

The efficacy of lindane and dimethoate against cabbage maggots in Finland

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Abstract. Various rates of lindane and dimethoate were used in different localities against cabbage maggots in cabbages and tests were done on hatching larvae of *Delia floralis* Fall. to determine the possible resistance of 3 field strains to these insecticides. Considerable differences were noted in the efficacy of both insecticides in various localities and significant differences were found in the susceptibility of different strains to both insecticides. The LC 50-values compared with those of the most susceptible strain were, however, less than 3-fold. The reasons for the poor efficacy of the insecticides are discussed.

Introduction

Since the early 1960's several reports have been published on the resistance of cabbage root fly, *Delia brassicae* Bouche, against chlorinated hydrocarbon and organic phosphate insecticides (e.g. HOWITT and COLE 1962, COAKER et al. 1963, HELLQVIST 1968, HENNEQUIN and AUGE 1975). Reports concerning resistance of the turnip root fly *Delia floralis* are considerably fewer owing to the fact that *D. floralis* is univoltine while *D. brassicae* usually has more than one generation in the area where it occurs. TAKSDAL (1966) found that *D. floralis* had become resistant against lindane and aldrin in northern Norway. According to STEWART and McKINLAY (1965) the third larval instar of *D. floralis* showed increased tolerance to heptachlor in the laboratory.

Because repeated claims have been made by the growers on the weakened effect of the insecticides against root maggots on cruciferous crops in Finland, investigations on the possible resistance to the insecticides generally used for this purpose were carried out in 1976. This paper reports on the results of these studies.

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Materials and methods

A questionnaire was sent to cabbage growers through the vegetable growing advisers of the Agricultural Centres in order to find out the possible resistant strains of cabbage root flies in Finland. 37 replies were received totalling up to 166 ha which is about 20 % of the cabbage growing area of the country. The smallest cabbage growing area represented was 11 a and the largest 30 ha, the mean size being 4.5 ha.

Field trials were carried out on some farms where, according to the questionnaire, previously successful root maggot control after a long use in the preceding years had failed and for comparison also in places where the effect of the insecticides had continued to be normal, and on the use of insecticides of shorter duration.

The plants grown in seedbed under glass were treated with insecticides after being planted in the field. In lindane treatments 0.46 % fine granulate (Agrocid 2) was mixed with the soil surface around the plant at rates given in Table 1. Dimethoate, 40 % emulsion (Roxion) in dilutions of 0.02, 0.04 and 0.08 %, was used as soil drench at the bases of the plants (Table 1). The dead plants were examined for root maggot damage during the growing season. In connection with the harvest every plant was checked for root maggot damage using a scale 0–5 (completely healthy–totally destroyed).

Testing for resistance. The larval test method described by READ (1965) for *D. brassicae* and modified by NEDSTAM (1974) was used. The testing time had, however, to be lengthened for *D. floralis*. The test insects were collected as larvae from the fields where the effect of insecticides was poor and for comparison from places where it was moderate. They were put in plastic pots Ø 22 cm filled with wet turf and kept in 20–23° C. Pieces of swedes were placed in the pots and added to when necessary. When all the larvae had pupated each pot was covered with a PVC rearing cylinder 37 cm high. The emerged flies, (1 349 specimens in all), were collected and identified daily. They were put in rearing cages 60 cm high and 30 cm square, 100–150 flies in each cage with equal numbers of males and females. A wet turf layer was placed on the bottom of the cages to preserve the moisture. A soyameal–yeast mixture 7:3 added with water was given for food. Sugar and fresh dandelion flowers were also available in each cage.

A week after the emerging of the flies the cages were provided with small glass vials with moist fine sand and a slice of swede for egg laying. The eggs were removed every second day with the sand layer and put in a glass vial filled with water which was stirred with a glass stick and sieved on a piece of dark cloth and used for testing 2.9–3.10. A total of 6 200 *D. floralis* eggs was examined. The insecticides used were lindane (Silvanol) and dimethoate (Roxion) in concentrations of 0.00125, 0.0025, 0.005, 0.01, 0.02, 0.04, 0.08, 0.16, 0.32 and 0.64 % active ingredient. The strains selected and tested on the base of field trials (locations in Fig. 1.) were: strains O (Oulu) and V (Vantaa) for lindane resistance and strains O and H (Haukivuori) for dimethoate resistance. Strain K (Kangasala) was used as a standard because of adequate control in the field trial with both insecticides combined with a relatively short use of insecticides and with no complaints over any reduced effect from the grower.

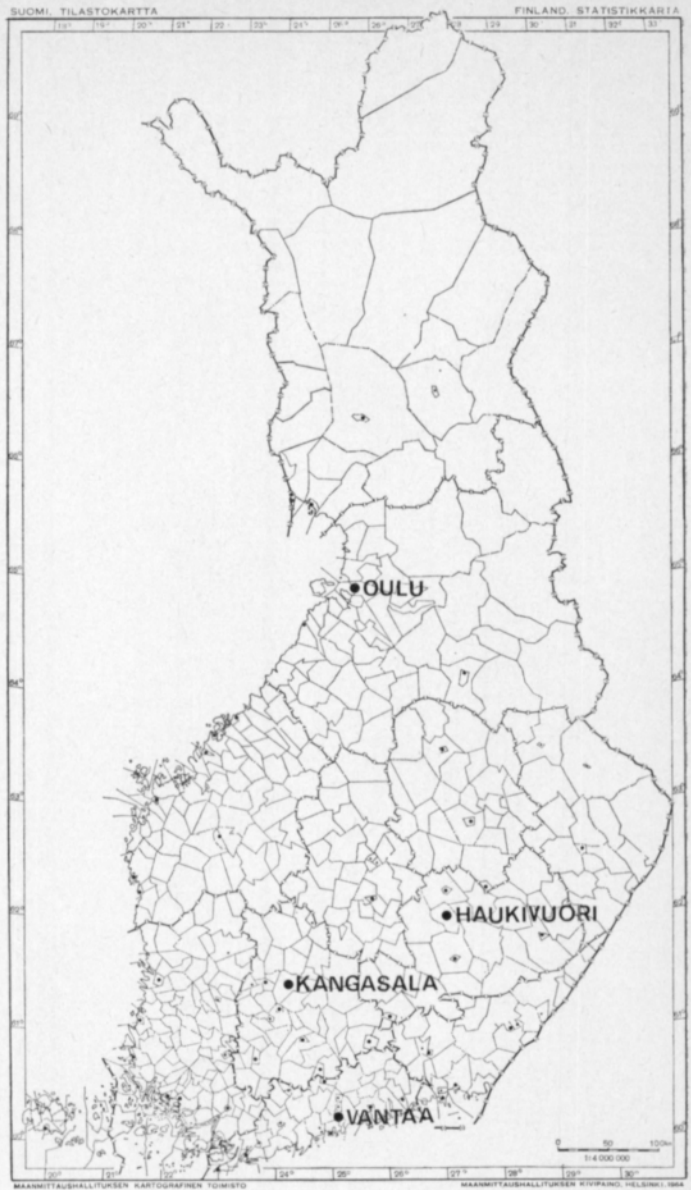


Fig. 1. Location of tested strains.

Results

The most general insecticide for cabbage maggot control was dimethoate, which was used on more than 2/3 of the cabbage growing area. Next in order was lindane followed by diazinon and trichloronate. Bromophos, parathion and malathion were also used to a minor extent.

Ten growers out of 37 considered the effect of insecticides not as good as in previous years.

In field trials the damage was very heavy in Oulu, where also the efficacy of both insecticides was poor (Table 1). In Haukivuori the efficacy of dimethoate was rather poor but that of lindane considerably better. In Kangasala and Vantaa there was less damage and the effect of both insecticides was moderate.

The highest dimethoate concentration 0.08 was phytotoxic causing marginal chlorosis. This phytotoxicity was also to be seen in the yield results in some places. In all field trials *D. floralis* was the dominant species (Table 2).

Table 1. Damage by root maggots after various treatments at different localities

Insecticide	AI g/plant	Damage (0-5)			
		Vantaa	Kangasala	Haukivuori	Oulu
Lindane	0.0046	1.2	0.9	1.7	4.3
	0.0092	0.7	0.3	1.5	4.7
	0.0184	0.8	0.3	1.4	4.2
Dimethoate	0.01	1.7	0.9	2.9	4.6
	0.02	0.7	0.6	2.6	3.6
	0.04	0.3	0.3	1.6	3.7
Untreated		2.1	1.3	3.3	4.9

Table 2. The occurrence of *Delia brassicae* and *D. floralis* on cabbages at different field trial localities

	<i>Delia brassicae</i>	<i>Delia floralis</i>	Other species	Total number
	%	%	%	
Vantaa	1.6	95.2	3.2	250
Kangasala	0	100	0.	285
Haukivuori	1.4	98.2	0.4	441
Oulu	0.3	82.8	16.9	373
				1 349

When lindane was used in resistance testing at the concentration recommended for growers, 0.04 %, the mortality of different strains varied from 73.6 (V) to 98.7 % (K). In the K-strain the LC 50 was significantly lower than in other strains (Table 3) between which no significant differences were noted. The resistance coefficients compared with that of the K-strain were as follows: O 2.5, H 2.7 and V 2.9. The regression coefficient in the K-strain was significantly higher than in the O and H strains.

When dimethoate was used at the concentration recommended for growers, 0.04 %, the mortality was high in each strain varying from 95.6 (V) to 100 % (O). In the K-strain the LC 50 was significantly lower than in other strains and in the O-strain significantly higher (Table 3). The resistance coefficients compared with those of the K-strain were as follows: O 2.9, H 1.6 and V 1.5. The regression coefficient in the O-strain was significantly higher than in the other strains.

Table 3. Regression coefficients (b) and LC50-values of different *Delia floralis* strains to lindane and dimethoate

Insecticide	Strain	b	s _b	LC ₅₀	±	t _{95 %}
Lindane	V	1.208	0.1615	0.0068		0.00119
	K	1.501	0.1710	0.0023		0.00035
	H	1.231	0.0897	0.0064		0.00054
	O	1.176	0.0982	0.0057		0.00062
Dimethoate	V	1.518	0.1755	0.0030		0.00042
	K	1.237	0.1253	0.0020		0.00030
	H	1.386	0.1163	0.0033		0.00032
	O	2.018	0.2148	0.0060		0.00049

Discussion

Cabbage maggots have been subjected to lindane in Finland for more than 25 years and to dimethoate for about 10 years. In the 1970's the use of dimethoate has increased so that it is now the most common insecticide used for this purpose. According to the inquiry made in connection with this study, dimethoate is estimated to be used in about 2/3 of the cabbage growing area of the country, which is c. 900 ha. Lindane is still used in about 1/5 of the cabbage area, especially in northern Finland.

In Finland both *D. brassicae* and *D. floralis* are common, but proportions of the species vary. In 1951–1961 when larvae and pupae of *Delia* species were collected in different parts of the country, *D. brassicae* was found to be the most common species (VARIS 1965). In the material collected for the present study, however, the proportion of this species was minute, *D. floralis* being responsible for practically all the damage. *D. brassicae* has two generations per year in southern Finland, *D. floralis* is univoltine. In northern Finland both species occur in one generation. If the treatment is given to the first generation of *D. brassicae*, as recommended in practice, it can not be expected to be effective against *D. floralis* in southern Finland where the latter species occurs about one month later. At that time the root systems of cabbage plants are, however, usually strong enough to withstand the damage. This is not the case in northern Finland where the attack of root flies is often very heavy and severe damage may occur. The difference between the occurrence times of these two species grows smaller towards the north (VARIS 1967) and thus the occurrence of *D. floralis* is there relatively earlier, but late enough for the early treatment. The effect of insecticides was poorest in Oulu, the northernmost place of the study where the damage was so heavy that without treatment practically no yield would have been obtained. The severity of the damage was considered normal by the growers, and in some localities even somewhat slighter than normal. This was also the case according to MARKKULA (1977).

Although the K-strain was most susceptible to both insecticides, the 2–3-fold differences in the LC 50 between it and other strains may not be explained as resistance (GEORGHIOU 1972). In the tests of READ (1965) and NEDSTAM (1974), made by the same method, the differences between susceptible and

resistant strains of *D. brassicae* against dieldrin were up to 1000-fold. The low level of resistance may, however, be evidence of a latent period needed before the higher levels of specific resistance are developed, as pointed out by BROWN (1971). Especially in northern Finland the refusal of insecticides has led to increasing rates in applications by the growers. The selection pressure in terms of per cent mortality has, however, not been high from the very beginning and the broadcasting of insecticide which according to COAKER et al. (1963) especially contributes to the developing of resistance, is generally not used. The increased use of insecticides will, however, have contributed to a reduction of natural enemies and thus to increased damage. In England sublethal aldrin and dieldrin residues reduced the numbers of natural enemies and, therefore, increased the attack by *D. brassicae* (COAKER 1965). Different soils and moisture contents also affect the efficacy of insecticides. (e.g. HARRIS 1964). In the present study the soil was mineral soil in all localities.

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Lindaanin ja dimetooatin teho kaalikärpäsiin Suomessa

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Ristikukkaiskasvien juuria vioittavat kaalikärpäset ovat useissa maissa kehittyneet torjunta-aineita kestäviksi. Kun myös meillä viljelijät ovat valittaneet aineiden tehon heikentyneen, pyrittiin tässä tutkimuksessa selvittämään johtuuko torjunnan vaikeutuminen kaalikärpästen torjunta-aineen kestävydestä.

Torjuntaa koskevat tiedot saatiin 37 kaaliviljelmältä, joiden viljelyala oli yhteensä 166 ha. Yleisimmin kaalikärpäsiä torjuttiin dimetooatilla, jota käytettiin kahdella kolmasosalla viljelyalasta sekä lindaanilla, jota käytettiin yhdellä viidesosalla viljelyalasta. Kymmenen viljelijää kolmestakymmenestäseitsemästä ilmoitti torjunta-aineiden tehon heikentyneen.

Kenttäkokeissa tutkittiin dimetooatin ja lindaanin tehoa Vantaalla, Kangasalla, Haukivuorella ja Oulussa. Kaalikärpäsvioitusta oli eniten Oulussa, jossa molemmat insektisidit tehosivat huonosti. Haukivuorella dimetooatin teho oli heikko, mutta lindaani tehoi dimetooattia paremmin. Kangasalla ja Vantaalla vioitusta oli vähän ja insektisidien teho hyvä. 0.2 %:n dimetooatti aiheutti useissa koepaikoissa kasvien vioittumista. — Juuria vioittaneet kärpästoukat olivat lähes yksinomaan isoa kaalikärpästä, *Delia floralis*. *D. floralis*-kantojen dimetooatin ja lindaanin kestävyys tutkittiin laboratoriossa saattamalla kaalikärpästen munat kosketukseen eri väkevyisten torjunta-aineliuosten kanssa ja laskemalla kuoriutuvien toukkien määrää. Vertailukohteena oli Kangasalan kanta. Sekä dimetooattia että lindaania käytettäessä vertailukannan LC50-arvo oli merkitsevästi alempi kuin muiden kantojen. Resistenssikertoimet Kangasalan kantaan verrattuna olivat kuitenkin vain 1.5–2.9, mitä ei vielä voida pitää osoituksena resistenssin kehitymisestä.

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