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Agricultural Research Centre

Department of Pest Investigation

90th Anniversary

FOREWORD

The present booklet has been published in honour of 90 years of organized agricultural pest investigation in our country.

The Agricultural Research Centre came into existence on August 11, 1898, by a decree, and its entomological institute was the first to be given the responsibility to begin operation on October 1st the same year. The impetus behind the prompt commencement of the institute's activities was provided by the protracted destruction on hayfields by the antler moth (*Cerapteryx graminis*). State Entomologist Enzio Reuter was appointed to serve as the institute's first director.

During the course of the institute's operation, the problems confronting pest research have changed continuously. Whereas the enormous development that began in the 1940s in chemical control has given farmers every possibility to assure their harvests, at the same time, however, the amount of knowledge that a farmer must command has increased manyfold. A greater obligation has thus been placed upon research to directly serve farmers.

The main subjects of the institute's current research programme include the development of new biological control methods and the specification of chemical control. The research on biological control methods include thrips control in greenhouses as well as the use of biological methods against pests of open cultivations. The specification of chemical control aims to reduce the use of pesticides without compromising the end result. The present task of research is to improve damage forecasting methods, determine threshold values of control and to produce knowledge on the most suitable times for control.

The contents of this booklet have not been especially planned, but include those writings of the institute's researchers that have been opportunely completed. The present booklet, also as such, will provide the reader with a picture of the current research programme at the institute.

Jokioinen
July 7, 1988

Martti Markkula

The staff of the Department of Pest Investigation. In front from the left: Tuomo Tuovinen, Irmeli Markkula, Seppo Korpela, Heikki Hokkanen, Martti Markkula, Katri Tiittanen, Sirpa Kurppa, Kari Tiilikkala and Isa Lindqvist. At the back from the left: Eeva Reiman, Kristiina Mäkitalo, Tarja Iso-Peura, Aija Viher-Vehmas, Merja Ilomäki, Päivi Saarinen, Kirsi Kuronen, Tarja Kallio, Jari Heikkilä, Jaana Grahn, Jarmo Ketola, Päivi Ronni, Bengt Lindqvist, Johanna Tyni, Sampo Kulmala, Arja Vasarainen, Ari Eskola and Irene Vänninen.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 263—269 (1988)

Seria ANIMALIA NOCENTIA N. 129 — Sarja TUHOELÄIMET n:o 129

EFFECT OF VARIOUS CULTIVATION METHODS ON EARTHWORM BIOMASSES AND COMMUNITIES ON DIFFERENT SOIL TYPES

JARI HAUKKA

HAUKKA, J. K. 1988. **Effect of various cultivation methods on earthworm biomasses and communities on different soil types.** Ann. Agric. Fenn. 27: 263—269. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

The effect of various cultivation methods on earthworm species composition and biomass was studied. The cultivation methods included ploughing, spring harrowing, autumn harrowing, rotatory cultivation, tillage with cultivator and zero tillage. In addition the effect of straw disposal was studied. Earthworm biomass was highest in clay soil with reduced cultivation. Ploughing decreased the biomass in all sites except sandy soil. The disposal of straw residues diminished earthworm populations by half. Different cultivation methods changed the composition of earthworm species. In heavy clay soil reduced cultivation increased the proportion of endogic species, but in clay loam soil the anecique group increased the most. There was a strong dependence between soil type and the of the earthworm community to the cultivation methods.

Index words: cultivation methods, earthworms, soil types, *Lumbricus terrestris*, L. *rubellus*, *Aporrectodea caliginosa*.

INTRODUCTION

Earthworms (Lumbricidae) form the major component of animal biomass in the arable soil of Finland (TÖRMÄLÄ 1979). The ability of earthworms to improve soil fertility and plant growth has been shown in many studies both in pot experiments (e.g. VAN RHEE 1965, ATLAVINYTE and ZIMKUVIENE 1985) and in field trials (e.g. EDWARDS and LOFTY 1978, 1980). Several soil related farm-management practices can affect the species spectra and abundance of earthworms. New methods in soil tillage, such as direct drilling, which have a less harsh effect on soil than conventional ploughing, have become more common recently. The exclusion of ploughing has some harmful effects on soil, e.g. bulk density rises and the nutrient release from plant residues declines. It is questionable whether soil animals which are normally more abundant in unploughed soil could compensate for the absence of ploughing.

Only a few studies on soil animals in arable land have been carried out in Finland, the most recent one being on the soil fauna on reserve field (TÖRMÄLÄ 1979). The aim of this work was to determine the influence of different cultivation methods on earthworm fauna and biomass in various soil types.

MATERIAL AND METHODS

Study sites and experimental design

The study sites were on three different soil types. In Jokioinen (60° 48′ N, 23° 29′ E) the soil was heavy clay, in Mouhijärvi (61° 20′ N, 24° 12′ E) clay loam and in Pälkäne (61° 31′ N, 22° 59′ E) sand. In Vihti (60° 17′ N, 24° 21′ E) the soil type was silty clay.

The experimental plots in Jokioinen, Mouhijärvi and Pälkäne were placed on the field according the split-split-plot design with four replicates (PITKÄNEN 1987). The main plot treatments were either sprayed with glyphosate every third year (C1) or were not sprayed (C0). The sub-plot factor was consisted of the plant residues: they were either left on the ground (B1) or removed (B2). The sub-sub-plot factor was the cultivation method: ploughing in autumn (A1), harrowing in autumn (A2) or harrowing in spring (A3). The plots were 4 m wide and 15 m long. The experiment was started in autumn 1979. Barley, oats and wheat were cultivated during the experiment. Only the C1 treatment was sampled for earthworms, thus the study design was that of the split-plot design.

KARA and RÄISÄNEN (1979) have described the experiment in Vihti. The experiment was started in 1975 and the last cultivations were in spring 1986. Only five treatments were sampled: zero tillage, autumn ploughing, rotatory cultivation, cultivator, and tillage with a S-tined harrow. One replicate was left out due to waterlogging. In addition randomization was incorrect: treatments were in the same order in every block. This rendered the statistical tests.

As the plots were quite narrow the question arises as to whether earthworms were able to migrate from one plot to another in order to find better environment. Such migration would diminish the differences between plots.

Sampling and treatment of material

Earthworms were sampled on the 9th of August in Vihti, the 2nd of September in Mouhijärvi, the 17th of September in Pälkäne and the 7th of October in Jokioinen. The summer of 1987 was very rainy therefore soil moisture remained high throughout. Soil temperatures at 20 cm depth were 13.5, 10.0, 9.5 and 8.0 degrees, respectively. Samplig was performed by formalin dilution: two times ten litres of 0.25 % solution and two times ten litres of 0.50 % solution on 0.5 square meters area at ten minute intervals. All of the earthworms that emerged within a forty-minute period were collected and stored in 4 contiguous samples were taken from every experimental plot. BOUCHE and GARDNER (1984) state that the formalin method is inefficient for the determination of absolute numbers and biomasses, but gives comparable results when used in similar environmental conditions. Especially small earthworms are poorly sampled by this method. At least two weeks after sampling earthworms were determined for species. In addition formalin and dry weights with gut contents were measured from all specimens.

Statistical analysis

Total earthworm dry weights were analysed by ANOVA according the split-plot design. For further analysis the split-plot factors were combined to form six treatment combinations. Multivariate analysis of variance or MANOVA (MORRISON 1976) was carried out using the dry weights of the most abundant species as variables, *Aporrectodea* juveniles were divided in proportion to adults. In MANOVA the analysis of variance is done simultaneously for several variables. Profile analysis is determined whether dependent variables react to the treatments in the same manner. MANOVA can only be carried out if profiles are similar. The dependence between formalin and dry weight was calculated by regression analysis without intercept. A SAS statistical package was used for computing.

RESULTS

A few species (*Aporrectodea caliginosa* (Sav.) and *L. terrestris* (L.)) formed the major part of the biomass in all sites (Table 1). Only in Vihti did *L. rubellus* form the greater part of the biomass in some treatments. *D. rubidus* was found only in sandy soil in Pälkäne, and *A.*

Table 1. Percentage of species dry weights of whole treatment dry weights (all row sums are not equal to one hundred because of roundings). A.C. = *Aporrectodea caliginosa*, A.r. = *A. rosea*, A.sp. = *A.* juveniles, D.r. = *Dendrodrilus rubidus* L.c. = *Lumbricus castaneus*, L.r. = *L. rubellus*, L.t. = *L. terrestris*, L.sp. = *L.* juveniles. Treatments: A1 = ploughing, A2 = harrowing in autumn, A3 = harrowing in spring, B1 = straw residues left on the ground, B2 = straw residues taken away.

	A.c.	A.r.	A.sp.	D.r.	L.c.	L.r.	L.t.	L.sp.
Jokioinen (clay)								
A1B1	68	6	6	0	0	0	21	0
A1B2	43	0	0	0	0	0	57	0
A2B1	47	1	3	0	0	0	48	0
A2B2	87	0	5	0	0	0	7	2
A3B1	60	0	9	0	0	0	31	1
A3B2	64	0	13	0	0	0	23	0
Mouhijärvi (clay loam)								
A1B1	60	0	32	0	0	0	6	2
A1B2	48	0	43	0	0	1	8	0
A2B1	94	0	6	0	0	0	0	0
A2B2	67	0	10	0	0	0	22	1
A3B1	48	2	21	0	0	0	28	1
A3B2	61	0	17	0	0	11	11	0
Pälkäne (sand)								
A1B1	57	0	25	8	0	10	0	0
A1B2	54	0	44	2	0	0	0	0
A2B1	79	0	11	1	0	9	0	0
A2B2	30	0	60	10	0	0	0	0
A3B1	55	0	45	0	0	0	0	0
A3B2	79	0	15	6	0	0	0	0
Vihti (silty clay)								
Zero tillage	19	0	3	0	1	1	76	1
Ploughing	19	0	3	0	0	19	58	1
Rotat. cult.	32	0	1	0	1	29	36	0
Harrowing	25	0	3	0	1	4	65	2
Cultivator	16	0	2	0	0	4	77	0

rosea (Sav.) was encountered only in soils with a high clay content. Few specimens of *L. castaneus* (Sav.) were found in Vihti.

In Jokioinen both the cultivation method and the straw handling method had significant effects on total earthworm dry weights (Table 2). Ploughing and removal of straw residues diminished dry weights (Table 3). In Mouhijärvi no significant treatment effects were found but the replicates appeared to be different. The experimental field was located on the slope of a hill and in downhill plots earthworm abundance was quite low, which maybe due to the waterlogging during the rainy summer. In Pälkäne there was a significant difference between the straw handling methods, but also the replicates were also different.

In Jokioinen, Pälkäne and Vihti profiles were significantly different (Table 4 and Fig. 1). This means that ordinary ANOVA were carried out for each species separately (MORRISON 1976). In Mouhijärvi the profiles of different treatments were similar and MANOVA could be performed. The analysis showed that the species had similar biomasses in different treatments in Mouhijärvi (Wilk's lambda 0.6044, significance 0.2501).

In Jokioinen only the biomasses of *A. caliginosa* were significantly different. In Pälkäne also the biomasses of *D. rubida* were significantly different in the treatment combinations. In Vihti the biomasses of *L. rubellus* and *L. terrestris* were significantly different in the various cultivation treatments (Fig. 1).

There were significant differences in dry weight contents among species (Table 5). The formalin weights can be assumed approximate live weights or biomasses.

Table 2. ANOVA tables of total earthworm dry weights (g/m^2). Factors are cultivation method (A) and handling of straw residues (B).

Source	df	Sign. of F		
		Jokioinen (clay)	Mouhijärvi (clay loam)	Pälkäne (sand)
A	2	0.0283	0.2562	0.1427
Sub-plot error	6	—	—	—
B	1	0.0107	0.9370	0.0474
A*B	2	0.1791	0.6402	0.0644
Rep	3	0.8982	0.0002	0.0016
Residual error	33	—	—	—

Table 3. Treatment means for total dry weights (g/m^2) of earthworms. Means with the same letter are not significantly different (Tukey's test in 5 % level). Treatments as in Table 1.

Treatments	n	Jokioinen (clay)	Mouhijärvi (clay loam)	Pälkäne (sand)
A1	16	0.35 B	0.33 A	0.48 A
A2	16	2.10 A B	0.66 A	0.29 A
A3	16	2.48 A	0.84 A	0.16 A
B1	24	2.23 A	0.62 A	0.41 A
B2	24	1.06 B	0.62 A	0.21 B

Table 4. Statistics for profile analysis (MORRISON 1976). The test shows if the most abundant species had reacted in the same way to the treatments.

	Wilk's lambda	F	Num df	Den df	Sign.
Jokioinen (clay)	0.2402	4.786	10	46	0.0001
Mouhijärvi (clay loam)	0.6044	1.317	10	46	0.2501
Pälkäne (sand)	0.4758	2.140	10	46	0.0400
Vihti (silty clay)	0.4451	2.370	8	38	0.0354

Table 5. Regression between formalin and dry weight of earthworm specimens without constant, data from all the sites is pooled.

Species	Regression coefficient	Std error	Number	r^2
Aporrectodea caliginosa	0.296	0.003	311	0.975
A. juv.	0.297	0.004	258	0.956
Dendrobaena rubida	0.323	0.010	17	0.984
Lumbricus castaneus	0.181	0.006	16	0.985
L. rubellus	0.203	0.003	70	0.982
L. terrestris	0.223	0.003	196	0.960
L. juv.	0.231	0.005	30	0.988

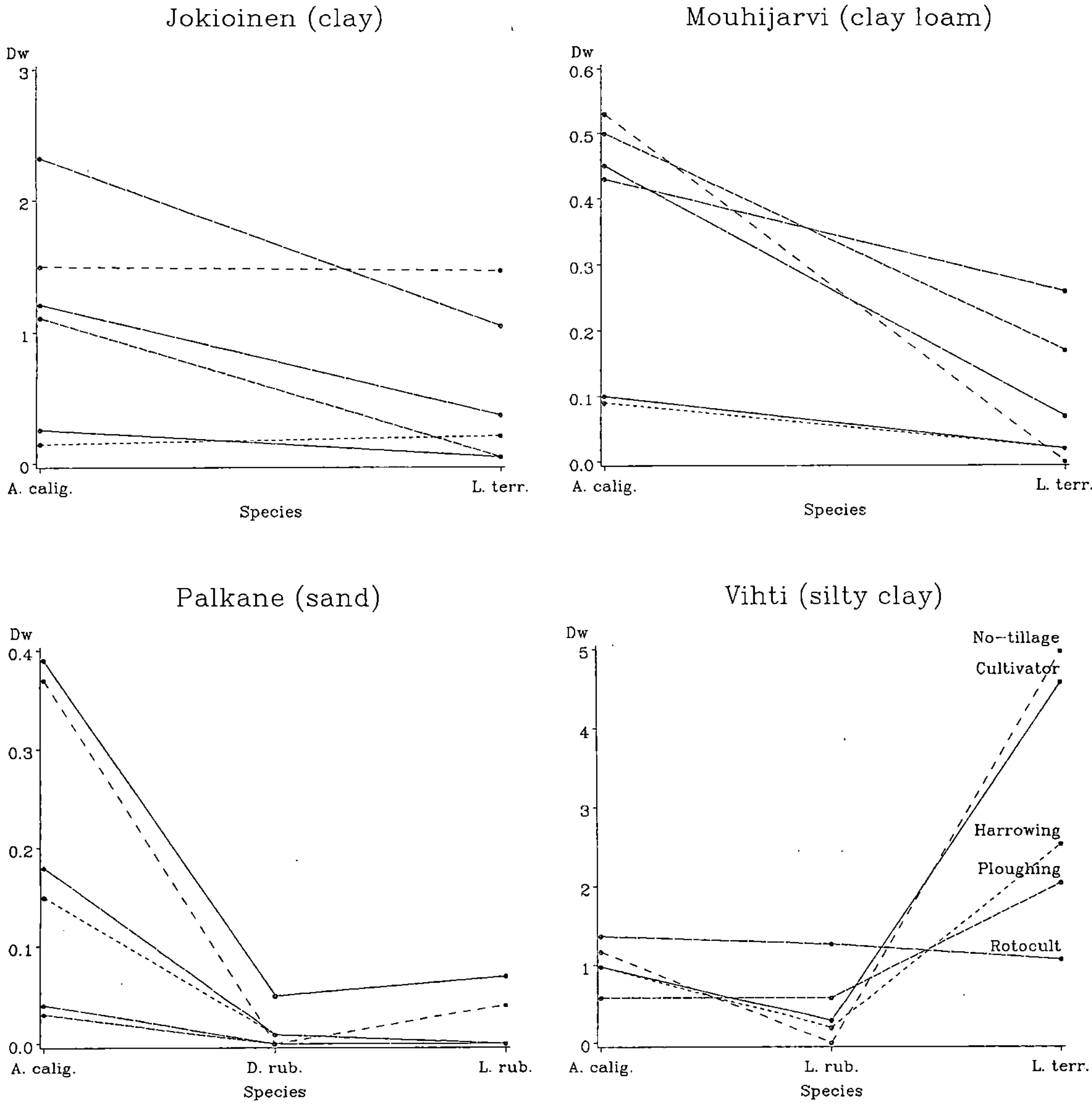

Fig. 1. Dry weights (g/m²) of most abundant species in different treatments (as in Table 1). Jokioinen, Mouhijärvi, Pälkäne: ———— A_1B_1, ········ A_1B_2, - - - - - A_2B_1, — — — A_2B_2, —— —— A_3B_1, ——— ——— A_3B_2

DISCUSSION

It was evident that various cultivation methods had strong effects on the earthworm populations. In Jokioinen and Mouhijärvi ploughing reduced the earthworm population very strongly, but no differences between autumn and spring harrowing could be seen. In Pälkäne, sandy soil ploughing increased the earthworm population, but the populations were very low in all of the treatments. The fact that ploughing is harmful to earthworms has been demonstrated in many studies (e.g. BOONE et al. 1976, GERARD and HAY 1979, EDWARDS and LOFTY 1982 and HOUSE and PARMELEE 1985). The reasons are probably that mechanical damage partly cuts adult worms and destroys their channels, and partly moves cocoons into overly deep soil layers. Ploughing also increases decomposition rate of plant residues thus depriving earthworms food. Ploughed soils generally appear to contain less biomass but a higher metabolic rate (HOUSE and PARMELEE 1985).

The removal of straw residues diminished the earthworm populations in Jokioinen and Pälkäne by half. This could have been due to a lack of food. Straw residues left on the ground also reduce moisture loss and ameliorate temperature extremes which improves the environment for earthworms. In this case, food may be the most important factor as no interaction between the cultivation method employed and the straw disposal method could be shown.

The species or species spectra varied significantly in different treatments in Jokioinen, Pälkäne and Vihti. In all of these sites there was a significant difference in the shape of the profiles among the different treatments. In Jokioinen we could see that ploughed treatments had very flat profiles. The situation was same in Vihti, where ploughing and rotator cultivation had flat profiles. In low biomasses the differences between species are slight. In Jokioinen *A. caliginosa* increased in unploughed treatments, but in Vihti *L. terrestris* increased the most. No such trend could be seen in Pälkäne. GERARD and HAY (1979), however, have shown that the species composition was the same for different cultivation methods (deep ploughing, ploughing, tined cultivation and direct drilling) and only the biomasses were affected. Soil type is clearly an important factor for the determination of how ecological groups react to different cultivation methods and further work will be needed to clarify this connection.

In this study the highest densities of earthworms occurred in soils with a high clay content. Furthermore reduced cultivation produced the highest increases in biomass in the same soil types. This is noteworthy because one of the most important functions of earthworms in improving the soil fertility is in the formation of large biopores which improve water infiltration and root penetration in heavy soils (EHLERS 1975, EDWARDS and LOFTY 1978). The anecique group (eg. *L. terrestris*), which forms deep vertical burrows is especially important.

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SELOSTUS

Muokkausmenetelmien vaikutus lierojen lajistoon ja määrään erilaisilla maalajeilla

JARI HAUKKA

Maatalouden tutkimuskeskus

Lierojen määrä aurattoman viljelyn koeruuduilla Jokioisilla (savi), Mouhijärvellä (hiesu) ja Pälkäneellä (hieta) tutkittiin. Muokkausmenetelminä kokeissa oli käytetty syyskyntöä, syysäestystä ja kevätäestystä; toisena käsittelynä oli olkien kokoaminen tai jättäminen maahan. Kyntö vähensi lierojen määrää (kuivapaino) 2 g:sta 0.3 g:aan/m^2 savella ja hiesulla. Hiedalla eroja ei ollut. Olkien kokoaminen pois ruudulta oli vähentänyt lierojen määrän puoleen savimaalla, kun taas hiesulla määrä oli pysynyt samana ja hiedalla jopa noussut.

Vihdissä tehdyssä minimimuokkauskokeessa tutkitut menetelmät olivat: syyskyntö, kyntämätön, syysäestys, jyrsin ja kultivaattori. Kyntämättömissä ja kultivaatorilla muokatuissa ruuduissa lieroja oli eniten (n. 6 g/m^2 kp.), muut käsittelyt olivat vähentäneet lierojen määrän noin puoleen.

Selvästi runsaimmat lierolajit olivat peltoliero (*Aporrectodea caliginosa*) ja kasteliero (*Lumbricus terrestris*). Kasteliero hyötyi selvästi eniten muokkauksen vähenemisestä, koska tällöin sen vakituiset käytävät eivät tuhoudu ja maanpinnalle jääneet oljet tarjoavat sille runsaasti ravintoa.

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Seria ANIMALIA NOCENTIA N. 130 — Sarja TUHOELÄIMET n:o 130

NON-CHEMICAL CONTROL METHODS AGAINST CABBAGE ROOT FLIES *DELIA RADICUM* AND *DELIA FLORALIS* (ANTHOMYIIDAE)

ILKKA HAVUKKALA

HAVUKKALA, I. 1988. **Non-chemical control methods against cabbage root flies *Delia radicum* and *Delia floralis* (Anthomyiidae).** Ann. Agric. Fenn. 27: 271—279. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

Oviposition barriers, a deterrent and *Bacillus thuringiensis* Berliner were tested for the reduction of cabbage root fly damages in southern Finland. Foam-rubber collars, *Sphagnum* moss, wood ash, rape seed oil pressing residue, charcoal-silica filter waste from a sugar syrup refining factory, turpentine-impregnated wood sticks and a thuringiensin-producing strain of *B. thuringiensis* were used in cabbage fields during six seasons. The plant root damage index correlated well with pupal numbers at low densities of pupae in the roots of the plant. Root damage during each year was inversely correlated with yield although yields varied considerably between years. Insecticide treatment (isofenphos) most effectively reduced root damage, followed by *B. thuringiensis*, charcoal-silica and the yellow foam-rubber collar. The same order of efficacy was found for the number of *Delia* pupae within roots at cropping time. Cabbage root fly control by insecticide treatment increased the cabbage yield on average by 27 % compared to untreated plants. Corresponding average yield increases by *B. thuringiensis* and foam collars were 15 and 16 %, respectively. Collars can be used advantageously in small-scale cultivation, but *B. thuringiensis* needs to be applied several times during the season for a good beneficial effect. The prospects of improving the performance of non-chemical and biological control methods are discussed.

Index words: cabbage, cabbage root fly, Anthomyiidae, *Delia radicum, Delia floralis,* oviposition barriers, foam collar, biological control, bacteria, *Bacillus thuringiensis.*

INTRODUCTION

The cabbage root flies *Delia radicum* (L.) and *Delia floralis* Fallén (Anthomyiidae) are serious pests of cultivated brassicas in Europe and North America. The larvae eat lateral roots and often also the main root and base of the stem. In general, the control of root-living anthomyiids has become more difficult due to their increased resistance to e.g. the earlier widely used seed dressing dieldrin (HILL 1987). Microbial degradation of newer compounds within the soil (READ 1986a) is also undermining the prospects of chemical control.

In Finland, however, no significant resistance of anthomyiids to the pesticides in use has been apparent, with the sole exception of lindane resistance in the onion fly *Delia antiqua* Mg. in the late 1950's (MARKKULA and KURPPA 1986) and in *Delia floralis* during the 1970's (VARIS and DALMAN 1980). Lindane has gradually been replaced by new compounds.

Abroad, the use of pesticides has been shown to reduce the effect of carabid and staphylinid predators on egg mortality (HASSAN 1969, EL TITI 1980). The most important larval and pupal parasites, *Trybliographa rapae* Westw. (Hymenoptera: Cynipidae) and *Aleochara bilineata* Mg. (Coleoptera: Staphylinidae) are also adversely affected by several commonly used pesticides (HASSAN 1973, FINLAYSON 1979, HASSAN et al. 1986). This necessitates the development of either non-chemical or biological alternative control methods.

Ovipositional barriers were already in use during the 1900's in the USA and Britain (SLINGERLAND 1894, WADSWORTH 1917), and in the 1930's in the USSR (SHAPIRO and ASYAKIN 1977). Damage reductions have been obtained both in field (WHEATLEY 1975, HAVUKKALA 1982, SKINNER and FINCH 1986) and in laboratory tests (HAVUKKALA et al. 1984). With the advent of new, cheaper materials interest has recently focused on the use of net covers in culinary vegetable cultivation (HOUGH-GOLDSTEIN 1987, MCKINLAY 1987).

Bacillus thuringiensis is a widely used biocontrol agent for a variety of pest insects, but there are few studies on its use against anthomyiids. OBADOFIN and FINLAYSON (1977) obtained a reduction in *Delia radicum* egg numbers by the *B. thuringiensis* -preparation Dipel in the field.

A thuringiensin-producing bacterial strain has been investigated by Gunnel Carlberg (HOLMBERG et al. 1980, CARLBERG et al. 1985, CARLBERG 1986), and put on the market by the Finnish company, Farmos Group Ltd. for the control of muscids in e.g. piggeries. Preliminary data indicate that this strain might be useful against cabbage root flies, too (HAVUKKALA 1983, 1986).

This paper reports on cabbage root fly control field experiments during 1980—86 using oviposition barriers and *Bacillus thuringiensis* in southern Finland.

MATERIAL AND METHODS

Field experiments were conducted in southern Finland at the Agricultural Research Centre in Tikkurila, Vantaa (Grid 27° E 668: 39, latitude 60° 15′ N) in 1980—1982 (site details, cf. HAVUKKALA 1982) and at Jokioinen (675: 30, 60° 41′) in 1983—1986 (cf. HAVUKKALA et al. 1984b). An additional site for the *B. thuringiensis* -test was situated in Salo (669: 28, 60° 11′) in a field of extensive and intensive commercial cabbage cultivation. Experimental layouts were randomized rows (1980, data from PIRILÄ 1984) or Latin Squares (see HAVUKKALA 1982). Treatments were compared with Mann-Whitney U-tests (root damage, pupal numbers) and t-tests (yields).

Planting and cropping dates and numbers of plants/replicate are shown in Table 1. Seedlings were pre-grown in a glasshouse to the 3—5 leaf stage in peat pots before being transplanted into the field. The cabbage variety was Ditmarsker Midi Enkona OE.

The experimental treatments were:

1) untreated control
2) isofenfos insecticide at the recommended rate (1 dl per plant of 0.1 % Oftanol with

Table 1. Planting and cropping dates and sampling data.

Year	planting date	cropping date	replicates	plants/ replicate
1980	29.V	11.VIII	5	10
1981	6.VI	20.IX	4	25
1982	5.VI	17.IX	6	25
1983	4.VI	20.IX	6	25
1984	7.VI	17.X	5	25
1986	30.V	26.IX	1	20

500 g/l active ingredient) applied at the time of planting

3) *Sphagnum* moss 3 cm thick up to 4 cm from the plant stem
4) yellow-brown foam-rubber collar 8 × 8 cm, 3 cm thick
5) blue foam-rubber collar 8 × 8 cm, 1.5 cm thick
6) turpentine-soaked (24 h) 15 = 1.5 × 1.5 cm pine sticks inserted in the ground 5 cm from the plant
7) ca. 60 g of pine wood ash sprinkled within 5 cm of the stem
8) ca. 0.2 l of active carbon/silica soil filter waste from a syrup sugar refinery similarly applied
9) rape seed oil pressing residue with crushed seed coats, ca. 0.2 l similarly applied
10) *B. thuringiensis* -preparation serotype 1 (Muscabac) (Farmos Ltd.)

B. thuringiensis was applied as follows: 20 ml of liquid formulation (containing ca. 0.5 × 10' 9 bacteria and spores per ml and ca. 100 mg thuringiensin/l) was poured around the plant stems. In 1982 and 1986 this was done once at the time of planting. In 1983—84 liquid was applied twice in June during the oviposition period of *Delia radicum*, and three times during the oviposition of *D. floralis* in July-August, at 5—10 days intervals depending on fly populations (monitored by yellow traps) and precipitation, to ensure moist conditions for bacteria during the peak period of oviposition. In 1986 a powdery formulation with ca. 10' spores and bacteria / gram was applied at the rate of 25 and 2.5 g/l, 20 ml of which was poured around plant stem.

Root damage was assessed visually on a scale of 0—5, where 5 corresponded to root damage index of 100. The soil around all plants 20 cm deep and up to 20 cm laterally was removed and sieved with water for the presence of pupae and larvae, which were identified by a stereo microscope. The numbers of *D. floralis* and *D. radicum* pupa were pooled for the assessment of total pest pressure on the plants. Cabbages were weighed individually in the field at the time of cropping.

RESULTS AND DISCUSSION

Root damage

The root damage indexes (Table 2) were consistently lowest in insecticide treated plants with the exception of 1986 at the Salo test site. This site had a strong *D. floralis* population which may have avoided toxic effects due to pesticide leaching or degradation in soil during the long period between planting and egg-laying. As isofenfos had been used at the site for several years it is possible that isofenfos-degrading micro-organisms had proliferated in the soil. This has been observed for e.g. carbofuran in Canada (READ 1986b).

B. thuringiensis -treatment reduced root damage in two years out of four. Optimal results were obtained when fresh bacteria were present in the soil surrounding the roots at the time of peak oviposition. The bacterial strain used against muscids disturbs molting. If this is

Table 2. Mean root damage by cabbage root flies in southern Finland in 1980—86. Scale of root damage index (RDI) from 0 (no damage) to 100. Column X % shows the mean percentage of root damage compared to untreated plants.

Treatment	X %	Year					
		1980	1981	1982	1983	1984	1986
Untreated	100	68	28	41	91	54	55
Ash	102		23	50			
Moss	100	68					
Collar, blue	95			39			
Rapeseed	87				79		
Collar, yellow	78	56	36	40	43*	31*	
Bacillus 1x	60			43	15*	16	48
Charcoal-silica	51				31*	34	
Bacillus 0.1x	22				20*		
Isofenphos	19	10*	4*+	15*	3*	14*	55

Asterisks (*) denote difference from untreated plants, P = 0.05 (U-test).

+ Data from an adjacent plot 50 m away.

the main mode of action in cabbage root flies, the reduction of feeding damage thus may not have been immediate.

The survival and growth of this bacterial strain in soil under different conditions should be studied, in order to obtain a long-lasting effect on root damage by a suitable treatment at planting time.

Charcoal-silica waste reduced damage in one year out of two. The material was difficult to apply due to its stickiness from the sugar residues within. It seemed to attract flies and also cabbage root flies, to feed. If such flies also tried to oviposit, the larger numbers of flies may have diminished the physical effect of hampering oviposition. It is unclear to what extent the charcoal absorbed root chemicals and thereby affected the orientation of hatched larvae to roots, as has been suggested for the wheat bulb fly, *Delia coarctata* Fall. (SCOTT and GREENWAY 1984).

Yellow foam-rubber collars afforded only moderate protection (78 % of root damage compared to untreated) with a large variation between years. The material could only partially accommodate the growth of the plant stem and the slit opened later in the season, allowing access to ovipositing flies. SKINNER and FINCH (1986) obtained a better result (60 %) using a close-fitting, foam-rubber carpet-underlay protective disc. Thus suitable collar material and careful positioning of the collar are needed to ensure good protection. The slit in the blue collars opened earlier during plant growth due to the thinner collar material.

Rapeseed material reduced root damage, but attracted flea beetles (*Phyllotreta* sp.) to the extent that severe leaf damage occurred early in the season. This made the material unsuitable for pest control.

Moss seemed ineffective, as was also found in laboratory experiments (HAVUKKALA et al. 1984a). Ash was not effective either, and it was easily blown away by the wind and dispersed by heavy rain.

Pupal populations

The severity of infestation varied considerably. In most years *D. floralis* dominated being responsible for most of the crop losses (HAVUKKALA, unpublished). In 1982 oviposition of *D. floralis* in the field was up to ten times higher per plant than in 1981 or 1983 (HAVUKKALA et al. 1984b) and was also reflected in pupal numbers (Table 3). In other years when populations

Table 3. Mean number of cabbage root fly pupae per cabbage plant in southern Finland during 1981—86. Column X % shows the mean percentage of pupal numbers compared to untreated plants.

Treatment	X %	Year				
		1981	1982	1983	1984	1986
Untreated	100	2.2	25.2	11.2	6.8	72.2
Turp. stick	108	2.7				
Ash	88	3.5	15.3			
Rapeseed press.	88			9.8		
Collar, blue	73		18.4			
Collar, yellow	73	4.4	12.9*	3.4*	2.2*	
Charcoal-silica	36			2.9*	3.1	
Bacillus 0.1x	28			3.1		51.3
Bacillus 1x	15		28.0	2.6*	1.1*	34.5*
Isofenphos	2	0*	0.9*+	0.1*	0.3*	81.0

Asterisks (*) denote statistically significant difference from untreated plants, P = 0.05 (U-test).
+ Data from an adjacent plot 50 m away.

of cabbage root flies were lower, the damage index correlated well with the numbers of pupae found in roots (Fig. 1). This indicates that in such years, once the level of pupal numbers is known, infestation might be estimated also by root damage indexes instead of by the laborious extraction of pupae from soil.

Insecticide treatment kept the numbers of pupae very low. *B. thuringiensis* -treatment was again the next best, followed by charcoal-silica, and yellow collar (Table 3). Ash reduced pupal numbers in one year out of two, but not statistically significantly. In laboratory experiments ash reduced egg-laying and decreased the penetration of first stage larvae to the roots (HAVUKKALA et al. 1984a) but these effects apparently were not fully obtained in the field.

In 1982 *B. thuringiensis* -treated plants had high numbers of pupae presumably due to the exceptionally high fly populations of that year (cf. above, Root damage).

In 1986 the parasitization of *Delia* -pupae by *Aleochara* in *B. thuringiensis* -treated plants was one third of that in untreated plants (HAVUKKALA, unpublished), so that harmful effects on natural enemies in field conditions should also be borne in mind. Another *B. thuringiensis* strain (Dipel) has been found to be harmless as a foliar spray in the field to the carabid predator *Bembidion lampros* (FINLAYSON 1979) and only slightly toxic in laboratory tests (OBADOFIN and FINLAYSON 1977).

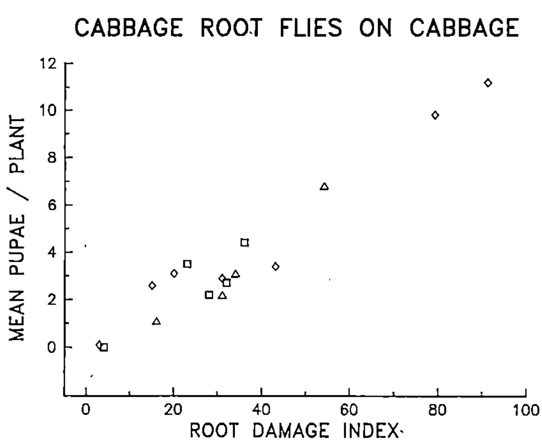

Fig. 1. The relationship between the root damage and the numbers of pupae in cabbage plant roots at low pupal densities in southern Finland. Data from Tables 2 and 3. Square: 1981; diamond: 1983; triangle: 1984.

Yields

Crop yields were consistently highest in insecticide -treated plants (Table 4), but *B.*

Table 4. Crop yields (mean cabbage head weight in kg) in southern Finland in 1980—1984. Column X % shows the mean percentage of crop yield compared to untreated plants.

Treatment		Year				
	X %	1980	1981	1982	1983	1984
Untreated	100	.78	1.19	.47	2.18	2.06
Turp. stick	90		1.07			
Collar, blue	96			.45		
Ash	101		1.23	.49		
Moss	115	.90				
Collar, yellow	115	1.26*	1.12	.46	2.43*	2.26*
Charcoal-silica	116				2.61*	2.30
Bacillus 1x	116			.54*	2.73*	2.20
Bacillus 0.1x	122				2.67	
Isofenphos	127	1.3*	1.23+	.57*	2.76*	2.40*

Asterisks (*) denote difference from untreated plants, P = 0.05 (t-test).
+ Data from an adjacent plot 50 m away.

thuringiensis performed well, too. Part of the yield increase may be due to the fertilization effect of the nutrients (possibly processed by the bacteria) contained within the formulation. Limited control tests with an autoclaved preparation did not increase yield (data not shown), but it is possible that the remains of the growth medium contained in the preparation and possibly processed later on by the bacteria may have changed the microbial fauna around the roots or otherwise increased plant growth.

B. thuringiensis shows some promise for maggot control but exact data on its mode of action are still lacking, and the long-term survival of bacteria (and thuringiensin) within soil in different conditions (soil type, pH, nutrient levels) should be ensured for good results. Furthermore, effects within soil on predatory beetles and parasites should be assessed before widespread use, especially in cultivations with high densities of natural enemies.

Foam-rubber collars did not perform quite as well as expected. The reasons for this may be two-fold: the incidence of predatory beetles may be lower than in warmer climates, and there may be less water stress due to lower summer temperatures. In Finland the years 1981 and 1986 were rainy, thus markedly reducing the water stress and presumably also reducing mortality of eggs and first stage larvae. The year 1982 was cold during the early season and dry in July.

In England oviposition collars have provided good control. There, the three main factors affecting yield losses by cabbage root flies are the reduction of oviposition, the aggregation of predatory beetles under the collar and the conservation of water around the roots of plants, thus reducing water stress to plants with damaged roots (SKINNER and FINCH 1986).

When carefully fitted, oviposition collars are a feasible alternative control method for small-scale cultivation, especially when natural enemies are abundant.

Ash treatment increased yield, but this was presumably due to a fertilization effect as root damages and pupal numbers increased rather than decreased. The crop increase by charcoal treatment can be attributed to a reduction in water evaporation from the soil and a reduced number of larvae reaching the roots.

Root damage correlated inversely with the yield within each year (Fig. 2), but yield level was mainly determined by the weather and other factors. However, in 1980—1984 the

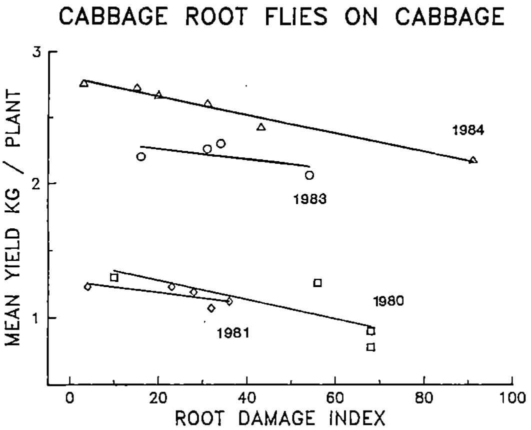

Fig. 2. The effect of cabbage root fly damage on cabbage yield in southern Finland. Data from Tables 2 and 4.

control of cabbage root flies by insecticide increased yield on average by 27 % (Table 4). Whether biological control methods can compete economically with the above remains to be seen.

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SELOSTUS

Kaalikärpästen luonnonmukaiset torjuntamenetelmät

Ilkka Havukkala

Maatalouden tutkimuskeskus

Kaalikärpänen (*Delia radicum*) ja iso kaalikärpänen (*Delia floralis*) ovat kaalikasvien pahimpia tuholaisia Suomessa. Kemiallinen torjunta on ennakoivaa; siemenet peitataan tai esikasvatetut taimet käsitellään torjunta-aineella istutettaessa.

Maatalouden tutkimuskeskuksen tuhoeläinosastolla on v. 1980—1986 selvitetty biologisten ja bioteknisten menetelmien kehittämistä täydentämään ja korvaamaan kemiallisia torjuntakeinoja avomaan viljelyksillä. Tämä tutkimus on osa näistä selvityksistä.

Kaalikärpästen torjuntaa luonnonmukaisin keinoin munintaesteillä ja karkotteilla tutkittiin 1980—1986 kenttäkokein Etelä-Suomessa. Keräkaalin suojaamiseen kokeiltiin 3 cm ja 1.5 cm paksuja vaahtomuovikauluksia, rahkasammalta, puutuhkaa, aktiivihiili-piimaa suodatinjätettä ja rapsiöljypuristeen kuorijätettä taimen tyvelle ripoteltuna, sekä tärpätissä liotettuja puutikkuja karkottimena. Biologista torjuntaa kokeiltiin *Bacillus thuringiensis* -bakteerivalmisteella.

Kaalikärpästen kemiallinen torjunta antoi keskimäärin 27 % sadonlisäyksen suojaamattomiin kaaleihin verrattuna.

Rahkasammal ja tärpättitikut eivät vähentäneet vioitusta eivätkä lisänneet satoa. Tuhka ei tehonnut vioitukseen, mutta saattoi lisätä satoa lannoitevaikutuksellaan. Rapsiöljyn kuoripuriste houkutteli kirppoja alkukesästä kasveille aiheuttaen lehtivioitusta. Hiili-piimaa oli hankala levittää tahmeutensa takia, vaikka se vähensikin vioitusta ja lisäsi satoa.

Kauluksista 3 cm paksu toimi paremmin kuin 1.5 cm paksu; juuristovioitus laski n. 22 % ja koteloituneiden kärpästoukkien määrä väheni n. 27 % suojaamattomiin kasveihin verrattuna. Sadonlisäys oli noin 15 % kontrollikasveihin verrattuna.

Bacillus thuringiensis -bakteerin käyttö vähensi selvästi juuristovaurioita, kun sitä käytettiin riittävästi kärpästen muninta-aikoina. Sadonlisäys oli lähes torjunta-aineella saavutetun veroinen. Bakteeri ei ehkä säily tällä käyttötavalla kyllin pitkään maassa, jotta yksi istutusaikainen käsittely suojaisi kasvit koko kesäksi. Bakteerin vaikutusta luontaisiin vihollisiin, myös hyönteispatogeenisiin sieniin, olisi tutkittava.

Huolellisesti asetetut vaahtomuovikaulukset soveltuvat pienimuotoiseen kaalinviljelyyn luonnonmukaiseksi torjuntakeinoksi. *Bacillus thuringiensis* -valmisteen käyttötapaa on vielä kehitettävä.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 281—294 (1988)

Seria ANIMALIA NOCENTIA N. 131 — Sarja TUHOELÄIMET n:o 131

NATURAL ENEMY CONSERVATION FOR THE INTEGRATED CONTROL OF THE RAPE BLOSSOM BEETLE *MELIGETHES AENEUS* F.

HEIKKI HOKKANEN, GUN-BRITT HUSBERG and MONA SÖDERBLOM

HOKKANEN, H., HUSBERG, G.-B. & SÖDERBLOM, M. 1988. **Natural enemy conservation for the integrated control of the rape blossom beetle *Meligethes aeneus* F.** Ann. Agric. Fenn. 27: 281—294. (Agric. Res. Centre, Dept. Pest. Inv., SF-31600 Jokioinen, Finland.)

Meligethes aeneus has been the most important target pest for chemical control in Finland in the first half of the 1980's. The widespread use of insecticides has helped protect crops, but has not reduced pest attacks. Natural enemies have apparently played a minor role in the overall control of the population size of the beetle during the expansion phase of rape cultivation. The potential effect of the most important natural enemies, two parasitoids and a disease, on natural control may have been negated or delayed by the use of insecticides per se, the choice of insecticides, the timing of chemical treatments, the practice of thorough soil cultivation, and maybe unfavourable crop rotation plans.

An integrated control scheme for *M. aeneus* in Finland should employ some or all of the following measures to enhance the effect of the natural enemies: growing of rape as close to the previous year's rape field as possible; spraying of insecticides, when necessary, not later than at growth stage 3.2 (usually around June 10th—15th); using 10—15 % of the rape area for an early flowering trap crop, where *M. aeneus* can be controlled early and cost effectively with insecticides; specifying the used control threshold levels for the main crop at the early bud stage to 2 beetles/plant at field edges and 1 beetle/plant in the center, or alternately only spraying the field edges; and using minimum tillage and direct drilling methods, if available, in establishing the successive crop after rape.

The level of natural control has increased steadily over the last three years (1985—87), and it may be that natural enemies will ease the *M. aeneus* problem in the near future even without any extra measures. Through the prescribed methods it should be possible to hasten this process and obtain more comprehensive control than without them.

Index words: integrated pest management, biological control, predators, parasites, pathogens, agricultural practices, trap crops, habitat management, insecticides, turnip rape, *Brassica campestris, Meligethes aeneus, Phradis morionellus, Diospilus capito, Nosema meligethii.*

Oilseed crucifers have been grown in Finland since the late 1940s. Until the mid-1970s mainly winter turnip rape was grown, but then a complete switch to the growing of spring turnip rape took place in just a few years. This was largely because the overwintering success of winter turnip rape was very unpredictable and usually rather poor (PAHKALA and SOVERO 1988). As new varieties of spring turnip rape, which were better suited to the Finnish climate became available, they quickly replaced the winter varieties. The annual cultivation area of winter turnip rape has never exceeded 20 000 ha (ANON. 1957—1970).

The cultivation area of spring oilseed crucifers increased in less than 10 years by over 10-fold, reaching 80 000 ha in 1987 (Fig. 1) (Anon. 1970—1988). At the same pace the severity of the damage by *Meligethes aeneus* F., the rape blossom beetle, increased from negligible to that of the most serious pest of field crops at the beginning of the 1980s (Fig. 1) (MARKKULA 1977—1988). The beetle never

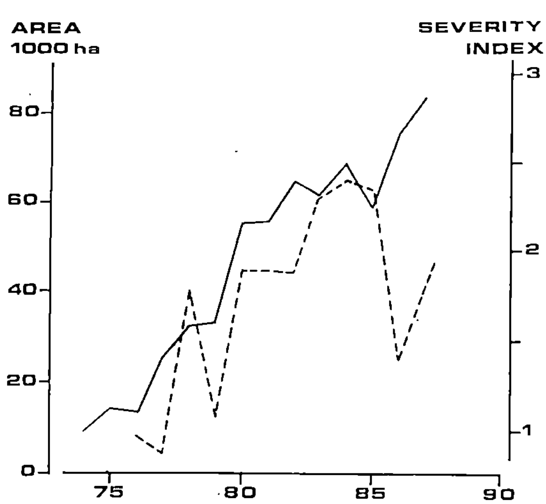

Fig. 1. The growing area of oilseed crucifers in Finland (solid line) 1974—1987, and the severity of *Meligethes aeneus* attack (index from 1 to 10; MARKKULA 1977—1988) on the average in 1976—1987 (broken line).

was so serious a problem to winter turnip rape as it now is to spring turnip rape, where it needs to be chemically controlled every year at least once in practically all rape fields. Often, two sprayings are necessary.

Present control tactics and recommendations are based on the research results reported in TULISALO (1984) and TULISALO and WUORI (1986). A threshold level of 1 beetle/plant is used for sprayings at the early bud stage, and a somewhat higher level at later stages (TULISALO and WUORI 1986). This often leads to two treatments: first at the early bud stage approximately in the beginning of June, and a second spraying just before flowering about 2—3 weeks later. Comprehensive, concerted regional sparyings are recommended (TULISALO and WUORI 1986), but these seldom have actually been carried out. When only one spraying is expected to be necessary, it is recommended to schedule it as close to flowering as possible (TULISALO and WUORI 1986).

Extensive and intensive chemical control of *M. aeneus* has not alleviated the problem. It can be estimated from sales statistics (e.g. HYNNINEN and BLOMQVIST 1987) that in the first half of the 1980s over 50 % of all insecticides sold in Finland were used for controlling the rape blossom beetle. In Sweden this is estimated to be up to 60 % (MÖRNER 1980). The quantities annually sold, after deducting the estimated use for other purposes, are enough for the spraying of all rape fields more than once. The most commonly used insecticide has been fenitrothion, which is now increasingly being replaced by synthetic pyrethroids (cypermethrin, permethrin, and deltamethrin).

Besides the permanent need for control in oilseed crucifers, the swarms of the new generation of *M. aeneus* adults emerging in August have attacked maturing cauliflower, causing yield losses of up to 40 % (see HOKKANEN et al. 1986).

The problems with *M. aeneus* have been similar in all of the Scandinavian countries, and therefore joint research efforts to solve them have taken place. Several reports have been published on the results (e.g. MÖRNER 1980, 1984, KARLTORP and NILSSON 1981, NILSSON 1980, 1985, 1986a, 1986b, CHARPENTIER 1985, WALLENHAMMAR and EKBOM 1986, MÖRNER and EKBOM 1987). In addition to the inter-Nordic project, the Academy of Finland supported a study by the present authors on the biological and integrated control of *M. aeneus* during 1984—1986. Since 1986 this research has continued at the Agricultural Research Centre (ARC), Department of Pest Investigation, and at several ARC research stations.

The aim of this paper is to synthesize the most important findings of these studies into a testable hypothesis for a management approach which might later be utilized to permanently lower the level of *M. aeneus* attack to tolerable levels.

MATERIAL AND METHODS

The importance and occurrence of different types of natural enemies of *M. aeneus* was studied during three years at Viikki, near Helsinki, at the experimental fields of the University of Helsinki, Faculty of Agriculture and Forestry (60° 13′ N, 25° 02′ E), as well as at the ARC fields in Jokioinen, SW Finland (60° 48′ N, 23° 28′ E), and the ARC Kymenlaakso research station in Anjala, SE Finland (60° 42′ N, 26° 47′ E). In addition, field surveys were made in all parts of the rape growing area in Finland.

Sweep netting throughout the larval period of *M. aeneus* during 3 years was used to determine the occurrence and relative importance of various potential predators in the rape fields. Nocturnal predators were assessed by sweeping every 3 hours throughout two 24-h periods in 1983.

15 pitfall traps were placed in rape fields in 1983 and 1984 for the whole growing period to determine the pattern of activity of epigeial predators. Their effect on *M. aeneus* population density was studied with exclusion techniques in 1985. Four 4 m^2 plots were surrounded with metal barriers and supplied with pitfall traps to exclude the predatory activity during pupation of the blossom beetles. 15 1 m^2 emergence cages, 8 in the protected area, were used to collect the new generation beetles for counting.

Sticky insect glue placed on the stem of 15 rape plants was employed to assess the occurrence of potential climbing predators in 1983.

The occurrence and role of egg parasitoids was studied in 1983 by moving about 10 000 *M. aeneus* eggs from the field into the laboratory and allowing them to hatch in miniature cages. 2000 eggs were monitored individually in petri dishes. No egg parasitoids were found.

In addition surveys of larval parasitism were conducted throughout the whole area of rape cultivation during three years, as well as in some reference areas where the populations of *M. aeneus* subsist solely on cruciferous weeds. As a rule, a sample of 100 larvae, collected from several different parts of the field, were taken from each location. In 1985 75 such samples were taken, and in 1986 and 1987 35 samples were collected in both years. In total about 15 000 blossom beetle larvae were collected and dissected for this purpose. Identification of some of the adult ichneumonid parasitoids was confirmed by Dr. K. Horstmann, Würzburg, F. R. G.

Surveys were made to determine the occurrence of *Nosema meligethii*, an important protozoan disease in some areas (ISSI and RADITSCHEVA 1979). Samples of approximately 200 beetles from five different areas were examined. Some samples were later checked by Dr. Issi in Leningrad for correct identification. Preliminary experiments were also made in the laboratory and in the field with general insect pathogenic fungi and nematodes with respect to their potential for blossom beetle control.

The effect of chemical control of *M. aeneus* on the larval parasitoids, likely the most important natural enemies of the beetle, was studied in the laboratory according to the IOBC/WPRS working group "Pesticides and beneficial organisms" guidelines (HASSAN 1977, 1985). The correct timing of the insecticide treatments was determined by the pattern of adult parasitoid emergence in the spring in cages, as well as by observations on the actual appearance of parasitoids in the rape fields. Four 1 m^2 emergence cages were used in 1985 and 15 in 1986.

The level of mechanical destruction of the parasitoids through ploughing and harrowing was studied during two years in experiments using emergence cages. Four 1 m^2 emergence cages were used in 1985 and 15 in 1986. About half of the cages were placed on soil normally prepared for the next crop, and half on the untreated stubble of the previous year's rape field.

Management of the pollen beetle and its natural enemy populations has been attempted on a minor scale at the ARC Kymenlaakso Research Station since 1985 through minimal use of pesticides, timing of insecticide applications, use of trap crops (cf. HOKKANEN et al. 1986), and minimum tillage of the rape field (cf. NILSSON 1985). These experiments were expanded considerably in 1986.

RESULTS

Natural enemies

Of the arthropod natural enemies of *M. aeneus* only two species of larval parasitoids are likely to be of any practical importance in the natural control of the beetle. The more important of them is *Phradis morionellus* (Holm.) (Hymenoptera: Ichneumonidae), and the other *Diospilus capito* Nees (Hymenoptera: Braconidae). Both of them occur throughout the whole area of rape cultivation in Finland. No other species of larval parasitoids have been found.

P. morionellus is known to be univoltine and host-specific. It overwinters in the soil of the rape field, whereas its host overwinters in the litter/soil layer in nearby forest areas (BÖRNER and BLUNCK 1920). *D. capito*, on the other hand, may have according to the literature two generations annually, and probably uses as its overwintering host certain species of cabbage weevils (*Ceutorrhynchus* spp.) or late season *M. aeneus* -larvae (KAUFMANN 1925, OSBORNE 1960, HERTING 1982). Its biology under Finnish conditions is still unclear, because the species cited in the literature as possible alternate hosts (*Ceutorrhynchus leprieuri* Brisout, *Psylliodes chrysocephala* (L.)) are very rare or do not occur in Finland. *Ceutorrhynchus assimilis* Paykull and *C. quadridens* Panzer are relatively common (VAPPULA 1965), but have not been recorded as hosts for *D. capito* (HERRSTRÖM 1964, HERTING 1973, 1982).

The rate of parasitism of *M. aeneus* by these two parasitoids was determined at three sites in 1984—1987 (Fig. 2). For the years 1985—1987 the whole rape growing area was sampled, and the overall parasitism determined (Table 1, Fig. 3).

On the whole, there has been a steady, rapid increase in the rate of parasitism during the study period, and both of the parasitoids were able to increase their percent parasitism considerably. *P. morionellus* raised its parasitism by 116 %, up to 37,0 % in 1987, and *D. capito* did proportionally even better: from 4,7 % in 1985 to 12,0 % in 1987. The overall rate of parasitism increased by 124 % in two years: from 21,8 % to 49,0 % (Table 1).

Table 1. Mean rate of parasitism of *Meligethes aeneus* larvae in Finland in 1985—1987 by the parasitoids *Phradis morionellus* and *Diospilus capito*. Sample means weighed with growing area of oilseed crucifers in each county in the study area. $N_{1985} = 7500$, N_{1986} and $N_{1987} = 3500$.

	Mean rate of parasitism			Change
	1985	1986	1987	85—87
Phradis morionellus	17.1	28.7	37.0	+116 %
Diospilus capito	4.7	7.3	12.0	+155 %
Total parasitism	21.8	36.0	49.0	+125 %

The figures in Table 1 are the absolute shares of *M. aeneus* last instar larvae destroyed

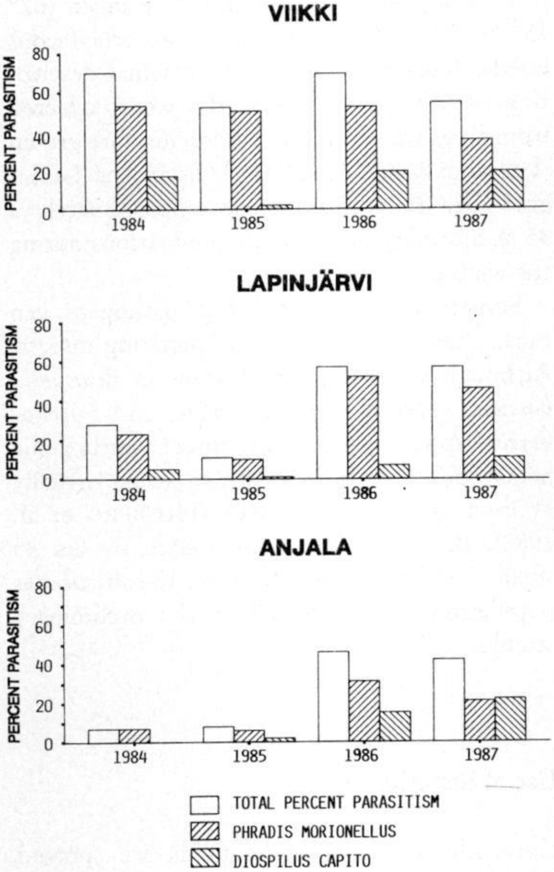

Fig. 2. Changes in percent parasitism of *Meligethes aeneus* larvae at Viikki (60° 13′ N, 25° 02′ E), Lapinjärvi (60° 35′ N, 26° 16′ E), and Anjala (60° 42′ N, 26° 47′ E) in 1984—1987, N > 100 for each year and location.

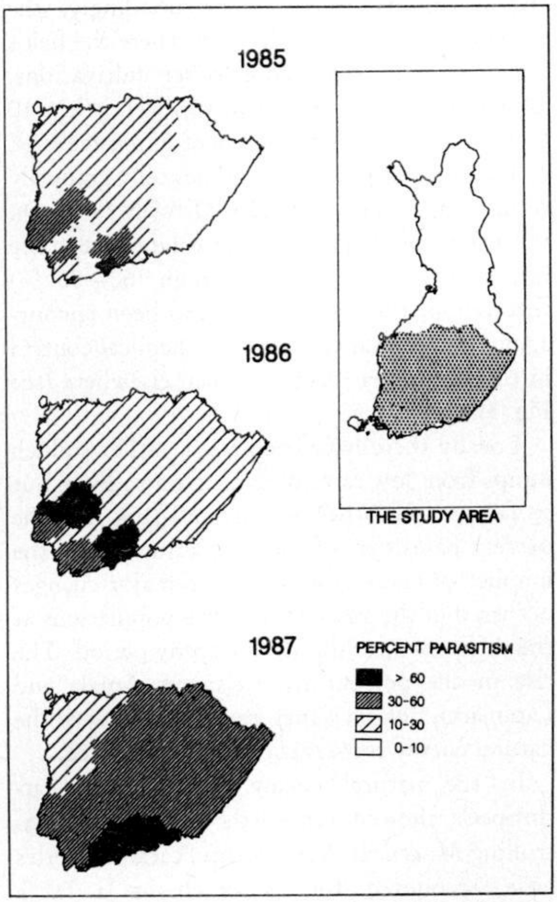

Fig. 3. Percent total parasitism of *Meligethes aeneus* larvae in the rape growing area in Finland, 1985—1987. $N_{1985} = 7500$, N_{1986} and $N_{1987} = 3500$.

by the parasitoids in each of the study years over the whole rape growing area in Finland. They are based on the percent total parasitism figures seen in Fig. 3, and weighed by the absolute area of oilseed crucifers grown in each of the 262 counties within the study area (obtained from the National Board of Agriculture, Statistical Office). Thus in 1987 these parasitoids destroyed one half of the *M. aeneus* last instar larval populations in Finland.

There exists, however, a large variation in the rate of parasitism in different parts of the rape growing area. It can be generalized that the percent parasitism has been lowest in areas where oilseed rape cultivation occurs over the largest uniform areas. Correspondingly, the rates tend to be highest in areas where the fields are more scattered among other cultivations. Thus the percent parasitism was well below 10 % in 1985 in most areas where extensive rape cultivation was practiced, and has only gradually risen to approximately 10—20 % in 1987. On the other hand, in some quite large areas the rate of parasitism was very high (60—80 %) throughout the study, and it has been encouraging to note that the need for chemical control in these areas has been less than elsewhere (see Fig. 3).

Locally there have been large, rather sudden jumps from low rates of parasitism to high, but so far not the other way around (Fig. 2). The percent parasitism of course is a function of the number of hosts as well, but no major changes occurred in the size of the beetle populations at the different sites during the study period. The rise in the percent parasitism at Anjala and Lapinjärvi, however, may be associated with the natural enemy conservation methods tested.

In the natural enemy surveys other arthropods showed very little promise in controlling *M. aeneus*. In Germany, carabid beetles have accounted for as much as a 50 % reduction of the pupal population of *M. aeneus* (BASEDOW 1973). These predators are numerous also in Finnish fields, but in our experiment they reduced the beetle population only by approximately 3 %. One explanation may be that in Finland there is rather little carabid activity during those 3—4 weeks in the middle of the summer when the beetles pupate and emerge (cf. VARIS et al. 1984).

The impact of microbial antagonists on the pollen beetle populations is difficult to determine. Our surveys showed that the microsporidian *Nosema meligethii* occurs, if at all, only sporadically in the blossom beetle population reproducing on cultivated rape. No mature spores were found in these samples, although some immature stages were detected. The disease was found, however, in its mature form in a beetle sample from Pieksämäki (62° 15′ N, 27° 15′ E), collected from cruciferous weeds. Note that also in the original description of the species the beetles were collected from areas where no oilseed crucifers are grown (ISSI and RADITSCHEVA 1979). In the Leningrad area the disease causes approximately a 35 % mortality in the beetle populations during the winter.

Sometimes soilborne insect pathogens can cause heavy mortality in the pupating insects. Although such fungal pathogens as *Beauveria bassiana, Metarhizium anisopliae,* and *Paecilomyces* spp., as well as insect pathogenic nematodes, have been shown to occur virtually everywhere in Finnish fields (HUSBERG et al. 1988), their concentrations apparently are so small that hardly any effect on the *M. aeneus* populations was detected in the preliminary studies.

Use of insecticides

Currently almost all rape fields are sprayed with insecticides. Many fields are treated twice: first at the early bud stage in the beginning of June, and again about two weeks later just before flowering.

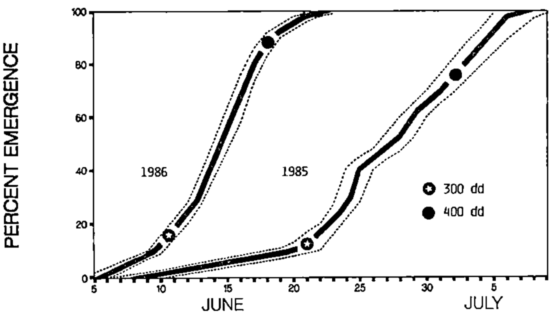

Fig. 4. Pattern of *Phradis morionellus* emergence in cages in 1985 (Viikki) and 1986 (Jokioinen) with respect to date and accumulated heat-sum in the air above + 5 °C (day-degrees, dd). Means ±-standard errors of the mean.

The first spraying does not affect the abundance of the larval parasitoids in any way, because they start to emerge and appear in the fields around mid-June (Fig. 4). The second treatment normally coincides with the peak abundance of *Phradis morionellus*, the most important parasitoid, and is likely to be very destructive to it. We have only scattered observations about the appearance of *Diospilus capito* in the fields, but it seems to arrive slightly later than *P. morionellus*.

The rather large differences in the appearance of the parasitoids in the fields between different years are likely to be similar to those in the development of the rape crop and the phenology of the host beetles. Normally *P. morionellus* starts to emerge when the cumulative heat sum above +5 °C in the air exceeds 280 (in day-degrees, dd), and peak emergence occurs around 330 dd (Fig. 4).

The effect on *P. morionellus* adults of the most commonly used insecticides fenitrothion and deltamethrin, as well as a potentially less destructive pyrethroid alfamethrin were tested in the laboratory. Fenitrothion was clearly more toxic to *P. morionellus* than the pyrethroids (Table 2). In the tests of initial toxicity (see HASSAN 1985) the parasitoids in the fenitrothion treatment were dead after 1.5 hours at all concentrations. In the treatments with pyrethroids at normal and reduced concentrations about 70—80 % of the parasitoids were still alive after 4 hours, but dead after 12 h. In all tests the visual appearance and the external vigour of the surviving parasitoids were clearly negatively affected, in comparison to the parasitoids treated only with water. The performance of the survivors from the treatments as parasitoids of *M. aeneus* remains to be tested, but in all cases it is likely to be greatly reduced. It thus appears that if chemical control of the blossom beetle is necessary, then pyrethroids should be used instead of fenitrothion in order to minimize the hazards to the parasitoids.

One possible way to avoid parasitoid mortality and to decrease the blossom beetle population in the spring effectively is through the use of trap crops (HOKKANEN et al. 1986). Part of the field, preferably 10—15 % of the total rape area, should be sown as early as possible, while delaying the sowing of the main crop until the end of May. This will normally result in a trap crop, which is about two weeks ahead of the main crop in development (c.f. HOKKANEN et al. 1986). The beetles will concentrate into this crop, and they can be sprayed very cost efficiently well before the larval parasitoids are active. In addition, the main crop seldom needs to be sprayed, resulting in a considerable decrease in the use of insecticides and associated costs (HOKKANEN et al. 1986). The trap crop can be harvested normally with the main crop in the autumn. Trap crops, however, should be sprayed with fenithrothion in order to avoid the repellent effect of pyrethroids.

Soil cultivation practices

Normally in Finland the rape field is ploughed in the autumn after harvesting and harrowed the following spring, in seedbed preparation for the following crop, usually cereals. This

Table 2. The effect of fenithrothion, deltamethrin, and alfamethrin on *Phradis morionellus* in the laboratory at three concentrations, observed for 12 hours after the beginning of experiment. a = the proportion in % of unaffected individuals, b = proportion of individuals in poor condition, c = proportion of dead individuals. At normal concentrations 15 individuals/treatment, otherwise 5 individuals. Reference = water, where all individuals remained alive through the experiment. Normal concentrations of use: fenithrothion 0.15 %, deltamethrin 0.05 %, alfamethrin 0.015 %.

A.	Double the normal concentration of use								
Time in h	Fenithrothion			Deltamethrin			Alfamethrin		
	a	b	c	a	b	c	a	b	c
0.5	20	80	—	20	20	60	100	—	—
1.0	—	—	100	—	40	60	20	20	60
1.5	—	—	100	—	40	60	—	40	60
2.0	—	—	100	—	40	60	—	40	60
2.5	—	—	100	—	40	60	—	20	80
3.0	—	—	100	—	20	80	—	20	80
3.5	—	—	100	—	—	100	—	20	80
4.0	—	—	100	—	—	100	—	—	100
12.0	—	—	100	—	—	100	—	—	100

B.	Normal concentration of use								
Time in h	Fenithrothion			Deltamethrin			Alfamethrin		
	a	b	c	a	b	c	a	b	c
0.5	33	66	—	60	40	—	87	14	—
1.0	7	7	87	20	73	7	60	20	20
1.5	—	7	93	7	87	7	20	60	20
2.0	—	—	100	—	93	7	7	73	20
2.5	—	—	100	—	87	14	—	73	27
3.0	—	—	100	—	80	20	—	73	27
3.5	—	—	100	—	80	20	—	73	27
4.0	—	—	100	—	80	20	—	73	27
12.0	—	—	100	—	—	100	—	—	100

C.	Half of the normal concentration of use								
Time in h	Fenithrothion			Deltamethrin			Alfamethrin		
	a	b	c	a	b	c	a	b	c
0.5	60	40	—	100	—	—	100	—	—
1.0	20	20	60	20	80	—	20	80	—
1:5	—	20	80	20	80	—	20	80	—
2.0	—	—	100	20	80	—	20	80	—
2.5	—	—	100	20	80	—	20	80	—
3.0	—	—	100	20	80	—	20	80	—
3.5	—	—	100	20	80	—	—	100	—
4.0	—	—	100	20	80	—	—	100	—
12.0	—	—	100	—	—	100	—	—	100

repeated soil cultivation has been shown to be destructive to the blossom beetle parasitoids that overwinter in the soil. In experiments in southern Sweden approximately 78 % of the parasitoids were destroyed through these soil cultivation methods (NILSSON 1985).

Cultivation therefore imposes high mortality on the most important natural enemies, whereas the blossom beetle avoids it by overwintering as a rule in the nearby woods. The extent of this mortality was studied under Finnish conditions in Viikki and Jokioinen, and the results partly confirmed the Swedish results. In Jokioinen ploughing and harrowing reduced the number of parasitoids by 77 % on the average. Parasitoid overwintering survival, independent of mechanical destruction, has not been reported in other studies. In our experiment in the uncultivated plots survival was only about 30 % (range 10—49), indicating additional strong mortality factors.

It can be concluded that soil cultivation is an important factor contributing to the overall potential of parasitoids in the biological control of *M. aeneus*. NILSSON (1985, 1986) has proposed the use of direct drilling methods after the rape crop, in order to protect the parasitoids. This is a reasonable approach also for other purposes, and it should be adopted as a part of an integrated control program for *M. aeneus*. It is not known whether this is actually necessary in Finland, because the parasitoids may control the beetle eventually even without such extra measures (c.f. Figs 1, 3). Direct drilling has been incorporated as a part of the expanded management experiments that were designed based on the results reported in this article.

The management hypothesis

The integrated management program for *M. aeneus* should be designed in such a way that the maximum benefits from the naturally occurring biological control, provided by the potentially most effective agents, could be realized. These agents under Finnish conditions include the parasitoids *P. morionellus* and *D. capito*, as well as the microsporidian *Nosema meligethii*. Augmentation of the soil dwelling insect pathogens may also be utilized. In order to optimize management either some or all of the following points should be considered: a) careful timing of insecticide use, b) manipulation of the parasitoid-host ratio, c) minimizing the use of insecticides, d) use of minimum soil cultivation after the rape crop, and e) optimum crop rotation plans.

a) Timing of insecticide use

The blossom beetle should be controlled chemically before the main rape crop reaches the growth stage 3.3 (HARPER and BERKENKAMP 1975), or before a 320 dd heat sum has accumulated. In normal years this is around June 13th in southern Finland (range June 4th—30th) (calculated from ANON. 1980—1987). This is in order to avoid killing the parasitoids, which arrive in the fields at that time. Preferably pyrethroid insecticides should be used, because they may be safer to parasitoids than other chemicals.

b) Host-parasite ratio

Through the use of trap crops and the associated use of insecticides it is possible to greatly reduce the beetle numbers that will lay eggs in the rape stands and damage the crop. When the sprayings are done early enough, the parasitoids are saved and the balance in numbers between the beetle hosts and the parasitoids is considerably affected. Typical host-parasite ratios currently in Finland are around 3:1—1:1, but this can be quite easily converted into about 1:3—1:4 through selective sprayings in the spring. JOURDHEUIL (1960) reports approximately 50 % parasitism of *M.*

aeneus in France at the host-parasite ratio 1:1, and over 90 % parasitism at the ratio 1:3.

Manipulation of this ratio may be particularly important in the beginning of the IPM program for *M. aeneus*, because typically the host beetles at this stage are very numerous and the parasitoid numbers rather low. Such manipulations may tip the balance quickly to a high degree of natural control, and they may not be necessary after 1—2 years.

c) Minimizing the use of insecticides

Even when we can avoid the deleterious effects of insecticide use on the larval parasitoids through correct timing, their steady use can have many other disturbing effects on the ecosystem, particularly in the long run (WINFIELD 1963, RZEHAK and BASEDOW 1982). A case in point may be the hypothesis concerning the rarity of *Nosema meligethii* in Finnish *M. aeneus* populations. ISSI and VORONINA (1983) point out that in insect populations where a microsporidian disease occurs, the disease can virtually be wiped out through the persistent use of insecticides because the diseased, weaker individuals are more likely to die than are the healthy ones. Such chemical selection therefore quickly breeds a beetle population without the disease. This could explain the absence of the disease in the Finnish blossom beetle populations — and also its occurrence in the "wild", unsprayed population from Pieksämäki.

The disease might spread again gradually, if considerably less insecticides were to be used in the control of *M. aeneus*. This should, in turn, contribute significantly to the natural control of the beetle.

Minimizing the use of insecticides might require a more careful assessment of the economic threshold levels of *M. aeneus* injury. The published levels may be academically quite precise, but their correct assessment in the field is difficult. Beetles tend to be less numerous in the middle of the field than at field edges where farmers normally count them. They also tend to be more or less aggregated, easily creating the feeling that there are many more beetles/plant than in reality. This all may result in unnecessary sprayings, as well as economic and ecological losses. For practical field use the action threshold densities of *M. aeneus* should therefore be specified separately for field edges and the center of the field. If aiming at only one spraying, probably 2 beetles/plant at the early bud stage at the field edges and 1 beetle/plant at the center would be correct for sparying the whole field. Consequently about 4 beetles/plant at the late stage at field edges and 2—3 in the middle would be the correct action threshold levels. Alternately one could spray according to the lower, current thresholds, but then only treating the field edges. In Central Europe the action threshold level for early bud stage has been lowered from an earlier 4—9 beetles/plant to 2 beetles/plant in the middle of the field and 4—8 beetles/plant at field edges (SCHÜTTE 1970). These new, specified threshold levels for Finland should help to avoid unnecessary insecticide treatments.

d) Soil cultivation

The balance in numbers between the host and the parasitoid can also be considerably affected by the methods of soil cultivation used after the rape crop. Through direct drilling 3—4 times as many parasitoids can be obtained from the previous year's rape field than from a field that has been conventionally ploughed and harrowed. This requires quite a change in management practice, and is not likely to be done solely for blossom beetle control. In comparison with the other proposed methods, the readiness to take this management tool quickly into widespread use is not very high.

e) Crop rotation

In all situations it is advantageous to the parasitoids if the rape crop is located as close to the previous year's rape field as possible. This becomes obvious when one thinks that the small, fragile parasitoids first will have to locate the new rape field, and then travel the distance from the site of emergence (previous year's rape field) to the new field. Losses due to this transfer will be minimized if the fields are in the same general area, preferrably right next to each other.

In fact, this might be the simplest point to take into consideration while planning an IPM project for *M. aeneus.* Points a), b) and c) are also easy to execute, whereas step d) often requires new investments by the farmer(s).

For an effective IPM program it would be best to first start with the maximum management including as many of the above principles as possible, and only later to simplify the procedure if the situation allows it. Management should also be targeted at the whole blossom beetle population in a particular area in order to be effective. Populations can be considered to be practically separate, if the distance to neighbouring rape fields is over 5—10 km (c.f. SCHÜTTE 1976). In practice this means that management should include most of the rape fields in any separate uniform growing area.

DISCUSSION

The management scheme arising from the results of the studies described above is rather different from that advocated by TULISALO and WUORI (1986). Their method includes repeated, widespread, and synchronized pesticide applications especially close to the flowering of the crop, in order to decimate the blossom beetle population and to help in controlling future outbreaks. According to TULISALO and WUORI (1986) this should be done even when there would be no acute need for blossom beetle control locally.

The size of the new generation *M. aeneus* population, and consequently the next year's population, can not, however, be influenced significantly by measures carried out in the spring before egg-laying. Density dependent mortality, which controls the population size, occurs mainly at the larval stage (HOKKANEN et al., unpublished), and only measures directed at that or later stages can decrease the number of beetles in the future. Parasitoids and diseases affect exactly these stages. A similar effect can be obtained through effective trap cropping in the autumn. This has been demonstrated in Masku, SW Finland, where the mass-trapping of *M. aeneus* in August to protect cauliflower crops (HOKKANEN et al. 1986) has considerably decreased the need for blossom beetle control in the neighbouring rape fields (GRANLUND, H. 1987, personal communication).

There is no doubt at the present, however, that the direct management approach currently used in Finland has been, and is likely to continue to be effective in protecting the rape crop from the beetle. However, it also is likely to guarantee a continuing, and perhaps attenuated blossom beetle problem in the future.

Other management schemes for *M. aeneus* in addition to those discussed above have been presented. SCHÜTTE (1976) and MÖRNER and EKBOM (1987) consider the possibility of controlling the beetle by concerted crop rotations over large areas. The idea is to occasionally deprive the beetles of their host plants at each particular location, causing the populations to collapse. Under such highly unstable circumstances, however, the specific nautral enemies normally are much more severely affected than the target pest species, causing further instability to the system. Thus the blossom beetle populations are likely to explode as soon as rape cultivation after the break is resumed in that area. This approach is also not feasible from a purely practical point of view, and it therefore shows little promise as a control method for *M. aeneus.*

It is not clear what precise role parasitoids play in the population dynamics of the rape blossom beetle. Thus questions have been raised as to whether they are capable of controlling the pest at all. Some studies have at least marginally dealt with the problem, particularly in connection with the effects of insecticide use on natural enemies (e.g. FRITZSCHE 1957, WINFIELD 1963, LEHMANN 1965, TULISALO and WUORI 1986). The general opinion has been that parasitoids are not very important, and therefore the insecticide treatments are not harmful to the balance. Most of these studies, however, have dealt with systems that are complicated having many different host crop plants and several other pest species, as well as a variety of natural enemies. The present practice of growing only spring oilseed crucifers in Finland and the relative simplicity of the pest — natural enemy complex may make it easier to manage it successfully through integrated or purely biological means. Moreover, there are over 200 successful cases of classical biological control (c.f. HOKKANEN 1985) to illustrate that parasites, predators and other natural enemies are capable of permanently controlling a pest below economic threshold levels. The potential of parasitoids and other natural enemies in controlling *M. aeneus* is not known yet. However, alternative approaches to control the pest are urgently needed. Whether the integrated control approach described in this paper will be more successful than other approaches in the rational management of the *M. aeneus* populations in Finland remains to be seen.

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SELOSTUS

Luontaisten vihollisten hyväksikäyttö rapsikuoriaisen integroidussa torjunnassa

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Maatalouden tutkimuskeskus

Rapsikuoriainen on ollut 1980-luvun alkupuolella kemiallisen tuhoeläintorjunnan tärkein kohdelaji sekä Suomessa että Ruotsissa. Yli puolet kaikista tuholaistorjuntaan myydyistä aineista arvioidaan käytetyn tähän tarkoitukseen. Laajamittainen torjunta-aineiden käyttö on turvannut vuotuisen sadon, mutta se ei ole juurikaan vähentänyt kuoriaisten määrää tai vuotuista torjuntatarvetta.

Luontaiset viholliset ovat olleet ilmeisen merkityksettömiä rapsikuoriaisen kannansäätelijöinä viljelyalan voimakkaan laajenemisen aikana. Tärkeimpien luontaisten vihollisten, kahden toukka-asteen loisen sekä erään patogeenin, tehoa ovat heikentäneet laaja-alainen ja jatkuva torjunta-aineiden käyttö, käytettyjen aineiden laatu, torjunta-ajankohdan valinta, maanmuokkaus ja sen ajoitus, sekä mahdollisesti epäedullinen viljelykierto.

Rapsikuoriaisen integroidussa torjunnassa tulisi maksimaalisesti hyödyntää luontaisten vihollisten kykyä torjua kuoriaista, samalla kun turvataan rypsisato tarvittaessa kaikin käytettävissä olevin keinoin. Suomessa tällaiseen ohjelmaan tulisi kuulua useimmat, ohjelman alussa mieluiten kaikki seuraavista seikoista:

Rypsipellon tulisi sijaita mahdollisimman lähellä edellisen vuoden rypsipeltoa, jotta luontaisten vihollisten siirtyminen uudelle viljelykselle onnistuisi hyvin.

Kemiallista tuholaistorjuntaa ei tulisi suorittaa kuin poikkeuksellisesti sen jälkeen kun tehoisan lämpötilan summa on ylittänyt 320 tai kun kasvusto on ohittanut kehitysasteen 3.2; normaalivuosina tämä on noin 10.—15. kesäkuuta. Tämän jälkeen tehdyissä ruiskutuksissa kuolee myös valtaosa tärkeimmistä luontaisista vihollisista.

Aikaista ja taloudellista kemiallista torjuntaa varten kullakin peltoaukealla tulisi kylvää erittäin aikainen houkutuskasvialue, joka on noin 10—15 % aukean koko rypsialasta. Varsinaisen rypsin kylvön tulisi tapahtua mahdollisimman myöhään toukokuun lopulla. Houkutuskasveilta kuoriaiset torjutaan normaalisti insektisideillä.

Rapsikuoriaisen torjuntakynnystä tulisi tarkentaa siten, että aikaisella nuppuasteella koko pellon ruiskutusta varten kynnys on reuna-alueilla 2 kuoriaista/kasvi ja pellon keskellä 1/kasvi. Myöhemmin arvot ovat kaksinkertaiset. Torjuttaessa alhaisemmalla kynnysarvolla (1 kuoriainen/kasvi pellon reunoilla), tulisi käsitellä vain pellon reunaosat.

Rypsin jälkeen tulisi mahdollisuuksien mukaan välttää pellon muokkausta ennen seuraavan kasvukauden puoltaväliä. Tämä onnistuu hyvin, mikäli rypsin sänkeen ehditään kylvää syysvilja suorakylvönä; kevätviljan kylvöä tällä tavalla on vielä tutkittava. Maanmuokkauksen välttämisellä turvataan rapsikuoriaisen loispistiäisten määrän nopea kohoaminen, sillä normaali muokkaus tuhoaa mekaanisesti kolme neljäsosaa pellossa talvehtivista pistiäisistä.

Luontaisten vihollisten merkitys on vuosina 1985—1987 koko maassa nopeasti kohonnut, ja saattaa olla että ne ilman mitään erityistoimiakin ennemmin tai myöhemmin pystyvät pienentämään rapsikuoriaisten määrän ainakin ajoittain alle taloudellisen tuhon kynnyksen. Tässä esitetyin menetelmin pitäisi olla mahdollista nopeuttaa tuota luontaista prosessia ja saavuttaa parempi ja pysyvämpi torjuntatulos kuin ilman niitä.

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Seria AGRICULTURA N. 90 — Sarja PELTOVILJELY n:o 90

THE INFLUENCE OF HONEYBEE POLLINATION ON TURNIP RAPE (*BRASSICA CAMPESTRIS*) YIELD AND YIELD COMPONENTS

SEPPO KORPELA

KORPELA, S. 1988. **The influence of honeybee pollination on turnip rape** *(Brassica campestris)* **yield and yield components.** Ann. Agric. Fenn. 27: 295—303. (Agric Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

The effect of honeybee pollination on turnip rape (*Brassica campestris*) seed yield and yield components was studied in 13 cage experiments from 1977 to 1983. The dependence of yield components on the activity of bees was studied by supplying part of the cages with queen-mating hives either for 1) the entire flowering stage, 2) the beginning half, or 3) the end half of the flowering stage. The results show that rape plants reacted to bee activity mainly by a higher number of seeds/pod, but also by a higher number of pods. Cages without bees compensated for a poor seed set by a 2—3 week longer flowering period and by producing heavier seeds. By counting the number of seeds/pod in relation to the position of pods on the terminal raceme the influence of bee pollination could be seen. The influence of differences in environmental variables between the experiments greatly affected the yield and it is suggested that they influenced the result of bee pollination also. In good growing conditions and weather favouring wind pollination the yield increase (caged plots with and without bees) due to bee pollination was ca. 10—15 %, but at lower yield levels and/or weather diminishing wind pollination, this increase was higher.

Index words: insect pollination, *Brassica campestris*, honeybee, yield components, cage experiment.

INTRODUCTION

In Finland the cultivated area of oilseed rape has increased considerably since 1975 being ca. 75 000 ha currently. Over 90 % of the rape area cultivated is turnip rape, *Brassica campestris*, due to its shorter growing period. The swede rape, *B. napus* is grown only in the southern coastal region.

The swede rape is commonly considered to be self-fertile and most varieties have been shown to yield well without insect pollination (OLSSON and PERSSON 1958, FREE and NUTTALL 1968, WILLIAMS 1978). Turnip rape, on the other hand, is considered almost completely self-sterile requiring cross-pollination to set seed. In windless conditions inside a glasshouse it produces a very low yield (WILLIAMS 1978). Therefore it can be assumed that wind contributes a great deal to turnip rape pollination. This has been observed in cage experiments, in which insects are excluded from the plants as well as in practical growing situations where no bees have been used for pollination and the area of the crop has been too large for other pollinators to be of much importance.

Turnip rape is generally considered to benefit further from insect pollination. However, compared to swede rape, few studies have been made on turnip rape pollination. KOUTENSKY (1958) and DOWNEY and BOLTON (1961) compared yields on fields with apiaries beside them and without bee pollination. According to the two studies, bees accounted for a 64 % and 30 % yield increase, respectively. LANGRIDGE and GOODMAN (1975), on the other hand, compared yields/plant in open and caged plots, with a yield difference of 46 % in favour of open plots. FRIES and STARK (1983) also had open and closed plots and their results indicate that yield and percentage of yield increase (50—73 %) between these treatments was dependent on the proximity of the apiary to the experiment sites. It is likely that the yield difference between open and closed plots also includes the negative influence of the caging on the plants in addition to the influence of insect pollination. The results may also be affected by varying wind conditions during the different experiments. Other weather variables affecting wind pollination, such as temperature, RH and precipitation, might also influence the role of bees in pollination.

The aim of the present study was to assess by cage experiments the influence of bee pollination on the seed yield and yield components of the turnip rape. In order to obtain results on the influence of different weather conditions on bee pollination the experiments were repeated during several years.

MATERIAL AND METHODS

The experiments were carried out in 1977—1982 at the Agricultural Research Centre, Tikkurila, near Helsinki and in 1983 at Jokioinen (60° 50′ N, 23° 30′ E).

In 1977—1978 the experiments were conducted at four sites, which were the same as those in the study of TULISALO and WUORI (1986). Experimental areas were adjacent to their insecticide-treated rape field portion. Rape stands were sprayed before flowering with permethrin to control the blossom beetle *(Meligethes aeneus).* In 1977 at site IV the experiment was set up on a separate 20 × 20 m area with no insecticide treatments.

The experimental areas were divided into plots 5 × 5 m just before flowering began. In the middle of each plot a 2 × 2 m plot was demarcated and the plants from these plots were harvested in the autumn. A part of these plots were covered with nylon-screen cages (1.8 m high) to exclude pollinating insects and a part of them were left open. The open plots were visited by the bees from nearby apiaries.

In 1979—1983 there was one experiment/year, still being adjacent to an insecticide-treated rape field. Besides open plots and cages without bees (NB) these experiments included cage treatments with bee pollination. Bees were supplied into these cages by hanging into one top-corner of the cage a queen-mating hive filled with 1.5 dl (about 400) bees and provisioned with candy food. The bees were left to stay in the cages either for the entire flowering stage (EF), the beginning half of flowering (BHF) or the end half of flowering (EHF).

In 1977—1980 there were four replicates and in 1981—1983 eight replicates of each treatment. In 1978 there was at one site an additional EHF cage, which was used only for plant characteristics measurements. In 1977—1978 the experimental design was fully randomized and in 1979—1983 a design with plots randomized in blocks was used.

The plots were harvested in autumn and the seed yield per plot was weighed after drying and cleaning the seeds. In addition, before harvesting the plots, plant samples (10 plants in 1977—1978 and 20 in 1979—1980) were taken to determine yield components and other plant characteristics. The first plant in a sample was selected at random and following the row, every third plant was taken thereafter. In 1979—1980 also the yield from the sample plants was determined. In 1981—1983 no plant samples were taken.

The following characteristics were determined in the plant samples: plant height, number of racemes containing pods, number of pods on the terminal and lateral racemes and number of seeds per pod. The mean weight of 1000 seeds was calculated from the weight of three random samples of 100 seeds each.

During the flowering period bees and bumble-bees foraging on a strip 100 m × 1 m adjacent to the cage area at each study site were counted between 13.00 and 14.00 h. Counts were done only if the weather permitted bee activity. In addition bees foraging in the cages were counted.

Weather data for Tikkurila were obtained from the Helsinki—Vantaa airport weather station located ca. 6 km from the experimental sites, and that for Jokioinen from a local weather station. The weather factors observed were temperature, sunshine hours, relative humidity and rainfall. Temperature and light are according to SZABO (1980) the most important factors that determine the flight activity of honey bees. Rainfall and RH were included to indicate periods when rainy weather disturbed bees' flight activity. In addition, notes were made on daily weather to determine the times on each day, when bees visited rape crops.

Plant characteristics data were subjected to analysis of variance and means were separated with Duncan's multiple range test ($P < 0.05$) (SAS Institute 1985).

RESULTS

Yield

Open plots produced in most cases 28—75 % more seed than cages without bees (Tables 1—5). Only in 1977, on sites II and IV was the difference smaller and not significant ($P = 0.44$ and $P = 0.095$, respectively). In experiments containing cages with bees the yield difference between best treatments with bees and treatments without bees was typically ca. 50 % of that between open plots and cages without bees (Tables 3—5).

In 1981—1982 there was a large variation in seed yield per plot due to an uneven experimental site, the coefficient of variation (CV) being from 26 to 31 % in 1981 and from 23 to 50 % in 1982. In 1981 there was crusting of the soil surface in some parts of the plot area and in 1982 the yield was hampered by severe drought. Due to this large variation within the site and the clearly better yield on open plots, the yields of EF and NB treatments were not different by Duncan's test. However if only cage treatments are compared, the large differences in seed yield, 31 % in 1981 and 59 % in 1982 in favour of EF over NB, were significant.

In 1983 EF plots produced only 7.9 % more seed than NB plots and the difference was not statistically significant even if only cage treat-

Table 1. Yield and plant characteristics data, 1977.

Site	Treatment	Yield g/plot	1000 seed wt g	Plant height cm	No. of branches	No. of pods tr	No. of pods lr	No. of pods total	Blind stalks on tr	No. of seeds/pod tr	No. of seeds/pod lr
I	open	549a	2.27b	95.1a	2.9a	17.5a	24.8a	42.2a	8.3a	14.8a	14.2a
	NB	390b	2.48a	93.3a	2.2b	14.9a	14.6b	29.5b	6.8a	8.7b	9.6b
II	open	444a	2.41b	99.1a	2.0a	21.2a	13.7a	34.9a	4.6a	14.1a	11.9a
	NB	412a	2.67a	98.5a	1.9a	18.8a	12.5a	31.3a	2.8a	8.4b	7.7b
III	open	599a	2.05b	98.1a	2.6a	26.4a	36.5a	62.9a	2.5b	17.0a	17.0a
	NB	390b	2.52a	98.0a	2.5a	16.6b	22.8b	39.4b	7.1a	9.9b	10.4b
IV	open	466a	2.40a	113.6a	2.9a	11.4b	21.7a	33.1a	20.9a	14.6a	16.9a
	NB	401a	2.36a	118.1a	3.1a	14.0a	27.4a	41.5a	15.5a	8.7b	10.7b

Means within a column and site followed by a common letter are not significantly different (P > 0.05; DUNCAN option [SAS 1985])
tr = terminal raceme, lr = lateral racemes, open = open plots, NB = cages with no bees

Table 2. Yield and plant characteristics data, 1978.

Site	Treatment	Yield g/plot	1000 seed wg t	Plant height cm	No. of branches	No. of pods tr	No. of pods lr	No. of pods total	No. of seeds/pod on tr in 10 pods at: base	No. of seeds/pod on tr in 10 pods at: top
I	open	660a	2.43b							
	NB	406b	2.93a							
II	open	530a	2.49b							
	NB	394b	2.70a							
III	open	654a	2.63b							
	NB	471b	2.85a							
IV	open	714a	2.44b	97.4a	4.2a	35.3a	35.3b	70.6b	20.2a	16.5a
	EHF	—	2.46b	90.0b	4.3a	38.7a	64.3a	103.0a	6.5c	15.9a
	NB	547b	2.77a	99.3a	4.2a	36.8a	45.6b	82.3b	8.7b	10.2b

Means within a column and site followed by a common letter are not significantly different (P > 0.05; DUNCAN option [SAS 1985])
tr = terminal raceme, lr = lateral racemes, open = open plots, NB = cages with no bees, EHF = cages with bees during the end half of flowering

Table 3. Yield and plant characteristics data, 1979.

Treatment	Yield g/plot	Sample yield g/plant tr	Sample yield g/plant lr	Sample yield g/plant total	1000 seed wt g	Plant height cm	No. of branches	No. of pods tr	No. of pods lr	No. of pods total	No. of seeds/pod on tr in 10 pods at: base	No. of seeds/pod on tr in 10 pods at: top	No. of seeds/pod on tr: mean
open	795a	1.26a	0.43a	1.69a	2.41d	113.3ab	2.1ab	32.3a	15.6ab	48.0a	17.9a	12.4c	15.6a
EHF	704ab	0.98b	0.66a	1.64a	2.62a	112.6ab	2.5a	28.8b	20.4a	49.2a	12.4b	13.3b	12.9b
EF	694ab	1.19a	0.64a	1.82a	2.48cd	116.5a	2.3ab	29.4b	19.5a	48.9a	17.9a	14.5a	16.7a
BHF	647b	1.01b	0.35a	1.36ab	2.51c	108.0c	1.9b	24.6c	12.4b	37.0b	18.1a	12.1c	15.9a
NB	623b	0.64c	0.33a	0.97b	2.85a	110.4bc	2.2ab	24.6c	15.0ab	39.6b	11.1c	7.3d	9.0c

Means within a column followed by a common letter are not significantly different
(P > 0.05; DUNCAN option [SAS 1985])
tr = terminal raceme, lr = lateral racemes, open = open plots, EHF = cages with bees during the end half of flowering,
EF = cages with bees during the entire flowering, BHF = cages with bees during the beginning half of flowering,
NB = cages with no bees

Table 4. Yield and plant characteristics data, 1980.

Treatment	Yield g/plot	Sample yield g/plant			1000 seed	Plant height	No. of	No. of pods			No. of seeds/pod on tr		
		tr	lr	total	wt g	cm	branches	tr	lr	total	in 10 pods at:		
											base	top	mean
open	602a	0.56a	0.47a	1.03a	2.48c	54.0b	1.8b	16.4a	14.3b	48.0a	14.9a	15.4a	15.4a
BHF	544ab	0.42bc	0.43a	0.86a	2.59bc	53.1b	1.9ab	14.1b	13.6b	49.2a	12.4b	13.5a	12.9b
EF	513ab	0.52ab	0.38a	0.90a	2.84b	53.3b	1.8b	15.4ab	10.8b	48.9a	13.5ab	14.2a	14.0b
EHF	492b	0.34c	0.55a	0.88a	2.80bc	57.2a	2.0ab	16.5a	20.8a	37.0b	6.3c	9.3b	8.7c
NB	448b	0.35c	0.40a	0.75a	3.25a	54.7ab	2.2b	14.1b	19.3a	39.6b	8.0c	7.8b	7.4d

Means within a column followed by a common letter are not significantly different
($P > 0.05$; DUNCAN option [SAS 1985])
tr = terminal raceme, lr = lateral racemes, for treatment explanations see Table 3

Table 5. Yield data, 1981—1983.

Treatment	1981		1982	1983
	Yield g/plot	1000 seed wt g	Yield g/plot	Yield g/plot
open	469a	2.01b	277a	738a
EF	351b	1.95b	119b	572b
NB	268b	2.42a	75b	530b

Means within a column followed by a common letter are not significantly different ($P > 0.05$; DUNCAN option [SAS 1985]), for treatment explanations see Table 3

ments are compared. Here, as in other treatments, the rather low number of replicates may have decreased the significance of the yield difference, but in all experiments the yield of best bee treatments was constantly, but to a varying degree, higher than the yield of NB cages.

Yield components

The yield differences between treatments were accompanied by corresponding changes in yield components. The reason why the NB yield remained lower than the yield of open plots and best bee cage treatments was mostly due to the low number of seeds/pod. Likewise in the bee treatments, where bees were present only during a part of flowering, there were corresponding changes in seed set/pod. Sometimes the component that most influenced yield reduction was the number of pods/plant, as in 1979 in the BHF treatment.

The influence of bee pollination could also be seen in the number of seeds of the 10 lowest and highest situated pods on the terminal raceme. In 1978 the number of seeds in the lowest pods was clearly highest on open plots. However, due to bee activity in the EHF treatment, the number of seeds/pod in the 10 top pods was as high as that on open plots. On open plot plants, pods low on the terminal raceme contained more seeds ($P = 0.0001$) than the 10 top-situated pods, while in the bee-cage the situation was the reverse (Table 2, Fig. 1). In addition in 1979 and 1980 the number of seeds/pod was higher ($P = 0.027$ and $P = 0.003$, respectively) on the 10 top pods than on the 10 basal pods only on EHF plants, but the difference was not as clear as in 1978. Both in 1979 and 1980 the seed number/pod in the 10 lowest pods was on the treatments open, BHF and EF higher than that on treatments NB and EHF.

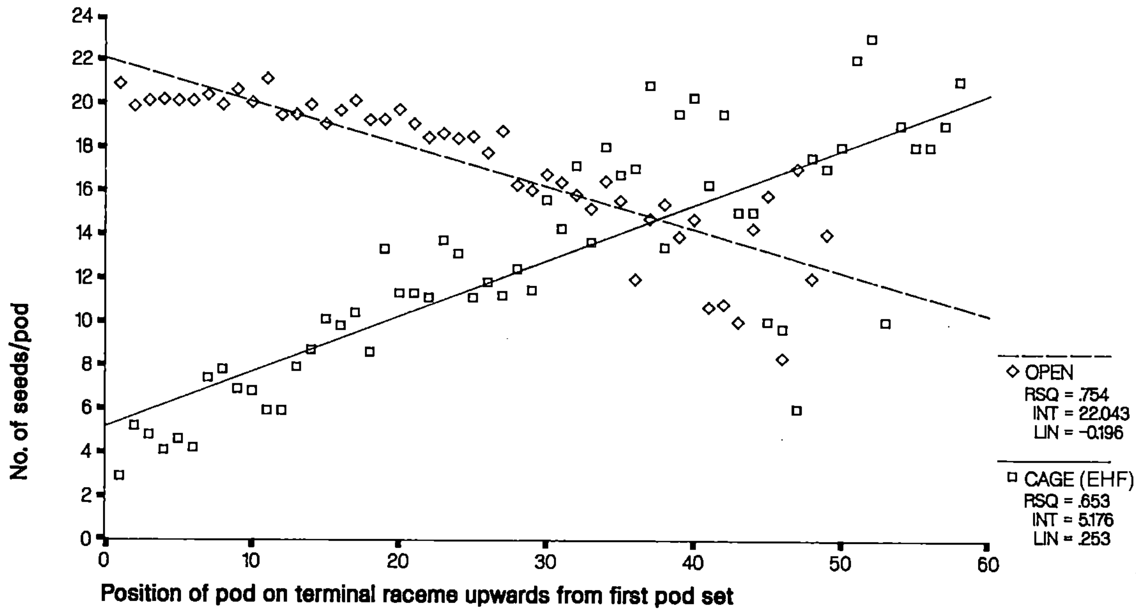

Fig. 1. Relationship between the position of a pod on the terminal raceme and the number of seeds it contains on plants on open and EHF treatments in 1978.

The influence of environmental factors on yield and yield components

The results were not uniform in all experiments. The differences between sites and years can partly be explained by variations in weather and soil factors. Further, the cage treatments BHF and EHF were not identical in 1979 and 1980.

In 1977 on sandy sloping site II, drought obviously affected the growth at the later phase of flowering and thus open plots could not produce as much seed on lateral racemes as plants on other sites. This can be seen in the lower values of all lateral branch yield components compared with other sites. On site IV, on the other hand, the smaller difference in open and NB treatment yields was caused by considerable damage due to blossom beetle (Table 1, blind stalks), especially on open plots. On these, the number of pods on the main racemes was lower than on other sites and even lower than that on NB treatment.

In 1979—1980 there were three bee cage treatments. In 1979 the EHF and in 1980 the BHF treatment yields and yield components were best from these treatments (Tables 3 and 4). In 1980 the change of bees from BHF to EHF cages was made much later in relation to flowering stage than in 1979, which partly explains the differing results. Weather conditions also influenced the results, however. In 1979 the weather was rather good during the initial phase of flowering (Table 6), and the seed number/pod was higher in the basal pods than in the top pods of the main raceme. However in 1980 the weather was rainy during the initial phase of flowering and bee activity was thus low. Bees started foraging on rape not until crops reached the 100 % flowering stage. Thus there were not only on EHF plants, but also on EF and open treatments no more seeds/pod in the basal part of the main raceme than in the upper part. On BHF plants, however, the upper pod seed number must also have been influenced by the bees owing to the late change of bees from BHF to EHF plots.

Table 6. Weather data for 1977—1983 pollination experiments.

Year	Flowering stage	Date	Site or treatment	Sunshine hours $\bar{x}$	Max. temp. °C $\bar{x}$	rain mm $\bar{x}$	RH $\bar{x}$	Total flight hours
1977	initial phase	6—13.7.	I, III	10.1	21.2	0.5	46	80
		6—11.7.	II, IV	7.7	22.0	0.3	46	60
	final phase	14—28.7.	I, III	3.8	16.8	5.9	76	52
		12—20.7.	II, IV	4.9	16.5	6.6	69	32
1978	initial phase	26.6.—8.7.	I, IV	5.7	20.4	2.6	62	99
		26.6.—4.7.	II	6.5	20.4	1.8	60	70
		26.6.—6.7.	III	5.6	20.5	2.4	62	84
	final phase	9—18.7.	I, IV	4.1	16.9	2.6	73	66
		5—14.7.	II	2.8	18.3	3.7	74	65
		7—18.7.	III	4.4	17.3	2.8	71	81
1979	initial phase	26.6.—4.7.	BF	7.4	18.2	1.6	59	71
	final phase	5—20.7.	EF	4.7	18.1	4.1	74	89
1980	initial phase	24—29.6.	BF	5.6	17.6	3.5	68	35
	middle phase	30.6.—7.7.	BF	7.2	19.3	0.2	56	66
	final phase	8—17.7.	EF	8.8	21.1	2.0	55	90
1981		29.6.—20.7.		8.8	21.1	2.0	55	
1982		2—19.7.		11.5	22.5	0.6	49	
1983	initial phase	1—13.7.		10.9	23.9	0.3	49	
	final phase	14—27.7.		9.4	20.8	2.1	61	

BHF = cages with bees during the beginning half of flowering, EHF = cages with bees during the end half of flowering
initial phase = time since bee activity started on the rape crop up to 6 days after crop reached 100 % flowering
middle phase = in 1980 time after initial phase until change of bees from BHF cages to EHF cages
final phase = time after initial phase, 1980 after initial and middle phase, until end of flowering

DISCUSSION

The yield differences between NB and open plots were many times of the same magnitude as in cage experiments of LANGRIDGE and GOODMAN (1975) and FRIES and STARK (1983). However these differences, as well as differences between cage treatments with and without bees, varied greatly between years and sites which indicate the great influence of environmental factors other than bee pollination. The reason for the consistently lower yields of best bee treatments compared to open plot yields is not clear. However, plant number/plot may have been lower in cages than on open plots. The setting up of the cages may decrease the number of plants bordering the cages (cf. 13 and 24 % more plants on open plots in the studies of LANGRIDGE and GOODMAN (1975) and FREE and NUTTALL (1958), respectively).

The yield difference between cage treatments with and without bees tended to decrease as the yield level of open plots increased. In 1982 yield level was lowest, ca. 700 kg/ha and the difference between cage treatments was the highest, 59 % and in 1979 and 1983 when seed yields were ca. 1900 kg, it was the lowest, ca. 10 %. Intermediate yields in 1980 and 1981 were also intermediate in this response to pollinator activity.

The best seed yields were obtained in 1979 and 1983. Clear differences in weather and plant stand conditions existed. In 1979 the weather turned rainy at mid-flowering and plants were lodged. In 1983 the weather stayed sunny (Table 6), and plants were not lodged. One may suppose that in 1979 pollination by pollen transported by wind and also wind-aided self pollination by plant shaking were less efficient than in 1983, and the effect of bee pollination was thus more clear in the 1979 results.

Bee activity data for 1983 are available only for June 11 with warm (29 °C), sunny weather. Bee density on cage plots was then 2.4 bees/m^2. Thus, bee activity was not lower than in earlier years (Table 7).

Table 7. Number of honeybees and bumblebees in 1977—1978 on different sites and in 1979—1982 on different treatments.

Year	Site or treatment	No. of insects/m^2		No. of counts
		honeybees	bumblebees	
1977	I	0.52	0.02	14
	II	0.80	0.02	14
	III	0.49	0.02	14
	IV	0.19	0.01	14
1978	I	0.65	0.09	17
	II	0.40	0.04	17
	III	0.53	0.04	17
	IV	0.32	0.21	17
1979	open	0.57	0.23	17
	BHF	2.04		7
	EHF	1.01		10
	EF	1.62		17
1980	open	0.63	0.05	14
	BHF	1.70		7
	EHF	1.70		7
	EF	1.20		14
1981	open	0.95	0.08	9
	EF	2.85		9
1982	open	0.24	0.01	4
	EF	2.77		4

For treatment explanations see Table 3

Obviously when wind pollination is favoured by windy and dry weather and plants develop in optimal growing conditions, pollinator activity does not affect the yield as much as during weather with lower wind velocities and a higher humidity level of the air and plants.

The lack of correlation between the yields and the density of pollinators on the plots in different experiments indicates that the differences in other variables between the conditions in each experiment may have masked the effects of differences in bee activity. Pollinator densities were also quite similar in different experiments. Although the yield difference between open plots and cages without bees is not the same as the benefit from insect pollination, by this comparison it is probably possible to reveal sites which benefit most from insect pollination, as also suggested by STARK and FRIES (1983). Accordingly in 1978, at sites II, III and IV there were an average of 0.51 bees/m^2 and the above yield difference was 34.6 %, but at site I, where bee density was 0.74 bees/m^2, the yield difference was 62.6 %.

There were some indications of compensational response in rape plants for poor seed set. Well-pollinated plants in cages with bees and open plots typically finished flowering 2—3 weeks earlier than plants in cages without bees. Furthermore, plants compensated for inadequate pollination by producing heavier seeds (Tables 1—5). Despite this compensation it is probable that in all growing situations turnip rape benefits from insect pollination. The exact nature of the influence of weather on the relative importance of wind and insect pollination still needs to be investigated further.

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SELOSTUS

Mehiläispölytyksen vaikutus rypsin satoon ja satokomponentteihin

SEPPO KORPELA

Maatalouden tutkimuskeskus

Maatalouden tutkimuskeskuksen tuhoeläinosastolla järjestettiin vuosina 1977—1983 häkkikoesarja, jonka tarkoituksena oli selvittää mehiläispölytyksen vaikutusta rypsin satoon ja satokomponentteihin: litujen määrä ja siementen määrä/litu. Vuosina 1979—1983 kokeissa oli avoimien ruutujen ja mehiläisettömien häkkien lisäksi myös häkkikoejäsenet, joissa häkkeihin oli asetettu pölyttäjiksi pienoismehiläiskunnat joko koko kukinnan ajaksi tai kukinnan alku- tai loppujakson ajaksi. Mehiläisten toiminta häkeissä näkyi etenkin siementen määrä/litu lisääntymisenä, mutta myös litujen määrän lisääntymisenä. Mehiläisettömien häkkien kasvit kompensoivat huonoa pölytystä kukkimalla 2—3 viikkoa pitempään kuin mehiläisten hyvin pölyttämät häkkikasvustot ja avoimet ruudut. Niissä myös 1000 siemenen paino oli yleensä 10—20 % suurempi, mutta silti mehiläishäkeissä oli kaikissa kokeissa parempi sato kuin mehiläisettömissä.

Ympäristötekijöiden erot eri kokeiden välillä aiheuttivat suuria eroja siemensatoihin ja on luultavaa, että niistä johtuivat myös erot mehiläisten satoa lisäävässä vaikutuksessa. Hyvissä kasvuolosuhteissa ja sään suosiessa tuulipölytystä mehiläishäkkien sato oli n. 10—15 % suurempi kuin mehiläisettömien häkkien, mutta alemmilla satotasoilla tai sään ollessa epäsuotuisa tuulipölytykselle, satoero oli suurempi.

Pölyttäjälaskennoissa mehiläisiä oli eri kokeissa ja eri vuosina avoimilla ruuduilla 0.19—0.95 kpl/m^2. Kimalaisten määrä oli vain yhdellä n. 1 ha koepaikalla kahtena vuotena (paikka IV, vuodet 1978 ja 1979) n. 0.2 kpl/m^2. Muissa kokeissa (myös paikalla IV vuosina 1977 ja 1980—1982) niitä oli vain 0.01—0.09 kpl/m^2. Normaalisti vain mehiläiskuntien sijainti rypsiviljelysten välittömässä läheisyydessä varmistaa riittävän suuren pölyttäjäkannan. Yleisohjeena pidetään 2—3 mehiläisyhdyskuntaa hehtaarille. Mehiläisten määrä kasvustolla riippuu kuitenkin rypsin viljelyalasta mehiläisten taloudellisen lentosäteen, n. 1.5 km, sisällä sekä samalla alueella olevista kilpailevista kasvilajeista. Mahdollisesti siihen vaikuttavat myös rypsilajikkeiden houkuttelevuuserot.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 305—314 (1988)

Seria ANIMALIA NOCENTIA N. 132 — Sarja TUHOELÄIMET n:o 132

OCCURRENCE OF PHYTOSEIID MITES (ACARI: PHYTOSEIIDAE) ON APPLE TREES IN FINLAND

DANUTA KROPCZYŃSKA and TUOMO TUOVINEN

KROPCZYŃSKA, D. and TUOVINEN, T. 1988. **Occurrence of phytoseiid mites (Acari: Phytoseiidae) on apple trees in Finland.** Ann. Agric. Fenn. 27: 305—314. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

Predatory mites of the family Phytoseiidae were identified and counted from a total of 9800 apple tree leaves collected in sprayed and unsprayed orchards or from home gardens (N = 40) in southern and central Finland. The most common species were *Euseius finlandicus* (found in 76 % of the samples containing phytoseiids), *Phytoseius macropilis* (66 %) and *Paraseiulus soleiger* (39 %). Other identified species were *Amblyseius canadensis, Amblyseius cucumeris, Anthoseius rhenanus, Anthoseius bakeri, Typhlodromus richteri* and *Typhlodromus gilvus.*

Phytoseiid mites were very scarce in sprayed orchards and could be found in 24 % of the samples but in unsprayed trees they averaged 1 mite per leaf and were found in 95 % of the samples. The European red spider mite averaged 15 mites per leaf in sprayed orchards and only 1 mite per leaf in unsprayed trees. Eriophyid mites were slightly more abundant in sprayed trees than in unsprayed ones.

Index words: apple tree, natural control, Phytoseiidae, *Panonychus ulmi, Euseius finlandicus, Phytoseius macropilis, Paraseiulus soleiger, Amblyseius canadensis, Amblyseius cucumeris, Anthoseius rhenanus, Anthoseius bakeri, Typhlodromus richteri, Typhlodromus gilvus.*

INTRODUCTION

The European red spider mite *Panonychus ulmi* (Koch) is one of the major pests of apple trees in Finland. In Finland the control of this pest is based on the use of the acaricides dicofol and chinomethionate and, in some cases, spring sprayings with tar oils or paraffin oil. Summer sprays containing organophosphates and pyrethroids used in the control of pest insects have been suspected to eliminate the predators of mites and thus causing outbreaks of the European red spider mite.

The aim of this study was to search for predators of the European red spider mite. Earlier, LISTO et al. (1939) thoroughly studied the life cycle as well as natural enemies of the European red spider mite in Finland, and noticed that there are some predatory mites which may be of importance, but not one of the species was identified. Because in many studies the mites of the family Phytoseiidae have proven capable of maintaining the spider mites at population densities below the economic threshold level, they were selected as the object of this study. A short account of the species found in this study has been published earlier (KROPCZYŃSKA and TUOVINEN 1987).

Finnish orchards are of particular interest in this kind of survey for several reasons: 1. the climate is so extreme that only species well adapted to low temperatures (even below -30 °C) can survive; 2. there are plenty of different natural habitats close to cultivated areas where numerous natural enemies of the pest species might be expected to occur; and, 3. the number of pests in orchards is restricted to a few important species which makes the integration of natural or biological and chemical control methods easier than in southern climates which have many pest species.

MATERIAL AND METHODS

Samples of 100 apple leaves were randomly collected from 40 orchards or home gardens in southern and central Finland in 26 localities (counties). Samples were taken between August 12 and September 23 in 1985. Half of the total number of 98 samples were taken from unsprayed trees, usually in small home gardens, and half from commercial orchards where insecticides, fungicides and acaricides were regularly used. A typical spraying program includes 1—3 insecticidal, 1—2 acaricidal and 4—6 fungicidal treatments, which are often combined. Leaf samples were collected in plastic bags and stored at +5 °C for 1—5 days before the inspection and counting of mites. All mite groups present on leaves were noted, and their numbers either counted or estimated. Phytoseiid mites were collected and preserved in alcohol before mounting for identification. Some samples were collected also from *Prunus, Acer* and *Tilia.*

RESULTS AND DISCUSSION

General

A general view on the occurrence and the abundance of the mites from the families Phytoseiidae, Tetranychidae (almost entirely *P. ulmi),* Tydeidae, Eriophyidae and Tarsonemidae is presented in Table 1. The average numbers of phytophagous mites, especially the red spider mites and gall mites, are partly based on estimates.

A general trend was that phytoseiids were present in almost all unsprayed trees and in only about one-fourth of sprayed ones. The occurrence and average density of spider mites

Table 1. Occurrence and abundace of various mite groups on apple trees in leaf samples collected in southern and central Finland in August and September 1985.

Mite group	Occurrence, % of the samples		Abundance, mites/leaf	
	unsprayed	sprayed	unsprayed	sprayed
Phytoseiidae	95	24	1.2	0.05
Panonychus ulmi	88	53	1.0	15.0
Tydeidae	80	26	3.1	0.8
Eriophyidae	62	62	5.2	8.5
Tarsonemidae	24	18	0.2	0.2

in sprayed and unsprayed trees was quite opposite to that of phytoseiids. The following situation was found in commercial orchards of all apple growing regions: harmful insecticides decreased the incidence of natural enemies and resulted in higher spider mite populations.

Tydeid mites were more frequent and present in higher densities on unsprayed than on sprayed apple trees. They feed mainly on detritus and fungi and thus are not important pests of apple trees in Finland.

Eriophyid mites occurred in equal frequency on sprayed and unsprayed trees, the average density being slightly higher for sprayed trees. This may be the result of the lower incidence of predacious mites which feed on eriophyids. Eriophyids seek for hibernation places in late August and thus they were totally absent in later leaf samples.

Tarsonemidae occurred in a low percentage of the samples and in a very low average population density. They are of no importance as a food source for predacious mites.

Occurrence of Phytoseiidae

In this study nine species of phytoseiid mites were collected and identified. The generic classification used herein is that of KARG (1983). Illustrations of the female ventrianal shields and spermathecas of each species are included to show characteristic details to facilitate identification (Figs. 1 and 2).

Euseius finlandicus (Oudemans 1915)
Seiulus finlandicus Oudemans 1915

E. finlandicus has been recorded in many countries throughout Europe, Asia and North America. The species has been collected on a wide range of plants including orchard trees, deciduous trees, shrubs and herbs (CHANT 1959, KROPCZYŃSKA 1970, CHANT and HANSELL 1971, KARG 1971, 1982). Scandinavian records of the species are from apple and prune leaves, as well as from a large variety of deciduous trees, shrubs and herbs in Denmark (HANSEN and JOHNSEN 1984) and Norway (EDLAND 1986, 1987). The first record of this species is from *Salix*, Finland (OUDEMANS 1915).

E. finlandicus is a fast moving species with globular, pale idiosoma. The dorsal shield is weakly sclerotized with slight reticulation. It is characterized by having preanal setae on the ventrianal shield in an almost transverse row (Fig. 1 a). All setae on the body are short.

Microscopic examination indicated that specimens collected in Finland are identical to those collected in Central Europe.

E. finlandicus appeared to be the most common phytoseiid on apple trees in Finland, being found in 76 % of samples containing phytoseiids. It was present also in the northernmost localities and was found also on plum trees. It frequently occurred in the presence of the apple rust mite *Aculus schlechtendali* Nal. (Eriophyidae). In these cases predatory mites displayed light brown gut coloration, indicating that they prey on eriophyiids. *E. finlandicus* was also observed on apple trees where there were no phytophagous mites which is quite typical to this species. It was found also on *Prunus cerasus*, *P. padus* and *Tilia cordata*.

Phytoseius macropilis (Banks 1909)
Sejus macropilis Banks 1909

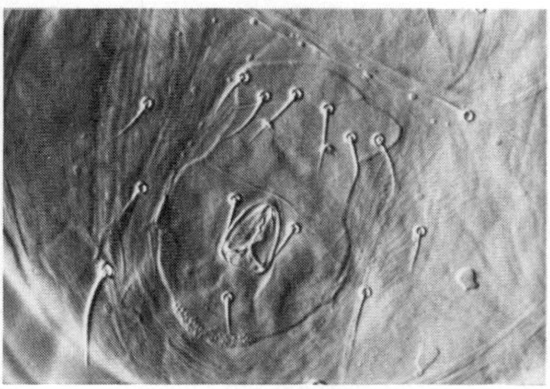
Ph. macropilis is widely distributed throughout Europe, North America, Australia and India in orchards and on many deciduous trees, shrubs and herbs (CHANT 1965, KARG 1971, 1982, BEGLYAROV 1981). It is quite common on trees and shrubs in Denmark and Norway (JOHNSEN 1986, pers. comm., EDLAND 1986, 1987).

Ph. macropilis is a slow moving species and is easily recognizable because of its long, thick and heavily serrated setae. The long, vase-shaped ventrianal shield has a variable number (1—3 pairs) of preanal setae (Fig. 1 b). The dorsal shield has a distinct sculpture.

Ph. macropilis occurred almost as frequently on apple trees as did *E. finlandicus.* It was found in 66 % of samples containing phytoseiids. Very often, both species inhabited the same leaves. In central and western Byelorussia in the USSR, *Ph. macropilis* is the dominant species together with *Anthoseius rhenanus* (SIDLYAREVITCH 1982). *Ph. macropilis* was observed on leaves that had many eriophyid and tydeid mites as well as spores of *Cladosporium* spp. The dark colorization of the gut showed that this species feeds also on spores of this fungus. *Ph. macropilis* was found on *Prunus cerasus* as well.

***Paraseiulus soleiger* (Ribaga 1902)**
***Seiulus soleiger* Ribaga 1902**

P. soleiger has been collected from a wide variety of deciduous trees including orchard trees in Europe, Canada, Asia and Australia (CHANT 1959, KARG 1971, CHANT and YOSHIDA-SHAUL 1982). Records from the Scandinavian countries are from Denmark on *Aesculus hippocastanea* and on *Alnus glutinosa* (HANSEN and JOHNSEN 1984), and from Norway on apple, plum and various berry-bushes (EDLAND 1986, 1987).



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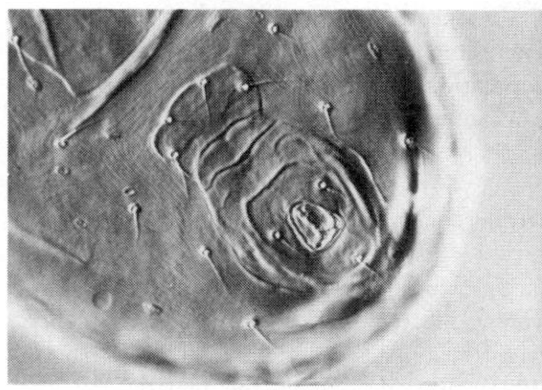

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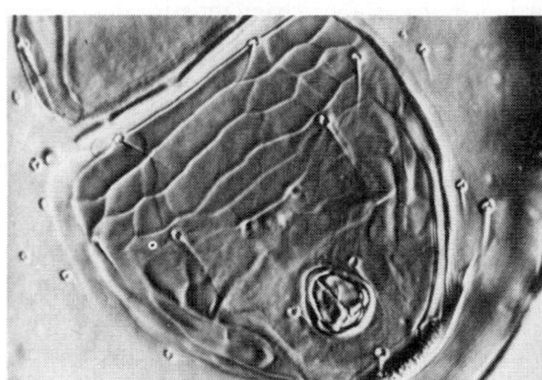

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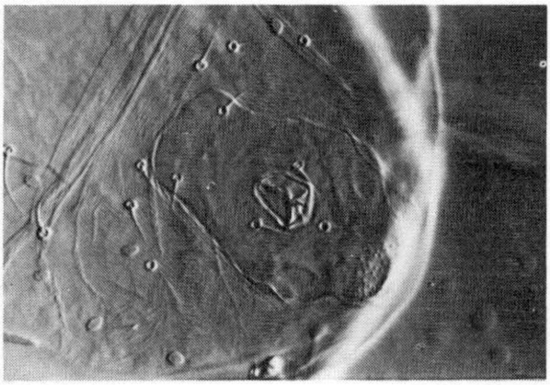

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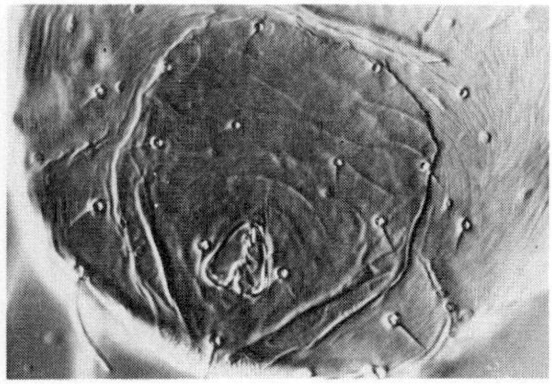

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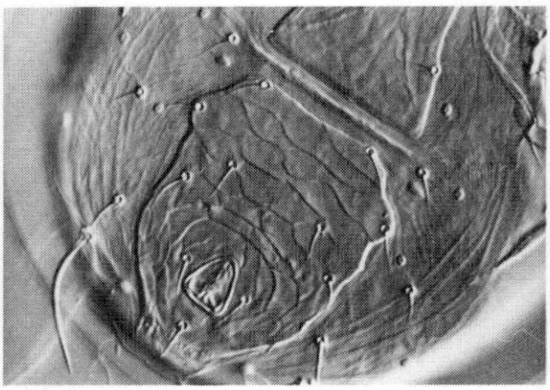

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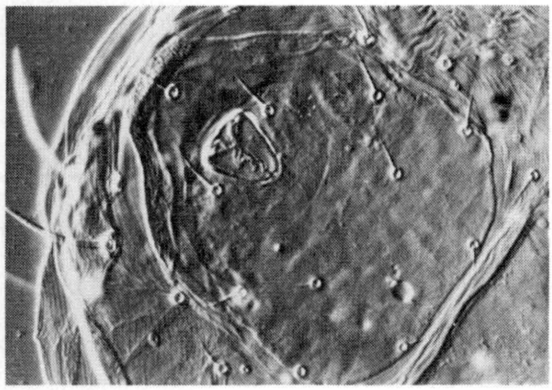

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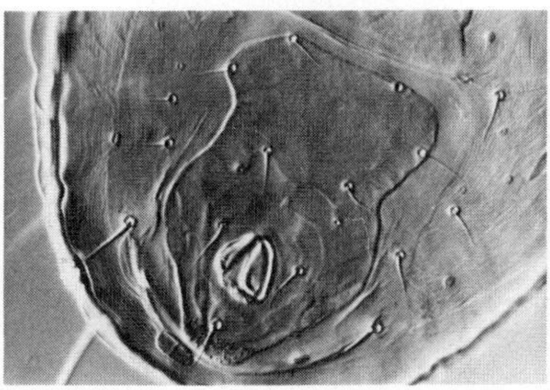

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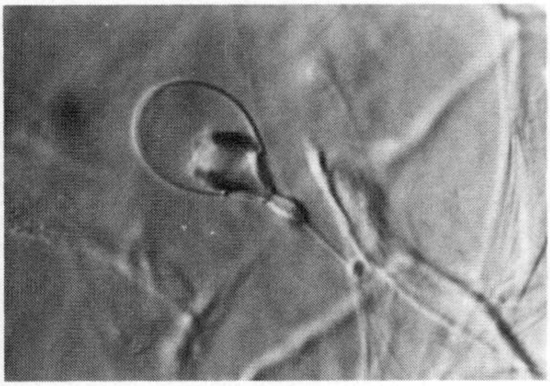
Fig. 1. Female ventrianal shields of phytoseiid mites: a) *Euseius finlandicus*, b) *Phytoseius macropilis*, c) *Paraseiulus soleiger*, d) *Amblyseius canadensis*, e) *A. cucumeris*, f) *Anthoseius rhenanus*, g) *A. bakeri*, h) *Typhlodromus richteri*, i) *T. gilvus*.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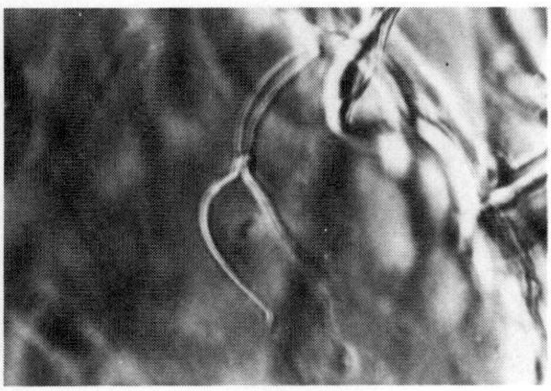
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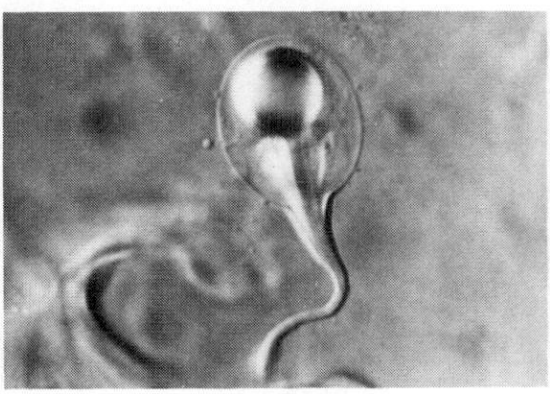
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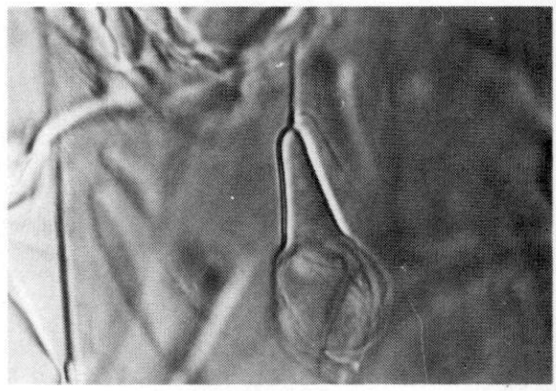
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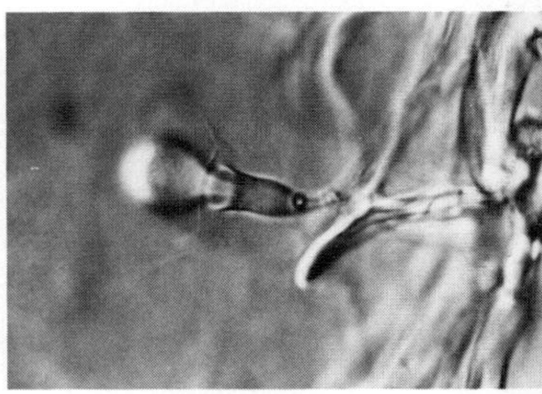
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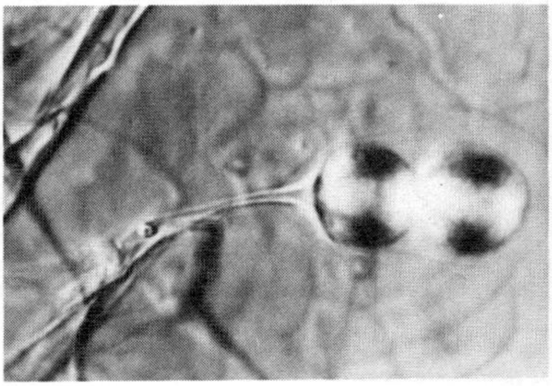

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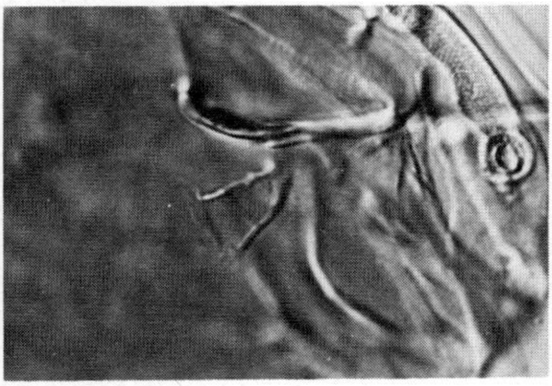

2h

Fig. 2. Spermathecas of phytoseiid mites: a) *Euseius finlandicus,* b) *Phytoseius macropilis,* c) *Paraseiulus soleiger,* d) *Amblyseius canadensis,* e) *A. cucumeris,* f) *Anthoseius rhenanus,* g) *Typhlodromus richteri,* h) *T. gilvus.*

P. soleiger can be recognized by its strongly sclerotized and distinctly reticulated, brown dorsal shield. It has a long ventrianal shield with a distinct waist and two pairs of preanal setae (Fig. 1 c).

In Finland *P. soleiger* appeared to be one of the three most common phytoseiids on apple trees. In the present survey it was collected in 13 out of 26 localities and was found in 39 % of samples containing phytoseiids. On some apple trees mites were very abundant and quite often they occurred together with *E. finlandicus* and *Ph. macropilis.* This species was found also in samples from *Prunus padus, Tilia cordata* and *Acer* sp.

Amblyseius canadensis (Chant & Hansell 1971)

Previous records of *A. canadensis* are from Canada on willow, muskeg, osier, birch, aspen, poplar, prune and labrador tea (CHANT and HANSELL 1971).

This species is easy to distinguish by its globular shape and dark brown coloration. The dorsal shield is sclerotized and markedly reticulate. It has a sclerotized, convex ventrianal shield as long as it is wide with 3 pairs of preanal setae and a pair of pores (Fig. 1 d).

In this study *A. canadensis* was found in 4 localities, mostly in the northern part of the collection area. As a rule there were only a few specimens of this species on apple leaves.

Amblyseius cucumeris (Oudemans 1930)
Typhlodromus cucumeris Oudemans 1930

A. cucumeris is distributed worldwide occurring on wide variety of plants and also in greenhouses (KARG 1971).

The body of this mite is lightly sclerotized and reticulate. Setae on the dorsum are relatively short. The dorsal shield has a number of large and small pores. The ventrianal shield is longer than it is wide, being lightly reticulate, with three pairs of preanal setae and one pair of pores (Fig. 1 e).

A. cucumeris was collected from 6 localities where it occurred often on apple leaves inhabited by eriophyiids. Several of these mites were observed feeding on eriophyiid mites. In two of the samples no prey mites were present on the leaves from which *A. cucumeris* was found.

Anthoseius rhenanus (Oudemans 1905)
Seiulus rhenanus Oudemans 1905

A. rhenanus is known to occur in Europe and North America on orchard and deciduous trees, while not as frequently on shrubs or herbs (CHANT 1959, WESTERBOER and BERNHARD 1963, KARG 1971, BEGLYAROV 1981, SIDLYAREVITSCH 1982). In Denmark it occurs on wide variety of plants: e.g. *Fagus silvatica, Aesculus hippocastanea, Rubus* spp., *Sambucus nigra* and apple trees (HANSEN and JOHNSEN 1984) and in Norway on various shrubs and herbs (EDLAND 1986, 1987).

This species has a dorsal shield sclerotized with a very conspicuous reticulation. Dorsal setae are moderately long. The ventrianal shield is subquadrate, reticulate and with four pairs of preanal setae (Fig. 1 f).

In the present study *A. rhenanus* was found on apple leaves only in one location in southwestern Finland. No phytophagous mites were present on the leaves of this sample. One specimen was found also on *Acer* sp.

Anthoseius bakeri (Garman 1948)
Seiulus bakeri Garman 1948

A. bakeri is widely distributed, known in Europe, North America and Australia to occur on deciduous trees and numerous herbs (CHANT 1959, WESTERBOER and BERNHARD 1963, KARG 1971). This species has also been collected in Denmark on *Fraxinus excelsior, Alnus glutinosa* and *Rosa* spp. (HANSEN and JOHNSEN 1984) and in Norway on apple tree and various shrubs and herbs (EDLAND 1986, 1987).

A. bakeri is a large and slow moving species, and is distinguished by a strong sclerotization of the dorsal shield and short dorsal setae. The ventrianal shield has a distinctive reticulation and four pairs of preanal setae and one pair of pores (Fig. 1 g).

A. bakeri was found in samples from 4 localities. It always occurred in very low densities, usually only a few mites per sample.

Typhlodromus richteri Karg 1970

T. richteri occurs in Central Europe and has been collected from forests in litter (KARG 1970, 1971). This species resembles *A. bakeri* and *A. rhenanus*, but it can be separated from them by the number of teeth on the digitus mobilis, the presence of seta Z1 and the absence of seta S2.

In this survey *T. richteri* was collected in 5 localities and always in low numbers.

Typhlodromus gilvus Wainstein 1975

This species has been collected earlier in the Jaroslav region of the USSR on bird cherry (WAINSTEIN 1975).

T. gilvus is characterized by a dorsal shield that is slightly reticulated with three pairs of conspicuous pores, a ventrianal shield with a distinct waist and three pairs of preanal setae and one pair of pores (Fig. 1 i).

In this study, 15 females of *T. gilvus* were found on apple in one location in southwestern Finland. This species occurred in the association of four other phytoseiids: *E. finlandicus, Ph. macropilis, P. soleiger* and *A. bakeri.*

CONCLUDING REMARKS

Of the nine phytoseiid species collected from apple trees, *E. finlandicus, Ph. macropilis* and *P. soleiger* were the most common. *E. finlandicus* has been shown to be a predator of the European red spider mite in Poland (KROPCZYŃSKA 1970) and in The Netherlands (van de VRIE 1973). Although attempts to mass breed this species have not been successful (OVERMEER 1981), further studies on the exploitation of this species are needed for estimation of its value in the biological control of red spider mites.

Ph. macropilis and *P. soleiger* seem to prefer the same habitat as that of *E. finlandicus*. Relatively little is known about their food requirements or consumption; more detailed studies are needed to assess their potential as a possible control agent of spider mites.

All the other species occurred in quite low densities, but *A. cucumeris* should be studied more carefully in the future, because of the easy mass rearing by which the two-spotted spider mite *Tetranychus urticae* Koch is used as food.

It is remarkable that the two phytoseiid species which commonly occur in Europe and are well known as important predators of the European red spider mite, namely *Typhlodromus pyri* Scheuten and *Amblyseius potentillae* Garman (McMURTRY et al. 1970) were not found in this study. The occurrence of *T. pyri* has been shown to be common in both Denmark and Norway on apple trees as well as on many other plants (HANSEN and JOHNSEN 1984, EDLAND 1986, 1987). The absence of this species in the habitats studied cannot be explained on the basis of present knowledge.

Acknowledgements — D. Kropczyńska thanks the Food and Agricultural Organization of the United Nations for the grant to conduct this study. The authors thanks Dr. Eiko Shaul for identification of *A. canadensis* and *T. gilvus*.

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SELOSTUS

Omenatarhoissa esiintyvistä petopunkeista

DANUTA KROPCZYŃSKA ja TUOMO TUOVINEN

Agricultural University of Warsaw ja Maatalouden tutkimuskeskus

Hedelmäpuupunkin tärkeimpiä luontaisia vihollisia ovat Phytoseiidae — heimoon kuuluvat petopunkit. Useissa maissa on todettu petopunkkien pystyvän pitämään hedelmäpuupunkkien määrän vahinkokynnyksen alapuolella mikäli omenapuita ei ruiskuteta petopunkeille vahingollisilla torjunta-aineilla. Koska Suomessa ei ole aikaisemmin tutkittu petopunkkien esiintymistä omenatarhoissa ja koska meillä hedelmäpuupunkin torjunnassa esiintyy vaikeuksia, katsottiinkin aiheelliseksi aloittaa selvitykset petopunkkien merkityksestä meillä.

Tutkimuksessa kerätyn lajiston määritti Maatalouden tutkimuskeskuksessa FAO:n myöntämän stipendin turvin vieraillut puolalainen tutkija tri Danuta Kropczynska Varsovan maatalousyliopistosta.

Tutkimuksessa kerättiin omenan lehtinäytteitä kesän 1985 aikana yhteensä 98 kpl, jotka olivat peräisin 40 tarhasta tai pihapuutarhasta 26 kunnan alueella. Yhdeksän eri petopunkkilajia määritettiin, näistä kolme esiintyi melko yleisenä koko näytteenottoalueella. Eniten petopunkkeja löytyi ruiskuttamattomista kotitarhoista kun sen sijaan torjunta-aineilla käsitellyillä ammattivilejyksillä petopunkkeja esiintyi erittäin niukasti. Hedelmäpuupunkin suhteen tilanne oli päinvastainen.

Tutkimus osoitti, että torjunta-aineiden käyttö aiheuttaa ongelmia hedelmäpuupunkin torjunnassa ja että hedelmäpuupunkin runsas esiintyminen ammattiviljelyksillä on osittain seurausta luontaisten vihollisten vähäisyydestä. Jatkotutkimuksilla pyritään selvittämään mahdollisuuksia integroidun torjunnan toteuttamiseen niin, että muiden tuholaisten torjunnasta aiheutuisi mahdollisimman vähän haittaa petopunkeille.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 315—322 (1988)

Seria ANIMALIA NOCENTIA N. 133 — Sarja TUHOELÄIMET n:o 133

DISTRIBUTION OF MIGRATORY PLANT PARASITIC NEMATODES IN CULTIVATED FINNISH SOILS

SIRPA KURPPA

KURPPA, S. L. A. 1988. **Distribution of migratory plant parasitic nematodes in cultivated Finnish soils.** Ann. Agric. Fenn. 27: 315—322. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

Two thousand two hundred samples were collected from cultivated Finnish soils. Of the root lesion nematodes *Pratylenchus crenatus* was the most common and occurred in 12 % of the samples. In addition, *P. neglectus* and *P. pratensis* were distributed throughout the country. *P. vulnus* occurred in fields in direct contact to greenhouses. *Rotylenchus robustus* was uncommon but *R. fallorobustus* was found in 12 % of the samples. *H. pseudorobustus* and *H. digonicus* were distributed throughout the country, but were present in less than 3 % of the samples. Central Finland formed the northern borderline for the distribution of *H. canadensis, H. vulgaris* and *H. varicaudatus. Tylenchorhynchus* spp. was found in 45 % and *Paratylenchus* spp. in 42 % of the samples. The viability of nematodes in prevailing climatic conditions was discussed.

Index words: *Pratylenchus crenatus, P. neglectus, P. penetrans, P. pratensis, P. vulnus, Rotylenchus fallorobustus, R. robustus, Helicotylenchus canadensis, H. digonicus, H. pseudorobustus, H. varicaudatus, H. vulgaris, Tylenchorhynchus dubius, Paratylenchus* spp., soil types, edaphic conditions, climatic conditions.

INTRODUCTION

Information on plant parasitic nematodes in Finland is scarce. Some old reports of stem nematode on red clover (TINNILÄ and KANERVO 1953) and a survey on nematodes in forest nurseries (LÖYTTYNIEMI and SARAKOSKI 1978) are available. This work was part of the European Plant Parasitic Nematode Survey, in which Finland is a participant. The European survey concentrated on virus vector species. Data on Finnish fauna has been published recently in the Atlas of Plant Parasitic Nematodes in Fennoscandia (ALPHEY 1985). Information concerning all other potential migratory plant parasites is presented here. This paper aims to give a qualitative description of Finnish migratory nematode fauna and discuss the climatic and edaphic background for nematode distiribution.

MATERIAL AND METHOD

Two thousand two hundred samples were collected in May—July 1979 and 1980 from cultivated soils, including arable land, nurseries and private gardens, throughout the country. Soil type varied from clay to sand and peat (Fig. 1). The distribution of soil types among samples represented the typical distribution of soil types in the area. Sampling depth was 20 cm and samples were taken with an auger or spade. Each 0.5 liter sample, was combined from several pooled subsamples. If necessary, samples were stored for a few days at 8 °C in the laboratory.

Nematodes were extracted from two 50 g aliquots of each sample by the modified sugar-flotation technique (CAVENESS and JENSEN 1955). This method was chosen because it is known to extract a wide spectrum of nematodes (HARRISON and GREEN 1976). Nematodes were heat killed at 60 °C and fixed in triethanolamine formalin (TAF). Subsamples of the specimens belonging to plant parasitic groups were mounted in glycerol. Soil types were identified by the Soil Analysis Service Ltd, Helsinki, Finland.

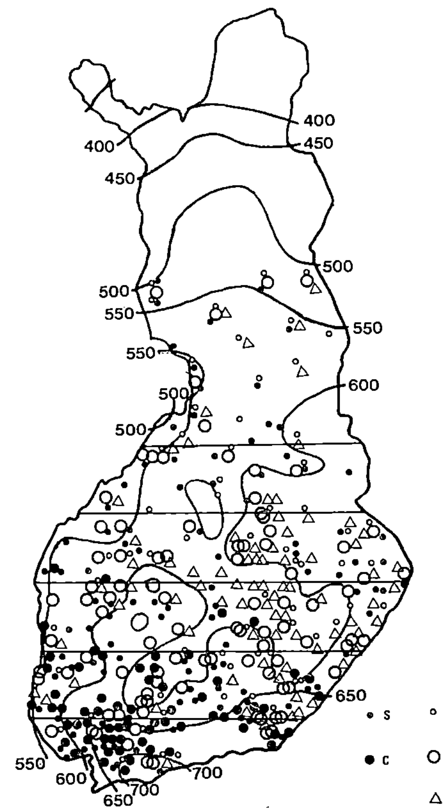

Fig. 1. Sampling sites marked according to the soil type, S = sand, C = clay, P = peat, M = mould, T = till. The country has been divided into six zones. The first five from the south are 100 kilometers broad but the northernmost zone covers the whole of northern Finland. The two thousand two hundred samples came from the zones from south to north as follows: 1. 30 %, 2. 23 %, 3. 17 %, 4. 19 %, 5. 5 % and 6. 6 % of the total number. The mean annual precipitation (1931—1960) is marked in millimeters.

RESULTS

1. Root lesion nematodes, *Pratylenchus* spp.

The most injurious root parasite of this genus, *P. penetrans*, occurred throughout the country being, slightly concentrated in southwestern and central Finland, however (Fig. 2, Table 1). In the north distribution extended to the ± 0 °C isotherm of annual daily mean temperature. It was found in 4 % of all samples. Of the infested samples 60—80 % were of finesand. In addition *P. penetrans* was found in finesandy clay and finesandy till.

P. crenatus, occurred throughout the area sampled and was most frequent in the southwestern coast and certain areas of the central Finland. Of all samples 18 % were

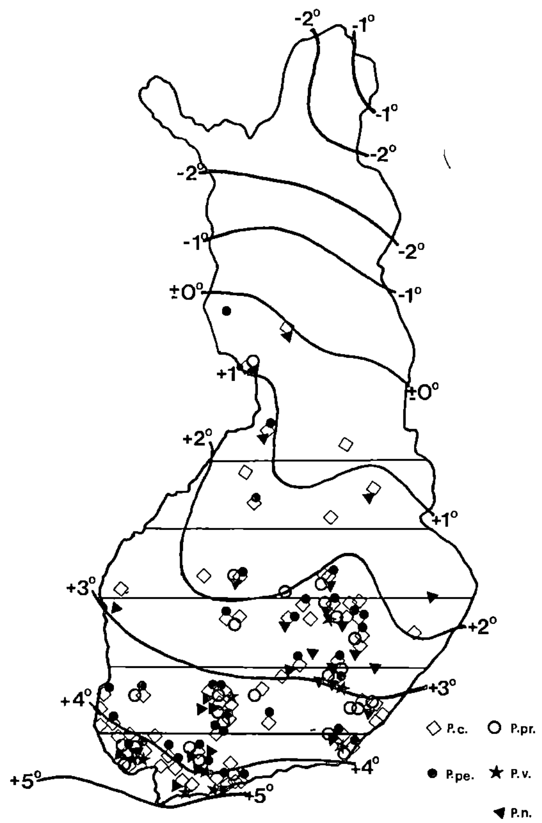

Fig. 2. Distribution of *Pratylenchus* spp. in cultivated Finnish soil. *P. c.* = *P. crenatus*, *P. n.* = *P. neglectus*, *P. pe.* = *P. penetrans*, *P. pr.* = *P. pratensis*, *P. v.* = *P. vulnus*. Annual daily mean temperature (1931—60) isotherms marked on the map.

Table 1. Occurrence of *Pratylenchus* spp. in cultivated Finnish soil from the south (zone 1) to the north (zone 6), percentages of samples infested.

	Zone					
	1	2	3	4	5	6
	Percentage samples infested					
P. crenatus	15	28	24	10	18	6
P. neglectus	2	2	4	2	1	2
P. penetrans	5	5	4	1	1	2
P. pratensis	2	3	3	1	0	.1
P. vulnus	2	1	.2	0	0	0

infested. In the south (zone 1) 40 % of the infested samples were in clay or silty clay and 37 % in finesand. Further north, infestations originated from finesand, in 20—50 % of infested samples, or finesandy till, in about 50 % of infested samples, or clay.

P. neglectus occurred in 2.4 % of all samples. It was present up to the ± 0 °C isotherm and tended to occur in the same areas as *P. penetrans* or *P. crenatus*. Of the infested samples 40 to 60 % were from finesand. All other infestations in the south occurred in silt or finesandy clay and in the central areas from finesandy till.

P. pratensis occurred as that described above in 2.4 % of all samples. There was one sample from the far north but most samples came from southern and central Finland. *P. pratensis* came from silt and finesandy clay in the south and finesand or finesandy till further in the central areas.

P. vulnus was present very occasionally, in 0.7 % of all samples. Distribution extended to the +2 °C isotherm. Infested samples were from finesandy till or finesandy clay. Infested sites were private gardens or nurseries in direct connection to greenhouses or to material from greenhouses which recently had been planted on the area.

2. Spiral nematodes, *Rotylenchus* spp. and *Helicotylenchus* spp.

R. fallorobustus was by far the most common of all spiral nematodes (Fig 3, Table 2). It occurred in 16 % of all samples. In the south (zone 1) most of the infested samples, 55 %, came from clay soil or from finesand, 24 %. Further north the nematodes were extracted

Table 2. Occurrence of spiral nematodes in cultivated Finnish soil from the south (zone 1) to the north (zone 6), in the percentage of infested samples.

	Zone					
	1	2	3	4	5	6
	Percentage samples infested					
H. canadensis	2	.4	0	0	0	0
H. digonicus	3	2	.3	1	0	.6
R. fallorobustus	25	18	12	7	16	9
H. pseudorobustus	2	3	5	3	1	2
H. varicaudatus	1	2	.3	0	0	
H. vulgaris	3	3	3	0	0	0

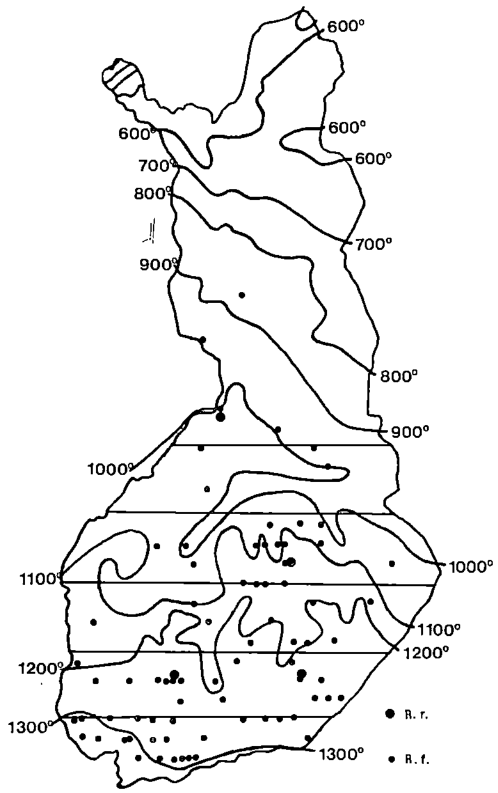

Fig. 3. Distribution of *Rotylenchus* spp. in cultivated Finnish soil. *R. f.* = *R. fallorobustus*, *R. r.* = *R. robustus.* Accumulated day-degrees °C above 5 °C of the growing season, mean daily temperature permanently above 5 °C, is marked on the map. The length of the growing season varies from 180 days (zone 1) to 100 (zone 6).

from 47 % of the infested samples from finesand, and finesandy till. A few infestations, 6 %, were from peat.

The other *Rotylenchus* species *R. robustus* was found only at 3 sites (Fig. 3).

H. pseudorobustus occurred in 2.6 % of all samples. It was the most widely distributed species of all *Helicotylenchus* spp. (Fig. 4). In the south (zone 1) this nematode was found in finesand, in 65 % of the infested samples, or finesandy clay, in 17 % of the infested samples. Further north infestations were spread by peat or mould in 30 to 40 % of cases, or from finesandy till, in 20 to 30 % of the samples, or from finesand. *H. digonicus* occurred in 1.5 % of the samples. These were from finesand and finesandy or silty clay. They came from southern areas except of two samples which originated from the far north.

All of the following *Helicotylenchus* species were present only in southern and central Finland (Fig. 4, Table 2). *H. vulgaris* was detected in 2 % of the samples. The southern (zone 1) soil type was clay and the other areas were finesand. *H. varicaudatus* was found in 0.7 % of all samples. These came from finesand or clay soil. The last one, *H. canadensis* occurred occasionally, in 0.6 % of the samples (Fig. 4, Table 2). These were in finesandy clay or finesand.

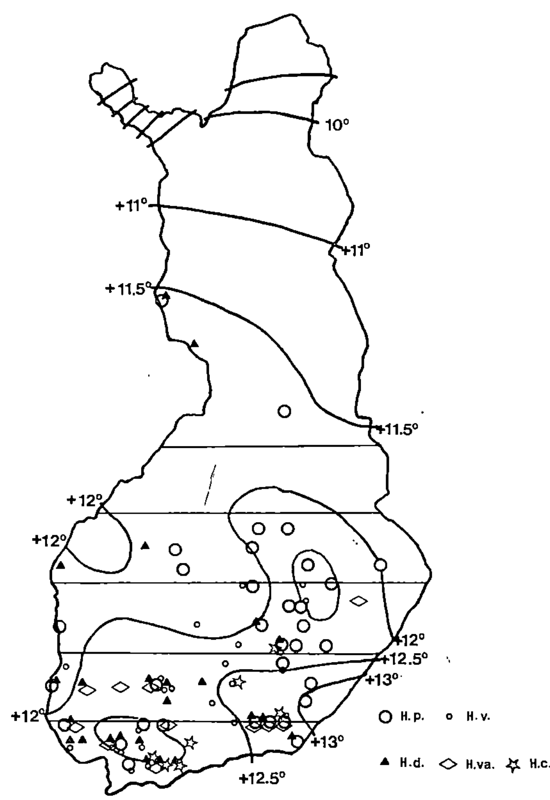

Fig. 4. Distribution of *Helicotylenchus* spp. in cultivated Finnish soil. *H. c.* = *H. canadensis*, *H. d.* = *H. digonicus*, *H. p.* = *H. pseudorobustus*, *H. va.* = *H. varicaudatus* and *H. v.* = *H. vulgaris*. The mean daily temperature of the growing season is marked on the map.

3. Other potential plant parasites

Tylenchorhynchus spp. occurred in 45 % of all samples. This genus was evenly distributed over the entire sampling area. The only species identified *T. dubius* was found in 7.7 % of all samples. Of the infested samples from the southern area 42 % came from finesand and 46 % from silt or finesandy clay. In the northern zones 80 % of the nematodes came from sand.

Paratylenchus spp. occurred in 42 % of the samples evenly distributed over the whole country. These nematodes were found from variable soil types. Of the infested samples 15 % were peat, 15 % finesandy till, 26 % finesand, 23 % silt and 16 % clay. The species were not identified.

DISCUSSION

Populations of *P. penetrans* and *P. crenatus* were well established troughout Finland. Here their distribution has extended further north than in Canada where it is limited by the 5 °C isotherm (TOWNSHEND et al. 1978). This isotherm hardly hits the southernmost island of Finlands southern coast. We could expect two generations of the both species in the south, and one generation of both in the north to develope per year, if we base the requirements of 350—450 °C over +10 °C for *P. penetrans* and 500—600 °C over +10 °C for *P. crenatus* (KRAUSE 1981). The results of this study easily verify the proposal of DAO (1970) +10—+15 °C is the optimum temperature for *P. crenatus.*

P. penetrans occurred mostly in finesand, its typical soil type. In the central area of the country it seems to inhabit finesandy till. Being a mixture of small and larger particles this soil might be fairly optimal for *P. penetrans*, at least soil pH requirement, 5—6.5 (WILLIS 1972) and air requirement (TOWNSHEND and WEBBER 1971) are fulfilled. *P. crenatus* preferred clay soils and dominated areas of clay soil in the southeast of Finland. The preference for clay has been observed earlier (FLORINI et al. 1987, BROWN et al. 1980). It has not been studied whether this preference results from the need of a higher moisture-holding capacity, an insensitivity to higher pH or to the minor need for movement by this parthenogenetic nematode.

P. pratensis was shown to occur occasionally in southern areas. This species occurs infrequently in southern Ontario, Canada (POTTER and TOWNSHEND 1973), but data on its distribution in other northern areas is missing. In Canada *P. neglectus* was distributed to the 5 °C isotherm (TOWNSHEND et al. 1978), here it is distributed to the 0 °C isotherm. According to ACOSTA and MALEK (1979) this nematode needs as high a temperature as over 25 °C to reproduce. However, its presence in Finland may be explained by its exceptional survival in cool, dry conditions (TOWNSHEND 1973). The occurrence of *P. vulnus* was surprising even though ACOSTA and MALEK (1979) suggest this nematode to prefer cool climate. Its distribution in Finland, however, is directly connected to plant material grown in greenhouses.

The *Pratylenchus* species never occurred in peat soil, not even *P. pratensis* even though peat is reported as its normal environment in the Netherlands (LOOF 1974).

The high threshold temperature for the life cycle, +6.5 °C, (BOAG 1982) and the high requirement of accumulated day degrees for development of a generation, 1487 °C, restrict the viability of *R. robustus* in Finland. It could easily survive by being able to feed in as very low a temperature as +0.5 °C (BOAG 1980b). The other more common species of this genus

R. fallorobustus, has been reported from Scotland (BOAG 1980a), but very little has been published about its requirements for life. This former species, in addition to the next *H. pseudorobustus* occurred in the south in finesand and sandy clay, which are their soil types (FERRIS and BERNARD 1971). But further north they occurred in sandy till and especially in peat and mould. The positive effect of organic matter, when mixed in light mineral soil, has been explained by the rise in field capacity (ELMILIGY and NORTON 1973). Thus in the north organic material seems to compensate for clay, which is absent there.

The cosmopolitan *H. pseudorobustus* most obviously lives here on the northern borderline of its distribution. Semiendoparasitic behavior has certainly helped this nematode to spread so widely. DAO (1970) has shown *H. pseudorobustus* as well as the previous *R. fallorobustus* to be able to survive in cool soil without roots for at least 3.5 months, which might be one fact that explains their distribution. The wide, though occasional, distribution of *H. digonicus* is not surprising, as in Canada this species has been shown to survive in freezing conditions (TOWNSHEND and POTTER 1973).

The northern limit for distribution was detected here for three other *Helicotylenchus* species. *H. canadensis*, *H. vulgaris* and *H. varicaudatus* occurred up to zones 2—3 (+2 °C isotherm) in central Finland. All of these species have been reported from Scotland (BOAG 1980a). *H. vulgaris* and *H. canadensis* are rather common on peas and beans, but the temperature requirements of these species have not been published.

Tylenchorhynchus spp. and *Paratylenchus* spp. were equally common and both were evenly distributed over the sampled area. *T. dubius* occurred in sandy soil typical to this species. It has been shown to reproduce in low temperatures 10—12 °C (MALEK 1980, SHARMA 1971) and forms possibly 2 generations per year in Finland. In addition, it prefers low pH (BRZESKI and DOWE 1969), a quality that is necessary in Finland.

Paratylenchus spp. was the only group of potential plant parasites that occurred in larger frequency and greater numbers in peat and mould. If identifications had been completed we might have found some ecological groups among this genera according to the soil type as WEISCHER (1960) did.

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SELOSTUS

Maassa vapaana elävien, kasveille haitallisten ankeroisten esiintyminen Suomen pelto- ja puutarhamaissa

SIRPA KURPPA

Maatalouden tutkimuskeskus

Maassa vapaana elävien, kasvituholaisina tunnettujen ankeroislajien levinneisyyden tarkastamiseksi kerättiin 2200 maatalous- ja puutarhamaanäytettä eri puolilta Suomea. Maita otettiin kaikilta maalajityypeiltä. Ankeroiset eristettiin sentrifugimenetelmällä, joka soveltuu parhaiten mahdollisimman monen eri lajin samanaikaiseen erotteluun erilaisista maalajeista. Viruksia levittävistä lajeista tulokset on esitetty jo yhteiseurooppalaisen levinneisyyskartoituksen yhteydessä (vrt. ALPHEY 1985).

Juurihaava-ankeroisista, *Pratylenchus* suvun lajeista, *P. crenatus* esiintyi yleisenä, 18 %:ssa näytteistä ja *P. penetrans* 4 %:ssa näytteistä. Jälkimmäinen esiintyi ainoastaan hieta- tai hietamoreenimaissa, edellinen hieman raskaammissa hiesussa tai hiesusavessa. Muut kolme tavattua tämän suvun lajia esiintyivät satunnaisena. *P. vulnus* löytyi yllättäen avomaalta mutta osoittautui kasvien tai mullan mukana vastikään kasvihuoneesta ulos päässeeksi. Pysyvän kannan muodostuminen avomaalla ei tunnu mahdolliselta.

Rotylenchus suvun ankeroisista meillä esiintyy yksi hyvin yleinen laji, *R. fallorobustus,* jota löytyi 16 %:ssa näytteistä. Toinen saman suvun laji *R. robustus* on hyvin harvinainen. *R. fallorobustus* ja *H. pseudorobustus* näyttävät viihtyvän useissa maalajeissa, Etelä-Suomessa hienossa hiedassa ja savessa ja pohjoisempana moreenissa ja erityisesti multamaassa ja turpeessa. Ratkaisevaa lienee maan riittävä vedenpidätyskyky, joka paranee sekä saveksen että orgaanisen aineksen lisääntyessä. Toinen tärkeä yhteinen piirre näille lajeille on, että ne säilyvät hyvin maassa ilman ravintoa, mikä osaltaan selittää niiden yleisyyttä. Lisäksi *H. pseudorobustus* on osittain sisäloinen, siis se kykenee kaivautumaan osittain kasvin sisään, mikä puolestaan ratkaisevasti lisää sen leviämismahdollisuuksia. *H. digonicus*-lajin esiintyminen näytteenottoalueen pohjoisrajoilla ei ole yllättävää, koska laji on Kanadassakin todettu kylmää kestäväksi. Muiden *Helicotylenchus*-sukuun kuuluvien kolmen lajin *H. canadensis, H. vulgaris* ja *H. varicaudatus* esiintymisen pohjoisraja löytyi Keski-Suomesta.

Tylenchorhynchus- ja *Paratylenchus*-sukujen ankeroisia esiintyi selvästi edellisiä yleisemmin, yli 40 %:ssa näytteistä. *T. dubius*, tärkein haittalaji, esiintyi 8 %:ssa hiekka- ja hietanäytteitä. *Paratylenchus*-sukua esiintyi kaikissa maalajeissa. Selvimmin maamme pohjoisen sijainnin vaikutus tuli esiin siinä, ettei äkämäankeroista tavattu lainkaan, ei edes kasvihuoneista levinneenä kuten *P. vulnus*-lajia.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 323—327 (1988)

Seria ANIMALIA NOCENTIA N. 134 — Sarja TUHOELÄIMET n:o 134

RESEARCH NOTE

PESTS OF CULTIVATED PLANTS IN FINLAND DURING 1987

MARTTI MARKKULA

MARKKULA, M. 1988. **Pests of cultivated plants in Finland during 1987.** Ann. Agric. Fenn. 27: 323—327. (Agric. Res. Centre, Dept. Pest. Inv., SF-31600 Jokioinen, Finland.)

Damage caused by nearly fifty insects and other animal pests to cereals, root crops, vegetables, sugar beet, apple, berries and other cultivated plants in Finland during 1987 is reported based on the results of questionnaire surveys.

The growing period was very cool and rainy. The average abundance of all pests in terms of a five-point scale was 2.1, i.e. clearly below the average of 2.5 during the twenty-year period of 1965—84.

Rhopalosiphum padi occurred in small numbers but in late summer the population strengthened and an abundance of winter eggs appeared in bird cherry. *Sitodiplosis mosellana* continued to occur in large numbers in wheat fields.

Meligethes aeneus occurred again in large numbers in rape fields, but cauliflower was spared from destruction by them. There were few pests in sugar beet and pea cultivations and in apple orchards. The *Migrotus agrestis* population was minimal following a peak year.

In glasshouse cultivations the new pests from abroad, *Frankliniella occidentalis* and *Bemisia tabaci* were encountered.

Index words: plant pest, severity of damage, *Rhopalosiphum padi, Sitodiplosis mosellana, Meligethes aeneus, Microtus agrestis, Frankliniella occidentalis, Bemisia tabaci.*

This survey is based on replies to inquiries sent to advisers of the Agricultural Advisory Centres. The network of 200 advisers covers all 461 municipalities of the country. Three inquiries were sent to advisers during the growing period. Their replies were as follows:

	Replies	%	Municipalities	%
Spring inquiry	104	45	142	31
Summer inquiry	108	47	150	33
Autumn inquiry	92	40	125	27

Each inquiry requested an estimate of the severity of damage due to insects and other pests specified in the questionnaire. A scale of 0—10 was used to assess severity.

In the autumn inquiry, advisers were also requested to make a general estimate of the pest situation throughout the growing period. For this purpose, a scale of 1—5 was employed: (1) very sparse, (2) sparse, (3) normal, (4) abundant, (5) very abundant. The same inquiry requested an estimate of the percentage of apples damaged by *Argyresthia conjugella* and *Cydia pomonella* and pea pods damaged by *Cydia nigricana*. The pest situation for a total of 101 municipalities was reported by advisers.

The weather conditions were highly exceptional during the entire year. The record frosts of the century occurred in January and the other winter months were cold also. The growing period was among the coolest of the century. Summer temperatures throughout the whole country were approximately two degrees below the average and rainfall was abundant, being record-breaking in some parts of the country.

The coldness and rainfall during the growing period slowed plant development and the ripening of the harvest. The yield of field plants remained generally from 20 to 40 % less than normal, and especially the quality of grain worsened so that the grain harvest of many farms was fit only for use as fodder.

RESULTS OF THE INQUIRIES

Due to the coldness and raininess of the growing period damage by pests remained slight. On the other hand, certain pest species occurred more abundantly than usual. For the entire growing period the average abundance of pests in terms of the 1—5 scale was 2.1. The corresponding figure for the previous year was 2.4 and that for the comparison period of 1965—1984 was 2.5.

In early summer flea beetle *(Phyllotreta vittula)* occurred very abundantly in some wheat fields. The severity of damage surpassed that of the previous year as well as the figures for the twenty-year period (Table 1).

The forecast for the occurrence of the oat-bird cherry aphid (*Rhopalosiphum padi*) was accurate. Aphids were sparse particularly in early summer. Due to the cool and damp weather, oat-bird cherry aphids lingered in bird cherry longer than usual. Aphids were quite abundant in wheat fields during late summer. Winter eggs appeared in bird cherry more abundantly than usual, and it can be concluded that damage will threaten spring cereals during the next growing period.

The orange wheat blossom midge (*Sitodiplosis mosellana* Geh.) continued to occur in large numbers in the wheat fields of southern Finland. Sprayings were necessary on many farms.

The rape blossom beetle (*Meligethes aeneus*) attacked rape cultivations at the beginning of its flowering in great numbers. The severity of damage (2.0) has now clearly surpassed that of the average (1.6) for the twenty-year comparison period. Cauliflower was spared from damage, however, as the second generation beetles did not appear until autumn when harvesting had already begun.

Sugar beet cultivations did not especially suffer damage by pests. The situation was also good for pea cultivations.

The usual variety of pests occurred on outdoor vegetable cultivations but they were generally less abundant than that for the twenty-year comparison period (Table 1). Occurrence of the mustard beetle *(Phaedon cochleariae)*, the important pest of the period from 1920 to 1930, was minimal (see VAPPULA 1965, p. 53). The pea moth *(Cydia nigricana)* inflicted damage on 6 % of pea pods.

The occurrence of the carrot psyllid (*Trioza apicalis*) was less than usual. The carrot fly (*Psila rosae*) was encountered in hazardous numbers in few carrot cultivations only. The species has not especially been a problem for a

Table 1. Results of questionnaires. Severity of damage on a scale of 0—10.

	Number of observations 1987	Severity of damage 1987	Severity of damage 1965—84
CEREALS			
Phyllotreta vittula (Redtb.)	115	1.0	0.7
Rhopalosiphum padi (L.)	114	0.5	1.1
Oscinella frit (L.)	211	0.3	0.8
FORAGE PLANTS			
Nanna spp.	95	0.3	1.3
RAPE AND TURNIP RAPE			
Meligethes aeneus (F.)	113	2.0	1.6
Phyllotreta spp.	84	0.8	
SUGAR BEET			
Pegomya betae (Curt.)	160	1.5	1.6
Lygus rugulipennis Popp.	102	1.2	1.6
Aclypea opaca (L.)	60	0.7	1.2
PEA			
Cydia nigricana (F.)	67	1.4	1.7
ROOT CROPS AND VEGETABLES			
Delia radicum (L.) and *D. floralis* (Fall.)	82	1.7	1.8
Plutella xylostella (L.)	72	1.7	1.7
Delia antiqua (Mg.)	86	1.5	1.5
Phyllotreta spp. on crucifers	180	1.4	1.6
Psila rosae (F.)	74	1.0	0.8
Trioza apicalis (Först.)	82	0.8	1.3
Phaedon cochlearie (F.)	56	0.3	0.9
APPLES			
Argyresthia conjugella Zell.	50	1.5	2.7
Lepus europaeus Pallas and *L. timidus* L.	111	1.4	1.8
Cydia pomonella (L.)	48	1.4	2.0
Aphis pomi (Deg.)	41	0.9	1.2
Panonychus ulmi (Koch.)	100	0.7	1.1
Yponomeuta padellus malinellus Zell.	36	0.6	1.2
Microtus agrestis (L.)	102	0.6	1.2
Psylla mali (Schmidbg.)	78	0.6	0.8
Arvicola terrestris (L.) root damages	97	0.4	0.7
BERRIES			
Tarsonemus pallidus Bks.	72	2.1	1.9
Byturus tomentosus (Deg.)	65	1.7	1.5
Cecidophyopsis ribis (Westw.)	126	1.6	2.0
Pachynematus pumilio Knw.	66	1.4	1.2
Nematus ribesii (Scop.) and *Pristiphora pallipes* Lep.	61	1.4	1.5
Lampronia capitella Cl.	94	0.9	1.7
Aphididae, on *Ribes* spp.	89	0.7	1.6
Anthonomus rubi (Abst.)	81	0.7	1.4
Zophodia convolutella (Hbn.)	69	0.3	0.8
PESTS ON SEVERAL PLANTS			
Deroceras agreste (L.) etc.	82	2.5	1.3
Hydraecia micacea (Esp.)	62	1.2	1.1

long time. This is partly due to the fact that during the control of the carrot psyllid the fly population is also weakened. The flying time of the carrot fly usually coincides with the best spraying times for the psyllid.

The damage to apple orchards was slight on the whole. The damage for apples was as follows:

	Percentage of apples damaged 1987	1986	1965—84	Replies 1987
Argyresthia conjugella	16	14	28	13
Cydia pomonella	9	14	19	12

The larvae of *Dasyneura tetensii* (Rübs.) occurred abundantly in the black currant cultivations of central Finland. On the other hand, the midge species *Resseliella ribis* (Marikovskij) was found to have spread to many black currant cultivations in southern Finland.

The field vole (*Migrotus agrestis*) population collapsed from the peak of the previous year (3.6) to the minimum (0.6). Signs of a new upswing began to appear in places. In addition, the water vole (*Arvicola terrestris*) population was weak.

The rainy and cool summer was favourable to slugs. The severity of damage (2.5) clearly surpassed that of the twenty-year average (1.3). Slugs damaged many plants, although no large-scale destruction was apparent.

In August, *Frankliniella occidentalis* (Pergande) thrips were encountered for the first time in our country in imported African violet (*Saintpaulia ionantha*) plants. Extensive inspections were put into effect immediately. Altogether 216 glasshouse cultivations were inspected, and surprisingly enough, thrips were found in a total of 86 plantations, or 40 %. The surprising situation led to the conclusion that thrips had passed into our country at least one or two years earlier.

The damage by *F. occidentalis* was difficult to prevent as the species inhabits sheltered areas in plants. It is also resistant to many pesticides (PARRELLA and ROBB 1987). The danger in the use of chemical control is that the control agents placed in glasshouse cultivations would be destroyed in the process. The phytoseiid mite *Phytoseiulus persimilis* A.—H., the chalcidid wasp *Encarsia formosa* Gahan and the aphid midge *Aphidoletes aphidimyza* (Rond.) are in general use in Finland (e.g. MARKKULA and TIITTANEN 1982.).

Research has begun on the biological control of *Frankliniella occidentalis* employing the predatory mites *Amblyseius barkeri* (Hughes) and *A. cucumeris* (Oud.).

In October, it was discovered that another new pest, *Bemisia tabaci* (Gennadius), had also been carried into our country. The species was determined by Dr. Larry Huldén of the University of Helsinki Zoological Museum, Department of Entomology. *B. tabaci* would not seem to be as great a threat to our glasshouse cultivations as *F. occidentalis.*

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SELOSTUS

Viljelykasvien tuhoeläimet 1987

Martti Markkula

Maatalouden tutkimuskeskus

Kasvukauden poikkeuksellinen viileys ja sateisuus vähensivät tuholaisvahinkoja. Viljapellot säästyivät tuomikirvan tuhoilta, mutta loppukesällä kirvakanta voimistui. Kun tuomikirvan talvimunia ilmaantui runsaasti tuomiin, on olemassa vahva perusta kirvan joukkoesiintymiselle seuraavana kesänä. Rapsikuoriaiset esiintyivät jälleen runsaina öljykasveilla. Sokerijuurikkaassa ja herneviljelyksillä tuholaisia oli vähän.

Peltomyyrän kanta oli edellisen vuoden huipun jälkeen minimissä. Merkkejä kannan uudesta noususta havaittiin paikoin.

Suomenkielinen katsaus on julkaistu Koetoiminta ja Käytäntö -lehdessä 26.1.1988.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 329—338 (1988)

Seria ANIMALIA NOCENTIA N. 135 — Sarja TUHOELÄIMET n:o 135

THE PEST POTENTIAL OF *MELOIDOGYNE HAPLA* IN NORTHERN FIELD CONDITIONS

KARI TIILIKKALA, ANNIKKI LAHTINEN and DAVID TRUDGILL

TIILIKKALA, K., LAHTINEN, A. & TRUDGILL, D. 1988. **The pest potential of *Meloidogyne hapla* in northern field conditions.** Ann. Agric. Fenn. 27: 329—338. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

The survival and development of *Meloidogyne hapla* was investigated in Finland between 1984 and 1987. The first egg-laying female on carrots was found after the plants had accumulated 413 day °C above the temperature threshold of 8.25 °C and the first fully embryonated egg after 554 day °C. Newly hatched larvae were found in the soil only in plots growing perennial clover when 631 day °C above the threshold had accumulated. In the carrot plots the heat sum from crop emergence to harvest never exceeded 600 day °C and no hatched larvae were found. A laboratory experiment shows that a total of 555 day °C above a threshold of 8.25 °C was required for development from hatched second stage larvae to the first hatched larvae of the next generation and more than 1100 day °C was required for maximum reproduction. The laboratory results were shown to provide a useful basis for predicting the development of *M. hapla* and it was concluded that in Finland *M. hapla* is unlikely to become a serious pest on annual field crops.

Index words: root-knot nematode, *Meloidogyne hapla*, overwintering, development, threshold temperature, pest potential.

INTRODUCTION

The northern root-knot nematode, *Meloidogyne hapla*, is a quarantine pest that affects many field and glasshouse crops. It is a pest of field crops in the Netherlands, Germany, Denmark, southern Sweden and southern England, and introductions into Finland occur regularly via infested planting stocks (KURPPA 1985). In 1982 and 1983 a survey was made of symptomless rose root-stocks imported into Finland and 6.1 % were found to be infested with *Meloidogyne* spp. (LAHTINEN, unpublished). In preliminary studies TIILIKKALA (1982) showed that *M. hapla* can survive the winter in southern Finland and SASSER et al (1983) reported that it was able to survive in soils with an average temperature of as low as — 15 °C for the coldest month. BANCK (1985) reported that in southern Sweden *M. hapla* was able to reproduce in the field and caused considerable damage to carrots. *M. hapla* has not been found to be an established pest in Finnish fields, but is a fairly common pest in glasshouses. Periodically, the peat-based growth media used in many glasshouses is removed and generally spread on adjacent fields. Thus, the potential for *M. hapla* to become established as a pest of field crops has considerably increased.

The aim of this study was to determine whether *M. hapla* could become a pest in Finnish fields. The problem was studied in two steps. Firstly, the threshold temperature and day degree requirements for the development of *M. hapla* were determined by laboratory experiments in Scotland. Secondly development of the nematode was studied outdoors in Finland and the predictive value of the laboratory results was tested in field conditions. Results from the laboratory experiments have been mainly reported by LAHTINEN et al. (1988) while results from the field experiments are described in this paper.

MATERIAL AND METHODS

Field experiments

Overwintering and rate of development of *M. hapla* was studied in field plots during 1985—1987. The population originated from infested peat in a commercial rose growing glasshouse. The peat was removed in October 1984 and piled up to a height of about 5 m.

In spring 1985 two similar field experiments were started; one at Hyrylä, 20 km north of Helsinki, the other at Toholampi (63° 45′ N 24° 15′ E) 400 km north of Helsinki. The soil was a fine sand at Toholampi and clay at Hyrylä. At each site thirty plots (60 × 60 cm) were established by removing the top 10 cm of soil and replacing it with 45 l of mixed peat taken from the surface and 1 m and 2 m deep from the infested peat. Each plot was separated from its neighbour by a 1.5 m wide strip of grass (Timothy).

The plots were fertilized with 50 g commercial fertilizer (10—8—17) each spring. Six plots were sown in 1985 with Timothy grass and six were left unsown. The remaining eighteen plots were sown with carrot cv. Nantes Tip Top in four rows per plot. The sowing dates in 1985 for grass and carrots were May 31 at Toholampi and June 14 at Hyrylä. In 1986 and 1987 the carrots were re-sown on May 31 and May 28 at Toholampi and June 6 and June 8 at Hyrylä. The seedlings were thinned to 100 carrots per plot and plots were handweeded twice during the growing season. The carrots were harvested in three different ways when the soil temperature at 10 cm dropped below 8.25 °C. All the roots were harvested from six plots, in six other plots 5 % of the carrots were left to simulate commercial harvesting and from the remaining six plots only 10 roots were harvested.

The harvested carrot roots were divided into four grades: healthy, slightly injured, moderately injured and heavily injured (Fig. 1.)

The peat heap and the non-seeded plots had no plants during 1985, but in 1986 and 1987 white clover covered the non-seeded plots at Toholampi and grasses *(Poaceae* sp.) covered those at Hyrylä. In addition, some white clover became established in 1986 and 1987 in the Timothy plots at Toholampi.

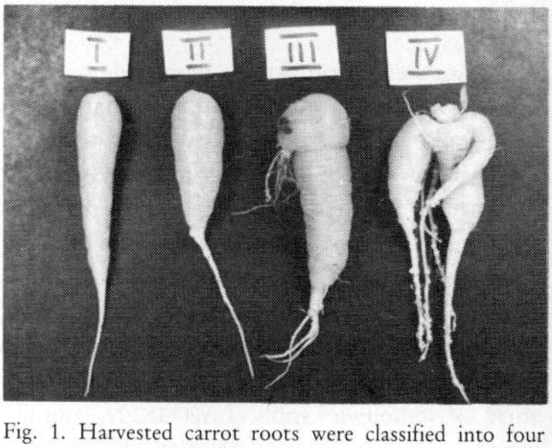

Fig. 1. Harvested carrot roots were classified into four grades: I healthy, II slightly injured, III moderately injured and IV heavily injured.

Sampling and extraction of nematodes

The nematode densities in each plot were determined during the sowing and harvesting of the carrots. Each of the soil samples was composed of 25 cores taken with a 2 cm diam. probe to a depth of 20 cm. From the peat heap four samples were taken from the surface and from 1 m and 2 m deep using a spade in December 1984, in May 1985 and in May 1986. All soil samples were stored in plastic bags at +8 °C for 3—4 weeks before extraction except the samples from Hyrylä taken in spring 1986 which were extracted immediately after sampling. After each sample had been thoroughly mixed, subsamples of 250 ml were taken from each sample and these were vigorously mixed in a food processor (Moulinex Moulinette S) for 30 seconds. After mixing 50 ml of the soil was mixed with 75 ml of water using a "Warring blender" and free larvae were extracted by centrifugal flotation (GOORIS and D'HERDE 1972).

The infectivity of the second stage larvae in the soil sampled in spring 1985 and 1987 from the field plots and from the peat heap in spring 1985 was tested in pots by planting 0.45 l of soil from each sample with a 3-week old tomato plant. The tomatoes were grown for 2 months in a glasshouse at 19/24 °C after which the numbers of galls/g root were counted.

The development of *M. hapla* females was monitored at Hyrylä during summer 1986 by sampling ten roots/plot every 10 days starting from July 27. Galled roots were washed, examined under a microscope and nematodes were extracted by the centrifugal flotation method (COOLEN and D'HERDE 1972).

Soil temperature records

Soil temperature records were obtained from the routine measurements made by the Finnish Meteorological Institute at Jokioinen (90 km northwest of Hyrylä) and at Ruukki (90 km north of Toholampi). At Jokioinen daily minimum- maximum values at 10 cm were recorded and mean temperatures at 20 cm every fifth day. At Ruukki only temperatures at 20 cm were recorded and the 10 cm values were estimated by employing the ratio 10 cm/20 cm measured at Jokioinen.

Heat accumulation at 10 cm was calculated as day °C above 8.25 °C, which is the threshold for development calculated by LAHTINEN et al. (1988) (Fig. 2). The emergence of carrots requires 150 day °C above 0 °C, measured as air temperature in Finland (SUHONEN 1984). Effective soil temperature accumulation for carrots was calculated starting from the day when the air temperature accumulation after planting was 150 day °C. Total and effective heat sums above 8.25 °C, the lowest winter soil temperatures at 20 cm and the numbers of days/winter, when soil temperatures were less than 0 °C, are presented in Table 1.

In Finland the 1985 growing season was slightly cooler than average and the 1986 season was warmer than normal. The winter of 1986—1987 and the summer of 1987 were exceptionally cold (ANON. 1984—1987).

Laboratory experiments

The same population of *M. hapla* was tested in a laboratory experiment. Pots (7.5 cm diam.) without drainage holes and growing tomato plants cv. Rutgers were inoculated with 200 newly hatched larvae and transferred in groups of four to water baths at 20, 24 and 28 °C. The temperature in one pot in each bath was monitored continuously so that the mean temperature achieved could be calculated at the end of the experiment. Just prior to the hatching of the second generation larvae, the roots of the tomato plants were washed free of soil and the plants re-potted into pots with drainage holes in coarse gravel. These pots were

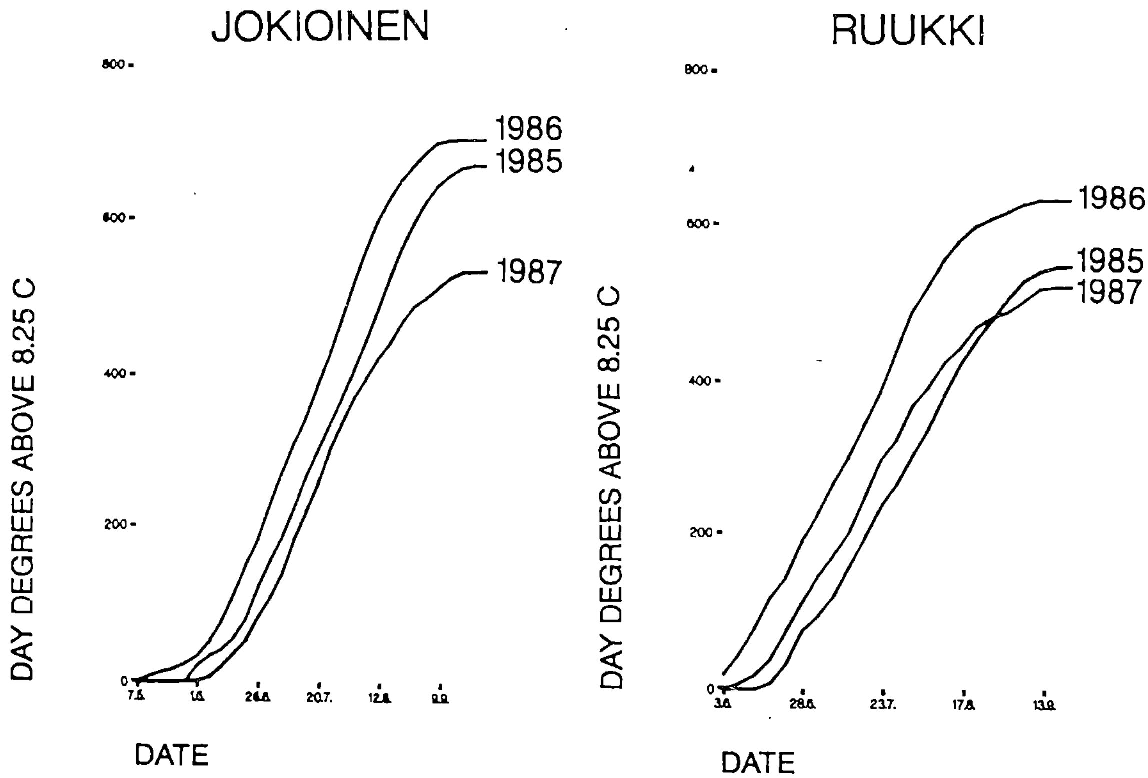

Fig. 2. Accumulated day degrees in soil (10 cm) above 8.25 °C at Jokioinen (southern Finland) and at Ruukki (central Finland)

Table 1. A. Minimum winter soil temperature at 20 cm, number of days when soil temperatures were less than 0 °C, and total accumulated soil temperatures above 8.25 °C.
B. The calculated effective day °C above a threshold of 8.25 °C available for the development of *M. hapla* on carrot.

A.	JOKIOINEN			RUUKKI		
year	Temp. min. (°C)	No. days <0 °C	Total heat sum (day °C >8.25 °C)	Temp. min. (°C)	No. days <0 °C	Total heat sum (day °C >8.25 °C)
1984/85	−3.6	116	672	−2.6	126	546
1985/86	−1.8	127	705	−0.6	111	631
1986/87	−8.4	125	534	−2.3	130	520

B. Effective heat sums (day °C above 8.25 °C) after the germination of carrots

1985	566	546
1986	592	554
1987	480	502

placed inside a second pot without holes and these double pot units were returned to the water baths.

Newly emerging larvae were collected each day for counting by pouring about 150 ml of water through the gravel. The collection of larvae ceased after 32, 36 and 28 days respectively for plants maintained at average temperatures of 20.3, 24.1 and 28 °C.

RESULTS

Overwintering in peat heap

In December 1984 there were on average 176 free larvae in 50 ml of soil and in the spring of 1985 this number had decreased to a mean of 41 larvae per sample (a mean of six larvae per sample from the heap surface and 55 and 60 larvae per sample from 1 and 2 m depths, respectively). No larvae were found at any depth in the spring of 1986 when the samples were analyzed immediately after sampling. In the bioassay test with tomato the numbers of galls/1 g root were nine in the spring of 1985 and 17 in the spring of 1986. Galls were formed on plants growing in soil taken from each depth in the heap. As the peat heap was totally free of weeds these results indicate that eggs of *M. hapla* can survive over two winters at least.

Failure to reproduce on carrots at Hyrylä

Approximately 45 free larvae/50 ml soil were found in June 1985 when the carrots were sown, but only few (the mean was less than 0.0) were found in the autumn 1985 when they were harvested. In timothy plots there were 46 larvae in June and 0.3 in September and in unsown plots 31 and 0.3, respectively. No free larvae were found in any plots in the the spring of 1986 when samples were analyzed immediately after sampling and very few were found at harvest time. No free larvae were found in any plots in 1987 (Fig. 2).

The bioassay test with tomato showed that in the spring of 1985 viable larvae were present in all plots; the mean numbers of galls/g tomato root were 9, 8 and 16 in the soil from the carrot, Timothy and unsown plots, respectively. In the spring of 1987 no galls were found on any of the bioassay tomato plants.

The quality of the carrots was reduced in the summer of 1985, but not in 1986 nor in 1987. The percentage of the carrots in the four quality classes are presented in Table 2.

Unharvested carrots did not prevent a rapid decrease in the population density of *M. hapla*, nor affect carrot quality in the successive seasons.

Very few galls were found on the carrots taken at 10-day intervals during 1986. Two egg-laying females were found on August 6 when the carrots had accumulated 413 day °C above the threshold of 8.25 °C. The egg masses had not developed and the 30—40 eggs inside one of the females were at different embryonic stages. The first fully embryonated eggs were found on August 27 when, from germination,

Table 2. The quality of the carrots as percentage/quality class.

		Percentage of carrots in each quality class.			
Place	year	healthy	slightly injured[1]	moderately injured	heavily injured
Hyrylä	1985	11.0	19.2	37.7	32.1
	1986	92.0	8.0	0	0
	1987	93.1	6.9	0	0
Toholampi	1985	76.5	23.5	0	0
	1986	96.0	4.0	0	0
	1987	97.0	2.2	0	0

[1] Any injury e.g. fanging of roots, was sufficient to down-grade the carrots.

the carrots had accumulated 550 day °C above 8.25 °C. At harvest in 1987, when 480 day °C had accumulated, only one female was found in the carrot plots. All eggs were in the early stages of embryogenesis.

Reproduction on white clover at Toholampi

In spring 1985 the mean of 40 larvae/50 ml soil per plot was found, whereas less than one was found in the autumn. No larvae were found in spring 1986, but at harvest the respective averages were 0.4 larvae per carrot plot, 7.8 larvae per Timothy plot and 61.0 larvae per unsown plot which by then were cowered with white clover. In spring 1987 0.7, 2.2 and 5.8 larvae were found, respectively. No larvae were found at harvest time.

The bioassay tests with tomato showed that in the springs of 1985 and 1987 infective larvae were present. In 1986 the test tomatoes were destroyed and no results were obtained. In 1985 a mean of 11 galls per plant was formed on the samples from the carrot plots, seven on samples from the Timothy plots, and seven on the samples from the unsown plots. In 1987 the corresponding values were 0.1, 0.4 and 0.4 galls per tomato plant, respectively. The percentage of the carrot roots left unharvested had no significant effect on overwintering larvae, infectivity in the bioassay, nor on carrot quality (see Table 2). The numbers of free larvae are presented in Fig. 3.

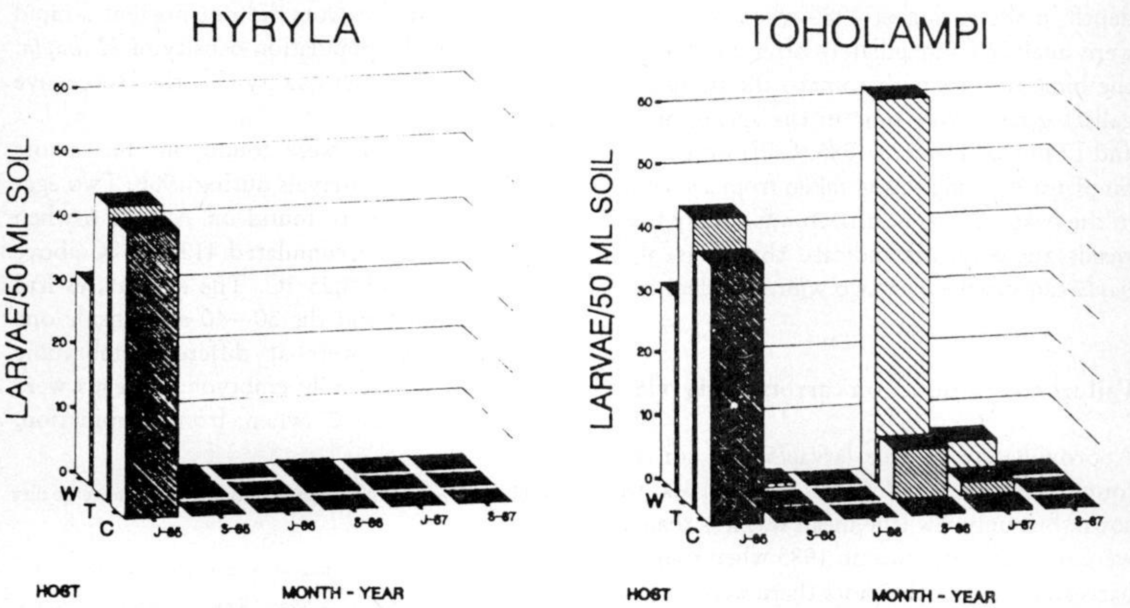

Fig. 3. Free larvae on the experimental fields at Hyrylä and at Toholampi. The numbers are means of 18 plots for carrots (C), of 6 plots for Timothy (T) and 6 for unsown, weed-covered (W) plots. Samples were taken in June and in September 1985, 1986 and 1987.

The maximum rate of reproduction in the laboratory experiments

At average temperatures of 20.3, 24.1 and 28.0 °C the first larvae were collected after 46, 35 and 28 days, respectively. Plotting the reciprocal of the time expended for development from larvae to larvae against average temperature produced a straight line which intervepted the temperature axis at 8.25 °C. This was taken as

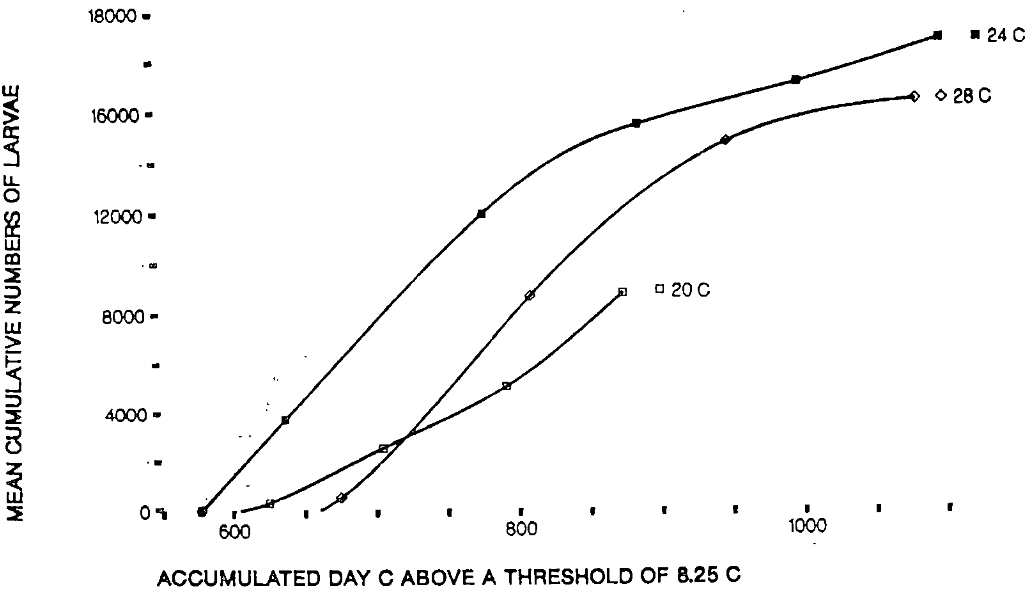

Fig. 4. Cumulative numbers of *M. hapla* collected and plotted against accumulated day °C above a threshold of 8.25 °C. The results are for plants monitored at 20.3, 24.1 and 28.0 °C and are means of four plants each inoculated with 200 larvae.

the threshold temperature for development (LAHTINEN et al. 1988). The total thermal time requirement for the development of the first newly hatched larvae for each temperature was then estimated and was found to be 552, 555 and 553 day °C, respectively above the threshold of 8.25 °C. The numbers of larvae collected rapidly and progressively increased (Fig. 4). Most larvae were produced by the plants maintained at 24.1 °C, with a mean of almost 19 000 collected from plants initially inoculated with 200 larvae. The maximum rate of output of larvae occurred when the plants had accumulated between 700 and 900 day °C above a threshold of 8.25 °C, but larvae were still being collected when the plants had accumulated 1100 day °C, i.e. sufficient time for the onset of a third generation.

DISCUSSION

In Finland *M. hapla* readily overwintered in the peat heap. No free larvae were found when the samples from the peat heap were extracted immediately after sampling in the spring of 1986. Even so, many galls developed on the roots of tomato planted in the same soil. These results indicate that in Finland *M. hapla* overwinters in the egg stage. VRAIN and BARKER (1978) reported that the egg stage is the most cold-resistant stage. SAYRE (1963) found that *M. hapla* could survive in frozen soils in Canada and STEPHAN (1982) showed that, although the hatch of five populations of *M. hapla* was markedly reduced, all withstood -5 °C for 7 days. The presence of viable larvae in samples taken from the peat heap in the spring of 1986 also indicates that a part of the population remained in diapause for more than 1 year and survived through the winters of 1986 and 1985. These findings are consistent with those of FRANKLIN (1937) who reported that diapause could last for at least 16 months.

Storing the soil samples for 3—4 weeks at >8 °C apparently induced hatch and facilitated the collection of larvae. The threshold temperature for the hatching of *M. hapla* was reported by INSERRA et al. (1983) to be below 10 °C and they reported a slight hatch at 4 °C. They also reported that total hatch was obtained by 60 days at 10 °C and 30 days at 15 °C. Therefore, in Finnish field conditions hatching was probably completed in July and most or all of the larvae found at harvest time had probably developed during that season.

We first detected eggs in samples taken in early August when 413 day °C had accumulated above the threshold of 8.25 °C. VRAIN et al. (1978) reported that development of egg laying females of *M. hapla* required from 354 to 469 day °C above the threshold of 8.8 °C depending on the cultivation site and the date of inoculation. The rate of nematode development in our field experiment is consistent with that observed by VRAIN et al. (1978).

In 1986 the first unhatched larvae in our field experiments were found when the germinated carrots at Hyrylä had accumulated 550 day °C above 8.25 °C. In the same year at Toholampi the carrots had accumulated 554 day °C, but no free larvae were found in samples collected at harvest time. In the unsown plots that produced a natural stand of white clover, the plants had accumulated 631 day °C and many free larvae were found. Consequently, the estimated requirement of 553 day °C above 8.25 °C for the development of *M. hapla* from newly hatched larvae is in reasonable agreement with the observed field results.

Our laboratory results show that maximum reproduction by *M. hapla* requires at least 1100 day °C above 8.25 °C and consequently, even on a perennial crop such as clover and in the warmest year (1986), the nematode was unable to express its full potential in Finland. In the coldest year (1987) *M. hapla* would have been unable to complete one generation, and survival in the long-term would require the ability of females or unembryonated eggs to overwinter.

When determining the potential of a introduced pest such as *M. hapla* to become established, various factors such as winter survival, host range, weed flora as well as the date of sowing, emergence and harvest are all important. Our results clearly demonstrate that where temperature is a limiting factor, annuals are poorer hosts than perennials. This is probably due to the fact that in the spring the heat accumulated before crop germination is lost for nematode development. This effect is particularly severe when the winter is very cold and the soil remains frozen well into the spring, as occurred in Finland during 1987. Annual crops will also differ in their host suitability depending on their patterns of growth. A crop such as potato which can be planted early and has a rapidly growing root system may be a better host than later planted, more slowly growing crops such as carrot.

In Finland the risk of *M. hapla* becoming a serious pest is much less than in southern Sweden, where the total heat accumulation above 8.25 °C is more than 1000 day °C per growing season (ANON. 1981—1983). BANCK (1985) found *M. hapla* to reproduce well in southern Sweden, but to cause few problems in the Uppsala area where the heat sum is almost the same as that in southern Finland. Consequently, *M. hapla* seems to have reached the limit of its distribution in southern Sweden, and is unlikely to become a field pest in Finland. Other *Meloidogyne* species such as *M. chitwoodi*, which appear to have a lower threshold temperature or a lower thermal requirement for development (SANTO and O'BANNON 1981) might be much more harmful in northern Europe, but, as yet, the detailed information for such an assessment is not available.

Acknowledgements — The advice and comments of Prof. Martti Markkula and Dr. Heikki Hokkanen are greatly appreciated.

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SELOSTUS

Juuriäkämäankeroisen, *Meloidogyne hapla*, mahdollisuus tulla avomaantuholaiseksi Suomessa

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Maatalouden tutkimuskeskus, Maatilahallitus ja Scottish Crop Research Institute

Juuriäkämäankeroinen, *Meloidogyne hapla*, on moni-isäntäinen tuholainen, joka elää mm. porkkanalla, perunalla, kaali- ja juureskasveilla sekä lukuisilla koristekasveilla. Suomessa laji on todettu tuholaisena vain kasvihuoneissa, mutta muualla Euroopassa ja esim. Kanadassa se on yleinen avomaan tuholainen.

Tämän tutkimuksen tavoitteena oli selvittää *M. hapla*-lajin lisääntymiskyky avomaalla Suomen oloissa. Tutkimus toteutettiin kahtena osana: ensin *M. hapla*-lajin lisääntymisen riippuvuutta lämpösummasta tutkittiin Skotlannissa ja sen jälkeen avomaalle siirretyn ankeroisen lisääntymistä ja lämpösumman kertymistä seurattiin kahdessa kenttäkokeessa Suomessa.

Tutkimuksessa käytetty ankeroiskanta saatiin n. 1000 m suuruiselta lasinalaiselta ruusuviljelmältä Hyrylästä. Ankeroisen saastuttama kasvuturve kasattiin ulos syksyllä 1984. Keväällä 1985 turvetta siirrettiin koekentille Hyrylään ja Toholammille. Ankeroisen määrää ja elinvoimaisuutta seurattiin turvekasasta sekä porkkanaa, timoteitä ja pelkästään rikkakasveja kasvaneista kenttäkoeruuduista vuosien 1985—1987 ajan.

Laboratoriotutkimusten mukaan *M. hapla*-lajin kehityksen kynnyslämpötila on 8.25 °C ja kehityksen edellyttämä tehoisa lämpösumma 553 °C (day-degrees). Osan I tulokset julkaistaan Nematologica-sarjassa vuoden 1988 aikana.

Suomessa tehtyjen tutkimusten mukaan *M. hapla*-laji talvehtii hyvin ulos kasatussa sekä pellolle levitetyssä turpeessa. Saastutettuun maahan kylvetyt porkkanat vioittuivat levityksen jälkeisenä kesänä, mutta eivät sen jälkeen. Tärkein lajin lisääntymistä rajoittava tekijä on kasvukauden lyhyys ja viileys. Maan tehoisa lämpösumma ei yleensä ylittänyt 553 °C rajaa porkkanan itämisen ja korjuun välisenä aikana eikä myöskään uusia toukkia todettu syntyvän. Monivuotisella isäntäkasvilla, joka Toholammin kenttäkokeessa oli rikkakasviruutuihin kasvanut valkoapila, lämpösumma oli 631 °C vuonna 1986 ja uusia toukkia kehittyi runsaasti. Lämpösumma 553 °C todettiin käyttökelpoiseksi kriteeriksi lajin lisääntymistä laskettaessa, mutta lajin merkitystä tuholaisena arvioitaessa myös muut tekijät kuten, talvehtiminen, isäntäkasvilaji, itämis- ja korjuuaika sekä rikkakasvit tulee ottaa huomioon.

Tulosten perusteella voidaan arvioida, että *M. hapla*-laji ei ole kovin haitallinen kasvintuhooja avomaalla yksivuotisia kasveja viljeltäessä. Monivuotisilla isäntäkasveilla laji voi säilyä elinvoimaisena useita vuosia kasvupaikasta riippuen. Alttiita yksivuotisia kasveja ei tule viljellä saastuneessa maassa ensimmäisenä saastukkeen levitystä seuraavana kasvukautena eikä ankeroisen saastuttamaa turvetta tule käyttää monivuotisten isäntäkasvien kasvualustana Etelä-Suomessa.

Ilmeisesti *M. hapla*-lajia huomattavasti vaarallisempi juuriäkämäankeroinen on *M. chitwoodi*, joka viime vuosina on muodostunut vaikeasti torjuttavaksi tuholaiseksi Kanadassa. Se lisääntyy *M. hapla*-lajia nopeammin alhaisissa lämpötiloissa ja elää mm. viljoilla. *M. chitwoodi*-lajin ei toistaiseksi ole todettu esiintyvän Euroopassa.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 339—343 (1988)

Seria ANIMALIA NOCENTIA N. 136 — Sarja TUHOELÄIMET n:o 136

UTILIZATION OF DIAPAUSE IN MASS PRODUCTION OF *APHIDOLETES APHIDIMYZA* (ROND.) (DIPT., CECIDOMYIIDAE)

KATRI TIITTANEN

TIITTANEN, K. 1988. **Utilization of diapause in mass production of *Aphidoletes aphidimyza* (Rond.) (Dipt., Cecidomyiidae).** Ann. Agric. Fenn. 27: 339—343. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

The possibility of utilization of long-term storage in diapause for the mass production of *Aphidoletes aphidimyza* (Rond.) was determined in the present study. Diapause was maintained 1—12 m at two temperature levels +2 °C and +10 °C in moist peat. Not one of the larvae kept at +2 °C survived to adult stage. After a 7-m storage period at +10 °C 66 % of the larvae emerged while during continuous rearing without diapause 71 % of the larvae emerged. After storage periods of 3—6 and 8 m about half of the larvae emerged. Emergence was poor following a storage period shorter than 3 m and longer than 8 m. Length of storage affected both the start of development and the time required for emergence. The shorter the storage period was the longer it took for development to begin and its completion required a longer period of time. The results show that diapause storage can be utilized in the mass production of the predatory midge.

Index words: *Aphidoletes aphidimyza,* Cecidomyiidae, diapause, long-term storage, emergence, mass production.

INTRODUCTION

The predatory midge is used for the control of aphids in greenhouses in the Soviet Union (BONDARENKO and MOISEYEV 1978), Finland (MARKKULA et al. 1979), Canada (GILKESON and HILL 1986), Denmark (HANSEN 1985) and the Federal Republic of Germany (HEINRICHS 1986). The basic method is the distribution of predatory midges in the cocoon stage into an aphid infested plant stand.

Methods for the mass production of predatory midges have been studied especially in the Soviet Union (BONDARENKO and ASYAKIN 1975), Finland (MARKKULA and TIITTANEN 1976, MARKKULA et al. 1979, RIMPILÄINEN 1980) and in the Netherlands (LIEBURG and RAMAKERS 1984).

Initially mass production was carried out in the Soviet Union as well as in Finland under yearlong, long day conditions with 18 h light at +20—+25 °C and sufficient nutrition. However, production costs for the maintenance of growth would greatly increase during the autumn and winter seasons when predatory midges diapause naturally and are not needed in greenhouses of northern regions where aphid infestation is slight at that time. Thus it was necessary to investigate the possibilities to rear as many predatory midges as possible at a suitable time, keep them in diapause and take them into use when necessary.

In the predatory midge diapause is induced in the larval stage by the effects of photoperiod. The critical photoperiod is 17 h (BONDARENKO et al. 1979, HAVELKA 1980). According to a study by FORSBERG (1980) 96 % of larvae remained in diapause when the conditions for the laboratory rearing of predatory midges were an 8 h photoperiod at +25 °C and 16 h of darkness at +10 °C.

BONDARENKO and MOISEYEV (1982) also investigated storage during diapause and found that the laboratory population could not be stored at +3 °C for a period longer than 20 d without decisively lowering emergence. A greenhouse population, on the contrary, endured a 180-d storage well and over half emerged even after a 360-d storage period. In the study by FORSBERG (1980) in which diapause stage was preserved at +5 °C, emergence was poor after 90- and 360-day periods of storage. The present study assessed in laboratory the use of diapause for the purpose of practical mass production of the predatory midge.

MATERIAL AND METHODS

A laboratory population of predatory midges reared without diapause since 1973 was used in the study. Larvae collected from the wild in late summer were added into the population yearly. Emergence in the laboratory population has been 70—80 % all along. Diapause was induced according to the method of FORSBERG (1980). Predatory midges were allowed to oviposit on plants infested by peach aphids for 2 d in the laboratory under conditions of +25 °C, 18 h light and 6 h darkness. The plants were then transferred to a growth chamber and a photoperiod of 8 h at +24 °C and 16 h darkness at +10 °C. Temperature was changed over a period of 2 h. Humidity was 80 % all the time.

When larvae were full or nearly full-sized leaves were separated from plants and placed into dishes filled with moist peat (MARKKULA and TIITTANEN 1976, MARKKULA et al. 1979). After all larvae were transferred into the peat, dishes were moved to storage areas and kept in darkness at +2 °C and +10 °C. Peat moisture was checked weekly. The dishes were transferred to the laboratory monthly for a long illumination period of 18 h light, 6 h darkness at +25 °C and the number of adults that emerged was calculated daily. Each dish contained 100 larvae. The test was performed 4 times, or from each storage period on 400 larvae. The continuously growing laboratory population was the control.

RESULTS AND DISCUSSION

In Finland, peat has been the pupation substrate almost exclusively used in the rearing of predatory midges. Thus an even moisture content has been ensured and the drying out of cocoons prevented during their delivery to growers. However, peat is probably an unsuitable pupation substrate for cold storage as out of a total of 4 800 diapausing larvae stored at +2 °C, not one emerged. The result might have possibly been different if the cocoons had not been transferred directly from +2 °C to +25 °C. A considerable change in temperature did not appear to affect cocoons stored in sand (BONDARENKO and MOISEYEV 1982). At the storage temperature of +10 °C diapausing larvae could be stored in peat from 3 to 8 m (Table 1). The greatest emergence % was obtained after a 7-m storage period. At that time 66 % of the larvae emerged to adults, half of them during a 14-d period, and it took only 9 days for emergence to begin. The result was nearly identical to that during continuous rearing.

The period of storage during diapause clearly affected both the start (Fig. 1) and duration of

Table 1. The effect of storage time on emergence of diapausing larvae of the predatory midge *Aphidoletes aphidimyza*. Diapause was induced in larvae by keeping them in short photoperiods: 8 h light, +25 °C, 16 h darkness, +10 °C from the egg stage. After storage they were transferred to a long photoperiod of 18 h light, 6 h darkness, +25 °C. There were 400 larvae in all storage periods.

Storage period in months	Emerged avg. %	Days to start of emergence	Days to 50 % emergence	Days to 100 % emergence
1	9,5	32	39	55
2	11,5	31	38	55
3	44,0	21	31	55
4	44,5	18	27	55
5	50,5	13	22	55
6	45,7	13	19	55
7	66,5	9	14	45
8	41,2	11	17	45
9	24,7	5	12	22
11	7,2	11	23	24
12	4,0	5	15	31
F-value	11,81^{xxx}	54,17^{xxx}	16,79^{xxx}	
Without diapause	71,0	10	11	13

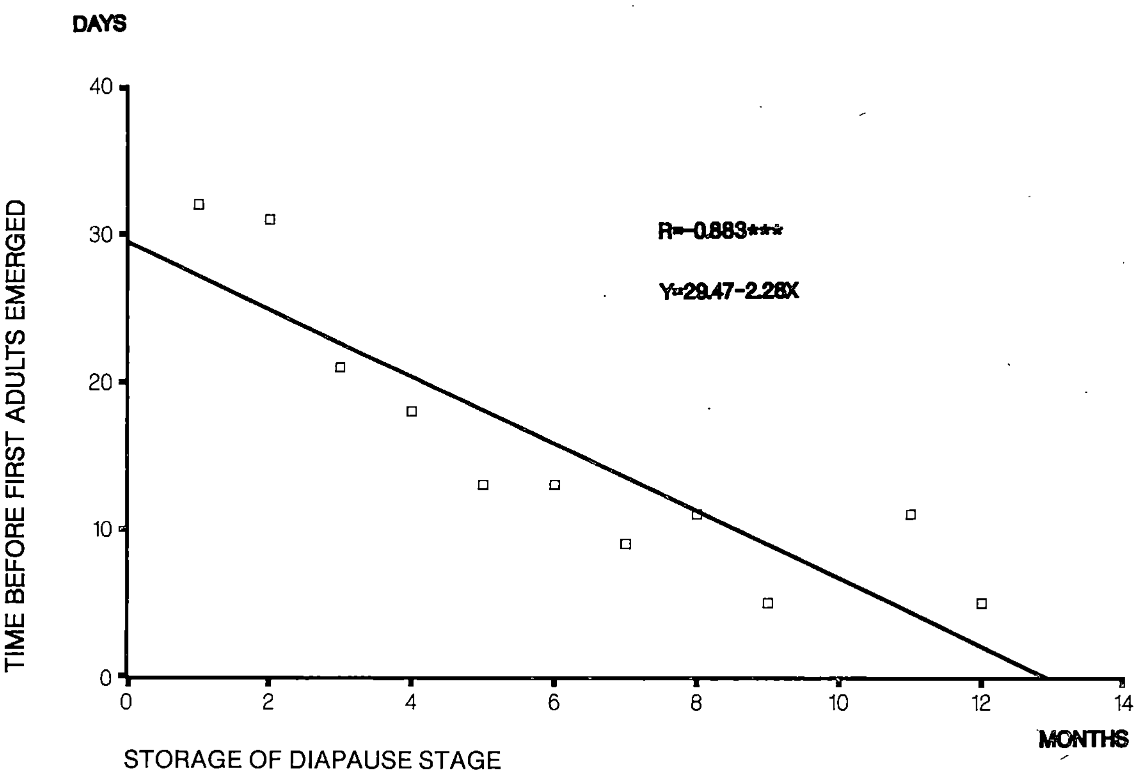

Fig. 1. The effect of storage time on emergence of diapausing larvae of the predatory midge *Aphidoletes aphidimyza*. The effect of start of emergence.

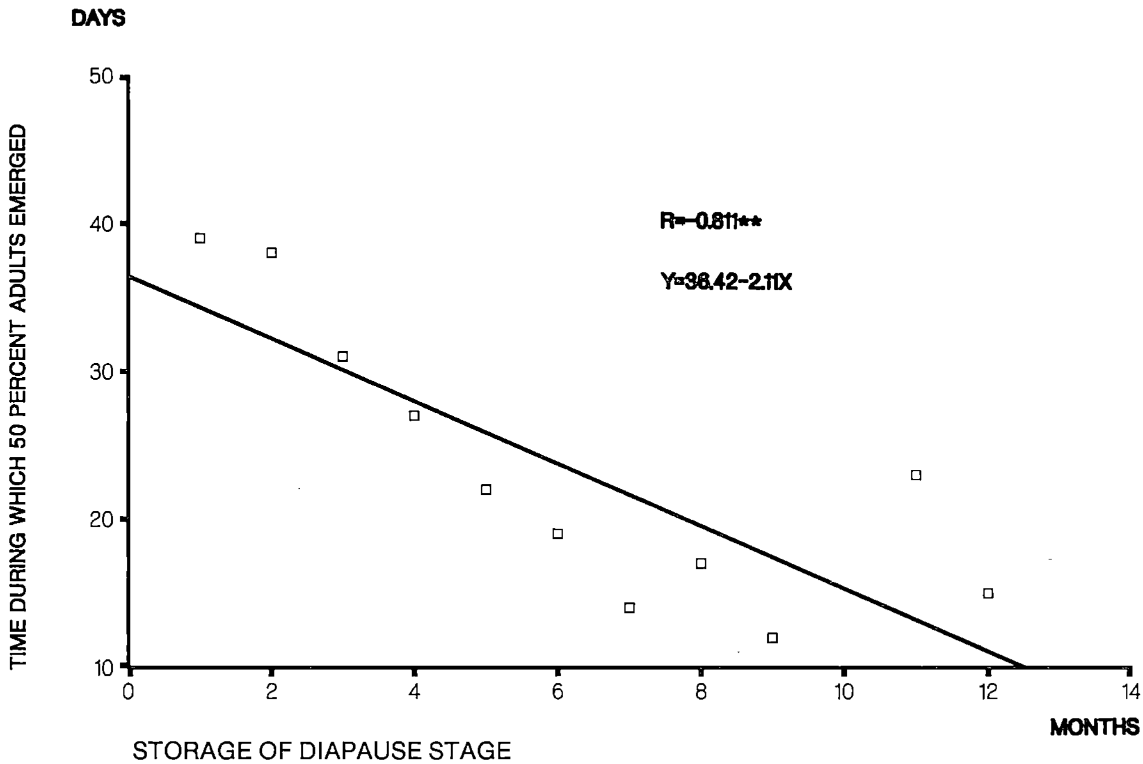

Fig. 2. The effect of storage time on emergence of diapausing larvae of the predatory midge *Aphidoletes aphidimyza*. The effect to duration of emergence.

emergence (Fig. 2). The shorter the storage period was the longer it took for emergence to begin and emergence took longer. The storage of a greenhouse population in diapause would probably produce a better result for emergence (BONDARENKO and MOISEYEV 1982). However, if the utilization of diapause storage is desired not only for the interruption of mass production during the winter season, but also as a supplement to mass production during the growing season, this must be able to be accomplished from a continuously growing laboratory population.

On the basis of the present results the mass production of predatory midges can be completely interrupted in September for 7 m and in early spring diapausing larvae can be utilized for the control of aphids. As a supplement to mass production diapausing larvae also stored from 3 to 8 m can be put to use provided it has been taken into account that only half of these will emerge.

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SELOSTUS

Kirväsääsken *Aphidoletes aphidimyza* (Rond.) (Dipt., Cecidomyiidae) diapausin hyväksikäyttö massatuotannossa

KATRI TIITTANEN

Maatalouden tutkimuskeskus

Kirvasääskeä on käytetty Suomessa lehtikirvojen biologiseen torjuntaan kasvihuonevihanneksista vuodesta 1978 lähtien. Niitä on tuotettu ympärivuotisesti tilassa, jossa valoisa jakso on 18 tuntia, lämpötila +20 °C—+25 °C. Kirvasääskiä ei Suomessa ja muissa pohjoisen alueen maissa tarvita syys- ja talvikuukausina. Sen tähden pidettiin tarpeellisena tutkia mahdollisuuksia kasvattaa kirvasääskiä kasvukauden aikana mahdollisimman paljon, säilyttää niitä diapausissa ja ottaa käyttöön tarvittaessa.

Diapausiastetta säilytettiin 1—12 kuukautta kahdessa lämpötilassa +2 °C ja +10 °C kosteassa turpeessa. Yksikään +2 °C säilytetty diapausitoukka ei aikuistunut. Seitsemän kuukauden +10 °C säilytyksen jälkeen toukista aikuistui 66 %, kun jatkuvassa kasvatuksessa ilman diapausia olleista toukista aikuistui 71 %. Kolmen — kuuden ja kahdeksan kuukauden säilytyksen jälkeen aikuistui noin puolet toukista. Kolmea kuukautta lyhyemmän ja kahdeksaa kuukautta pidemmän säilytyksen jälkeen aikuistuminen oli heikkoa. Säilytysaika vaikutti sekä aikustumisen alkamiseen että aikuistumisaikaan. Mitä lyhyempi säilytysaika oli sitä pidempi aika kului aikuistumisen alkamiseen ja sitä pidemmän ajan kuluessa aikuistuminen tapahtui.

Tulosten perusteella kirvasääsken massatuottaminen voidaan kokonaan keskeyttää syyskuussa seitsemäksi kuukaudeksi ja käyttää alkukeväällä kirvojen torjuntaan diapausitoukkia. Massatuottamisessa voidaan käyttää täydennyksenä myös 3—8 kuukautta säilytettyjä diapausitoukkia, kun otetaan huomioon, että niistä aikuistuu vain puolet.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 345—353 (1988)

Seria ANIMALIA NOCENTIA N. 137 — Sarja TUHOELÄIMET n:o 137

EFFECT OF PESTICIDES ON FOUR SPECIES OF ENTOMOPATHOGENIC FUNGI *IN VITRO*

IRENE VÄNNINEN and HEIKKI HOKKANEN

VÄNNINEN, I. & HOKKANEN, H. 1988. **Effect of pesticides on four species of entomopathogenic fungi *in vitro*.** (Ann. Agric. Fenn. 27: 345—353. Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

The effects of oxamyl, dimethoate, diazinon, pirimicarb, cypermethrin, thiram, vinclozolin, propiconazole, benomyl, metalaxyl + mancozeb, MCPA, glyphosate, trifluralin and simazine were evaluated *in vitro* on the entomopathogenic fungi *Metarhizium anisopliae* (Metsch.) Sorok., *Beauveria bassiana* (Bals.) Vuill., *Paecilomyces fumoso-roseus* (Wize) Br. et Smith and *P. farinosus* (Holm ex S.F. Gray) Br. et Smith. The fungicides propiconazole, thiram and vinclozolin, and the herbicide trifluralin inhibited the linear growth of fungi the most. Propiconazole and thiram also clearly reduced the sporulation of the fungi. The fungicide benomyl had no notable effect on *B. bassiana*. The other species were inhibited by it during the first 3 days after the treatment, but after one week only *P. fumoso-roseus* was still affected. Only *B. bassiana* was sensitive to the herbicides MCPA and glyphosate, whereas simazine affected only the two *Paecilomyces*-species. The effect of simazine was delayed and became apparent one week after the treatment. *P. fumoso-roseus* was sensitive to the fungicide metalaxyl + mancozeb. Chemicals that did not affect the growth or sporulation of any of the fungi tested were the insecticides diazinon, pirimicarb and cypermethrin, and the nematicide/insecticide oxamyl.

Index words: entomopathogenic fungi, pesticides, *Metarhizium anisopliae*, *Beauveria bassiana*, *Paecilomyces farinosus*, *Paecilomyces fumoso-roseus*, oxamyl, dimethoate, diazinon, pirimicarb, cypermethrin, thiram, vinclozolin, propiconazole, benomyl, metalaxyl-mancozeb, MCPA, glyphosate, trifluralin, simazine.

INTRODUCTION

The use of insect pathogenic fungi as microbial control agents often needs to be integrated with the use of different agrochemicals. Succesful integration requires detailed knowledge of the compatibility of the chemicals and pathogens. It is also useful to avoid potential disruption of the natural control of insect pests by entomofungi. In recent years a number of studies on the subject have appeared in the literature. The effect of pesticides on deuteromycetous entomofungi has usually been studied in the laboratory (ROBERTS and CAMPBELL 1977 give numerous references; see also ZIMMERMANN 1975, TEDDERS 1981, CLARK et al. 1982, LORIA et al. 1983, WATT et al. 1984, GARDNER and STOREY 1985), but some laboratory experiments have also been supplemented with tests in the field (CLARK et al. 1982, LORIA et al. 1983). The use of the fungicide mancozeb, for example, has been observed to reduce the natural mortality of the colorado potato beetle by the entomofungus *Beauveria bassiana* (CLARK et al. 1982). The use of pesticides can thus lead to secondary pest problems in the field if the adverse effect of the chemicals on beneficial entomofungi is either not known or is ignored.

For our study we selected 14 different chemical pesticides commonly employed for plant protection and particularly some that are used in the soil. The effect of a few of the selected chemicals on *Beauveria bassiana* and *Metarhizium anisopliae* has been studied by others also, but their influence on the species belonging to the genus *Paecilomyces* is less well known. We wanted to test their effect on the four fungal species separately and as pesticide groups. Additionally this study aimed to assess the response of some recently isolated Finnish strains of these fungi to the pesticides, because there may exist variation between strains in this respect.

MATERIAL AND METHODS

All fungi tested were isolated from Finnish soil in 1986 employing the bait method described by ZIMMERMANN (1986), but using *Tenebrio molitor* larvae as bait insects. *Metarhizium anisopliae* was isolated from the soil under a rowan tree (*Sorbus aucuparia*) in Maaninka, Central Finland; *Beauveria bassiana* from a strawberry field in Närpiö on the west coast; *Paecilomyces farinosus* from an oilseed rape field in Tohmajärvi, in eastern Finland, and *P. fumoso-roseus* from an apple orchard in Viikki, Helsinki.

The pesticides chosen for the experiment are among the most commonly used plant protection chemicals in Finland (Table 1), the only exception being the oxamyl nematicide/insecticide, which is not registered for use in Finland. It is, however, commonly used in other countries. The pesticides were used as suspensions in distilled, sterile water in concentrations and dosages corresponding to those recommended for field use, when 400 1 of water per ha is applied. Distilled, sterile water was used as the control.

Our method of testing differed slightly from those employed by previous studies reported in the literature. The effect of pesticides on entomopathogenic fungi has usually been tested in the laboratory by adding the chemical to the growth medium of the fungi before inoculation (e.g. ZIMMERMANN 1975, BAJAN and

Table 1. The 14 chemicals used in the experiment: trade names, active ingredients and their concentrations (g of active ingredient/l) in suspensions used for the treatments. 1 ml of the solution was sprayed on a petri dish (Ø 9 cm).

Trade name	Active ingredient	Concentration g/l
Nematicides:		
Vydate	oxamyl	5
Insecticides:		
Roxion	dimethoate	0.5
Basudin 10	diazinon	0.2
Pirimor	pirimicarb	0.25
Ripcord	cypermethrin	0.1
Fungicides:		
Tirama 50	thiram	1.5
Ronilan	vinclozolin	0.5
Tilt 250 EC	propiconazole	0.3
Benlate	benomyl	0.2
Ridomil MZ 63 WP	metalaxyl + mancozeb	0.5/3.5
Herbicides:		
Hormoneste	MCPA	1.9
Roundup	glyphosate	3.6
Super-Treflan	trifluralin	0.7
Simatsin-neste	simazine	1.9

KMITOWA 1977, TEDDERS 1981, CLARK et al. 1982, GARDNER and STOREY 1985). We wanted to give the fungi first the possibility to grow normally, as in nature, and only thereafter to expose them to the chemicals. The results showed this method to be at least equally reliable to the methods used earlier.

The fungi were treated with the chemicals as follows: Fungi were inoculated onto Petri dishes (ø 9 cm) filled with 15 ml of solid potato dextrose agar (Difco). Four replicates per each chemical and the fungal species were used in the experiment. Fungi were allowed to grow at room temperature (+22 °C) until the colonies were approximately 1 cm in diameter. After 3—4 days the edges of the colonies were marked on the bottom of the petri dish. Then the fungi were treated with the chemicals by spraying them with 1 ml of the pesticide solutions (see Table 1). After the treatment the dishes were kept at room temperature. Linear growth in excess of the markings that had been made on the day of the treatment was measured on the 3rd and 7th day following the treatment. Growth was measured at four points at the different sides of the colonies, and the mean value of these measurements was used in the calculations. Data were analyzed by one-way analysis of variance and Duncan's multiple range test.

Two weeks after the treatment the intensity of sporulation was checked relative to the intensity of sporulation in the control dishes treated with water only. A piece of scotch tape was gently placed onto to hyphal colony and transferred to an object glass with lactophenol-cotton blue. The intensity of sporulation was assessed microscopically by checking the relative amount of spores in several microscopic fields. The sporulation intensity was ranked either significantly weaker than in the controls or similar to that in the controls.

RESULTS

Linear growth of the fungi

As expected, the fungicides as a group inhibited the growth of the entomopathogenic deuteromyceteous fungi the most (Table 2). Fungicides caused approximately a 50 % reduction in the growth of the fungal colonies. Herbicides and insecticides ranked second. Oxamyl, the nematicide/insecticide, had the slightest effect. However, the differences between the groups explained only 15.5 % (3 days after the treatment, $p < .000$) and 8.4 % (7 days after the treatment, $p < .000$) of the variation (one-way analysis of variance), indicating that large differences among the chemicals belonging to one particular group existed.

Among the most inhibitive chemicals there were 3 fungicides (propiconazole, thiram and vinclozolin) and 1 herbicide (trifluralin) (Table 3). Their inhibitive effect continued throughout the whole experiment. Propiconazole, thiram and vinclozolin affected the fungi the most: the growth of the fungal colonies treated with these chemicals was only approximately 40 % or less than in the control. Benomyl (a fungicide) was a rather strong inhibitor of *M. anisopliae, P. farinosus* and *P. fumoso-roseus* during the first three days following the treatment, but 7 days after the treatment it continued to inhibit only *P. fumoso-roseus*. The inhibitive effect of simazine, on the other hand, was not clear until 7 days after the treatment. It significantly affected the growth of the two *Paecilomyces* species. The inhibitive effect of glyphosate on *M. anisopliae* and *P. fumoso-roseus* showed also only after 7 days from the start of the treatment.

There were no clear differences between the

Table 2. Effect of the selected fungicides, herbicides, insecticides and a nematicide on the mycelial growth of the entomopathogenic fungi *(Metarhizium anisopliae, Beauveria bassiana, Paecilomyces farinosus* and *P. fumoso-roseus*) as a group, measured on the 3rd and 7th days after the treatments. The table also gives the mean growth measurements in mm, standard deviations (s.d.) and the number of cases (n). Groups followed by the same letter do not differ significantly from each other ($p < .05$, Duncan's multiple range test). Four replicates, four measurements in each.

	Growth in % of the control	Mean growth in mm	s.d.	n
3 days after the treatment:				
Fungicides	50.7	1.68 a	1.053	77
Herbicides	72.5	2.40 b	1.332	64
Insecticides	78.3	2.60 b	1.369	76
Nematicide/insecticide	98.9	3.28 c	0.930	16
(Water)	100.0	3.32 c	1.246	16
7 days after the treatment:				
Fungicides	51.0	2.678 a	1.838	77
Herbicides	64.0	3.36 ab	2.427	63
Insecticides	71.5	3.76 b	2.316	74
Nematicide/insecticide	77.6	4.08 bc	2.056	16
(Water)	100.0	5.26 c	2.849	15

four fungal species in the average reaction to the chemicals. The growth of the colonies compared with that in the control dishes 3 days after the treatment was 68.0, 69.1, 72.7 and 73.0 % in *P. farinosus, B. bassiana, P. fumoso-roseus* and *M. anisopliae*, respectively. The four species reacted, however, somewhat differently to different chemicals (Fig. 1). Vinclozolin had a very strong inhibitive effect on the growth of *P. fumoso-roseus.* The same was true for metalaxyl + mancozeb, the effect of which in other species did not differ from the control. On the other hand, the growth of *P. fumoso-roseus* was not influenced so strongly by propiconazole as that of other species. In fact, vinclozolin was the strongest inhibitor for *P. fumoso-roseus. B. bassiana* was strongly affected by the herbicides glyphosate and MCPA, whereas the three other species were not significantly inhibited by these chemicals. *Beauveria bassiana* was the only species that was not significantly inhibited by the fungicide benomyl.

Table 3. The pesticides ranked according to their inhibitive effect on the average mycelial growth of all 4 entomopathogenic fungi on the 3rd and 7th day after the treatments. The growth in the treatments above the broken line differed significantly from that in the control dishes ($p < .05$, Duncan's multiple range test).

3 days after the treatment	Growth, % of the control (= 100 %)	7 days after the treatment	Growth, % of the control (= 100 %)
Propiconazole	16.0	Propiconazole	27.5
Thiram	37.9	Thiram	39.2
Trifluralin	54.9	Vinclozolin	44.8
Vinclozolin	57.1	Trifluralin	55.2
Benomyl	64.3	Simazine	61.8
MCPA	75.4	Glyphosate	66.0
Dimethoate	78.7	Cypermethrin	70.2
Diazinon	79.4	Benomyl	70.3
Metalaxyl + mancozeb	79.4	Metalaxyl + mancozeb	71.8
Glyphosate	79.6	MCPA	73.1
Simazine	80.1	Dimethoate	74.2
Cypermethrin	92.3	Pirimicarb	77.0
Oxamyl	99.0	Oxamyl	77.6
Pirimicarb	99.8	Diazinon	88.0

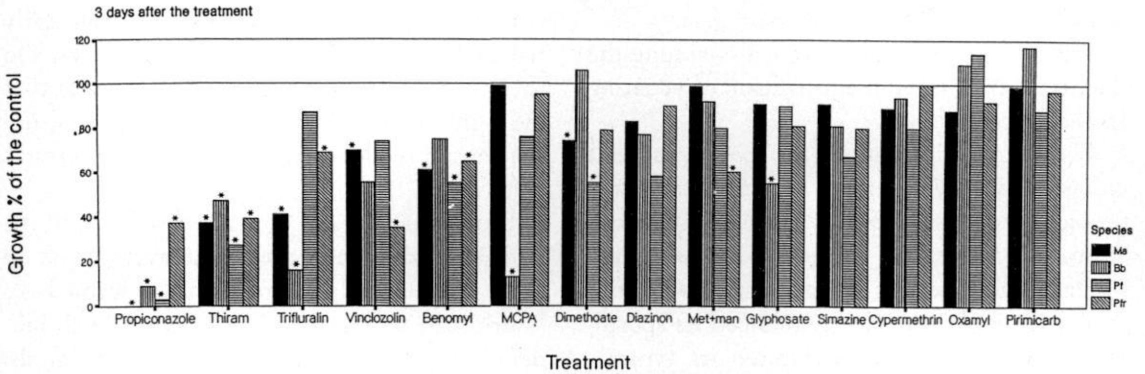

Fig. 1. The effect of different pesticide treatments on the growth of *Metarhizium anisopliae* (Ma), *Beauveria bassiana* (Bb), *Paecilomyces farinosus* (Pf) and *P. fumoso-roseus* (Pfr) 3 days after the treatment, expressed as percentages of the growth in the control. The asterisks indicate that the growth was significantly ($p < .05$) inhibited. Met + man = metalaxyl + mancozeb.

Changes in the external appearance and sporulation of the fungi

Spraying with propiconazole caused a dim glazing and usually yellow coating on the hyphal colonies of all the four species (Table 4). The effect was most clearly seen in *M. anisopliae:* the colonies turned finally dark brown and could not produce spores at all. In addition, *P. farinosus* and *P. fumoso-roseus* reacted to propiconazole by producing very few spores, but in *B. bassiana* the sporulation was

Table 4. Effect of different pesticides on the intensity of sporulation and outer appearance of the fungi. * = sporulation weaker than in the water control. CO = yellow or brown coating formed on the hyphal colonies, DEL = sporulation delayed. The treatments without asterisks sporulated like the controls.

	Fungal species			
Treatment	*Metarhizium anisopliae*	*Beauveria bassiana*	*Paecilomyces farinosus*	*Paecilomyces fumoso-roseus*
Nematicides:				
Oxamyl				
Insecticides:				
Dimethoate	* DEL			
Diazinon				
Pirimicarb				
Cypermethrin	*			
Fungicides:				
Thiram	* DEL	*	* CO	*
Vinclozolin				* CO
Propiconazole	* CO	CO	* CO	* CO
Benomyl	* DEL	CO		CO
Metalaxyl + mancozeb				
Herbicides:				
MCPA		*	CO	
Glyphosate	* DEL	*		CO
Trifluralin		* CO	CO	
Simazine	* DEL			
Water (control)				

abundant beneath the yellow coating.

Trifluralin and benomyl were also among the chemicals that caused the formation of a coating on the fungal colonies.

The sporulation of *P. farinosus* was least reduced by the chemical treatments. Only propiconazole and thiram reduced its sporulation to some extent. *P. fumoso-roseus* reacted similarly, but besides propiconazole and thiram, also vinclozolin clearly reduced its sporulation. *P. fumoso-roseus* exhibited its typical pink colour of the spores only in three treatments (pirimicarb, metalaxyl + mancozeb and trifluralin), in addition to the control, but its absence did not correspond to the ranking of inhibitiveness (metalaxyl + mancozeb and trifluralin were among the most inhibitive chemicals for this species).

In *B. bassiana* the reduction in sporulation was marked in the treatments with MCPA, trifluralin and thiram, which also significantly reduced the linear growth of the colonies. On the other hand propiconazole, the chemical that most inhibited the growth of this species, did not cause a reduction in the sporulation per unit area.

Propiconazole and cypermethrin caused *M. anisopliae* to sporulate less than average. As already mentioned, propiconazole seemed to "burn" the hyphae of *Metarhizium*, which hindered fungal sporulation. Some chemicals: thiram, benomyl, dimethoate, glyphosate and simazine seemed to delay the sporulation of *Metarhizium*. On the day when the intensity of sporulation was checked, the spores in these treatments were light green (just being formed) in comparison with the dark green colour of the spores in the control and the rest of the treatments.

DISCUSSION

In general, half of the tested pesticides affected the entomopathogenic fungi significantly. In all the cases where there was an effect, it was inhibitive and can be regarded as fungistatic. The only exeption was the clearly fungicidal effect of propiconazole on *M. anisopliae*. None of the pesticides tested stimulated the growth of the four fungal species in our experiments. In some laboratory experiments (e.g. BAJAN and KMITOWA 1977) a stimulative effect by certain chemicals at low doses has been noted, but it may be that our concentrations were not low enough for this effect.

Broad-spectrum fungicides (in this case especially thiram and propiconazole) can be expected to have a harmful influence on entomopathogenic fungi as well. This also proved to be the case. Of the five fungicides tested only metalaxyl + mancozeb had no negative effect on *M. anisopliae, B. bassiana* and the two *Paecilomyces*-species, which all belong to the group Deuteromycetes. In Finland this fungicide is used to control *Phytophtora infestans*, which belongs to the group Oomycetes.

The effect of most chemicals was rather consistent on all of the species tested, but some of the results show that species may display different reactions to certain chemicals. This indicates the need for the testing of each species with each chemical separately, in order to obtain the knowledge of their compatibility.

The effects of trifluralin, benomyl, simazine and diazinon on some of the four species have been tested to some extent earlier by others (cf. RAMARAJAH et al. 1967, OLMERT and KENNETH 1974, ZIMMERMANN 1975, TEDDERS 1981, GARDNER and STOREY 1985). The results of our respective experiments were largely in agreement with those previously obtained. It was surprising, however, that the fungicide benomyl did not inhibit the growth of *B. bassiana* significantly in our experiment. This contradiction could be explained by the different method we used, but there may also be a large variation in the sensitivity to a particular chemical among isolates of the same fungal species, as noticed by OLMERT and KENNETH (1974). In their experiment, however, the variation in sensitivity among different isolates of *B. bassiana* was lowest to benomyl.

The herbicide simazine has been shown to be relatively harmless to *Beauveria bassiana* (GARDNER and STOREY 1985), which was true also in our test. On the other hand, simazine proved to be inhibitive to both of the *Paecilomyces* species. Its effect was, however, delayed and first appeared only 7 days after the treatment, indicating that it could have degraded to more toxic metabolites.

Even though the intensity of sporulation was assessed rather crudely, it did show that the inhibition on mycelial growth is not necessarily followed by a reduction in sporulation. Of the chemicals inhibiting the growth of the fungi most, propiconazole and thiram also reduced the sporulation of three species out of four. Trifluralin and benomyl did not notably affect sporulation intensity. This is connected with the fact that an inhibition of mycelial growth is not necessarily a good indication of other fungicidal effects such as reduction in sporulation or spore viability and, consequently, the decrease of pathogenicity (ZIMMERMANN 1975).

The overall actual effect of the pesticides tested on the populations and performance of insect pathogenic fungi in the field is difficult to evaluate. It is certain that most of the time the concentrations of the chemicals that reach the fungi in the soil are smaller than those employed in our experiment. Locally, however, the concentrations may be much higher and exceed the normal ones. This may be especially true for pesticides that are applied directly into the soil, such as trifluralin, diazinon or oxamyl. On the other hand, fungi growing on agar in petri dishes are grown under optimum conditions, which may make them more tolerant to the chemicals than what can be expected in nature where suboptimal growing conditions, many different antagonists, and adverse weather conditions prevail. In such situations even a small additional stress factor may significantly lower their fitness and performance. On the other hand, also pesticides are affected and degraded by different environmental factors on the plant and in the soil. Therefore it cannot be assumed that the pesticides considered "safe" here are, in fact, safe in actual use. Similarly, it is not clear that the pesticides that are harmful in laboratory experiments will have the same effect in the field (cf. CLARK et al. 1982). It is clear that only field experiments can be used to accurately assess the effects of pesticides on beneficial antagonists such as insect pathogenic fungi (see e.g. CLARK et al. 1982 and LORIA et al. 1983). The results of laboratory experiments can serve, however, as a useful starting point for such a study.

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SELOSTUS

Torjunta-aineiden vaikutus neljään hyönteispatogeeniseen sienilajiin laboratoriossa

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Maatalouden tutkimuskeskus

Laboratoriossa petrimaljoilla tutkittiin oxamylin, dimetoaatin, diatsinonin, pirimikarbin, sypermetriinin, tiraamin, vinklotsoliinin, propikonatsolin, benomyylin, metalaksyylin ja mankotsebin seoksen, MCPA:n, glyfosaatin, trifluraliinin ja simatsiinin vaikutusta *Metarhizium anisopliaen, Beauveria bassianan, Paecilomyces fumoso-roseuksen* ja *P. farinosuksen* kasvuun ja sporulointiin. Sienten annettiin ensin kasvaa agaralustalla n. kolmen päivän ajan +22 °C:ssa, jonka jälkeen kasvustojen päälle suihkutettiin 1 ml torjunta-aineliuosta. Sienten kasvu mitattiin 3 ja 7 päivän kuluttua käsittelystä. Sporuloinnin intensiteettiä eri käsittelyissä verrattiin vedellä käsiteltyjen kontrollikasvustojen sporulointiin 3 viikon kuluttua kokeen alkamisesta.

Puolet kokeessa käytetyistä torjunta-aineista ehkäisi merkitsevästi sienten kasvua. Keskimääräinen kasvu oli 60—70 % kontrollikäsittelyjen kasvusta. Laaja-alaiset fungisidit propikonatsoli, tiraami ja vinklotsoliini sekä trifluraliini-herbisidi ehkäisivät sienten lineaarista kasvua voimakkaimmin. Näissä käsittelyissä sienten kasvu oli vain 40 % tai vähemmän kontrollikäsittelyihin verrattuna, ja ne olivat kasvua pahimmin ehkäiseviä aineita molemmilla mittauskerroilla. Propikonatsoli ja tiraami vähensivät selvästi myös sienten sporulointia. Perunaruton torjuntaan tarkoitettu fungisidi metalaksyyli + mankotsebi ehkäisi ainoastaan *P. fumoso-roseuksen* kasvua. Aikaisempien vastaavien kokeiden tuloksista poiketen benomyyli ei vaikuttanut *Beauveria bassianan* kasvuun merkitsevästi, kun taas muiden lajien kasvua tämä aine vähensi selvästi. Sen vaikutus hävisi kuitenkin viikon kuluttua käsittelystä lukuunottamatta *Paecilomyces fumoso-roseusta.* Simatsiinin vaikutus *Paecilomyces*-lajeihin oli päinvastainen. Niiden kasvu hidastui vasta viikon kuluttua käsittelystä. Muiden lajien kasvuun simatsiini ei vaikuttanut. MCPA ja glyfosaatti ehkäisivät vain *B. bassianan* kasvua. Dimetoaatti, diatsinoni, pirimikarbi, sypermetriini ja oxamyyli eivät ehkäisseet minkään sienilajin kasvua.

Sienten kasvuun voimakkaimmin vaikuttaneet aineet muuttivat kasvustojen pinnan usein kellertäväksi, nahkeaksi ketoksi, jonka alla sporulointi saattoi kuitenkin olla voimakasta. Propikonatsoli vaikutti erittäin voimakkaasti *Metarhizium anisopliaen* ulkonäköön "polttaen" kasvuston kokonaan ruskeaksi, eikä sieni pystynyt sporuloimaan lainkaan.

Torjunta-aineiden todellinen merkitys hyönteispatogeenisille sienille vaatii testausta myös kenttäolosuhteissa, jossa sieniin vaikuttavat samanaikaisesti myös muut ympäristötekijät, kuten mahdolliset antagonistiset mikro-organismit ja epäedulliset sääolosuhteet. Erityisesti maaperässä käytettävien aineiden konsentraatiot voivat olla paljon suurempia kuin tässä kokeessa käytetyt. Laboratoriossa haitattomiksi tai haitallisiksi osoittautuneiden aineiden vaikutus voi siksi olla toisenlainen niiden normaalissa käyttöympäristössä.

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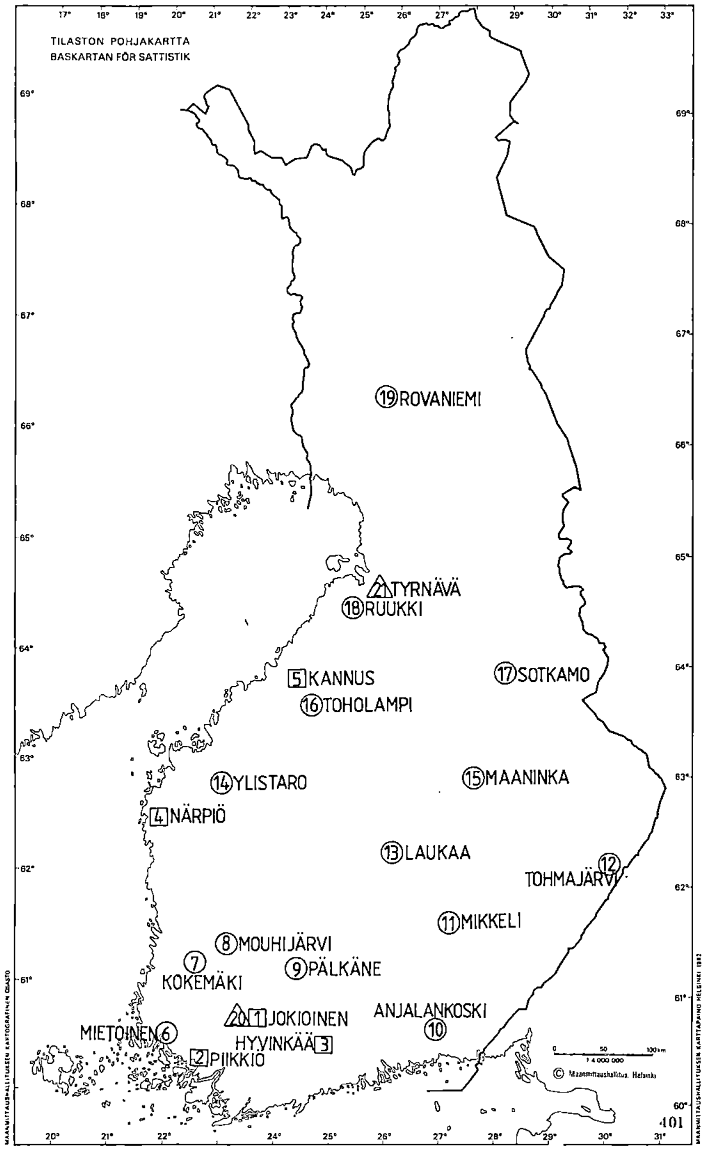

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