compare results of traps D, E & F - Fig. 2ii) would be expected to be caught on a vertically-orientated sticky trap with a surface area of 200 cm^2. Providing the same colour is used for the traps, the numbers of female cabbage root flies expected when a particular number is caught on 200 cm^2 of a sticky trap or a Wellesbourne water trap can be predicted by multiplying or dividing the numbers of trapped flies by five.

In the past, many of the members of the Working Group have concluded that the populations of cabbage root flies monitored with sticky traps have been smaller than those monitored at Wellesbourne with water traps. Past data should be reviewed in light of the present findings to determine the actual scale of local cabbage root fly populations.

I thank Miss Marian Elliott, Mr G. Skinner and Dr T.H. Jones for invaluable help during the course of these experiments.

REFERENCES

ECKENRODE, C.J. & CHAPMAN, R.K. (1972). Seasonal adult cabbage maggot populations in the field in relation to thermal-unit accumulations. Annals of the Entomological Society of America **65**, 151-156.

FINCH, S. & COLLIER, ROSEMARY H. (1986). Forecasting the times of attack of the cabbage root fly (Delia radicum) on vegetable brassica crops. Aspects of Applied Biology **12**, 37-46.

FINCH, S. & SKINNER, G. (1974). Some factors affecting the efficiency of water traps for capturing cabbage root flies. Annals of Applied Biology **77**, 213-226.

FINCH. S. & SKINNER, G. (1982). Trapping cabbage root flies in traps baited with plant extracts and with natural and synthetic isothiocyanates. Entomologia Experimentalis et Applicata **31**, 133-139.

FINCH, S., FREULER, J. & STADLER, E. (1980). Trapping Hylemya brassicae adults. SROP/WPRS Bulletin 1980/III/1: Integrated Control in Brassica Crops, pp. 11-17.

FREULER, J., FISCHER, S. & BERTUCHOZ, P. (1982). La mouche de la carotte, *Psila rosae* fab. (diptera; psilidae). II. Mise au point d'un piége. *Revue Suisse Viticulture, Arboriculture and Horticulture* 14, 137-142.

MADDER, D. J. & MCEWEN, F.L. (1982). Integrated pest management in onions and carrots. *Report of the Department of Environmental Biology, University of Guelph, Canada*, 94pp.

SEARS, M. K. (1984). Feasibility of monitoring cabbage maggot flies in rutabagas. *Report of Project for Provincial Lottery Research Programme of the Ontario Ministry of Agriculture and Food, University of Guelph, Canada.* 42pp.

STADLER, E. (1969). Untersuchungen zur Verbreitung, zeitlichem Aufreten und Bekampfung der Mohrenfliege. *Gemusebau* 32, 1-4.

Three years experience of using a warning system to predict the times of attack by the cabbage root fly (Delia radicum)

By BENT BROMAND

National Research Centre for Plant Protection, Institute of Pesticides,
Lottenborgvej 2, DK-2800 Lyngby, Denmark

SUMMARY

A warning system to predict attacks by the cabbage root fly has now been operating in Denmark for 3 years. The system has been developed with the assistance of growers and is based on the catch of eggs collected from egg-traps. Each grower uses 10 egg-traps, which he empties twice a week. He telephones the numbers of eggs collected to the Plant Protection Centre and warnings for the start of the attacks by the first and second generation of flies are then sent to both the the advisory service and to the appropiate state TV network.

INTRODUCTION

In 1984 good agreement was found between the numbers of female cabbage root flies caught in yellow water traps and the number of cabbage root fly eggs recovered from egg-traps (Bromand, 1987).

As a result of this finding, it was decided to produce a warning system against the cabbage root fly based on the numbers of cabbage root fly eggs collected from several localities throughout Denmark. Egg-traps (Freuler & Fischer, 1982 and 1983) were used in 12, 22 and 40 localities in 1985, 1986 and 1987, respectively. During 1987, 19 of the growers using the egg-traps forwarded the numbers of eggs collected for use in the general system while the remainder just used the egg-traps for their own benefit.

MATERIALS AND METHODS

In 1985 12 growers in the main cabbage growing areas in Denmark agreed to participate in collecting data to develop the warning system. Each grower was sent 10 egg-traps, instructions on how to use the traps, sheets on which to write the numbers of eggs collected, and a figure showing the expected flight curve of the cabbage root fly. The growers agreed to count the eggs in the egg-traps each Monday and Thursday and then telephone the information concerning numbers of eggs collected to the Plant Protection Centre. Since egg-laying can increase very rapidly, the participating growers agreed to count eggs on a routine basis to avoid being too late with the control warnings.

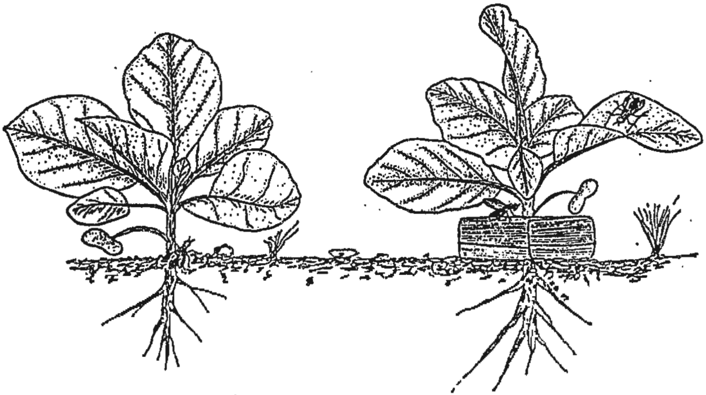


Figure 1. Diagrams of plants without and with egg-traps.

Each egg-trap is made of a role of felt, glued at the bottom and cut at the one side to make it fit around the stem of a cabbage plant. A burdock lock ensures that the egg-trap fits firmly around the stem of the plant. In the field, 10 egg-traps are placed on every second or third plant in the chosen row. This row was generally a few rows into the field and preferably along the hedge-row where the heaviest egg-laying is expected.

The system is intended to give a warning of the times when the egg-laying of the two generations begins to increase. The numbers of eggs collected cannot in any way be used as a damage threshold.

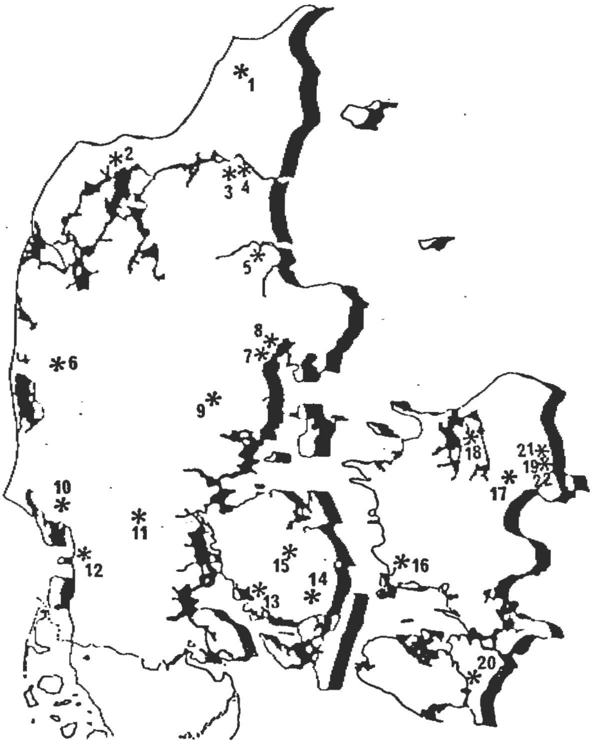


Figure 2. Localities with egg-traps in Denmark in 1986.

In 1986 and 1987 the number of sites monitored was increased to obtain a better coverage of the country. Figure 2 shows the approximate localities where eggs were sampled in 1986. The majority of the growers were asked to record the numbers of eggs collected between 14 May - 15 June and between 25 June - 27 July. These periods were chosen to ensure that the start of egg-laying by both the first and second generation of the cabbage root fly were included in the sampling periods. A few growers agreed to sample eggs throughout the season to produce complete curves of egg-laying activity.

The warning consists of a postcard showing the numbers of eggs collected at the various localities together with comments and recommendations on how to apply the appropiate control measures.

RESULTS

The results for the first and second generation in 1986 are shown in Tables 1 & 2, respectively. From 19 June onwards, the numbers of eggs collected from localities 1-4 have not been included in the totals, since these sites are situated in the northern part of Jutland where most ot the eggs laid during this period are those of the turnip root fly (Delia floralis). The preponderence of turnip root flies in these samples was verified by taking samples of larvae from the plants at the beginning of July.

The results indicated that there could be a difference of 5-7 days in the time egg-laying started in the different areas sampled in Denmark.

The results of the 1987 samples are shown in Tables 3 and 4. Figure 3 shows the curves of the egg-laying in 1985, 1986 and 1987 and the dates when warnings were sent out. Figure 3 also shows that there is a period between the 2 generations when very few eggs are recovered.

DISCUSSION

In Denmark, the cabbage root fly normally completes 2 and sometimes a partial third generation, each year. The third generation is normally of little importance with respect to control. Previously the first generation was considered to be the most important one and was said to merge gradually into the second generation. Hence, control of the cabbage root fly was necessary throughout most of the summer and many sprays were applied routinely. Since 1970, the area of oilseed rape has increased tremendously. Many flies of the first generation of the cabbage root fly now lay their eggs in oilseed rape crops and consequently the importance of the pest is reduced in cabbage. Although little damage is evident on the oilseed rape, the insects multiply on this crop. When the second generation emerges to lay eggs the oilseed rape plants are no longer suitable. Consequently, the flies lay in cabbage crops and as a result the second generation is the most numerous and most important generation now infesting cabbage crops.

One important finding is that few eggs are laid in the period between the 2 generations. Hence, no control measures are required during this period. In addition, the use of egg-traps for timing control of the second generation can be very accurate if previous control, plant size, etc. are taken into consideration.

In the spring, first flies can be expected from 10 May but egg-laying rarely occurs before mid-May. In 1985, 1986 and 1987, spring was cold and as a

Table 1. Number of cabbage root fly eggs collected per day from 10 traps during 1st generation 1986.

	MAY					JUNE									JULY	
Date	* 16	20	22	26	29	2	5	9	12	16	19	23	26	30	3	7
Locality																
1. Hjørring	0	8	53	71	52	448	126	54	63	104	-	-	1206	1017	686	241
2. Fjerritslev	-	-	-	-	-	-	-	-	9	22	10	19	2	26	31	21
3. Gistrup	0	1	4	12	11	36	36	19	-	-	-	-	-	-	-	-
4. Storvorde	-	-	-	-	-	-	37	17	29	53	-	26	23	9	10	17
5. Havndal	0	0	0	3	2	6	-	-	-	-	-	-	-	-	-	-
6. Spjald	1	10	27	15	30	7	8	4	7	2	-	-	-	-	-	-
7. Egå	0	1	5	4	0	12	16	4	2	1	-	-	-	-	-	-
8. Lystrup	-	-	-	-	12	1	37	5	8	8	5	-	-	-	-	-
9. Yding	0	0	32	11	18	26	14	33	8	12	-	-	-	-	-	-
10. Skast	0	2	15	12	7	8	2	13	1	0	-	1	-	-	-	-
11. Vejen	-	-	50	31	42	35	13	18	25	9	13	2	1	4	7	2
12. Ribe	-	-	-	-	-	-	-	-	-	-	-	0	-	6	4	11
13. Fåborg	-	-	-	-	0	3	0	4	4	13	-	-	-	-	-	-
14. Stenstrup	-	-	-	-	0	1	1	2	0	8	-	-	0	0	0	0
15. Årslev	0	10	87	31	44	31	30	24	52	28	60	-	4	2	0	0
16. Vemmelev	1	19	40	28	62	33	10	3	6	11	-	-	-	5	2	2
17. Hedehusene	3	8	21	45	38	49	70	22	10	-	-	-	0	0	0	0
18. Jægerspris	51	63	53	43	56	81	7	25	31	-	-	-	-	-	-	-
19. Lyngby	0	21	15	44	39	23	19	1	10	8	10	9	5	3	3	2
20. Nykøbing F.	-	-	6	2	0	6	0	4	5	0	0	-	-	-	-	-
21. Virumgaard	8	50	23	39	73	39	35	8	16	5	6	7	2	1	0	2
22. Lyngby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	64	193	431	391	486	845	461	260	286	284	104	19	12	21	16	19
Average	4.9	14.8	28.7	26.1	27.0	46.7	25.6	14.4	15.9	17.8	14.9	3.8	1.7	2.3	1.8	2.1

* The traps were put on the plants 13 May.

Table 2. Number of cabbage root fly eggs collected per day from 10 traps during the 2nd generation, 1986.

	JULY							AUGUST								SEPTEMBER
Date	7	14	17	21	24	28	31	4	7	11	14	18	21	25	28	1
Locality																
1. Hjørring	187	55	32	13	141	149	-	-	-	-	-	-	-	-	-	-
2. Fjerritslev	15	1	36	10	64	74	-	-	-	-	-	-	-	-	-	-
3. Gistrup	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Storvorde	10	10	13	8	171	292	636	322	377	188	116	-	20	3	3	-
5. Havndal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Spjald	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Egå	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Lystrup	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. Yding	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. Skast	0	0	12	25	59	174	-	-	-	-	-	-	-	-	-	-
11. Vejen	8	14	303	116	169	121	-	88	102	65	26	18	9	12	-	1
12. Ribe	2	2	97	48	138	85	-	-	-	-	-	-	-	-	-	-
13. Fåborg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. Stenstrup	4	4	34	24	93	71	-	-	-	-	-	-	-	-	-	-
15. Årslev	1	10	20	22	31	47	53	74	311	85	47	-	-	-	-	-
16. Vemmelev	1	3	51	36	98	129	267	-	-	-	-	-	-	-	-	-
17. Hedehusene	2	1	5	15	46	64	158	144	143	59	-	-	-	-	-	-
18. Jægerspris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19. Lyngby	6	5	22	5	-	-	-	-	-	-	-	-	-	-	-	-
20. Nykøbing F.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21. Virumgaard	6	8	28	18	28	-	-	-	-	-	-	-	-	-	-	-
22. Lyngby	-	27	80	35	54	31	136	102	86	17	10	5	0	5	2	-
Total	30	74	652	344	716	722	614	408	642	226	83	23	9	17	2	1
Average	3.3	7.4	65.2	34.4	79.6	90.3	153.5	102.0	160.5	56.5	27.7	11.5	4.5	8.5	2.0	1.0

Table 3. Number of cabbage root fly eggs collected per day from 10 traps during 1st generation 1987.

	MAY				JUNE									JULY			
Date	* 18	21	25	29	1	4	9	11	15	18	22	25	29	2	6	9	13
Locality																	
1. Hjørring	0	0	0	0	2	11	11	14	5	12	18	5	0	2	0	0	16
2. Fjerritslev	-	-	-	-	-	-	-	-	-	-	-	-	1	6	4	0	0
3. Storvorde	-	-	-	3	3	24	2	19	12	1	5	10	16	1	3	0	0
4. Egholm	-	-	50	65	58	20	7	13	-	-	-	-	-	-	-	-	-
5. Gandrup	13	11	70	31	51	50	0	19	-	-	-	-	-	-	-	-	-
6. Spjald	0	1	5	30	6	19	1	26	6	-	-	-	0	1	0	0	1
7. Auning	51	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Lystrup	-	-	-	1	-	20	-	-	-	-	-	-	-	-	-	-	-
9. Samsø	0	6	38	14	12	22	-	-	-	-	-	-	-	-	-	-	-
10. Nordborg	5	2	22	24	59	-	12	67	-	-	7	-	-	-	-	-	-
11. V. Hæsinge	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
12. Stenstrup	-	-	-	23	3	2	2	0	3	12	7	7	0	0	0	0	0
13. Årslev	0	0	10	2	2	10	6	50	10	-	-	-	4	1	0	0	0
14. Vemmelev	-	19	44	31	5	16	12	17	4	-	-	-	8	0	4	4	5
15. Skælskør	-	-	4	6	19	6	3	33	19	7	0	10	5	0	0	1	0
16. Sandved	0	0	51	54	13	3	9	9	3	-	-	-	0	0	0	0	0
17. Hedehusene	0	0	6	27	32	23	11	25	14	-	-	-	2	3	0	0	0
18. Amager	0	0	29	18	30	30	21	45	17	-	-	-	-	-	-	-	-
19. Lyngby	0	0	5	2	1	11	6	1	1	0	1	0	0	3	0	6	3
Total	69	39	334	331	296	267	103	338	94	32	38	32	36	17	11	11	9
Average	6.3	3.3	25.7	20.7	19.7	17.8	7.5	24.1	8.5	6.4	6.3	6.4	3.0	1.4	0.9	0.9	1.0

* The traps were put on the plants 14 May.

Table 4. Number of cabbage root fly eggs collected per day from 10 traps during 2nd generation 1987.

	JULY					AUGUST								SEPTEMBER			
Date	16	20	23	27	30	3	6	10	13	17	20	24	27	31	3	7	10	14
Locality																		
1. Hjørring	25	0	5	9	36	71	55	-	526	785	392	438	90	58	62	16	7	0
2. Fjerritslev	0	10	48	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Storvorde	1	2	15	10	39	78	133	202	139	-	-	-	-	-	-	-	-	-
4. Egholm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Gandrup	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Spjald	0	0	0	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Auning	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Lystrup	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. Samsø	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. Nordborg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11. V. Hæsinge	0	0	14	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. Stenstrup	0	0	3	2	25	-	-	-	-	-	-	-	-	-	-	-	-	-
13. Årslev	0	6	1	7	22	16	19	37	48	167	190	148	154	17	14	-	-	-
14. Vemmelev	5	24	21	16	65	91	78	77	46	148	112	77	50	19	-	-	-	-
15. Skælskør	2	-	13	20	63	-	32	-	70	-	-	-	-	-	-	-	-	-
16. Sandved	0	0	1	29	41	16	-	-	-	-	-	-	-	-	-	-	-	-
17. Hedehusene	0	0	0	2	31	24	24	-	-	-	-	-	-	-	-	-	-	-
18. Amager	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19. Lyngby	23	2	17	19	21	34	61	54	147	143	205	133	31	14	14	0	0	1
Total	30	32	70	109	268	181	214	168	311	458	507	358	235	50	28	0	0	1
Average	3.3	4.0	7.8	12.1	38.3	36.2	42.8	56.0	77.8	152.7	169.0	119.3	78.3	16.7	14.0	0.0	0.0	1.0

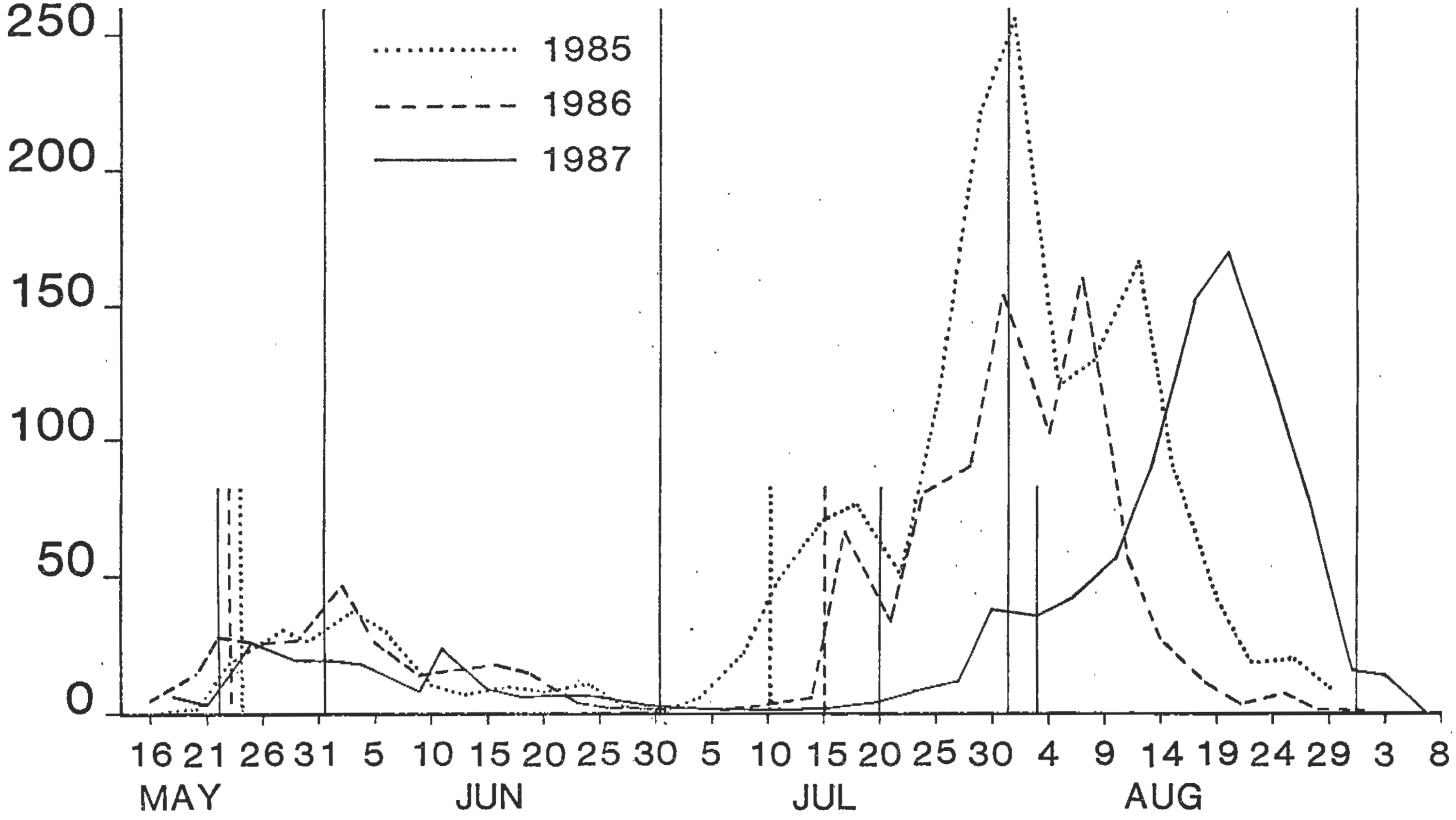


Figure 3. Number of cabbage root fly eggs collected per day from 10 traps. The vertical lines indicate the dates when the warnings were sent out.

consequence egg-laying was delayed and warning were only sent out 22-24 May. The information used to produce this general warning was limited, because most of the growers had not transplanted their cabbage and those that were transplanted were not large enough to put the egg-traps on. In addition, growers tended not to report when no eggs were found in the traps.

The second generation 1985 typifies the "normal" situation. Warning should be sent out when egg-laying starts to increase. In 1985, the warning was sent out on 10 July whereas 5 July would have been a more appropiate date cf. figure 3. The main problem is that the warning is based on using the numbers of eggs collected on 2 consecutive dates in order to judge whether the increase is real or whether it is just an artefact resulting from a few days of weather ideal for egg-laying.

In 1986 it was hot and dry from 23 June to 14 July. Under such conditions, although an increase in egg-laying was expected at the beginning of July, it did not occur. A slight increase occurred on 14 July. However, soil samples containing pupae revealed that about 50% of the flies had already emerged and so a warning was sent out on 15 July. Subsequent egg counts confirmed that this was the appropiate date for the warning. The reason for this delay remains unknown, since aestivation seems unlikely in Denmark. Even if the air temperature is 30°C the soil temperature around the pupae will be well below the temperature of 22°C, which according to Finch & Collier (1985) is the temperatue at which the insects start to enter aestivation. The most likely explanation is that the soil surface was too dry for egg-laying and hence the flies retained their eggs. According to Schnitzler (1969) the cabbage root fly prefers a soil with a water content of 15 per cent for egg-laying.

In 1987 a slight increase in egg-laying occurred on 19 July. Although this was much later than expected, a warning was sent out the next day. (See Figure 3). This particular warning indicated that most of the flies were active and that in sunny and dry weather heavy egg-laying could be expected. However, the weather continued to be cold and rainy and egg-laying only really started towards the end of the month. Obviously the flies had retained their eggs during the initial period of the inclement weather but eventually could no longer retain the eggs and so were forced to lay.

Despite several weak points, the warning system has proved satisfactory for detecting the start of egg-laying under varied conditions during the 3-year period of this investigation. In the near future, attempts will be made to establish correlations between temperature, rainfall and egg-laying using the data collected in 1985, 1986 and 1987.

CONCLUSION

This 3-year investigation using egg-traps to monitor cabbage root fly egg-laying has produced the following conclusions:

1. The trapsare suitable for use by the actual growers.

2. Traps sited in 20 different localities provide sufficient information to produce a general warning for the start of egg-laying of both the first and second generation of flies in Denmark.

3. There is a period, 1-2 weeks, between the 2 generations when very few eggs are laid.

4. A better understanding of egg-laying allows more accurate advice to be given to the growers about the need for control and the likely influence of such factors as plant size, previous control etc.

5. Reduction in the use of chemicals is possible, since the grower can now avoid using chemicals when they are not necessary. This has been confirmed by several growers who have adopted the system.

6. Several growers have reported that they had great advantage of being in the field so often keeping track of the activity of the cabbage root fly.

7. It is not possible to produce a damage threshold based on the number of eggs found in the traps.

ACKNOWLEDGEMENT

I sincerely thank Dr. Stan Finch for a his numerous comments and corrections during the preparation of this manuscipt.

REFERENCES

BROMAND, B. (1987) : Varsling mod den lille kålflue. 4. Danske Planteværnskonference 1987: 325.

FINCH, S. & COLLIER, ROSEMARY, H. (1985): Laboratory studies on aestivation in the cabbage root fly (Delia radicum). Entomologie experimentalis et applicata 38: 137-143.

FREULER, J. & FISCHER, S. (1982): Description d'un piège à œufs pour la mouche du chou, Delia brassicae Wiedemann. Mitteilungen der Schweizerichen Entomologischen Gesellschaft 55: 77-85.

FREULER, J. & FISCHER, S. (1983): Le piège à œufs, nouveau moyen de prévision d'attaque pourla mouche du chou, Delia radicum (brassicae) L.Revue suisse Viticulture Arboriculture Horticulture 15 (2): 107-110.

SCHNITZLER, W.H. (1969) : Über den Einfluss des Bodens, der Düngung, der Bewässerung, des Aussaattermins und der Sorten auf den Befall von Rettich und Radieschen durch die kleine Kohlfliege, *Phorbia brassicae* Bouché (Diptera : Anthomyiidae). Zeitschrift für angewandte Entomologie 64: 353-377.

INDUCTION OF DIAPAUSE IN POPULATIONS OF CABBAGE ROOT FLY PUPAE; RELATIONSHIP BETWEEN SITE LATITUDE AND CRITICAL DAYLENGTH

BY ROSEMARY H. COLLIER, M.HOMMES, S.FINCH, A.N.E.BIRCH, E.BRUNEL, J.FREULER, I.HAVUKKALA AND H.DEN OUDEN.

1. AFRC Institute of Horticultural Research, Wellesbourne, Warwicks CV35 9EF, U.K.
2. Institute for Plant Protection in Horticultural Crops, Messeweg 11/12, D-3300 Braunschweig, Federal Republic of Germany.
3. AFRC Institute of Horticultural Research, Wellesbourne, Warwicks CV35 9EF, U.K.
4. Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, U.K.
5. Station de Zoologie - INRA, Domaine de la Motte au Vicomte, B.P. 29 - 35650, Le Rheu, France.
6. Federal Agricultural Research Station of Changins, 1260 Nyon, Switzerland.
7. Agricultural Research Centre, Institute of Pest Investigation, SF-31600, Jokioinen, Finland.
8. Research Institute for Plant Protection, Binnenhaven 12, P.O.B. 9060, 6700 GW Wageningen, The Netherlands.

(Addresses listed in same order as author's names)

SUMMARY

Cabbage root fly populations from several sites between latitudes $46-61^{\circ}$N in Northern Europe were reared at a constant temperature of $17\pm1^{\circ}$C under five different photoperiods. Diapause was induced in all pupae reared with less than 14 hours light per day. With photoperiods of 16 and 19 hours, the proportion of pupae that entered diapause was related to the latitude from which the original insects were collected. Almost all pupae from the two most northern sites entered diapause; very few pupae from the southern sites entered diapause; and variable proportions of pupae from the intermediate sites entered diapause. In general, the critical photoperiod for diapause induction decreased with the latitude of the collection site. A parameter accounting for this variation should be included in models for forecasting attacks by the cabbage root fly. This would then help to make forecasts more directly-applicable to a wider range of localities.

INTRODUCTION

Development of a cabbage root fly forecast (Finch & Collier, 1986) has involved the accurate measurement of the temperatures and photoperiods for the development of each stage in the life-cycle of the fly. This has included the thermal requirements for the egg, larval, pupal and adult stages, the temperatures and photoperiods required for the induction/completion of diapause and the temperature threshold for the induction of aestivation. Using such information, oviposition activity in the Midlands region of the United Kingdom can now be forecast accurately in any season. However, additional refinements to the original model may be necessary before cabbage root fly activity can be forecast accurately in other regions, particularly if the pattern of fly activity varies from region to region.

The cabbage root fly occurs between latitudes 35-60°N in the temperature zone of the holarctic region and can complete between one and five generations in a year (Coaker & Finch, 1971). Prevailing climatic conditions are a major factor in determining the pattern of activity but there may also be inherent differences in the cabbage root fly populations. Certain populations show delayed emergence folowing winter diapause and have been termed "late emerging" (Finch & Collier 1983). Although late-emerging flies have been found at several sites in Northern Europe (Finch et al, 1988) the times at which such flies emerge do not appear to be related to latitude.

The cabbage root fly is a "long day" insect which enters diapause when days are short and cool (Zabirov, 1961). At Wellesbourne, cabbage root fly eggs laid after about 1 August (when the daylength is 15.5 hrs) give rise to diapause pupae (Hughes, 1960; Finch & Collier, 1985). Daylength changes consistently with latitude and in many insect species the photoperiod required for diapause induction also changes with latitude (Beck, 1980). If this is true for the cabbage root fly then an additional parameter may have to be incorporated into the current forecasting model to account for the effects of latitude on the photoperiodic response of the fly. This paper describes an initial survey to show how latitude affects the way photoperiod influences diapause induction in cabbage root fly populations collected from various latitudes in Northern Europe.

MATERIALS AND METHODS

Details of the sites from which cabbage root fly pupae were collected are given in Table 1. Samples of 100-200 pupae were forwarded by scientists from each participating country and these insects were then used to start laboratory colonies of the various cabbage root fly populations. At some sites, pupae were hand-picked from the field by scraping away the soil from around the base of damaged plants (Finch & Collier, 1983). Where this was not possible, pupae were obtained from laboratory cultures originating from pupae collected in the particular locality. Samples of pupae, sent to Rosemary Collier at Wellesbourne were maintained at 18±1°C to allow flies to emerge and then eggs laid by these flies were used in experiments to investigate diapause induction.

Table 1. Details of sites from which root fly pupae were collected.

Latitude (°N)	Collector	Country	Population*
60.5	Havukkala	Finland	F
57.4	Birch	Scotland	F
52.1	Finch	England(Midlands)	F
51.6	Ouden	Netherlands	L
50.6	Hommes	West Germany	L
50.6	Collier	England(South-West)	F
48.1	Brunel	France	L
46.2	Freuler	Switzerland	L

* Field population (F) or laboratory culture (L).

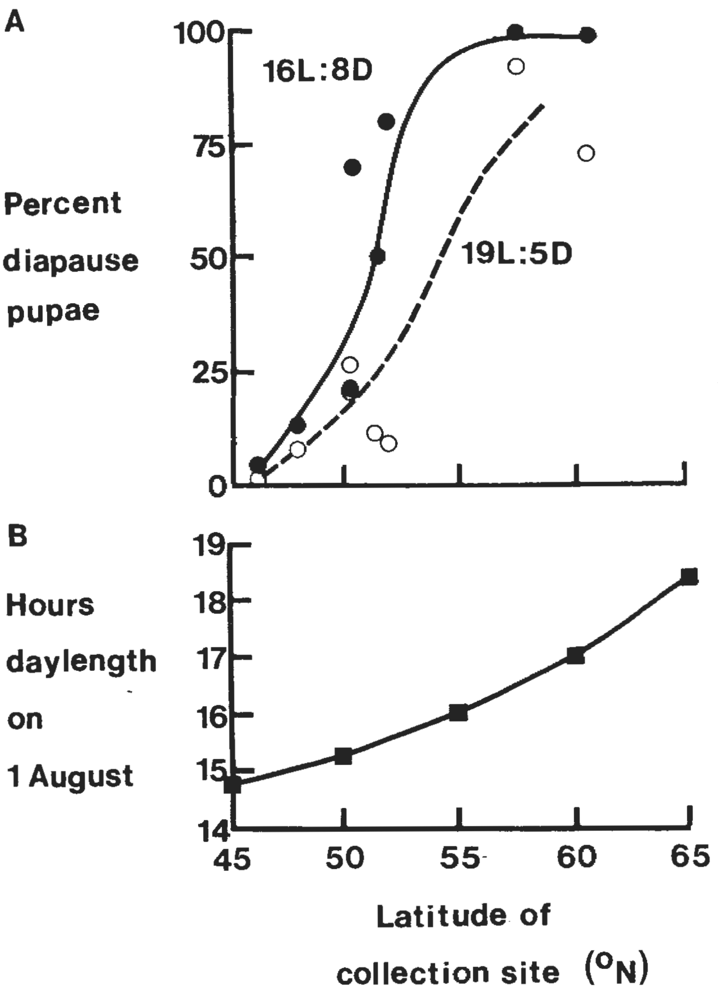


Figure 1. A. Diapausing pupae in eight populations of cabbage root fly reared at 17±1°C with a light:dark regime of 16L:8D and 19L:5D
B. Daylength on 1 August at the different collection sites.

The cabbage root flies were reared in cooled incubators at 17±1° with light:dark regimes of 9L:15D, 12L:12D, 14L:10D, 16L:8D or 19L:5D. A temperature of 17°C was chosen to simulate the average summer temperature occurring in the middle of the distribution range of the cabbage root fly. In all experiments, 50 fly eggs were used for each replicate of each treatment. Each batch of eggs was initially inoculated onto 50g of swede root (Brassica napus var. napobrassica) held in a clear plastic pot (80 cm diam x 110 cm high) part-filled with moist vermiculite. Each treatment was replicated 5-10 times. Whenever necessary, new pieces of swede were provided for the developing larvae.

Pupae were formed 4-5 weeks after eggs were inoculated onto the swede and flies generally emerged 2-3 weeks later. Pupae remaining 12 weeks after the eggs were inoculated were considered to be in diapause. The full and empty pupae in each pot were then counted to estimate the percentage of pupae in diapause.

RESULTS

At 17°C and with photoperiods of 9L:15D, 12L:12D and 14L:10D all pupae entered diapause. With photoperiods of 16L:8D and 19L:5D, the numbers of pupae that entered diapause depended largely upon the latitude from which the original insects had been collected. Figure 1A shows the response of insects kept at 17°C and a photoperiod of 16L:8D or 19L:5D. Almost all pupae from the two most northern sites, Finland and Scotland (Tables 1&2), entered diapause whereas few pupae from the southern populations, France and Switzerland, entered diapause. As expected, variable numbers of pupae from the four intermediate sites entered diapause. On average, less pupae entered diapause when the photoperiod was 19 hours (19L:5D) than when it was 16 hours (16L:8D). Fig. 1B also shows how the daylength on 1 August varies with the latitude of each collection site. This date was selected because progeny developing from eggs laid after 1 August at Wellesbourne are subjected to a sufficiently short photoperiod to be induced into diapause.

The "critical" daylength (at 17°C) for each population, defined as the daylength at which 50% of the pupae enter diapause, was estimated from the percentage response of each population at each photoperiod. The "critical" daylengths for pupae from the 8 sites are given in Table 2. In general, critical daylength decreased with latitude and was positively related, though not identical, to the daylength on 1 August at the locality where the insects were collected.

Table 2. Estimated critical daylengths (at 17°C) of cabbage root fly populations collected from sites at seven latitudes.

Collection Site		
Latitude (°N)	Country	Estimated critical day length (hr)
60.5	Finland	>19
57.4	Scotland	>19
52.1	England (Midlands)	16 - 19
51.6	Netherlands	16 - 19
50.6	West Germany	16 - 19
50.6	England (South-West)	14 - 16
48.1	France	14 - 16
46.2	Switzerland	14 - 16

DISCUSSION

In the experiments described in this paper, a constant rearing temperature was maintained and only photoperiod was varied. However, temperature itself, may also alter the critical daylength for diapause induction. With several insects that require "long days" to complete their development, higher temperatures generally reduce the critical daylength (Danks, 1987). Although Zabirov (1961) concluded that changes in temperature did not markedly alter the photoperiodic requirement of the cabbage root fly, his study was restricted to a population of insects collected from just one locality. Therefore, the way that temperature affects the photoperiodic response could be important when comparing the activity of fly populations subjected to markedly different climates.

Induction of diapause in cabbage root fly pupae is determined during the larval instars and depends on daylength and temperature (Zabirov, 1961). The critical daylength for inducing diapause in cabbage root fly populations is positively related to latitude. Thus the calendar date on which insects enter diapause may be similar for insects at northern sites, where days are very long during summer, and at southern sites where summer days are shorter. More accurate estimates of the critical daylengths involved may show that all populations enter diapause after a fixed date or within a comparable time from the onset of winter. In any case, if the cabbage root fly forecast (Finch & Collier, 1986) is to be accurate over a wide range of latitudes then a parameter expressing how latitude affects the photoperiodic induction of diapause should also be included in the model.

This work was carried out under Licence No. PHF 428A/89(87) issued under the Import and Export (Plant Health) and Plant Pests (Great Britain) Order 1980.

REFERENCES

BECK, S.D. (1980). Insect Photoperiodism. Academic Press Inc. 387 pp.

COAKER, T.H. & FINCH, S. (1971). The cabbage root fly, Erioischia brassicae (Bouché). Report National Vegetable Research Station for 1970: 23-42.

DANKS, H.V. (1987). Insect Dormancy: an Ecological Perspective. Biological Survey of Canada. Monograph series No. 1. 439 pp.

FINCH, S. & COLLIER, R.H. (1983). Emergence of flies from overwintering populations of cabbage root fly pupae. Ecological Entomology 8, 29-36.

FINCH, S. & COLLIER, R.H. (1985). Development of methods for monitoring and forecasting the incidence of Delia radicum (brassicae) populations on brassicas. CEC Programme on Integrated and Biological Control. Final Report 1979/1983 pp 287-302.

FINCH, S. & COLLIER R.H. (1986). Forecasting the times of attack of the cabbage root fly (Delia radicum) on vegetable brassica crops. Aspects of Applied Biology 12, 37-46.

FINCH, S., BROMAND, B., BRUNEL, E., BUES, M., COLLIER, R.H., DUNNE, R., FOSTER, G., FREULER, J., HOMMES, M., VAN KEYMEULEN, M., MOWAT, D.J., PELERENTS, C., SKINNER, G., STADLER, E. & THEUNISSEN, J. (1988). Emergence of cabbage root flies from puparia collected throughout Northern Europe. In Progress on Pest Management in Field Vegetables. Eds. R. Cavalloro and C. Pelerents. P.P. Rotondo - D.G. XIII - Luxembourg. No. EUR 10514. (In press).

HUGHES, R.D. (1960). Induction of diapause in Erioischia brassicae Bouché (Dipt., Anthomyiidae). Journal of Experimental Biology 37, 218-223.

ZABIROV, SH. M. (1961). Factors governing the seasonal development cycles of the spinach leaf miner (Pegomyia hyosciami Panz.) and the cabbage maggot (Hylemyia brassicae Bouché (Diptera, Anthomyiidae). Entomological Reviews 40, 148-151.

CONTROL OF THE CABBAGE ROOT FLY (DELIA RADICUM)

By C. HAWKES, G.L. BRINDLE AND R. KOWALSKI
Department of Biological Sciences, Plymouth Polytechnic,
Drake Circus, Plymouth PL4 8AA, Devon, U.K.

SUMMARY

Emergence and water traps were used to assess the emergence pattern and the incidence of later emergence in populations of the cabbage root fly on commercial farms in South Devon, U.K. The proportion of flies observed to emerge from overwintering puparia after May (late emergers) varied from site to site and appeared to be related to availability of host crops to the first generation. At one site late emergence occurred from June until September.

The effect of temperature on emergence was investigated by monitoring the production of carbon dioxide of individual pupae. The observed temperature thresholds for post-diapause development were higher in late emerging flies than in flies from a standard laboratory culture. There was substantial individual variation in the observed thresholds. There appears to be difficulties in developing a generalised method of forecasting cabbage root fly emergence, because of the variation within and between populations.

INTRODUCTION

When cabbage root fly, Delia radicum (L.), developed resistance to organochlorine insecticides (Coaker, Mowat and Wheatley, 1963), a number of alternative methods of control were investigated. These include chemosterilisation (Coaker and Smith, 1970; Finch and Skinner, 1973), attractants (Finch and Skinner, 1974, 1982) and plant resistance (Ellis and Hardman, 1975). There has, as yet, been no commercial application of these methods and more recently the emphasis has turned to the rational use of insecticides and monitoring and forecasting (Finch and Collier, 1984). At present control is dependent on organophosphorus and carbamate insecticides, but these have not proved to be effective replacements for the organochlorines in all cases, particularly on culinary swedes (McKinlay, 1986; S.J. Tones, personal communication) because of their lack of persistance. Recently carbofuran, commonly used for cabbage root fly control on swedes, has failed to provide control in some localities due to accelerated degradation in previously treated soils (Suett, 1986). In addition, there is the danger of resistance to organophosphates and carbamates as some populations may have been exposed to these compounds for up to 70 generations.

Forecasting of cabbage root fly to improve the timing of insecticidal applications may improve control of cabbage root fly on swedes and, may ultimately reduce the amount applied. Our recent work at Plymouth has attempted to increase our understanding of the temperature relationships of development in cabbage root fly in particular to predict late emergence from overwintering puparia (Alexander, 1983; Finch and Collier, 1983). We have also been assessing differences between local populations in the frequency of late emergence. Our work is intended to provide information on populations additional to those being studied by Finch and co-workers (see Finch, Collier and Skinner, 1986). We conclude that there are difficulties in developing a generalised method of forecasting cabbage root fly and that rational use of insecticides may not be progressed readily in some situations.

MATERIALS AND METHODS

In order to investigate the emergence patterns of cabbage root fly in field populations, a range of commercial sites were selected with contrasting cropping practices. Emergence traps were used to capture flies as they emerged from the soil. These consisted of 188mm diameter plant pots, 200mm high, with a collecting tube inserted at the top (Brindle, 1987). Generally 400 traps were used at each site, covering a total ground area of $10m^2$.

Yellow water traps were also used to supplement the information obtained from the emergence traps. Twenty traps were placed alongside hedgerows at the sites of production of overwintering puparia. The females captured were dissected to determine their age (Hawkes, 1975), so that newly emerged females could be identified.

The emergence traps were also used to obtain live flies for the establishment of cultures from various sites and periods of emergence. The culture method used was described by Finch and Coaker (1969). Once sufficient numbers had been produced, diapause was induced and pupae were maintained at 5°C for 4 months to permit the completion of diapause development. Further development of pupae was monitored to study their individual variation. The method had to be non-destructive and capable of detecting the small differences in metabolic activity between diapausing pupae and pupae that had started post-diapause development. The method used is described by Brindle (1987) and is based on the detection by gas chromatography of the carbon dioxide produced by pupae during respiration. Pupae were sealed in glass vials for 7h and then a sample of air was extracted from the vial, passed through a methanator to convert carbon dioxide to methane and the methane was then analysed using a flame ionisation detector.

The progress of post-diapause development was monitored under conditions intended to simulate the gradual increase in temperatures experienced under field conditions. In the experiments pupae were first exposed to a temperature of 3°C which was then increased at rates of either 1° or 2°C twice per week up to 20°C. The metabolic activity of pupae was assessed twice weekly until flies had emerged or had died. Comparison of the experiments allowed the effects of both temperature and length of exposure to be determined.

RESULTS AND DISCUSSION

Emphasis will be given here to presenting results which have implications for forecasting and pest control. At Venn Farm, a mean of 68% of flies captured in emergence traps were late emergers having emerged after the usual April and May period. Late emergence was occurring not only in June and July but in August in 1984 and up to 13 September in 1985 (Fig. 1). There was a good correlation between water trap captures and emergence trap captures but it should be noted that water trap data should only be used for the determination of emergence patterns where immigration of flies is at a low level.

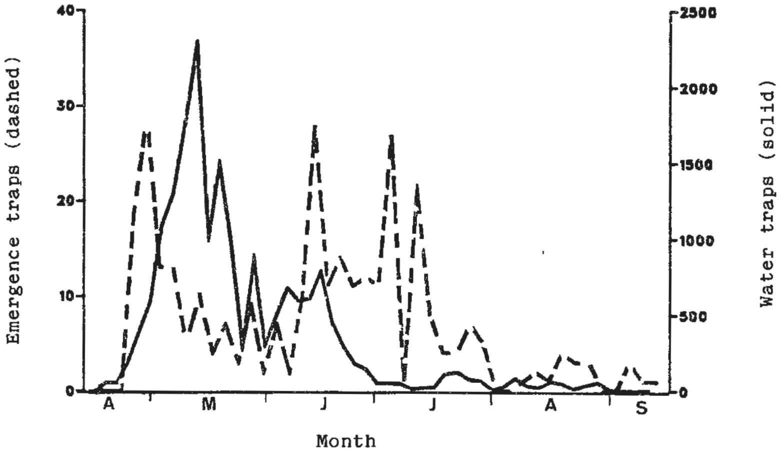


Fig. 1. The total numbers of cabbage root flies captured (½ week periods) in 1985 at Venn Farm

The frequency of late emergence in a population may be related to the cropping pattern in a particular locality. At one site where brassicas were grown throughout the year, late emergence was not observed. At Venn Farm, the preponderance of late emergers can be related to the problems of finding a host crop at the time of the first generation. Table 1 shows the percentage of the area growing cabbages at the time of the first generation and swedes at the time of the second and third generations at Venn Farm over a six year period. No crop has been available to the first generation since 1982 and presumably this has selected for late emergence. The variation reported here is similar to that shown by Finch, Collier and Skinner (1986) for the south-west Lancashire area.

Table 1. Brassica growing at Venn Farm, Devon, England, over a six year period. Modified from Hawkes et al. (1987)

Year	Percentage of area growing Cabbages (Early sown)	 Swedes (Late sown)
1979	1.1	1.5
1980	1.7	7.9
1981	0.1	2.4
1982	zero	5.5
1983	zero	5.1
1984	zero	3.7

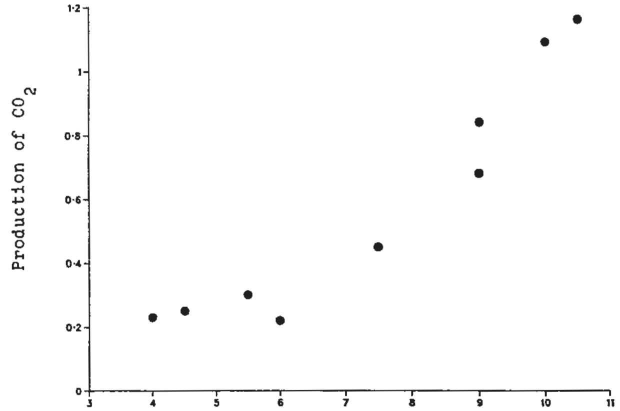
In addition to emergence delayed by one to four months, emergence and water trap captures (Table 2) have indicated that emergence may be delayed by one year at Venn Farm (Hawkes, Kowalski & Brindle, 1987). The flies caught in water traps could have come from another source but the closest alternative source was 1005m distant in 1985. The numbers of flies caught were over two orders of magnitude greater than expected from immigration (calculated from the numbers caught at the alternative source and dispersal rate; Alexander, 1983). The flies found in the emergence traps could have developed on the wild hosts in the field in 1984. Inspections in 1984 showed that the potato crop present and the associated chemical treatments and cultivations kept cruciferous weeds at very low denisities. The trap data therefore provides firm evidence of emergence delayed by one year.

Table 2. Captures of Delia radicum at a field sown to swedes in 1983 (from Hawkes et al., 1987)

	Period 17/4/84 - 19/6/84		Period 16/4/85 - 18/6/85	
	20 water traps	400 emergence traps covering $10m^2$	20 water traps	600 emergence[1] traps covering $15m^2$
Males	2790	12	1691	0
Females	1809	9	1281	39
Total	4599	21	2972	39

[1] Emergence traps were put out on 3/5/85, apparently after males had emerged.

The study of the metabolic activity of pupae exposed to increasing temperature regimes provided data which can be used to estimate the post-diapause development threshold for individuals (Fig. 2). The thresholds observed were related to the rate of increase in temperature while variation between and within



Temperature (°C)

Fig. 2. Response to increasing temperature of <u>Delia radicum</u> pupa from the Plymouth culture. Production of CO_2 is expressed relative to a standard of concentration 1.05%.

populations was not. Initially, there was no detectable change in metabolic activity as shown by carbon dioxide production, until a threshold temperature was reached above which there was a liner relationship with temperature. This temperature is taken as the post-diapause development threshold. Thresholds obtained from pupae from some of the sources is shown in Table 3. There is a marked difference in the observed thresholds for late emerging flies obtained from Venn Farm in comparison with material from a laboratory culture at Plymouth. In addition, there is substantial variation within populations, indicating that selection could result in changes in the temperature relationships of emergence.

Table 3. The observed post-diapause development thresholds of pupae from two sources (temperature increasing by 1°C twice per week)

	Source of pupae	
	'Culture' 1 year cold experience (°C)	Late emerging (Venn Farm) (°C)
	2.4	10.5
	2.6	11.5
	3.2	12.4
	3.6	12.8
	3.7	12.8
	5.8	12.8
	7.7	12.8
	7.7	13.1
	12.6	13.3
		13.5
		14.2
Mean	5.5	12.7
s.e.	3.4	0.3

Post-diapause development can start in some individuals below 3°C. A developmental threshold of 6°C was used by Coaker and Wright (1963) and Eckenrode and Chapman (1971) but revised (Collier and Finch, 1985) to 4°C as a more accurate estimate of the developmental zero. Clearly, an even lower threshold may be appropriate for some individuals.

To illustrate the problem of predicting emergence, the trap data has been used to calculate the day degree requirements of development for early and late emerging flies for the various sites. A threshold of 6°C has been used, largely to ease comparisons with previously published work. The day degrees above 6°C between 1 February and the principal periods of early and late emergence are shown in Table 4. The most striking feature of the data for early emergence was the broad similarity of sites within any one year and, the substantial differences between years. In 1985, early emergers appeared to require a greater accumulation of day degrees before emergence than in 1984. The results for late emergers showed the greatest variation making the prediction of emergence difficult.

Table 4. Day-degrees above 6°C to the principal periods of early and late emergence

Early emergers

1984		1985	
Seale Hayne	160	Seale Hayne (a)	165-215
Great Stert	125-160	Seale Hayne (b)	165-215
Clotworthy	125-160	Great Stert (a)	180-215
Venn	145-185	Great Stert (b)	180-215
		Venn (a)	135-235
		Venn (b)	180

Late emergers

1984		1985	
Clotworthy	230-260	Venn (a)	420-650
Great Stert	250-300	Venn (b)	350-500
Venn	580-800	Seale Hayne (a)	350-500
		Seale Hayne (b)	350-500
		Great Stert (a)	450-650
		Great Stert (b)	450-650

A number of factors have been identified which makes accurate forecasting of the time of emergence of cabbage root fly difficult. The period of emergence can be protracted at least at some sites and it is anticipated that the pattern of emergence could change rapidly as cropping practices change. The frequency of late emergence in a population cannot, at the moment, be predicted and therefore the importance of late emergence is not predictable. If delays in emergence of one year are common, another source of variation is introduced.

It is clear that using simple criteria such as day degree requirements are unlikely to be useful in some localities. The factors affecting emergence would be subject to local conditions and the question then arises whether sufficient data will be available to make useful predictions particularly within areas where local conditions vary substantially. Certainly within the south Devon area and in south-west Lancashire (Finch et al., 1986), forecasting presents serious problems. Only if individual growers were able to obtain data for their particular farm over a period of several years, might it be possible to predict emergence with some accuracy. The records would have to be continuously maintained so that any changes in emergence patterns could be monitored.

If forecasting of cabbage root fly is difficult, insurance spraying or applications at doses incorporating considerable safety margins are likely to continue and problems such as accelerated degradation and resistence to insecticides may increase. It is, therefore, expedient to maintain research programmes which offer some prospects for non-insecticidal control.

REFERENCES

ALEXANDER, K.I. (1983). The dispersal of cabbage root fly in relation to agricultural practice. Unpublished Ph.D. thesis, CNAA.

BRINDLE, G.L. (1987). The emergence of Delia radicum in relation to agricultural practice. Unpublished Ph.D. thesis, CNAA.

COAKER, T.H., MOWAT, D.J. & WHEATLEY, G.A. (1963). Insecticide resistance in the cabbage root fly in Britain. Nature, London, 200, 664-665.

COAKER, T.H. & SMITH, J.L. (1970). Sterilisation of the cabbage root fly (Erioischia brassicae (Bch.)) (Dipt., Anthomyiidae) with tepa: laboratory and field cage tests. Bulletin of Entomological Research, 60, 53-9.

COAKER, T.H. & WRIGHT, D.W. (1963). The influence of temperature on the emergence of the cabbage root fly (Erioishcia brassicae (Bouché)) from overwintering pupae. Annals of Applied Biology, 52, 337-343.

COLLIER, R.H. & FINCH, S. (1985). Accumulated temperatures for predicting the time of emergence in the spring of the cabbage root fly, Delia radicum (L.)(Diptera; Anthomyiidae). Bulletin of Entomological Research, 75, 395-404.

ECKENRODE, C.J. & CHAPMAN, R.K. (1981). Effect of various temperatures upon rate of development of the cabbage maggot under artificial conditions. Annals of the Entomological Society of America, 64, 1079-1083.

ELLIS, P.R. & HARDMAN, J.A. (1975). Laboratory methods for studying non-preference resistance in cruciferous crops. Annals of Applied Biology, 79, 253-264.

FINCH, S. & COAKER, T.H. (1969). A method for the continuous rearing of the cabbage root fly Erioischia brassicae (Bouché) and some observations on its biology. Bulletin of Entomological Research, 58, 619-627.

FINCH, S. & COLLIER, R.H. (1983). Emergence of flies from overwintering populations of cabbage root fly pupae. Ecological Entomology, 8, 29-36.

FINCH, S. & COLLIER, R.H. (1984). Development of methods for monitoring and forecasting the incidence of Delia radicum (brassicae) populations on brassicas. In: Agriculture C.E.C. Programme on Integrated and Biological Control. Final Report 1979/1983 (ed. by R. Cavalloro and A. Piavaux), pp. 287-302. Official Publication of the European Communities, Luxembourg.

FINCH, S., COLLIER, R.H. & SKINNER, G. (1986). Local population differences in emergence of cabbage root flies from south-west Lancashire: implications for pest forecasting and population divergence. Ecological Entomology, 11, 139-145.

FINCH, S. & SKINNER, G. (1973). Chemosterilisation of the cabbage root fly under field conditions. Annals of Applied Biology, 73, 243-58.

FINCH, S. & SKINNER, G. (1974). Some factors affecting the efficiency of water-traps for capturing cabbage root flies. Annals of Applied Biology, 77, 213-226.

FINCH, S. & SKINNER, G. (1982). Trapping cabbage root flies in traps baited with plant extracts and with natural and synthetic isothiocyanates. Entomologia experimentalis et applicata, 31, 133-139.

HAWKES, C. (1975). Physiological condition of adult cabbage root fly (Erioischia brassicae (Bouché)) attracted to host-plants. Journal of Applied Ecology, 12, 497-506.

HAWKES, C., KOWALSKI, R. & BRINDLE, G.L. (1987). An alternative to migration in agricultural insects? Functional Ecology, 1, 165-167.

McKINLAY, R.G. (1986). Insecticidal control of cabbage and turnip root flies in swede turnips. Tests of Agrochemicals and Cultivars No. 7 (Annals of Applied Biology 108, Supplement), pp. 34-35.

SUETT, D.L. (1986). Accelerated degradation of carbofuran in previously treated field soils in the United Kingdom. Crop Protection, 5, 165-169.

Relations entre le climat et les populations d'adultes de Mouche du chou (*Delia radicum*, *Diptera Anthomyiidae*) dans l'ouest de la France : recherches des périodes critiques auxquelles les populations sont sensibles

E. BRUNEL
I.N.R.A. Laboratoire de Zoologie BP. 29 - 35650 LE RHEU

RESUME

La Mouche du chou présente des arrêts de développement qui sont conditionnés par les facteurs du climat. A partir de données de captures réalisées de 1975 à 1986 et les données climatiques, on recherche les périodes critiques du début de l'année qui peuvent avoir une incidence sur l'abondance relative de Delia *radicum*. Le programme de calcul "Cumul" est utilisé pour calculer la somme (ou la moyenne) d'une mesure météorologique pour une période donnée, le coefficient de corrélation entre cette série de valeur et celle des densités d'animaux des années homologues ici, les pics des captures de *D. radicum*. Le traitement des données montre l'importance de deux périodes critiques l'une à la fin du mois de janvier, l'autre à la fin du mois de février, qui agissent pendant une courte période. Ces résultats renforcent ceux de l'action de chocs thermiques de courte durée appliqués à des pupes en fin de diapause.

INTRODUCTION

La biologie de la Mouche du chou (*Delia radicum*) est étudiée depuis de nombreuses années. Les auteurs ont précisé les données de biologie fondamentale pour expliquer les mécanismes de la dynamique des populations. Or malgré les connaissances qui ont été accumulées sur l'action des facteurs abiotiques : température, humidité, sur la durée et la vitesse de développement, ainsi que sur les arrêts de développement; et sur les relations entre l'insecte et sa plante hôte : reconnaissance de la plante, choix du support de ponte, action plus ou moins dépressive de la plante sur le développement de l'insecte, il existe peu de données sur les fluctuations de l'insecte, sur de longues périodes et sur la détermination des moments clés qui agissent sur les populations en relation avec le climat. Des résultats intéressants ont déjà été obtenus pour d'autres groupes d'insectes (PIERRE et DEDRYVER, 1984); il nous a parus intéressants de les tester sur un groupe tel que les diptères. Nous tentons une nouvelle approche de l'étude des relations entre les insectes récoltés au moyen d'un système de captures : le piège jaune et les données climatiques dans l'ouest de la France en vue de préciser les périodes critiques qui peuvent avoir une incidence sur l'abondance relative de D. *radicum* aux champs.

MATERIEL ET METHODE

Piègeage des insectes

Les données de captures au piège jaune recueillies ces douze dernières années sont à la base de ce travail. Le piège jaune utilisé est un bac de 30 x 30 cm et de 7 cm de hauteur. Un piège est posé au sol et un autre à 0,70m dans deux parcelles conduites en monoculture de blé et de maïs (BRUNEL, 1983) situés dans une zone de polyculture. Des parcelles de crucifères ont toujours été présentes à proximité : colza, chou fourrager, navet, chou-fleur. Les pièges sont maintenus en place du 1er janvier au 31 décembre et sont relevés trois fois par semaine.

Données climatiques

Les données climatiques proviennent d'un poste météorologique de la station I.N.R.A. Le Rheu, le poste est à moins de 100 m des postes de piégeage. Ces informations sont stockées sur ordinateur et disponibles à tout moment. Dans l'étude présentée, nous avons uniquement utilisé les données de températures recueillies à deux mètres sous abris.

Outil statistique

L'outil statistique qui permet de rechercher des effets à long terme du climat sur les populations et de déceler les éventuelles périodes critiques est le corrélogramme de Goldwin (GOLDWIN, 1982) repris par Pierre (PIERRE et al, 1986) pour une étude comparable sur les pucerons des céréales. Ce dernier auteur a mis au point un programme appelé "CUMUL" qui permet dans le cas des pucerons de fournir une aide puissante à la recherche de variables météorologiques intégrables dans des protocoles de prévision et d'avertissement agricole. Les premiers résultats obtenus sur les populations de D. radicum sont présentés ici.

La méthode consiste à calculer la somme (ou la moyenne) d'une mesure météorologique pour une période donnée, le coefficient de corrélation entre cette série de valeur et celle des densités d'animaux des années homologues ; nous avons choisi de prendre les pics du 1er, 2è et 3è vol. Il s'agit de réitérer le processus en faisant varier le début et la durée des périodes étudiées suivant un plan systématique. L'ensemble des résultats des coefficients de corrélation forme une surface de réponse ou les périodes critiques se manifestent par des pics et des creux, en projection plane par des courbes de niveau. Pour les aspects mathématiques, nous renvoyons à la publication de Pierre et al (1986).

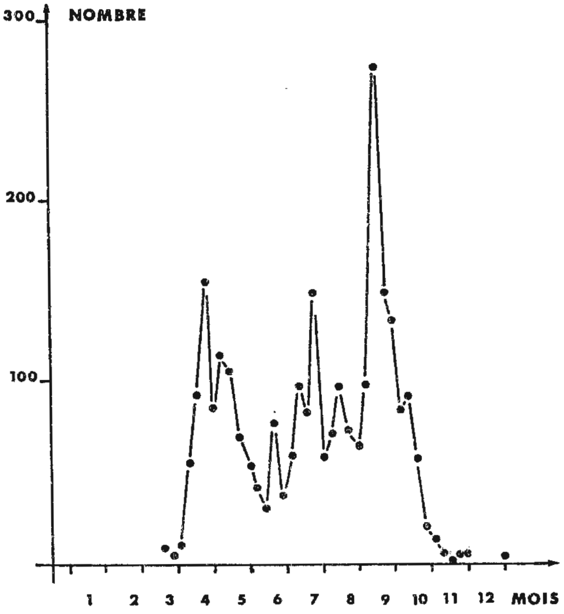


Fig. 1 : Courbe des fluctuations de population annuelle de Delia radicum à Le Rheu de 1975 à 1986.

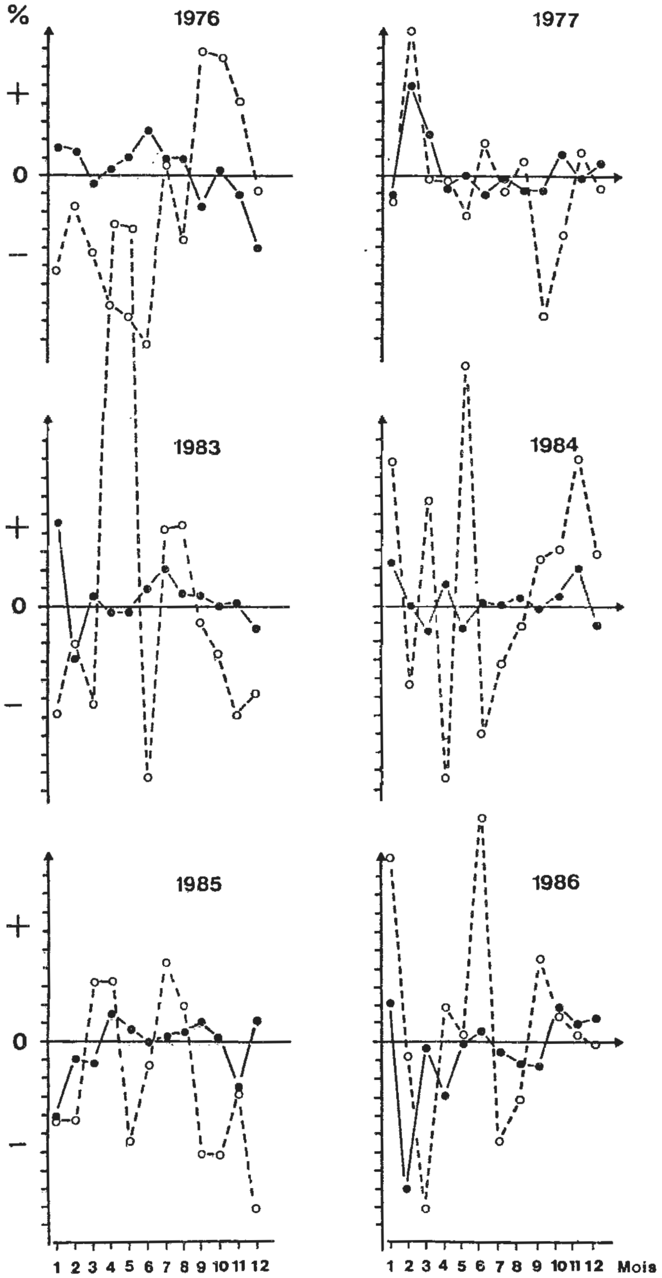


Fig. 3 : Ecarts à la normale mensuelle trentenaire de la température(.) et des précipitations (0) pour quelques années à Le Rheu.

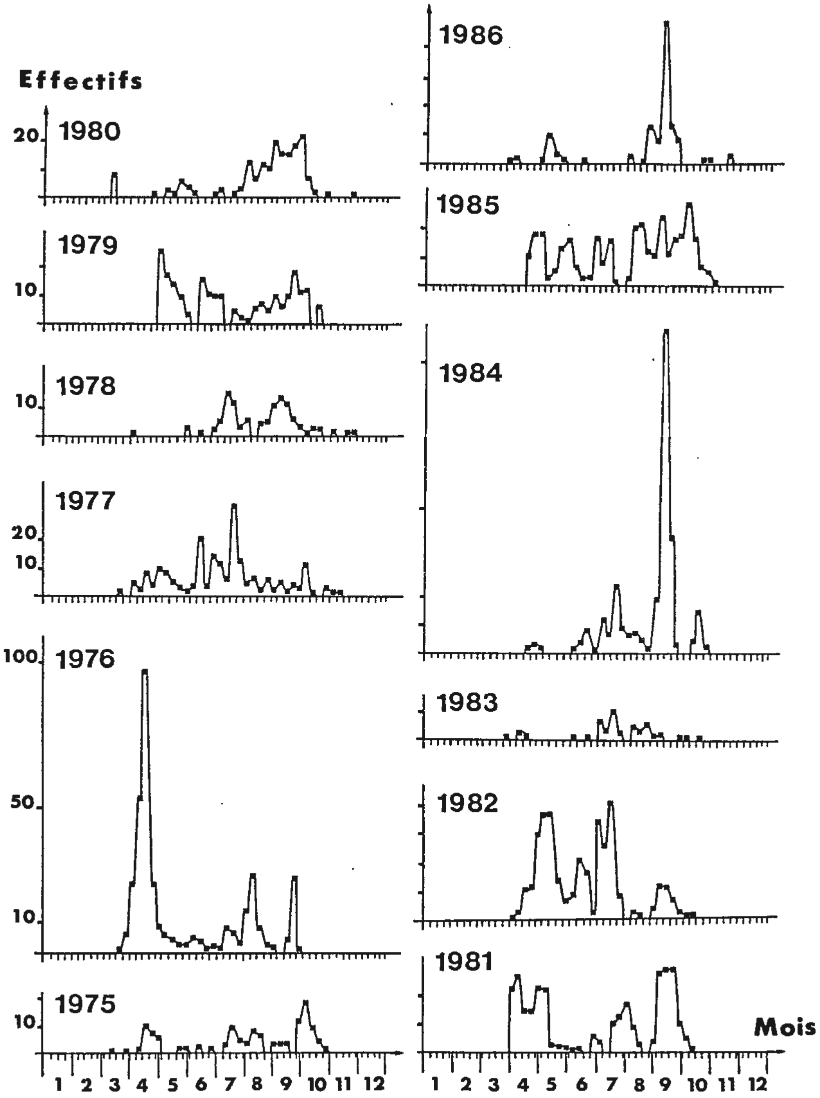


Fig. 2 : Capture de Delia radicum de 1975 à 1986 à Le Rheu au moyen de piège jaune.

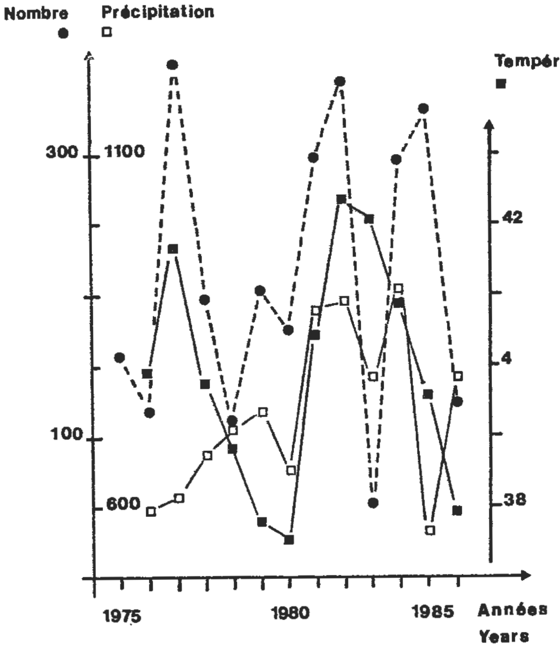


Fig. 4 : Fluctuation des températures, des précipitations et des populations de D. rdicum à Le Rheu de 1975 à 1986.

Relation entre les données climatiques annuelles et les effectifs totaux de D. radicum

Les fluctuations des sommes annuelles de température et des précipitations sont représentées sur la figure 4 pour la période de 1975 à 1986, ainsi que les effectifs de Mouche du chou. La pluie semble avoir eu une action défavorable sur les populations de D. radicum en 1980, en 1983 et en 1985. La température a été favorable en 1976, 1981, 1982 et 1985 et semble avoir agit défavorablement les autres années. On remarque que dans cette analyse globale, les températures basses des hivers 1984, 1985 et 1986 n'ont pas agit de manière négative sur les populations.

Recherche des périodes critiques

D. radicum passe l'hiver à l'état de diapause. Cet arrêt de développement induit par les températures basses de l'automne (MISSONNIER, 1963) et par le raccourcissement des jours ne peut être interrompu que lorsque la pupe a subit une certaine quantité de froid. Les différents auteurs s'acccordent pour dire que la diapause est achevée au début du mois de janvier. L'insecte est alors sensible à toute augmentation de température au-dessous de son seuil de développement pour pouvoir éclore au printemps. La réalisation ou non de températures favorables a une conséquence primordiale sur la dynamique ultérieure de la population car elle détermine la synchronisation des sorties. De qualitatif en hiver, le facteur température a une valeur quantitative à partir du printemps. L'utilisation du programme cumul permet de mettre en évidence non seulement l'importance du facteur mais également de savoir s'il a un effet différé.

Le traitement réalisé sur D. radicum à partir des données des pics c'est à dire 16e, 18e, 24e, 29e, 35e et 37e semaines de l'année montre l'importance de deux périodes l'une à la fin du mois de janvier, l'autre à la

RESULTATS

Captures de D. radicum de 1975 à 1986.

Les effectifs de Mouche du chou capturés de 1975 à 1986 sont présentés sur la figure 1. Ils montrent l'étendue des vols de D. radicum au cours de l'année et les périodes de plus grande abondance ou pics. Dans les conditions de l'ouest, l'insecte peut être présent depuis la 12ème semaine, à la mi-mars, jusqu'à la fin de l'année civile. Les périodes de plus grande abondance s'étendent du 15 avril au 15 mai, du premier juillet au 15 août et de la fin août au 5 octobre. Le découpage est cependant plus difficile à réaliser lors de l'examen des années prises séparément lorsque l'on sait que les générations sont difficiles à dissocier (LAHMAR, 1983). L'effet du climat agit profondément en particulier lors des années à été chaud, le deuxième vol peut être beaucoup plus réduit en importance comme ce fut le cas en 1976, 1980, 1981 et 1986. D'autres causes peuvent être évoquées qui ont réduit l'abondance des captures comme le parasitisme ou les maladies en 1975, 1978 et surtout en 1983 où nous avons capturé seulement 49 individus. Le détail des captures de 1975 à 1986 est montré sur la figure 2.

Caractéristiques du climat

Deux approches différentes ont été effectuées. Dans la première nous examinons le climat de l'année dans sa globalité en essayant de classer les années. Ce classement est possible à partir des totaux obtenus en faisant la somme des températures moyennes annuelles et la somme de la pluviométrie (tableau 1)

Tableau 1. Classement des données climatiques, température et population annuelle, de Le Rheu de 1975 a 1986.

Années	Températures	Précipitation	Années
1982	4239	907	1984
1983	4209	892	1982
1976	4169	878	1981
1984	4092	785	1986
1981	4044	783	1983
1975	3993	737	1979
1977	3978	713	1978
1985	3949	677	1977
1978	3884	652	1980
1986	3796	615	1976
1979	3779	597	1975
1980	3751	564	1985

Quelques regroupements sont possibles pour les années les plus semblables ou les plus extrêmes. Ainsi 1982 et 1983 sont des années chaudes et humides, 1979, 1980 et 1986 des années chaudes à moyennement chaudes et sèches. On constate, dans cette analyse globale, la difficulté de trouver une année type qui soit moyenne en température et en pluviométrie.

La moyenne annuelle estimée à 10°9, 3069° dans l'année, varie de 10°3 en 1980 à 11°6 en 1982 ; ce qui est peu en valeur absolue, mais représente une différence de 1°3 par jour.

Dans la deuxième approche nous avons analysé les années en exprimant la température en pourcentage par rapport à la moyenne trentenaire. Le même calcul a été réalisé avec la pluie. Quelques résultats sont donnés dans la figure 3. Les périodes inhabituelles, anormales s'expriment en positif ou en négatif, nous sommes amenés à faire le constat d'une très grande hétérogénéité d'une année sur l'autre. Il devient aléatoire par la technique graphique de déceler une particularité du climat qui agissent sur la biologie de l'insecte.

fin février, qui agissent pendant une courte période. Leur effet intervient sur les deux premiers pics mais peuvent encore se constater sur les deux pics suivants. Les sommes des températures cumulées à partir du début de l'année sont fortement corrélées avec le premier vol. Par contre quel que soit le pic considéré, nous n'avons pas constaté la présence de périodes critiques à proximité de la date des pics. La figure 5 illustre les résultats obtenus avec le 1er pic et les températures du début de l'année pour les périodes de 1975 à 1986.

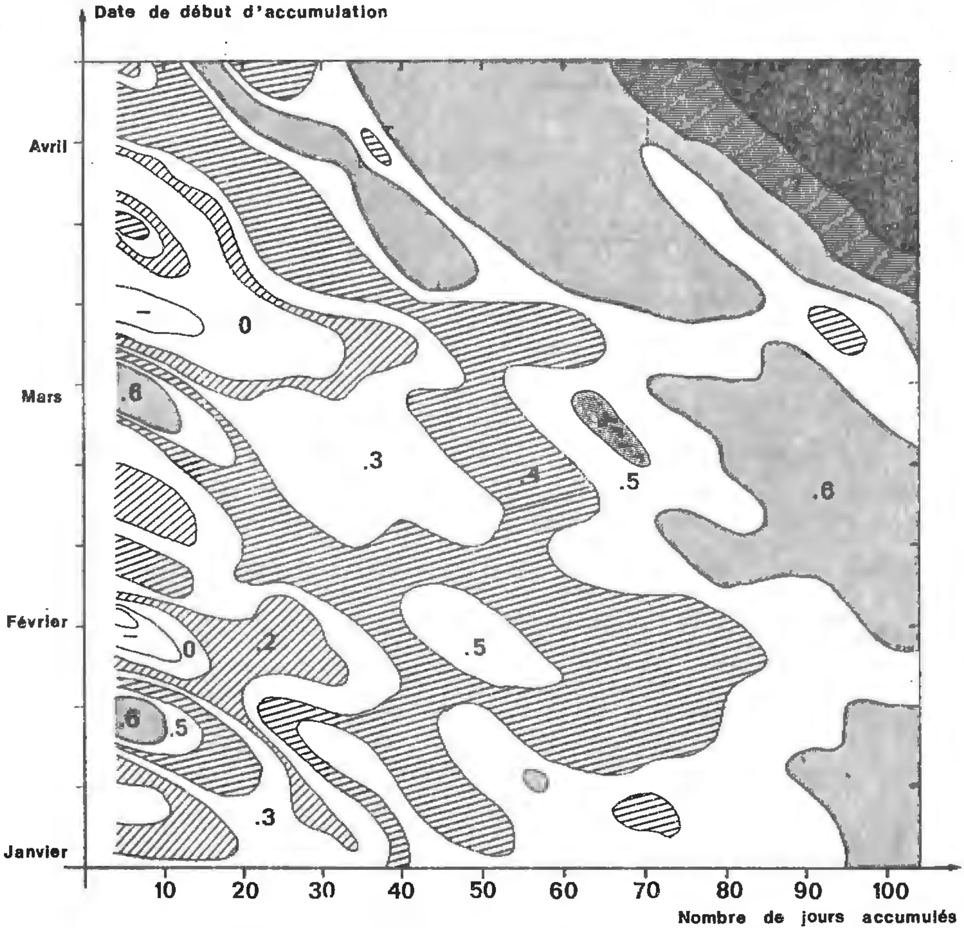


Fig. 5 : Valeur du coefficent de corrélation entre le 1er pic de l'année de _Delia radium_ *et la température additionnée à partir de la date (jour, semaine) de 4 à 104 jours (D).*

CONCLUSION

La Mouche du chou inféodée aux crucifères est un ravageur dont la biologie est complexe du fait d'arrêts de développement en hiver et en été. Ceux-ci s'expliquent par l'action de facteurs telle que la température. On constate cependant qu'il n'est pas aisé d'utiliser les connaissances que nous avons de ces mécanismes pour permettent une prévision des sorties d'adultes au printemps et de leur corréler les générations suivantes. L'utilisation de méthode descriptive et exploratoire est intéressante à prendre en compte et permet d'obtenir des indications intéressantes pour des voies de recherches en biologie des populations. Les résultats présentés ici permettent de confirmer le rôle des conditions du début de l'année sur l'évolution des populations : les deux périodes critiques telles que celle qui est observée à la fin du mois de janvier, début du mois de février et celle du début du mois de mars renforcent l'importance des résultats de l'action de chocs thermiques de courte durée appliquée à des pupes en fin de diapause (BRUNEL et LAHMAR, 1983). La méthode utilisée donne des résultats d'autant plus sures que l'on a affaire à des séries longues ; ici 12 années ont servi et il a été obtenu des valeurs du coefficient de corrélation voisin de 0,7 et 0,8 qui semblent très intéressantes. Cette voie de recherche sera poursuivi de façon à préciser l'action de variables météorologiques intégrables dans des protocoles de prévision et d'avertissement agricole de D. radicum

BIBLIOGRAPHIE

BRUNEL E., 1983. Les ravageurs des céréales et du maïs dans les rotations céréalières. Journée d'études des rotations céréalières intensives, ONIC Paris 16-17 mai sp.

BRUNEL E., LAHMAR M., 1983. Influence de chocs thermiques et des conditions météorologiques sur le développement de Psila rosae et de Delia brassicae : prévision des sorties printanières. Bulletin OEPP., 13, 201-207.

GOLDWIN G. K., 1982. A technique for studying the association between components of the weather and horticultural parameter. Science Horticulture, 16, 101-107.

LAHMAR M., 1983. Contribution à l'étude de la biologie de la mouche du chou dans les conditions de l'ouest de la France, Thèse Docteur-Ingénieur E.N.S.A. Rennes 73p.

MISSONNIER J., 1963. Etude écologique de développement nymphal de deux diptères muscidés phytophages Pegomyia betae Curtis et Chortophila brassicae Bouché. Annales Epiphyties, 14, 1-186.

PIERRE J.S. ; DEDRYVER C.A., 1984. Un modèle de régression multiple appliqué à la prévision de pullulation d'un puceron des céréales, Sitobion avenae F. sur blé d'hiver. Acta oecologica. Oecologia Applicata, 5, 153-172.

PIERRE J.S. ; GUILLOME M. ; QUERRIEN M.T., 1986. Une recherche statistique de recherche des périodes de l'année, où les populations animales sont particulièrement sensibles à une composante donnée du climat (période critique). Application au cas des pucerons des céréales. Acta oecologica Oecologia Generalis, 7, 365-380.

SEQUENTIAL SAMPLING OF INSECT PESTS IN BRUSSELS SPROUTS

J. THEUNISSEN
Research Institute for Plant Protection
Wageningen, the Netherlands

SUMMARY

Sequential sampling methods have been developed for use in Brussels sprouts. Based on variable tolerance levels for the caterpillar complex and cabbage aphid infestations during the entire growing period, sequential sampling schemes for both pest categories are given. Their value to the grower under various conditions is discussed. Sequential sampling seems to be useful at tolerance levels of 20% of infested plants and higher. Sampling takes increasingly less time when the infestation is different from the relevant tolerance levels. Varietal differences may influence sampling costs.

INTRODUCTION

Cabbage crops are among the most important vegetables all over the world. These crops are infested by a large number of insect pest species. Despite this variety, most species can be grouped into complexes such as caterpillars and aphids. When possible it is more practical to direct control measures against such complexes instead of against individual species. This enhances pest management procedures where simplicity is essential to enable growers to take their own pest control decisions. Supervised control methods as a contribution to pest management in cabbage crops have been developed. Depending on the local conditions the operators concerned with the practical implementation of these methods can be different. In the United States methods have been developed for use by scouts and pest management consultants (Hoy et al., 1983), whereas in Europe the grower is encouraged to carry out field sampling and to take pest control decisions (Theunissen & Den Ouden, 1985).

In supervised control there are two main requirements:

1. a simple and practical field sampling method
2. a set of criteria for the sampling result that include both fixed (Wilson et al., 1983) or variable tolerance levels (Theunissen, 1984; Theunissen & Den Ouden, 1985) as practical approximations of theoretical control thresholds.

A field sampling method for cabbage based on systematic sampling (Theunissen & Den Ouden, 1983; Theunissen, 1984a) and sets of variable tolerance levels have been tested for a number of years in commercial Brussels sprout and white cabbage crops (Theunissen & Den Ouden, 1985). While the field sampling method is functioning satisfactorily for heading cabbage crops, the growth of Brussels sprout plants involves an increasing amount of time spent on sampling as the season progresses. This encouraged growers to devise their own methods that considerably reduced the sample size. To prevent possible failures of supervised control due to incorrect sampling less time consuming sampling methods for use in Brussels sprout crops by means of sequential sampling have now been developed.

METHODS

Since the infestation of the crop is expressed as percentage infested plants, as are the variable tolerance levels, sequential sampling schemes have been based on a binomial distribution of infested plants. The desired precision has been set at ± 20% of the relevant tolerance level. For type I errors, i.e., overestimation of the pest population, the acceptable probability has been fixed at 0.30. The acceptable probability of type II errors, i.e., underestimation of the pest population, has been determined at a lower level of 0.10. The calculation of these schemes took place according to Onsager (1976).

The characteristics of the sequential sampling schemes for the various tolerance levels are presented in Table I.

Table I: Data of sequential sampling charts for use in supervised control of pests in Brussels sprouts, based on a margin of ± 20% of the valid tolerance level, = 0.30 and = 0.10.

tolerance level*	intercept of		slope
	H_1	H_2	
4	-4.610	2.603	0.0394
10	-4.327	2.443	0.0987
20	-3.850	2.173	0.1980
40	-2.889	1.631	0.3983
50	-2.400	1.355	0.5001

* in % infested plants

The charts consist of regression lines (H) expressing the relationship between accumulated sample size (x-axis) and the accumulated number of infested plants (y-axis) under given conditions relating to crop protection decisions (Fig. 1). The regression lines divide the quadrant between both axes into three sections: 1) a zone of indecision between the straight lines which indicates a need for more samples, 2) a section below the lowest line which represents the decision that a treatment is not necessary, and 3) a top section which stands for the decision that a control treatment is necessary.

RESULTS

The example given in Fig. 1 is of a sequential sampling chart valid for a tolerance level of 50%. To facilitate the use of sequential sampling in the field a tabular form of the charts is presented in Table II.

DISCUSSION

Successful pest management methods, including supervised control, for growers to follow require to be done simply and quickly. Simplicity is achieved by developing, as far as possible, tolerance levels for pest complexes. Under Dutch conditions the caterpillar complex in cabbage consists of the larvae of Mamestra brassicae, Pieris rapae, Plutella xylostella and Evergestis forficalis. Other species of Lepidoptera may occur but are not considered to be regular pests for various reasons. The aphid complex consists of one species only, Brevicoryne brassicae. Pests of local importance are Delia brassicae and Contarinia nasturtii. The latter species impairs the full implementation of supervised control in white cabbage in one important growing region in the Netherlands. Differences in the sensitivity of crops to infestation are reflected in variable tolerance levels and are expressed in simple terms such as the percentage of infested plants. Growth stage refers to weeks after transplanting for maximum simplicity, although more refined definitions are available (Theunissen and Sins, 1984).

The time spent following the prescribed method in the field is important for acceptance by the growers. Therefore, time spent sampling is important both in practical and scientific terms. For low crops such as heading cabbage the recommended systematic sampling method is satisfactory, especially in situations where the need for a control treatment is not obvious. In situations of extremely low or high pest populations the outcome is quickly determined and sampling to a fixed sample size cannot be expected from the growers. In Brussels sprouts, a tall growing crop, sampling takes an increasingly larger time as the crop grows. In red cabbage the maximum time taken to sample 100 plants/ha is 64 minutes (1.06 manhours) (Theunissen & Den Ouden, 1983) and in Brussels sprouts 162 minutes (2.7 manhours) (Theunissen, 1984b).

To optimize sample size sequential sampling can be used. Examples are presented here for Brussels sprouts but similar schemes can be used in other cabbage crops (Theunissen & Den Ouden, 1987). A risk of a 30% overestimation of the pest population is allowed because the consequences of a wrong decision are acceptable: i.e., one or more unnecessary sprays. A smaller risk of underestimation (10%) is taken because a wrong decision may cause economic damage to the crop when necessary sprays are delayed or omitted. The level of desired precision (± 20%) is arbitrarily set to obtain an acceptable sampling result.

From the Tables it will be clear that sequential sampling is most effective in more or less extreme population conditions. In such cases a decision can be taken quickly. At populations around the valid tolerance level the sampling procedure does not give a decisive answer. Based on the experience that 100 plants/ha will give a good picture of the pest population and the fact that growers in general are not prepared to take bigger samples, a decision has to be taken after 100 plants have been sampled. What this decision is will be determined by local conditions. To prevent wrong decisions being made due to either taking to few samples or by accidental sampling within a cluster of pests, at least 10 samples are recommanded to be taken before making any decision and to spread the samples across the field as has been described earlier for routine systematic field sampling (Theunissen, 1984a).

Sequential sampling is most rewarding at the higher tolerance levels. At the 4% tolerance level a minimum of about 160 plants must be sampled and found to be uninfested before a "no spray" decision can be taken. In this case it is obvious that the systematic sampling procedure recommended earlier is less time consuming. During the 1985 growing season, the time required to reach a decision was recorded (Table III). Crops were sampled according to both the recommended systematic sampling procedure and the appropriate sequential sampling scheme in the same field on the same day.

Table III: Time (minutes) required for one person to reach a decision in a Brussels sprout crop, when sampling a caterpillar complex.

systematic*	sequential	% reduction**	tolerance≠	location
6***	2.5	58	50	OBS
8***	4	50	40	PAGV
8***	4.5	44	40	PAGV
55	8	85	40	PAGV
51	14	72	40	OBS
98	7	93	40	PAGV
122	19	84	40	PAGV
87	14	84	40	OBS
87 (1)	83 (1)	4	10	OBS
94	135	-44	10	PAGV
69	69	0	10	OBS

* sample size fixed at 70 plants

** reduction as percentage of "systematic"

*** pilot samples (n=10) at high tolerance levels and low population densities

≠ tolerance level in % infested plants

(1) decision taken for cabbage aphids

Two locations were used: the Experimental Station for Vegetable Growing (PAGV) and the Experimental Station for Development of Farming Systems (OBS), respectively at Lelystad and Nagele.

Varieties: Rampart (PAGV), Acropolis (OBS).

From these data it appears that considerable saving of sampling time can be achieved by using sequential sampling schemes if the population levels in the field differ sufficiently from the current tolerance levels. If not then sequential sampling may require a sample size even larger than the fixed sample size for routine systematic sampling, especially at low tolerance levels. Usually the tolerance levels for cabbage aphid infestation are well below those for the caterpillar complex. This means that two tables have to be used in the field which cause no problems. A peg board or more sophisticated counting devices may help in the recording procedure.

Later in the season when the Brussels sprout plants are taller differences between varieties influence the sampling time as shown in Table IV.

Table IV: Effect of varietal differences on sampling time at two tolerance levels.

location	variety	tolerance levels	
		10%	20%
PAGV	Rampart	135*	54
OBS	Acropolis	69	27

* sampling time in minutes by sequential sampling necessary to reach a decision

The difference in sampling time was caused by the growth habit of each variety. Rampart has leaves with firm stems which grow perpendicular to the main stem. Moving between the rows is difficult and slows down the sampler. Acropolis has hanging leaves with more pliable stems. This leaves some space between the rows and facilitates movement. Since most of the sampling time is spent walking through the field these varietal differences can affect sampling costs. In both cases the pest situation was similar and caused no differences in sampling time.

A problem is the required sample size for low tolerance levels. No grower is prepared to sample more than 100 plants in order to be sure that the pest popoulation level is below a specified low level. Neither systematic nor sequential sampling offers a solution of this problem. In practice, growers will start to sample for symptoms of injury which may be old and not relevant for the present situation. Essentially the growers have the choice of spraying upon finding the first infested plant, which may not be economically justifiable, or spraying at much higher tolerance levels than they claim are acceptable and which are covered by the sample size that they are prepared to take in the field. Based on our experience with field verifications tolerance levels of 20% and higher appear to be accounted for by using sequential sampling. The sample sizes and the time needed to take them are within the range growers are prepared to accept.

ACKNOWLEDGEMENTS

The assistance of Miss Anja Steenkiste and Mr Siert Folkertsma in collecting the field data is gratefully acknowledged.

REFERENCES

HOY, C.W., JENNISON, G., SHELTON, A.M. and ANDALORO, J.T. (1983). Variable-intensity sampling: a new technique for decision making in cabbage pest management. Journal of Economic Entomology 76: 139-143.

ONSAGER, J.A. (1976). The rationale of sequential sampling, with emphasis on its use in pest management. Technical Bulletin No. 1526, USDA.

THEUNISSEN, J. (1984a). Supervised control in cabbage crops: theory and practice. Mitteilungen aus der Biologischen Bundesanstalt 218: 76-84.

THEUNISSEN, J. (1984b). Development and application of sampling methods of pests in Brassica crops. CEC Programme on Integrated and Biological Control, Final Report 1979/1983, EUR 8689: 303-307.

THEUNISSEN, J. and DEN OUDEN, H. (1983). Praktijkbemonstering van plagen in vollegrondsgroenten 3. Geleide bestrijding in rode kool. Gewasbescherming 14: 119-124.

THEUNISSEN, J. and SINS, A. (1984). Growth stages of cabbage crops for crop protection purposes. Scientia Horticulturae 24: 1-11.

THEUNISSEN, J. and DEN OUDEN, H. (1985). Tolerance levels for supervised control of insect pests in Brussels sprouts and white cabbage. Zeitschrift für angewandte Entomologie 100: 84-87.

THEUNISSEN, J. and DEN OUDEN, H. (1987). Tolerance levels and sequential sampling tables for supervised control in cabbage crops. Mitteilungen der Schweizerischen Entomologischen Gesellschaft (in press).

WILSON, L.T., PICKEL, C., MOUNT, R.C. and ZALOM, F.G. (1983). Presence-absence sampling for cabbage aphid and green peach aphid (Homoptera: Aphididae) on Brussels sprouts. Journal of Economic Entomology 76: 476-479.

Table II: Sequential sampling tables for caterpillars and cabbage aphids in cabbage crops.

	NO TREATMENT	number of:	TREATMENT	
tolerance level (%)	infested plants	sampled plants	infested plants	remarks
4		20	≥4	
		40	5	
		60	5	
		80	6	
		100	7	
	=0	120	8	
10		10	≥4	max. 70 plants, no decision reached: control
		20	5	
		30	6	
		40	7	
	=0	50	8	
	≤1	60	9	
	2	70	10	
20		10	≥5	max. 60 plants, no decision reached: no control
	=0	20	7	
	≤2	30	9	
	4	40	11	
	6	50	13	
	8	60	15	
40	≤1	10	≥6	max. 30 plants, no decision reached: no control
	2	14	8	
	4	18	10	
	6	22	12	
	8	26	14	
	10	30	16	
50	≤2	10	≥7	max. 20 plants, no decision reached: no control
	3	12	8	
	4	14	9	
	5	16	10	
	6	18	11	
	7	20	12	

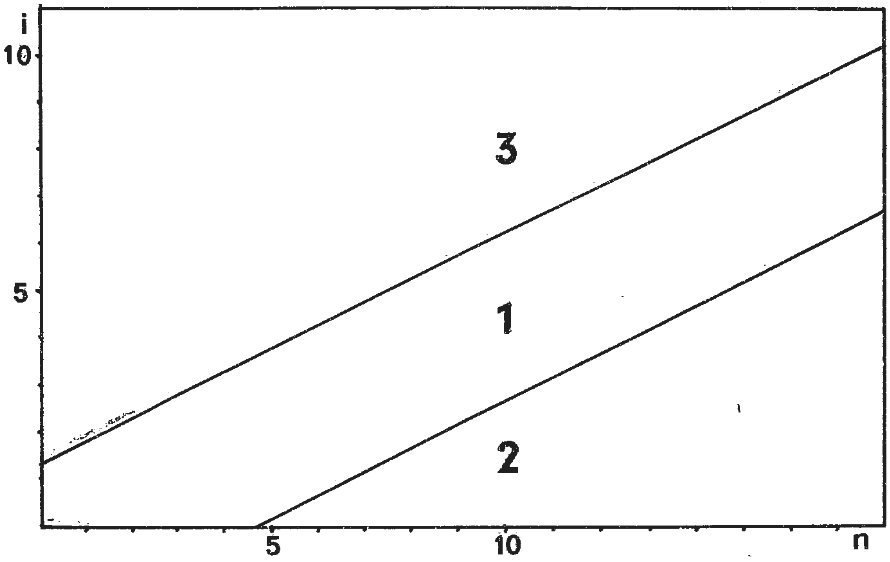


Fig. 1. Sequential sampling chart for use in Brussels sprouts. Abcissa; accumulated number of samples (n). Ordinate; accumulated number of infested plants (i). The chart is valid for the tolerance level of 50% infested plants.

TESTING DAMAGE THRESHOLDS FOR CATERPILLARS AND APHIDS ON CABBAGE IN FIVE EUROPEAN COUNTRIES - REPORT ON A COLLABORATIVE PROJECT DONE IN 1985 AND 1986

M. HOMMES, R. DUNNE, P.R. ELLIS, S. FISCHER, J. FREULER, A. KAHRER and C. TERRETAZ

First author's address: Federal Biological Research Centre, Institute for Plant Protection in Horticulture, Messeweg 11-12, D-3300 Braunschweig

SUMMARY

Simple damage thresholds based on the percentage of plants infested with caterpillars and aphids were verified on white cabbage in five European countries: Austria, England, Federal Republic of Germany, Ireland and Switzerland. Results of the first two years experiments showed that pest control based on the tested threshold values, could reduce the average amount of insecticide used by 50% and the average number of sprays by 25% in comparison to a regular spray program at fortnightly intervals. Yield and proportion of marketable cabbage heads did not differ significantly between the threshold and routine plots. Further investigations were done on pest attack and yield in the untreated plots. When no insecticide sprays were applied head weight was reduced by up to 50% and unmarketable heads by 89% from cabbage aphid attack and up to 77% by caterpillar damage. For all experiments, the mean percentages of unmarketable heads attributed to attack by the cabbage aphid and caterpillars were 23% and 31%, respectively.

INTRODUCTION

There have been several investigations to develop supervised pest control methods for cabbage pests (1,3,4,5) which have shown that the amount of insecticide applied can be reduced without increasing the risk of yield losses. In comparison with other monitoring techniques, like pheromone traps, damage thresholds have the advantage that they relate to the actual pest attack in the field. However, the disadvantage of basing control measures on damage thresholds is the time required to assess individual fields and to determine insect density, which is sometimes complicated. To encourage implementation of supervised pest control methods in practise a collaborative project was undertaken by the IOBC/WPRS—Working Group on Integrated Control in Field Vegetables. At the beginning of the project simple tolerance levels, based on the percentage of infested plants within a minimum sample size were tested. The aim of these trials was to determine thresholds at different sites under various infestation conditions. In this paper results of the experiments done in 1985 and 1986 are presented.

MATERIALS AND METHODS

Members from five countries participated in the collaborative experiment (Table 1). Simple damage thresholds, as shown in Table 2, were tested on field plots of white cabbage varieties grown commercially for the fresh market.

Table 1: Participants of the collaborative project

Participant	Country	Site
Kahrer	Austria	Wien
Ellis	England	Wellesbourne
Hommes	F.R. Germany	Fischenish/Braunschweig
Dunne	Ireland	Dublin
Freuler & Fischer	Switzerland (I)	Changins
Terretaz	Switzerland (II)	Chateauneuf

Table 2: Damage thresholds tested

FOR CATERPILLARS

year	first two samples	further samples till harvest
1985	10 % infested plants	5 % infested plants
1986	10 % infested plants	5 % infested plants

FOR CABBAGE APHID

year	first two samples	further samples till harvest
1985	10 % infested plants	5 % infested plants
1986	for all samples: 30 % infested plants with small colonies or 6 % infested plants with large colonies (large colony = more than 100 aphids)	

Each field trial had three treatments, each with a minimum plot size of 200 sq m. These included an untreated control and a routine spray treatment, which received sprays of a tank mixture of deltamethrin (5 ml a.i./ha) and pirimicarb (75 g a.i./ha) at fortnightly intervals from two weeks after transplanting until harvest. In the third treatment the same insecticides and doses were applied, either singly or as a tank mix, but only when the threshold values were reached.

The numbers of plants infested with caterpillars and aphids were recorded on the untreated and threshold plots. The number of *Pieris rapae*, *Pieris brassicae*, *Plutella xylostella* and *Evergestis forficalis* larvae were also counted. Sampling started 14 days after transplanting and was repeated at two-week intervals until harvest. At each sampling date 50 plants per plot (10 observation points of 5 plants regularly distributed over the whole plot) were examined. At harvest, aphid and caterpillar damage was recorded from 5 subsamples of 20 plants per plot from all the treatments, with each cabbage being graded according to damage level as shown in Table 3.

Table 3: Damage classes of cabbages attacked by caterpillars and aphids

---

A CATERPILLAR DAMAGE

1 = no feeding on the wrapper leaves and into the head
2 = feeding only on the wrapper leaves, head without damage
3 = feeding into the head, not marketable

B APHID DAMAGE

1 = clean, no aphids on the wrapper leaves and in the head
2 = aphids only on the wrapper leaves, head without aphids
3 = head infested with aphids, not marketable

RESULTS AND DISCUSSION

In 1985, the infestation by cabbage aphid in the threshold plots exceeded the tolerance values of 10 and 5% most of the time (Table 4). Only at the beginning and end of the growing period were they below the threshold values. In Switzerland, where a severe attack by cabbage aphid occurred (83% and 43% unmarketable cabbage heads in the untreated plots), spray treatments were reduced from 6.5 to 4.5 (Table 6). There was no significant difference between the proportion of marketable cabbage heads from the routine and threshold plots. In the experiment done in Austria there was no difference between the percentage of marketable cabbage heads from the untreated and the two treated plots. However, because aphid attack at the beginning of the crop reduced the average head weight by 50%, the application of insecticides to control this pest was justified.

Following the 1985 results higher threshold values (Table 2) were tested in the 1986 trials. The results from these experiments (Table 4 and 6) indicated that in general, an additional spray application could be saved compared with 1986 by using the higher thresholds. Discrimination of plants infested with small or large aphid colonies was not practical because when large colonies were taken into consideration the percentage of infested plants with aphids alone exceeded the tolerance level of 30%.

In contrast to the cabbage aphid attack, caterpillar infestation was lower (Table 7 and 8). The highest value in 1985 was 38% infested plants and in 1986 50%. The most common species found were *Mamestra brassicae*, *Pieris rapae* and *Plutella xylostella* (Table 9 and 10). *Pieris brassicae* was the most numerous species in 1985, but only at two sites, and in 1986 it was not observed in any of the trials.

The thresholds tested for caterpillars proved to be suitable for different infestation levels. The number of deltamethrin sprays could be reduced in the threshold plot without decreasing the efficiency of the control measure (Table 11). Insecticide usage was reduced by 54% (1985) and 48% (1986) compared with routine spraying, and there was no significant difference between the proportion of marketable heads from the threshold and routine plots. In most of the experiments the number of marketable cabbage heads with slight damage was slightly higher in the threshold plots than in the routine plots. This suggests that the threshold levels are at their limit. The risk of getting unmarketable cabbages following pest attack is higher for caterpillars than for aphids.

Comparison of all the treatments in each of the experiments showed that fewer sprays were applied when they were used against either the aphids or caterpillars singly than when they were applied as mixtures against both groups (cf. Tables 4 and 7; 5 and 8). Combined sprays were used in 54% and 43% of the applications in 1985 and 1986, respectively.

CONCLUSION

The results obtained from the experiments showed that the number of insecticide applications, when based on threshold values, were reduced by 28% in 1985 and 26% in 1986 compared to routine fortnightly sprays. The efficacy of the control measures was found to be satisfactory under different pest densities and sites.

Further experiments are needed to confirm these findings and the sampling techniques need to be improved to reduce the time spent inspecting the crop to determine pest infestation levels (2,3,6). This is essential if farmers are to accept this supervised control method for cabbage pests.

REFERENCES

1. HOMMES, M. (1984). Integrierte Bekämpfung von Raupen und Blattläusen im Kohlanbau. Mitt. Biol. Bundesanst. Land-Forstwirtsch. Berlin-Dahlem H. 218, 85-107.
2. HOY, C.W., JENNISON, G., SHELTON, A.B. and ANDALORO, J.T. (1983). Variable-intensity sampling: a new technique for decision making in cabbage pest management. J. Econ. Entomol. 76, 139-143.
3. SEARS, M.K., SHELTONN, A.M., QUICK, T.C., WYMANN, J.A. and WEBB, S.E. (1985). Evaluation of partial plant sampling procedures and corresponding action thresholds for management of Lepidoptera on cabbage. J. Econ. Entomol. 78, 913-916.
4. THEUNISSEN, J. (1984). Supervised control in cabbage crops: theory and practice. Mitt. Biol. Bundesanst. Land-Forstwirtsch. Berlin-Dahlem H. 218, 76-84.
5. THEUNISSEN, J. (1985). Tolerance levels for supervised control of insect pests in Brussels sprouts and white cabbage. Z. ang. Ent. 100, 84-87.
6. WILSON, L.T., PICKEL, C., MOUNT, R.C. and ZALOM, F.G. (1983). Presence-absence sequential sampling for cabbage aphid and green peach aphid (Homoptera: Aphididae) on Brussels sprouts. J. Econom. Entomol. 76, 476-479.

Table 4. Infestation levels of the cabbage aphid recorded in the threshold plots (1985)

Country Sample no.	% infested plants with cabbage aphid 1	2	3	4	5	6	7	8
(Threshold values)	10	10	5	5	5	5	5	5
Austria	40	88	100	26	30	0	2	2
England	89	100	54	8	1	3	1	-
F. R. Germany	2	0	8	32	16	4	-	-
Ireland	6	84	64	56	4	0	-	-
Switzerland I	96	100	64	62	12	12	-	-
Switzerland II	100	100	58	14	6	12	-	-

number underlined = threshold value reached or exceeded

Table 5. Infestation levels of the cabbage aphid recorded in the threshold plots (1986)

Country Sample no.	% infested plants with cabbage aphid 1	2	3	4	5	6	7	8
(Threshold values)	30	30	30	30	30	30	30	30
Austria	54	100	76	90	2	0	0	0
England	100	100	100	40	2	6	2	0
F. R. Germany	12	42	98	98	96	-	-	-
Ireland	38	18	6	48	88	-	-	-
Switzerland I	100	100	10	2	12	2	0	4
Switzerland II	100	100	54	6	0	0	-	-

number underlined = threshold value reached or exceeded

Table 6: Results of the collaborative field trial on control thresholds for aphids on cabbage (1985 and 1986)

	1985			1986		
Country/Plot	A / B	W	S	A / B	W	S
AUSTRIA						
untreated	100/ 1	830	-	96/ 1	-	-
routine	99/ 1	1520	8	100/ 0	-	8
threshold	100/ 0	1530	5	99/ 0	-	4
ENGLAND						
untreated	98/43	-	-	99/18	-	-
routine	100/ 1	-	7	100/ 0	-	7
threshold	100/ 1	-	4	100/ 1	-	4
F. R. GERMANY						
untreated	78/72	-	-	11/10	-	-
routine	97/ 4	-	6	68/32	-	4
threshold	98/ 7	-	3	60/39	-	4
IRELAND						
untreated	99/27	-	-	64/21	1503	-
routine	100/ 0	-	6	93/ 7	1556	5
threshold	97/ 2	-	3	79/16	1513	3
SWITZERLAND I						
untreated	17/13	-	-	100/ 0	257	-
routine	72/19	-	6	98/ 0	535	8
threshold	67/23	-	6	99/ 0	513	2
SWITZERLAND II						
untreated	57/24	-	-	100/22	1343	-
routine	86/15	-	6	100/ 7	1314	6
threshold	94/16	-	6	100/ 1	1486	3
MEAN						
untreated	75/30		-	78/12		-
routine	93/ 7		6.5	93/ 7		6.3
threshold	92/ 8		4.5	89/ 9		3.3

A = total no. of marketable cabbage heads
B = no. of marketable heads with slight damage symptoms
W = average weight per cabbage head
S = no. of pirimicarb sprays

Table 7. Infestation levels of caterpillars recorded in the threshold plots (1985)

	% infested plants with caterpillars							
Country Sample no.	1	2	3	4	5	6	7	8
(Threshold values)	10	10	5	5	5	5	5	5
Austria	38	2	26	12	22	16	2	0
England	0	1	8	9	6	6	1	-
F. R. Germany	8	0	10	8	6	0	-	-
Ireland	0	0	4	4	0	0	-	-
Switzerland I	0	26	6	4	0	6	-	-
Switzerland II	0	22	16	2	2	18	-	-

number underlined = threshold is reached or exceeded

Table 8. Infestation levels of caterpillars recorded in the threshold plots (1986)

	% infested plants with caterpillars							
Country Sample no.	1	2	3	4	5	6	7	8
(Threshold values)	10	10	5	5	5	5	5	5
Austria	0	0	8	0	8	12	12	4
England	16	20	12	12	10	0	0	0
F. R. Germany	2	6	50	14	8	-	-	-
Ireland	6	16	0	0	2	-	-	-
Switzerland I	2	10	6	2	12	8	2	0
Switzerland II	2	32	8	46	2	2	-	-

number underlined = threshold is reached or exceeded

Table 9. Number of larvae of the different Lepidoptera pests found during the experiment in the untreated plots (1985)

	Number of caterpillars					
Country	Noct.	PR	PB	PX	EF	Total
Austria	3	47	8	95	1	154
England	7	23	0	2	22	59
F. R. Germany	44	33	0	13	0	90
Ireland	0	2	82	1	0	85
Switzerland I	14	54	266	5	0	339
Switzerland II	128	8	0	2	0	138
	196	167	356	118	23	863

Noct. = Noctuidae, PR = *Pieris rapae*, PB = *Pieris brassicae*, PX = *Plutella xylostella*, EF = *Evergestis forficalis*

Table 10. Number of larvae of the different Lepidoptera pests found during the experiment in the threshold plots (1986)

	Number of caterpillars					
Country	Noct.	PR	PB	PX	EF	Total
Austria	3	16	0	3	0	22
England	3	16	0	18	2	39
F. R. Germany	99	0	0	23	1	123
Ireland	0	3	0	35	0	38
Switzerland I	14	9	0	2	2	27
Switzerland II	140	2	0	0	0	142
	259	46	0	81	5	391

Noct. = Noctuidae, PR = *Pieris rapae*, PB = *Pieris brassicae*, PX = *Plutella xylostella*, EF = *Evergestis forficalis*

Table 11: Results of the collaborative field trial on control thresholds for caterpillars on cabbage (1985 and 1986)

	1985			1986		
Country/Plot	A / B	W	S	A / B	W	S
AUSTRIA						
untreated	42/42	830	-	91/25		-
routine	95/81	1520	8	100/ 1		8
threshold	97/40	1530	5	100/ 5		4
ENGLAND						
untreated	80/40		-	72/68		-
routine	99/ 1		7	100/ 1		7
threshold	99/11		4	100/ 2		5
F. R. GERMANY						
untreated	38/31		-	23/20		-
routine	100/ 0		6	98/ 9		4
threshold	97/ 2		3	94/22		3
IRELAND						
untreated	85/70		-	100/62	1503	-
routine	100/39		6	100/10	1556	5
threshold	100/47		0	100/21	1513	1
SWITZERLAND I						
untreated	82/33		-	62/50	257	-
routine	99/ 1		6	100/ 0	535	8
threshold	99/ 5		3	99/ 1	513	4
SWITZERLAND II						
untreated	47/23		-	98/97	1343	-
routine	100/ 6		6	100/17	1314	6
threshold	92/ 4		3	100/33	1486	3
MEAN						
untreated	63/40		-	75/54		-
routine	98/21		6.5	99/ 8		6.3
threshold	95/16		3.0	99/16		3.3

A = total no. of marketable cabbage heads
B = no. of marketable heads with slight damage symptoms
W = average weight per cabbage head
S = no. of deltamethrin sprays

IMPLEMENTATION OF SUPERVISED CONTROL IN COMMERCIAL CABBAGE GROWING

J. THEUNISSEN AND H. DEN OUDEN

Research Institute for Plant Protection,
Wageningen, the Netherlands

SUMMARY

The conditions and constraints that affect the implementation of research results into field practices are discussed in the light of experience gained while introducing supervised control methods into commercial cabbage crops in The Netherlands.

INTRODUCTION

To carry out research on methods of pest management is one thing, to get the results applied in the field by commercial growers is quite another. This is illustrated by the relatively low number of pest management methods actually used by growers in their regular cropping practices, compared to the number of methods which are potentially useful or which are applied by researchers on a (semi-)experimental basis.

As a part of a pest management approach of insect pests in cabbage crops, supervised control has been developed for the cabbage caterpillar complex and for the cabbage aphid, Brevicoryne brassicae (Theunissen & den Ouden, 1985). For some years, these control methods have been tested in commercial cabbage crops in cooperation with the plant protection specialists and the horticultural extension service in the Netherlands. This is a slow and vulnerable process which requires careful consideration of the various factors which stimulate and protect its acceptance. Since we presume that this is a process which will be developed elsewhere in a similar manner in future, we will try to name, define and analyse the factors that are important for the practical implementation of pest management under European conditions.

REQUIREMENTS

Demands will be made concerning any new method that is to be recommended for use by growers. Such demands will originate from both extension staff and growers and will pertain to several categories.

Communication requirements

Implementation of almost every new development in commercial growing depends directly on the cooperation between researcher, extension specialists and the progressive grower. Therefore it is of paramount importance for the researcher to establish and maintain good relations with those specialists (in the Netherlands called "plant protection specialists") who disseminate technical and economic knowledge to general extension workers and growers. To maintain this chain of information successfully the extension specialists should be told as soon as possible about any interesting new developments. Such an open attitude allows useful information to be incorporated spontaneously into extension. In this way extension workers are able to anticipate possible problems. It is important that extension specialists participate in cooperative experiments in their own region and form their own opinion on the feasibility of any new methods arising from the research. If they are involved in the development of these methods from an early stage there will be no need to convert them later on. When the new method is sound in their opinion, they will defend it as their own baby.

Another necessity in establishing a good relationship between research and extension is that the researcher must respect the competence and territory of the extension worker. There should be no direct and permanent contact between research and grower. This is the territory of extension. Contact can be made upon mutual request and with cooperation of extension for special reasons such as a study tour. Similarly, information from research to grower should be channelled through extension. Extension can then adapt the information to suit particular audiences and this they should do since they speak the appropriate language. Extension workers should be allowed to develop their own advice packages so that they become respected as authorities by the growers. In this situation the researcher should stay in the background and supply vital and complete information only to the extension specialists. All parties concerned will benefit from such a policy.

An open attitude of the researcher is important from the point of view of risk analysis by the extension worker. The latter has to assess to what extent the researcher is really sure of what he wants the growers to be told. It is the extension workers who runs the risks of failure of any new recommendations given to growers and he cannot afford to run such risks. Therefore, early information on, and participation in, new developments is very important for the mutual relation and cooperation when suggesting new methods to the growers.

Researchers may write in growers' journals about new developments. Apart from the general policy of first communicating new information through extension, virtually no grower will take information in journal articles seriously until he has obtained the opinion of the local extension worker. The role of such publications therefore is to back up and confirm the advice being given by the extension officer.

Technical requirements

Any new method or approach should obviously be technically sound. This is a research matter. For implementation, however, any technical action must be feasible from a growers' point of view. Therefore, these technical actions should be as simple as possible. Operating water traps or light traps, for instance, is out of the question. Using pheromone traps with a more selective catch of species and one dominating target species could be feasible, provided the species concerned can easily be recognized and the number of traps per hectare is limited. Field sampling should take only a short time and the sample size should be acceptable to the grower. In general, there are limits to what growers are willing to do in the field outside their standard working practices.

If the benefits are large, more "complicated" and time-consuming actions may be acceptable. In some cases there will be an absolute minimal requirement to the growers to be able to use a pest management method at all, unless the extension service is able to do the job. An example is supervised control of carrot rust fly, Psila rosae. Monitoring the flies using modified Berlinger traps (den Ouden and Theunissen, 1988) is quite possible for a farmer who really wants to minimize chemical control. However, because the extension service simply does not have the necessary manpower, it is not possible for the extension service to monitor fly populations at the farm level.

Proof of the technical feasibility of any method has to be obtained by verifying the method in the field during a number of seasons. This has been done for Brussels sprouts and white cabbage in the Netherlands (Theunissen and den Ouden, 1985). It is very important to give extension workers and growers tangible examples of what they can expect from both the technical and economic point of view. A convincing risk-analysis from field data may lead to a feeling of security in dealing with the new methods and may enhance their implementation.

Economic requirements

One of the first questions asked about any new method is usually concerned with some form of cost-benefit analysis. The minimal requirement of any new method is that the financial outcome should be comparable to the current method and there should also be some other benefit. This benefit could merely be an easier decision, a faster way of achieving a certain result, or not having to handle a pesticide. Most growers dislike pesticides but feel that they cannot avoid their use. When convinced of a method which enables them to skip one, more, or all chemical control treatments, most growers are prepared to use the method provided the financial returns remain the same. A few growers are even prepared to accept a smaller financial return. In principe, however, the financial return should be equal to or larger than previous returns to initiate an action. In this context, costs required to carry out the recommended method are seen as production costs. For instance, costs of traps, sampling time and possible recording devices are considered to be added production costs. Benefits are the savings on unnecessary pesticides, machinery and spraying time. Items of environmental concern are usually not included in the economic picture. Avoided losses of yield in quantity or quality by less mechanical damage and soil compaction in the crop are also not usually included. While minimizing additional costs, savings should be maximized, since profit is the best incentive to any grower.

Socio-psychological requirements

Public opinion about the advantages and disadvantages of pesticide use is changing slowly. For both the extension worker and the grower this has now created the situation in which there is a certain urge to use the minimum amounts of pesticide possible. When this is made possible technically and economically a grower is considered progressive if he is willing to adopt such changes. Backing up extension with relevant information, the researcher can make both extension officer and grower independent of biased information presented by pesticides salesmen. The entire set-up of this communication is to give the grower the confidence and competence to make his own pest control decisions independent of anyone else, including extension workers. To enable the grower to gain this decisiveness he must obtain both the technical tools (methods) and the moral backing (self-confidence and knowledge of the biological rationale of the methods). Both can be developed by regional training sessions with extension workers.

The support of the growers' organization is very important to the rapid adoption of modern cropping methods, including pest management. In the Netherlands the growers' study clubs are important sources of information and reference in this respect. Mainly during the winter months, these clubs hold discussion meetings concerning varieties, fertilizers, crop protection and storage and also review and evaluate the information currently being provided by the extension service. Obviously pest management information must be channelled through these study clubs.

CONSTRAINTS

Given the technical feasibility of a pest management strategy like supervised control there are several constraints that can prevent it being implemented in commercial vegetable growing.

At the communications level, the following difficulties can exist:

* Disrupted communications between researchers and extension workers can be a major constraint for practical implementation of research results. In the case of implementation into commercial cabbage growing in the Netherlands communications have been established carefully resulting in effective and pleasant working relationships. Much depends on the temperaments of the people

---

involved. However, in many countries the organizational set-up of both research and extension prevents smooth cooperation between the two types of workers, difficulties that often arise from aspects of competence, territory and traditional antagonism.

* The traditional cautiousness of farmers towards outsiders, including researchers, also has an influence. This situation calls for an exclusive role of extension in their contacts with farmers as argued previously.

* Overload of the growers by the constant flow of information. Continuous changes take place in many aspects of crop production. Crop protection is just one of these aspects. Growers tend to select priorities according to their personal preference; they can't keep up with everything new.

* Conflicting information reaches the growers which causes uncertainty on what to believe and on what to do. The pesticide industry tries to obstruct the implementation of pest management methods by increasing the feelings of uncertainty amongst growers. They suggest excessive risks when such methods are applied. Conservative workers within the extension service may also stick to old methods in their advice.

On the <u>technical level</u> constraints may be experienced by growers:

* Complicated or time-consuming methods may form a barrier. This is a subjective matter. Even a very simple sampling method may be found to be too complicated. Similarly, monitoring using just a few pheromone traps may be considered too time-consuming. This will vary from grower to grower but can be a real problem.

* Among cropping methods, those involving pest management (here supervised control) are relatively complicated. Many species of insects and fungal diseases can be involved. The identification and damage assessment of pests and diseases produces major problems for the grower. Without clear, simple instructions and adequate training he will not acquire the self-confidence to make independent pest control decisions.

* Growers often think that conventional chemical control leaves their crop without insects. This is not correct. Populations of pest insects may be as large as those in fields under supervised control. The point is that conventionally-sprayed fields are rarely checked for the effectiveness of the chemical control treatment.

At the <u>economic level</u> constraints may be:

* The risk-aversion of the grower. Without proof that he is going to gain, he usually will not be receptive to new ideas or methods. Pesticide salesmen play on this tendency of risk-aversion. They generally obstruct the adoption and implementation of pest management methods and tend to present their own advise. Sufficient and convincing field evaluation is the right remedy as advocated earlier.

* Availability of cheap insecticides. Some insecticides are extremely cheap, for example parathion. When such insecticides are effective, little can be saved by reducing the number of chemical treatments and the growers' risk aversion may prevail. According to the Dutch governments' declared policy of supporting non-chemical and reduced chemical pest control strategies, a levy on pesticides could provide added incentives for the development of such strategies.

<u>Socio-psychological</u> constraints have to do with attitudes and opinions within the groups of extension workers, growers and policy makers:

* Conservatism is widespread among policy makers. Usually this originates from ignorance about new developments in research. It results in immobility and little support for institutes, groups and individuals working on these developments. Instead of leading by anticipating and guiding new developments they lag behind thus causing constraints for implementation.

* Extension workers also tend to be conservative because they cannot afford to give wrong recommendations. This is another, a different kind of conservatism and this generally changes if these workers take part in field verifi-

cation exercises. In some cases extension workers stick to old methods regardless of positive results from the new systems.

* Besides risk-aversion, there is a particular attitude of a grower which may prevent the implementation of a new method. This attitude is based upon the viewing of growing crops as a kind of industrial activity instead of working with biological phenomena and within the laws of life. In such a case the grower is open to changes, provided they increase the scale of farming and permit the use of machinery, chemical compounds and labour saving devices. Getting off the tractor to see what is happening in the crop is considered old fashioned by these people, since most have lost the feeling for farming as a natural process. Such an attitude is strengthened when middle men explicitly want to buy only products grown in a conventional way. This happens out of sheer ignorance, an unreasoned hostility towards new developments and an intuitive kind of risk-aversion of the middle men. Increased awareness of the consumer on the possibilities of less pesticide usage could reverse this attitude.

* In the Netherlands, the extension services are being reduced. This is the government's policy to save on public services and promote free enterprise in agricultural activities. A serious constraint for introducing and implementing new methods of any kind is the lack of manpower within the extension service to give the necessary training to interested growers. What the policy makers do not realize is that they also break down the effectiveness of agricultural research. When research results cannot be passed to growers, because of an ineffective extension service, what is the benefit of research?

CONCLUSIONS

Incorporating research results into commercial vegetable production is a long process which has to be guided carefully. Actively the conditions expected by growers must be met and any constraints must be limited if new ideas and methods are to be adopted by farming communities.

REFERENCES

OUDEN, H. DEN AND THEUNISSEN, J. 1988; Monitoring of the carrot rust fly, Psila rosae, for supervised control; this bulletin.

THEUNISSEN, J. AND DEN OUDEN, H. 1985; Tolerance levels for supervised control of insect pests in Brussels sprouts and white cabbage; Zeitschrift für angewandte Entomologie 100, 84-87.

DEVELOPMENT OF VARIOUS FORMULATIONS FOR CONTROLLED RELEASE OF NAPHTHALENE AS A REPELLENT AGAINST OVIPOSITION OF THE CABBAGE ROOT FLY, DELIA RADICUM (BRASSICAE)

H. DEN OUDEN
Research Institute for Plant Protection (IPO)
Wageningen, the Netherlands

SUMMARY

Clay loaded carboxymethylcellulose and plaster of Paris granules have been manufactured as substitutes of initially tested synthetic polymers as controlled release matrices for the repellent naphthalene. The formulations loaded with different percentages of active ingredient have been used in field experiments with cauliflower, attacked by the cabbage root fly, Delia radicum (brassicae). Their efficacy was compared with that of a conventional insecticide treatment.

INTRODUCTION

It has been shown that the possibilities for application of repellents against D. radicum are limited by the necessity to use large quantities of a controlled release formulation with a low quantity of active ingredient (Den Ouden, et al., 1984, Den Ouden, 1984). The period of activity must be at least six weeks. The problems are caused mainly by the high volatility of the available repellents which prevent the use of very small particles. As a consequence quantities of approximately 500 kg of formulated product per ha should be spread around the stems of brassicas. The cost of the degradable polymers for this purpose have recently risen considerably and therefore experiments have been carried out with granules of clay matrices for the cheapest synthetic repellent available i.e. naphthalene. These formulations can be used only against the cabbage root fly when it is attacking the root system. They are useless for control of oviposition and larvae in the heads of cabbage and buttons of Brussels sprouts.

MATERIALS AND METHODS

For the production of granules with a sufficient long retention time of the active ingredient two parameters are important: stability and size. When materials such as clay powder and fodder wheat flour are used for the granules, these should be protected against degradation e.g. by rainfall. As a stabilizer carboxymethylcellulose (CMC) was chosen being a relatively cheap and degradable polymer which can be mixed easily with clay or flour. For additional stability a hydrophilic emulsion of the hydrophobic polyvinylacetate (PVAc) has been applied.

For the 1984 experiment 10 kg clay powder or flour was mixed with 1600 g and/or 800 g of ground naphthalene flakes. This mixture was then added to 7 l of gel containing 7.5% of CMC and 3.8% of PVAc emulsion and spread as a 1 cm thick layer in a tray for about 10 days at 21°C to dry. The concretelike plate was then broken into roughly 0.75 cm fragments.

Manufacturing granules from plaster of Paris in 1985 was simpler. Powder of this substance was mixed with 7%, respectively 15% of naphthalene powder. Water was sprayed as fine droplets onto the mixture which was turning round in a concrete mixer until granules with an average diameter of 4 mm were formed. These were spread on a tray and dried over 12 h. Irregularly shaped granules could have been made by crushing dry plates of plaster of Paris, previously cast on a plastic sheet.

Naphthalene has no strong effect on D. radicum at a distance of a few cm or more (Den Ouden et al., 1984). The field experiments were laid out on sandy soil in three randomized blocks. Plots of 7 x 7 cauliflowers, var. Alpha, were planted in early May. About ten days later the plants were treated with different amounts of repellent granules around the stem base. Standard treatments of trichloronate (100 ml 0.1% Phytosol per plant) and pure naphthalene (twice 1, 3 or 6 g per plant on May and June 1) were included.

Root damage indices (RDI) were determined according to the IOBC/WPRS Brassica Working Group (Thompson, 1980). The indices varied from 1 (no damage by maggots in the root) to 4 (seriously damaged root). Significance of differences was determined by the ^{2} test. Plants with RDI 3 and 4 were considered to yield an inferior curd.

In the second half of the season 1985 an experiment with plaster of Paris granules recorded only a slight attack by cabbage root fly. In this experiment the curds were harvested and the yield compared with those from the trichloronate-treated plots.

RESULTS AND DISCUSSION

Table 1 shows the results of the 1984 experiment. The first three formulations did not differ significantly although clay with 16% and flour with 8% naphthalene were a little better. The absence of a dose effect may have been caused by the small differences in dosages and also because D. radicum lays its eggs near to the stem and consequently may have been repelled even with small dosages.

Table 1. The repellent effect of various formulations of naphthalene on stand (scores ranging from 0-2) and root damage (1-4) of cauliflowers. Figures with - and . do not differ from the treatment with Phytosol 100 ml at P > 0.05 and 0.05 > P > 0.02 respectively.

Formulations	Clay + 8% a.i.	Clay + 16% a.i.	Flour + 8% a.i.	Pure a.i.,2x	Untreated -	Phytosol 0.1%
Dosage (g/plant)	10 20 30	10 20 30	10 20 30	1 3 6	- - -	25 50 100
% plants with stand 2 on July 5	$87^{\cdot}$ 90^{-} 82	91^{-} 90^{-} $86^{\cdot}$	93^{-} 78 87^{-}	58 61 60	45 64 68	94 75 94
% plants with RDI 1+2 on July 9	87 78 68	88 93^{-} $90^{\cdot}$	94^{-} 88 $90^{\cdot}$	71 59 72	58 77 72	99 90 97
Average block total stand						
May 30	98 99 95	98 98 98	98 98 98	97 97 97	98 96 97	98 95 98
June 28	89 95 88	92 93 86	93 85 89	73 74 71	63 78 77	93 88 92
July 5	90 92 86	93 92 89	94 85 89	70 72 70	60 76 74	95 83 94

The RDI showed clay granules with 8% naphtalene to be inferior to the 16% granules and the flour with 8% napthalene for both the 20 and 30 g dosage.

A poor effect was obtained from pure naphthalene applied twice around the stems of the cauliflowers. If it had been applied as coarse particles instead of flakes e.g. Caulin rings (de Wilde, 1947) the effect may have been better due to slower evaporation.

Table 2 shows that plaster of Paris granules were as effective as the clay and flour formulations. There was a significant difference between the RDI on the 7% and the 15% treatments for the 10 g dosage ($P < 0.01$), and the 20 g dose ($P < 0.05$). The RDI from the naphthalene formulations and the trichloronate treatment were significantly different ($P < 0.01$). The percentages of seriously attacked plants treated with 10 and 20 g of granules with 15% naphthalene did not differ significantly ($P > 0.05$) from trichloronate treatment.

Table 2. The effect of various dosages of naphthalene formulated in plaster of Paris on the infestation rate and RDI on cauliflower plants.

Formulations with % active ingredients	Plaster of Paris				Untreated	Trichloronate (Phytosol 0.1%)
	7% a.i.	15% a.i.	7% a.i.	15% a.i.	-	
Dosage in g	10	10	20	20		100
% plants seriously attacked						
at May 28	0	0	0	0	9	0
at June 4	1	1	5	1	32	0
at June 11	3	1	7	2	37	0
% plants with RDI 1+2						
at June 21	77	91	81	90	22	98

GLC tests done at the Department of Organic Chemistry of the Agricultural University, Wageningen showed that the drying procedure of the clay and the flour granules caused a loss of about 23% of the naphthalene. Granules kept in a field depot under conditions comparable to those under the stembase of the plants released another 50% from May 10 to June 6 thereby reducing the load to less than 3% by June 29.

Control of the cabbage root fly with naphthalene formulations may have been obtained not only from their repellent effect but also by the increasing tolerance of the plants and the decrease of the population density of the fly as the plants developed.

It should be emphasized that the cheap formulations described will require a specially adapted machine for application in commercial crops. In private gardens hand application can provide an easy means of control of cabbage root fly. The granules should be stored in a cool place to avoid sublimation of the active ingredient.

Finally the result of the comparison between trichloronate treated and naphthalene-plaster of Paris treated crop should be mentioned. In a test with in total 512 curds, there was no significant difference ($P >> 0.1$) in the ratios between the percentages of curds belonging to grade I + II (different somewhat in shape only) and the curds of grade III being of an inferior quality and size.

ACKNOWLEDGEMENTS

Thanks are due to Dr. G.M. Sanders and Mr. E.J.C. van der Klift of the Department of Organic Chemistry of the Agricultural University, for carrying out the naphthalene analyses in clay granules, to Mr. J.L. Kalthoff of Enka bv, Arnhem for providing a CMC supply and to Messrs J. Freriks, J. van der Beek ans S. Folkertsma for assistance in the field experiments.

REFERENCES

OUDEN, H. den, 1984. Untersuchungen über Repellents im Einsatz gegen die kleine Kohlfliege. Mitteilungen aus der Biologischen Bundesanstalt für Land und

Forstwirtschaft 218: 51-59.

OUDEN, H. den, THEUNISSEN, J. and HESLINGA, A., 1984. Protection of cabbage against oviposition of cabbage root fly Delia brassicae L. by controlled release of naphthalene. Zeitschrift für angewandte Entomologie 97: 341-346.

THOMPSON, A.R., 1980. The assessment of damage caused to cruciferous crops by larvae of *Hylemyia brassicae* in soil WPRS Bulletin III/1: 19-26.

WILDE, J. de, 1947. Onderzoekingen betreffende de koolvlieg en zijn bestrijding. Staatsdrukkerij 's-Gravenhage 1947.

CHEMICAL CONTROL OF *DELIA RADICUM* (L.) IN BRASSICA CROPS AND ACCELERATED MICROBIAL BREAKDOWN OF CHLORFENVINPHOS AND TRICHLORONATE*

F. VAN DE STEENE(1) & G. DE SMET (2)

Summary

The effectiveness of the insecticides chlorfenvinphos, trichloronate, carbofuran, diazinon, chlorpyrifos, furathiocarb, fonofos, bromophos-ethyl, carbosulfan and tefluthrin in controlling larvae of the cabbage root fly, was investigated during 1984, 1985 and 1986. Experiments were carried out in 4 regions of Belgium; namely Staden, St.-Katelijne-Waver, Oppuurs and Opdorp.
Microbial degradation of chlorfenvinphos and trichloronate, applied to soils from these 4 regions, was also determined, under laboratory conditions.

Introduction

In Belgium, the insecticides chlorfenvinphos, trichloronate, chlorpyrifos, diazinon, fonofos and bromophos-ethyl have been recommended for application to soil to protect brassica crops against damage by larvae of the cabbage root fly *Delia radicum*. Although it is the general practice to rotate crops of brassicas to limit the development of club root (Anonymous, 1984), cauliflowers have been grown in the same small fields for several successive seasons in some regions of Belgium. These regions include Sint-Katelijne-Waver and Oppuurs.

The insecticides chlorfenvinphos and trichloronate have been applied during successive years on some of the small fields already mentioned. Repeated use of a chemical at a particular site can, under certain conditions, lead to the development of highly active microbial populations which are able to degrade the chemical more rapidly, a phenomenon known as 'enhanced' or 'accelerated' degradation (Walker and Suett, 1986). However, accelerated degradation of carbofuran following repeated applications to some field soils has been reported from the U.S.A. (Felsot, Maddox and Bruce, 1981), Canada (Read, 1983) and the United Kingdom (Suett, 1986).

The effectiveness of different soil insecticides in controlling larvae of the cabbage root fly was investigated in 4 different regions of Belgium. The extent to which degradation of chlorfenvinphos and trichloronate had been enhanced in treated soils from the four regions was also investigated.

---

* Research subsidized by the Institute for Encouragement of the Scientific Research in Agriculture and Industry.

(1) Centre for research in Vegetable, Section V: Entomology (Dir.Prof.Dr. C. Pelerents) I.W.O.N.L., Faculty of Agricultural Science, Laboratory for Zoology, Ghent State University, Belgium.

(2) Centre for research of the utilisation of Pesticides in Agriculture (Dir. Prof.Dr. W. Dejonckheere & Dr. W. Steurbaut) I.W.O.N.L., Laboratory for Crop Protection Chemistry, Ghent State University, Belgium.

Materials and methods

Eleven insecticides (see table 2) were tested at one or two doses to compare their relative effectiveness at controlling larvae of the cabbage root fly. The experiments were done in 1984, 1985 and 1986 in 4 regions of Belgium; namely Staden (Exp. 1), St.-Katelijne-Waver (Exp. 2, 3 and 4), Oppuurs (Exp. 5, 6 and 7) and Opdorp (Exp. 8 and 9).

Plot design and layout

Plots consisted of 2 rows of 10 plants. Each insecticide treatment and untreated control was assigned to one plot per block. The positions of the plots within the three (four in exp. 1, 2, 3 and 4) replicated blocks were randomised. In experiment 1 and 3, plots consisted of 4 rows of 25 and 4 rows of 10 plants respectively. Data on these experiments are shown in table 1.

Insecticide treatments

A few days after planting, 100 ml of an aqueous suspension of the insecticide (e.c. or w.p. formulations: see table 2) were applied to the base of each plant. In experiment 5 and 6, chlorfenvinphos and trichloronate were also applied in 25, 50 or 75 ml suspensions. The granule treatments were applied just before planting (exp. 2) or at planting (exp. 1 and 3). Each insecticide tested and the respective doses are shown in table 2.

Assessment of cabbage root fly damage

Damage to the roots of cauliflowers by cabbage root fly larvae was assessed and recorded both 5-6 weeks, after planting and at harvest. With Brussels sprout crops, comparable assessments were camed out 6 and 12 weeks after planting (see table 1). In each experiment the damage to the cortex of the roots of 10 to 20 randomly selected plants was assessed on a five category scoring scale: clean (0%) damage, 1 to 3 mines in the stem, more than 3 mines in the stem, stem and root moderately damaged (50%) and stem and root completely damaged (100%). A mean root damage index (R.D.I.) was calculated for each treatment using the formula:

$$\frac{1a + 2b + 3c + 4d + 5e}{a + b + c + d + e}$$

where a, b, c, d, e are the respective numbers of plants having damage scores of 1, 2, 3, 4 and 5. The numbers of larvae and pupae were also recorded on the plants assessed for root damage and then mean numbers of larvae and pupuae per plant were calculated.

Degradation of chlorfenvinphos and trichloronate

The degradation of chlorfenvinphos and trichloronate was determined in soils from 4 different regions in Belgium. The main characteristics of these 4 soils are described in table 8.

Samples of soil, weighing 100 g, were placed into petri-plates and then treated with either 4.8 mg chlorfenvinphos (sterilized and non-sterilized soils) or 5.5 mg trichloronate (only non-sterilized soils). These petri-plates were placed subsequently in a controlled environment chamber at a temperature of 23°C. Each experiment was repeated twice. At regular intervals, residue levels were determined by extracting the remaining chlorfenvinphos and trichloronate from the soil using acetone. After filtration and the addition of distilled water, the insecticides were partitioned by liquid-liquid extraction using dichloromethane. The dichloromethane phase was dried over anhydrous sodium sulphate and evaporated to dryness. The solid residues were then dissolved in petroleum ether, the pesticides were detected using a gas-liquid chromatograph fitted with a flame-photometric detector (FPD) in the phosphor mode.

TABLE 1: EXPERIMENTAL DATA

Locality	Staden	St.-Katelijne Waver			Oppuurs			Opdorp	
Details of experiments	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6	Exp. 7	Exp. 8	Exp. 9
vegetable	Brussels sprouts	cauliflower	cauliflower	cauliflower	cauliflower	cauliflower	cauliflower	cauliflower	cauliflower
year	1986	1984	1985	1986	1984	1985	1986	1986	1986
planting	28/5	20/7	17/6	11/7	24/4	12/7	11/7	3/4	10/7
treatment	28/5	20/7	16/7	16/7	3/5	16/7	16/7	24/4	16/7
1st analysis of the stem and root	14/7	4/9	20/8	21/8	4/6	20/8	19/8	3/6	19/8
No. of plants assessed	20	12	15	10	10	10	10	10	10
2nd analysis of the stem and root	27/8	15/10	21/10	2/10	25/6	15/10	22/10	10/7	9/10
No. of plants assessed	20	12	15	10	20	15	20	15	10
n° of treatments	11	7	8	12	11	12	12	12	11
n° of replications	3	3	3	3	4	4	4	4	4
n° of plants/plot	100	20	40	20	20	20	20	20	20
total n° of plants	4800	480	1080	780	960	1040	1040	1040	960

TABLE 2: INSECTICIDES

Active ingredient	Trade name/Formulation	Dose mg a.i.
chlorfenvinphos	Birlane 250 g/l E.C.	25 or 50/pl
	Birlane 10G	62.5 m/row
		100 m/row
trichloronate	Agrisil 550 g/l E.C.	25 or 50/pl
chlorpyrifos	Dursban 25 W.P.	25 or 50/pl
	Dursban 5G	50/pl
furathiocarb	Deltanet 400 g/l E.C.	50/pl
	Deltanet 5G	62.5 m/row
		150/m²
carbofuran	Curater 5G	30 or 50/pl
		150/m²
	Curater 1G	150/m²
bromophos-ethyl	Nexagan 370 g/l E.C.	100/pl
fonofos	Dyfonate 250 g/l E.C.	75/pl
	Dyfonate 5G	150 m/row
diazinon	Basudine 162 g/l E.C.	100/pl
carbosulfan	Marshall 5G	150/m²
		62.5 m/row
tefluthrin	Force 0.5G	2.5/pl
chlorf.(6.6%)+ oxamyl(3.34%)	Allivin 5G	150/m²
		62.5 m/row

TABLE 3. MEAN R.D.I. AND MEAN NO. OF LARVAE AND PUPAE PER PLANT (EXP. 1)

Insecticides	dose a.i.	1st analysis		2nd analysis	
		mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl
chlorfenvinphos*	50 mg/pl	1.05	0.05	1.4	0.7
fonofos*	75 mg/pl	1.2	0.7	1	-
carbofuran*	50 mg/pl	1	-	1.1	0.1
carbosulfan*	50 mg/pl	1	-	1.1	0.1
furathiocarb*	50 mg/pl	1.05	0.05	1.4	0.6
chlorpyrifos*	50 mg/pl	1.05	0.1	1.8	1.5
tefluthrin*	2.5 mg/pl	1.85	1.8	1.1	0.4
fonofos*	150mg/m row	2.05	3.75	1.9	2
carbofuran*	62.5mg/m row	2.40	5.90	2.3	4.9
chlorfenvinphos*	100mg/m row	2.70	5.65	2.2	3.5
chlorfenvinphos	50 mg/pl	1.65	1.65	1.3	0.8
untreated	-	3.58	12.10	3.1	8.2

* granular formulation

TABLE 4. MEAN R.D.I. AND MEAN NO. LARVAE AND PUPAE PER PLANT (EXP. 2 and 3)

Insecticides	dose	Experiment 2			
		1st analysis		2nd analysis	
		mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl
	a.i./m²				
carbofuran 1G*	150	1.2	4.7	1.5	1.6
carbofuran 5G*	150	2.5	6.6	2.1	2.7
carbosulfan*	150	2.8	7	2.7	5.9
thiofurcarb*	150	1.8	2.3	1.7	1.4
chlorf.+oxamyl*	150	2.3	4.2	2.2	3.7
	mg a.i./pl				
chlorpyrifos	50	1	-	1.5	0.3
trichloronate	50	3.2	11.5	3.2	13.8
untreated	-	3.3	12.2	3.3	12.9

Insecticides	dose a.i.	Experiment 3			
		1st analysis		2nd analysis	
		mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl
	mg/pl				
chlorfenvinphos	50	1.4	0.8	3.2	37.2
trichloronate	50	1.4	0.9	3.3	43.1
chlorpyrifos	50	1.1	0.3	2.3	8.7
furathiocarb	50	1.3	1	3.2	42.1
	mg m.row				
carbosulfan	62.5	1.3	1.2	3.4	57
furathiocarb	62.5	1.4	0.8	3.2	54.1
carbofuran	62.5	1.3	1.2	3.3	59.7
chlorf.(6.66%) + oxamyl(3.34%)	62.5	1.1	0.2	2.4	15
untreated	-	2	4.2	3.6	55.1

* granular formulation

TABLE 5. MEAN R.D.I. AND MEAN NO. LARVAE AND PUPAE PER PLANT (EXP. 4 and 7)

Insecticides	dose (mg a.i./ pl)	Experiment 4				Experiment 7			
		1st analysis		2nd analysis		1st analysis		2nd analysis	
		mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl
chlorfenvinphos	25	2	1.9	1.9	1.3	1.4	0.9	1.6	0.8
	50	1.4	0.3	1.4	0.6	1.2	0.3	1.4	1.1
trichloronate	25	1.5	1.0	1.7	1.6	1	-	1.1	0.2
	50	1.2	0.3	1.5	0.9	1	-	1.1	0.1
carbofuran	30	1.7	0.8	1.7	1.0	1	-	1	-
	50	1.1	0.4	1.3	0.4	1	-	1.1	0.1
fonofos	75	1.2	0.8	1.4	0.9	1	-	1	-
furathiocarb	50	1.4	0.7	1.7	2.1	1	-	1.2	0.3
bromophos-ethyl	100	1.9	1.7	1.9	1.9	1	-	1	-
diazinon	100	1.2	0.3	1.4	0.2	1	-	1	-
chlorpyrifos	25	1.9	1.4	1.9	1.5	1	-	1	-
	50	1.6	0.7	1.5	1.0	1	-	1	-
untreated	-	2.7	8.1	3.0	15.1	1.8	4.2	2.3	7.6

TABLE 6. MEAN R.D.I. AND MEAN NO. LARVAE AND PUPAE PER PLANT (EXP. 5 and 6)

Insecticides	dose (mg a.i. /pl)	ml solution/ pl	Experiment 5				Experiment 6			
			1st analysis		2nd analysis		1st analysis		2nd analysis	
			mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean l + p/pl
chlorfenvinphos	50	25	1.8	2.1	3.05	9.55	1.7	2.4	2.5	9.3
	50	50	1.9	3.9	2.55	8.7	1.9	3.0	2.6	10.6
	50	75	1.5	1.9	2.45	6.65	2.1	3.4	2.6	14.4
	50	100	1.9	2.5	2.8	12.7	1.6	1.3	2.6	9.2
trichloronate	50	25	1.8	1.6	2.8	13.3	1.7	1.9	2.8	10.9
	50	50	1.8	2.6	2.65	10.2	1.9	2.6	2.4	8.7
	50	75	1.8	2	2.85	13.3	1.7	1.9	2.3	10.3
	50	100	1.8	2	2.65	13.65	1.7	1.8	2.5	10.8
chlorpyrifos	50	100	1	0	1.05	0.05	1.1	0.2	2.2	6.6
furathiocarb	50	100	not investigated				1.3	0.6	1.5	1.7
bromophos-ethyl	100	100	1	0	1.6	1.55	1.6	1.5	1.8	9.9
fonofos	75	100	1	0	1.1	0.15	1.3	0.9	1.7	3.3
untreated	-	-	2.8	9.1	3.15	23.7	1.9	2.9	2.8	20.1

TABLE 7. MEAN R.D.I. AND MEAN NO. LARVAE AND PUPAE PER PLANT (EXP. 8 and 9)

Insecticides	dose (mg a.i./ pl)	Experiment 8				Experiment 9			
		1st analysis		2nd analysis		1st analysis		2nd analysis	
		mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl	mean R.D.I.	mean no. l + p/pl
chlorfenvinphos	25	1.1	1.8	1.5	1.7	1.7	1.5	1.5	0.9
	50	-	1.4	1	0.7	1.2	0.2	1.1	0.3
trichloronate	25	2.7	2	2	2.4	not investigated			
	50	4.7	1.9	2.2	1.8	1.1	0.2	1.5	0.5
carbofuran	30	2.6	1.7	1.8	5.7	1.1	0.2	1.3	0.5
	50	0.8	2.2	1.3	6.7	1	-	1.1	0.1
fonofos	75	1.4	1.2	1.6	0.2	1.2	0.4	1.1	0.1
furathiocarb	50	5.2	2.8	1.9	13.8	1.4	0.4	1.3	0.5
bromophos-ethyl	100	2.8	1.6	1.9	4	1.2	0.2	1.4	0.5
diazinon	100	0.1	0.9	1.1	0.5	1.1	0.2	1	-
chlorpyrifos	25	2.6	1.9	1.9	3.2	1.2	0.5	2.4	4.1
	50	0.2	1.7	1.1	2.6	1.6	1.4	1.3	1.1
untreated	-	16.9	3.5	3.4	12.2	2.9	9.4	2.9	8.7

TABLE 8. MAIN CHARACTERISTICS OF THE SOILS USED

	Staden	St.-Katelijne Waver	Oppuurs	Opdorp
% clay 0-2µ	8.7	6.9	5.4	5.6
% loam 2-50µ	24.2	18.4	24	18.2
% sand >50µ	67.1	74.7	70.6	76.2
pH	5.78	6.10	7.11	5.08
% carbon	0.38	1.85	1.06	1.06
phosphor(ppm)	43	254	242	50.8
potassium(ppm)	120	405	240	105
magnesium(ppm)	80.6	123	89	92.7
calcium(ppm)	900	1400	1350	975

Results and discussion

The mean root damage index and the mean number of larvae and pupae per plant for each treatment and for untreated plants are shown in tables 3 (Exp. 1), 4 (Exp. 2 and 3), 5 (Exp. 4 and 7), 6 (Exp. 5 and 6) and 7 (Exp. 8 and 9).

The effectiveness of the insecticides at controlling larvae of the cabbage root fly was very good in the field at Staden. On this field, when Brussels sprouts were grown on the field for the first time. At St.-Katelijne-Waver (Exp. 2 and 3), trichloronate and chlorfenvinphos at 50 mg a.i. per plant did not adequately protect cauliflower plants against cabbage root fly larvae. In this field, cauliflowers had been cultivated in successive years. In 1986 (Exp. 4), in the same region, but in another field, where cauliflowers were cultivated for the first time, the effectiveness of all the insecticides tested was high. At Oppuurs, cauliflowers were cultivated in successive years and sometimes two crops were grown in the same year. In such fields, chlorfenvinphos and trichloronate were the most frequently applied insecticides. The results of experiments 5 and 6 show that these insecticides gave poor control of larvae of the cabbage root fly. The quantity of aqueous suspension applied to the base of the plant did not improve the level of control achieved. Finally, at Opdorp all insecticides tested were effective. At this site, however, cauliflowers were not grown in successive years.

The results of the residue analyses of the amounts of chlorfenvinphos and trichloronate remaining in non-sterilized soils indicate different rates of breakdown, depending on the origin of the soil (table 9 and figure 1 and 2). The time for 50% breakdown of chlorfenvinphos took about approximately 4 weeks in the St.-Katelijne-Waver soil, 3 weeks in the Oppuurs soil and about 7 weeks in the Staden and Opdorp soils. Similarly, with trichloronate, one half of the initial amount was decomposed after nearly 6 weeks in the St.-Katelijne-Waver soil, 4 weeks in the Oppuurs soil, and 10 weeks in both the Staden and Opdorp soils.

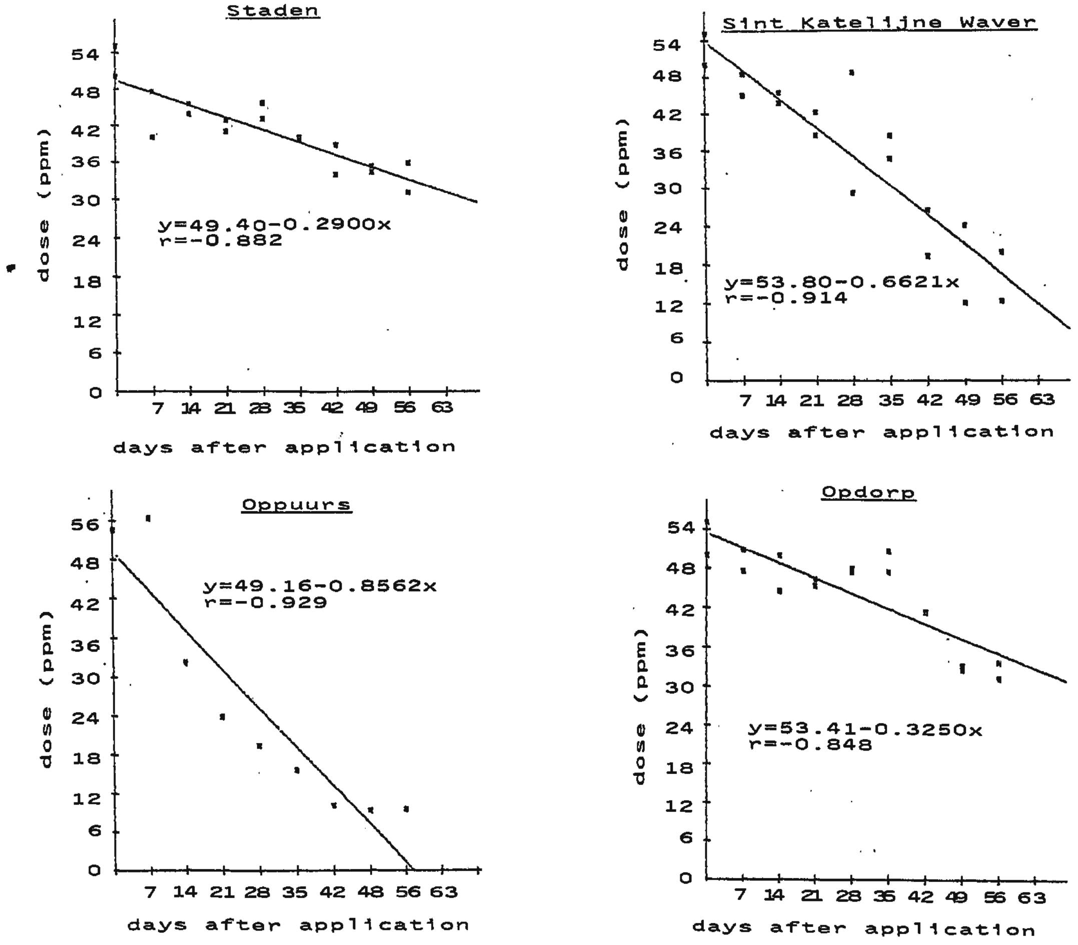
The soils from those regions in Belgium where chlorfenvinphos and trichloronate had been applied during several successive years, namely St.-Katelijne-Waver and Oppuurs, showed faster degradation rates for both insecticides.

Since there were no significant differences in breakdown patterns of chlorfenvinphos in sterilized soils, accelerated degradation in St.-Katelijne-Waver and Oppuurs was probably due to increased activity of soil microbes that had adapted to successive applications of chlorfenvinphos. This was probably also the case for trichloronate even though data were not obtained on the behaviour of this insecticide in sterilized soils.

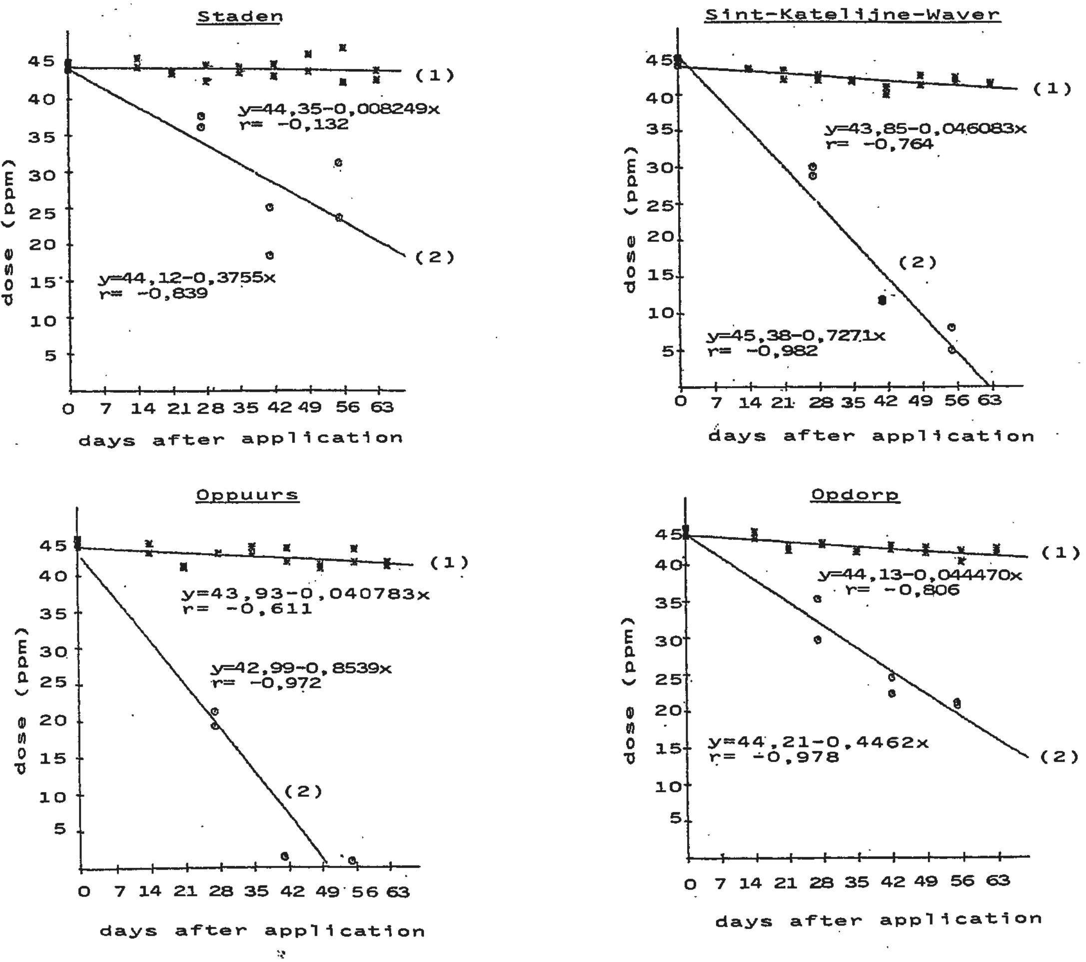
TABLE 9: DECLINE OF CHLORFENVINPHOS AND TRICHLORONATE RESIDUES IN NON STERILIZED (NST) SOIL AND OF CHLORFENVINPHOS RESIDUES IN STERILIZED (ST) SOIL

Locality	Residues (ppm)											
	Staden			St. Katelijne Waver			Oppuurs			Opdorp		
	chlorfenv.		trichl.	chlorfenv.		trichl.	chlorfenv.		trichl.	chlorfenv.		trichl.
Days after application	ST	NST		ST	NST		ST	NST		ST	NST	
0	44.5	44.5	52.5	44.5	44.5	52.5	44.5	44.5	52.5	44.5	44.5	52.5
7	-	-	43.8	-	-	46.7	-	-	54.3	-	-	49.1
14	44.9	-	45.7	43.4	-	44.6	43.7	-	32.3	44.0	-	47.2
21	43.6	36.8	41.9	42.6	29.4	40.4	41.1	20.3	23.8	42.3	32.5	45.9
28	43.4	-	44.3	42.2	-	39.0	42.9	-	19.3	42.9	-	47.7
35	43.9	-	39.8	41.9	-	36.6	43.5	-	15.6	42.0	-	49.1
42	43.8	21.7	36.4	40.5	11.7	22.9	42.6	1.3	10.1	42.4	23.5	41.5
49	44.0	-	34.8	41.9	-	18.1	40.9	-	9.3	42.2	-	33
56	49.5	27.3	33.4	42.0	6.4	16.2	42.1	0.8	9.5	41.2	21.0	32.5
63	43.1	-	-	41.3	-	-	41.2	-	-	41.9	-	-

Fig. 1. Decline of trichloronate residues in soil from Staden, St. Katelijne Waver, Oppuurs and Opdorp



Decline of chlorfenvinphos residues in sterilized (1) and non sterilized (2) soil from Staden, St. Katelijne Waver, Oppuurs and Opdorp



In clonclusion, the relative ineffectiveness of chlorfenvinphos and trichloronate in controlling cabbage root fly in brassica crops in particular fields of Sint-Katelijne-Waver and Oppuurs, was probably due to an enhanced microbial breakdown of these chemicals rather than to any decreased biocidal activities of the insecticides.

Acknowledgements

We are grateful to F. Benoit and N. Ceustermans (Vegetable Research Station, St.-Katelijne-Waver), to L. Vanparys (Provincial Research and Advisory Centre for Agriculture and Horticulture, Beitem), to the growers A. Smets (Oppuurs) and H. Hofmans (Opdorp) and to A. Callus (Bureau for Biometrics, Ghent) for their co-operation.

References

1. ANONYMOUS (1984). *Ministry of Agriculture, Fisheries and Food, Leaflet No.* 276. Lion House, Willowburn Estate, Alnwick, Northumberland: MAFF Publications.
2. FELSOT, A., MADDOX, J.V. and BRUCE, W. (1981). Enhanced microbial degradation of carbofuran in soils with histories of Furadan use. *Bull. Environ. Contam. Toxicol.*, 26:781-788.
3. READ, D.C. (1983). Microorganisms rapidly break down insecticide residues in some soils. *Proceedings of the 30th Annual Meeting. Canadian Pest Management Society, Truro, Nova Scotia, July 11-13, 1983*. Department of Agriculture and Marketing (1983) 21-28. Research Station.
4. SUETT (1986). Accelerated degradation of carbofuran in previously treated soils in the United Kingdom. *Crop protection*, 5(3)165-169.
5. WALKER and SUETT (1986). Enhanced degradation of pesticides in soil: a potential problem for continued pest, disease and weed control. *Aspects of Applied Biology* 12. Crop protection in Vegetables.