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Chemical control and economic damage threshold for *Collembola (Onychiurus sp.)* in sugar beets *(Beta vulgaris)*

Kemisk bekæmpelse og økonomisk skadetærskel for collemboler (Onychiurus sp.) *i sukkerroer* (Beta vulgaris)

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Summary

Damage by collembola in sugar beets is known all over Northern Europe. The damage occurs in the spring, when the collembola attack the seedlings. Seed dressing gives no protection when populations are dense, whereas granulated insecticides give sufficient control. This paper describes the effect of three granulated insecticides and indicate the economic damage threshold.

All the seed was treated with thiram and mercaptodimethur. Four treatments were carried out: Control, aldicarb (Temik 10 G), carbofuran (Curaterr) and thiofanox (Dacamox 10 G). To determine the number of soil-borne pests soil samples were taken twice and investigated by flotation. It was mostly collembola which were found. The collembola were identified only as belonging to the *Onychiurus* group. As a measure of the attack, a collembola index was worked out. The index is the average number of collembola found in the two soil samples.

The three insecticides were equally effective in depressing the level of collembola populations, but aldicarb and thiofanox gave higher yield than carbofuran when the level of collembola was high.

The cost of the chemical treatment necessitates an increse in yield of at least 4–5% to be profitable. The economic damage threshold was set at commembola index 8–10.

Key words: Collembola, *Onychiurus sp.*, sugar beets, *Beta vulgaris*, control, granulated insecticides, damage threshold.

Resumé

Skader i sukkerroemarker af collemboler tilhørende *Onychiurus*-gruppen er blevet konstateret over det meste af Nordeuropa. Skaderne sker om foråret, hvor frø og kimplanter angribes, og planterne kan skades af collemboler frem til fireblads-stadiet. Virkningen af bejdsning har vist sig ufuldstændig ved kraftige angreb, mens granuleret insekticid giver god beskyttelse ved selv tætte populationer.

Alt frø var bejdset med thiram og mercaptodimethur. Der blev udført 5 markforsøg på leret jord med 4 behandlinger: Kontrol, aldicarb, carbofuran og thiofanox. I hver behandling blev i kimbladstadiet og 4-bladstadiet taget 20 jordprøver til undersøgelse for jordboende skadedyr – collemboler, tusindben, symfyler, runkelroebiller og smælderlarver. Dyrene blev uddrevet ved flotationsmetoden.

Kun collemboler blev fundet i større mængder. Som mål for et eventuelt angreb, blev et collembol-index udregnet. Indexet angiver den gennemsnitlige forekomst af collemboler fundet i jordprøver taget på de to ovennævnte tidspunkter. Det er således et udtryk for det collembol-tryk, roerne har været udsat for i deres mest følsomme periode.

Alle tre granulerede insekticider var lige effektive til at holde bestanden af collemboler nede. I enkelte tilfælde var antallet af collemboler (collembol-index) temmelig højt i forhold til kontrollen. Dette kan skyldes, at de anvendte granulater er systemiske midler, som befinder sig lige omkring roden eller inde i planten. Collemboler, der befinder sig i periferien af jordprøven, vil derfor ikke nødvendigvis udsættes for så stor en påvirkning fra insekticiderne, at de vil dø.

Aldicarb og thiofanox gav højere merudbytte end carbofuran, når collemboler forekom i højt antal.

Beregnet ud fra 1983-priser på roer og granulater skal merudbytterne være på mindst 4–5%, for at nedfældning af granuleret insekticid kan betale sig. Den økonomiske skadetærskel kan ud fra disse resultater fastsættes til collembol-index 8–10.

Nøgleord: Collemboler, *Onychiurus sp.*, sukkerroer, bekæmpelse, granulerede insekticider, skadetærskel.

Introduction

In the spring of 1958 extensive inexplicable damage was seen in several sugar-beet fields in Western Germany. An investigation showed that it was due to collembola living underground (*Winner,* 1959). Later damage by collembola has been found in most of Northern Europe, for instance in other parts of Western Germany (*Winner & Schäufele,* 1967; *Ulber,* 1978), in Holland (*Heijbroek,* 1972), in England (*Dunning,* 1972; *Baker & Dunning,* 1975) and in Ireland (*Feeney,* 1979).

The noxious collembola belong to the *Onychiurus* group. They are all small and white measuring 0.5–2 mm (Fig. 1). The group comprises about 30 species. (*Winner,* 1959; *Brown,* 1983).

The whole life cycle takes place underground. The collembola hibernate at a frostfree depth and emerge in the seed bed in the spring as soon as the soil temperature has reached 5°C. Immediately they begin to breed and live on various kinds of plant material (*Heijbroek,* 1972).

The reason why they have not caused problems until recent years is a change in beet growing. Contrary to former practice, the beets are now sown as planting-to-stand, and herbicides are applied. As the collembola have no alternative food, they gather around the beets (*Heijbroek,*

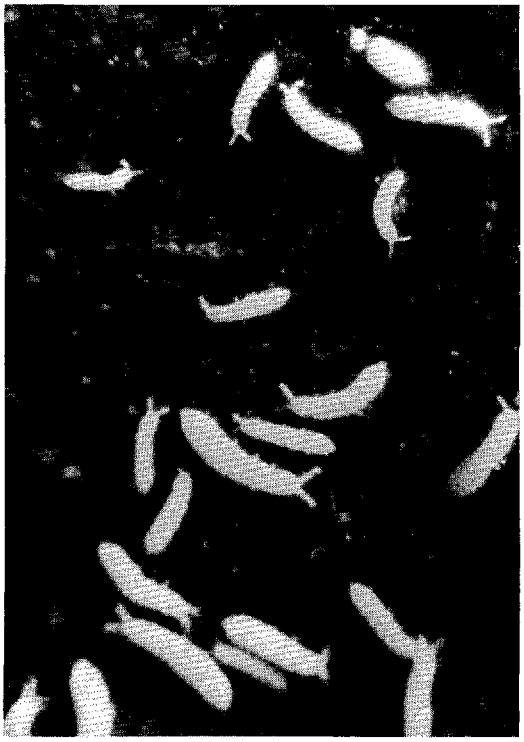

Fig. 1. Collembola belonging to the *Onychiurus*-group. *Collemboler tilhørende* Onychiurus-*gruppen.*

1972; *Heijbroek & Bund,* 1982; *Baker & Dunning,* 1975; *Ulber,* 1978).

The plants can be killed directly by collembola, but they usually die from secondary infections of fungi and bacteria. They are most susceptible to attacks in the seedling stage, but when they have four permanent leaves, they are quite resistant (*Brown,* 1981).

Practically all beet seeds are treated with a dressing of insecticides, but the use of seed dressing apparently offers protection against small attacks only, and the results from experiments with other kinds of chemical control have differed considerably (*Feeney,* 1979; *Brown,* 1981). Therefore the present experiments were conducted to describe the possibilities of control offered by the three granulated insecticides, and to determine the economic damage threshold.

Material and methods

5 experiments were carried out in 1981 and 1982. The experiments were made on two farms at different localities (clay) and they were part of the normal crop rotation with beets every third or fourth year.

The experimental fields were divided into strips with 6 replicates (Fig. 2) and plots of 25 sq.m.

All experimental fields except one, which was sown three weeks later, were sown at the normal time at the beginning of April and harvested during the last two weeks of October. The seeds were laid at 17-cm intervals with 50 cm between the rows. The beet seeds used were of the variety 'Monova'. They had been treated with thiram (Danatex 50), 12 g a.i. per unit (100,000 seeds) and mercaptodimethur (Mesurol WP 50), 10 g a.i. per unit. This means that fungicides and insecticides have been used on 'control' plots as well as on the other plots.

1A	1	1	1	1B	1	1	1
2A	2	2	2	2B	2	2	2
3A	3	3	3	3B	3	3	3
4A	4	4	4	4B	4	4	4

Fig. 2. Diagram of the experimental field. 'A' and 'B' are the sampling plots. (1: Control, 2: Aldicarb, 3: Carbofuran, 4: Thiofanox).
Diagram over forsøgsarealet. 'A' og 'B' er prøvetagningsparceller.

The strips were treated with the following granulated insecticides, which were applied at the time of sowing.

1. Control
2. Aldicarb (Temik 10 G), 0.7 kg a.i./ha.
3. Carbofuran (Curaterr), 0.6 kg a.i./ha.
4. Thiofanox (Dacamox 10 G), 0.6 kg a.i./ha.

Soil samples were taken with a conical auger (upper diameter: 6 cm, lower diameter: 5.5 cm) around the plants at a depth of about 8 cm.

20 soil samples (cores) were taken from each treatment. In order not to damage the experimental plots, the samples were taken from special sampling plots A and B, but the final sugar yield was determined from the experimental plots 1–6 (Fig. 2). Thus it is assumed that the average number of animals sampled in these plots are valid for the whole experiment. Samples were taken twice. The first time was at the seedling stage, the second time at the 4-true leaf stage of the beets. On the second occasion, other samples were taken and examined for sugar-beet nematodes (*Heterodera schachtii*) and the migrating nematodes *Trichodorus spp.* and *Longidorus spp.*

By the end of May, the plants were counted and examined for the larvae of the beet leaf miner (*Pegomyia hyoscyami*), black bean aphid (*Aphis fabae*) and peach-potato aphid (*Myzus persicae*).

The soil samples were packed in plastic bags to prevent drying. They were stored at max. 5° C until examination. The examination was carried out within 3 weeks.

The samples were examined for occurrence of collembola (*Collembola sp.*), millipedes

(*Blaniulus sp.*), symphylis (*Scutigerella sp.*), pygmy beetles (*Atomaria linearis*) and wireworms (*Agriotes sp.*).

The samples were examined by the method of flotation (*Southwood*, 1978). However, the method was somewhat simplified. Each of the 20 samples were put into a 1-litre plastic bucket which was filled with tap water. After 15 minutes the main part of the soil-borne pests in the sample had risen to the surface. The water was stirred in order to dissolve possible lumps of earth. After another quarter of an hour the remaining animals had risen to the surface. If the soil was very clayey, the stirring was repeated. The soil-borne pests on the surface were determined and counted directly. The collembola were determined with reference to the *Onychiurus* group (*Anon.*, 1973).

For the statistical analysis a one-way Anova test was used (*Helwig & Council*, 1979).

Results

At the examination of the samples, collembola were practically the only soil-borne pests found, no other pests were found in considerable numbers either.

In Table 1 the collembola index indicates the average number of collembola per plant at the two samplings. Thus it indicates the collembola pressure to which the plants have been exposed during their most susceptible period. The number of plants is the actual number of plants in the experimental plots, and the yield has been converted into tons of sugar per ha.

The experiment at Barløsegård, 1981, shows an inexplicable increase in yield with thiofanox although almost no collembola were found in the control.

A weak attack at Barløsegård 1982 gave a significant increase in yield with the use of carbofuran.

Table 1. Field experiment with granulated insecticides in 1981 and 1982.
Markforsøg med granulerede insekticider i 1981 og 1982.

	Insecticide *Insekticid*	Coll.-index *Coll.-index*	Plants/plot *Planter/parcel*	Yield t sugar/ha *t sukker/ha*
Skrillinge-gård, 1981	Control	14.9 (1.1)	195.0 (6.1)	7.7 (0.2)
	Aldicarb	14.7 (1.3)	194.7 (2.6	8.2 (0.1)*
	Carbofuran	9.0 (0.9)*	206.0 (4.3)	8.1 (0.2)
	Thiofanox	10.9 (1.0)*	212.2 (3.2)*	8.0 (0.1)
Barløse-gård, 1981	Control	1.6 (0.1)	176.2 (5.4)	7.4 (0.1)
	Aldicarb	1.6 (0.2)	168.7 (5.5)	7.6 (0.2)
	Carbofuran	1.1 (0.1)	178.8 (5.2)	7.5 (0.1)
	Thiofanox	0.8 (0.1)*	171.3 (6.0)	7.9 (0.1)*
Skrillinge-gård A, 1982	Control	13.6 (1.1)	182.2 (4.7)	10.5 (0.2)
	Aldicarb	6.6 (0.5)*	191.5 (4.6)*	11.3 (0.1)*
	Carbofuran	7.8 (0.9)*	180.3 (6.1)	11.0 (0.2)
	Thiofanox	5.3 (0.6)*	183.2 (3.7)	11.5 (0.2)**
Skrillinge-gård B, 1982 Late sowing	Control	9.6 (1.4)	159.7 (4.7)	9.6 (0.2)
	Aldicarb	7.6 (1.0)	182.7 (1.4)*	10.9 (0.1)***
	Carbofuran	4.9 (0.6)	166.2 (5.3)	10.2 (0.2)
	Thiofanox	4.7 (0.5)	170.0 (5.6)	10.9 (0.3)**
Barløse-gård, 1982	Control	5.9 (0.6)	168.0 (5.4)	9.9 (0.2)
	Aldicarb	3.9 (0.5)*	170.7 (1.4)	10.3 (0.2)
	Carbofuran	4.8 (0.5)	176.0 (3.5)	10.8 (0.1)**
	Thiofanox	3.8 (0.4)*	176.2 (4.2)	10.3 (0.1)

Means ± S.E. (N = 6). *Gennemsnit ± S.E. (N = 6).*
* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Table 2. Per cent increases in yields when treated with granulated insecticides in relation to index of collembola (the numbers give the percentage of the increase in yields).
Merudbytte i procent for behandling med granulerede insekticider i relation til collembol-index.

Insecticide *Insekticid*	Collembola index *Collembol index*				
	1.6	5.9	9.6	13.6	14.9
Aldicarb	2.7%	4.0%	13.5%***	7.6%*	6.5%*
Carbofuran	1.4%	9.1%*	6.3%	4.8%	5.2%
Thiofanox	6.8%*	4.0%	13.5%**	9.5%**	3.9%	

* = P< 0.05, ** = P < 0.01, *** = P < 0.001.

At Skrillingegård B 1982 significant increases in yields with aldicarb and thiofanox were found. The attack of collembola was intermediate. The experimental plots were sown about three weeks later than usual. Therefore the yields are lower than at Skrillingegård A 1982 which were sown in the same area.

At Skrillingegård 1981 and Skrillingegård A 1982 a medium to strong attack of collembola was found. In both years aldicarb gave significant increases in yields and in 1982 thiofanox as well.

In Table 2 per cent increases in yield are shown. The numbers are calculated from Table 1. For all the three granulated insecticides an increase was found, but only if this increase was 7% or more, was it significantly different from the control.

Discussion

Considering that only collembola were found in high numbers, it may be concluded that no other pests or disease had any influence on the experimental results.

Generally, the collembola-index for treated plots is lower than for the controls, which means that the three chemicals have an effect on the collembola. When the population is dense, the differences are significant in all cases except aldicarb Skrillingegård 1981. For intermediate to weak attacks only thiofanox from Barløsegård 1981 is significantly lower. The results show, that the insecticides were equally effective in depressing the level of collembola populations.

The granulated insecticides are systemic, and the active matter is found close by the root and inside the plant. This means that collembola can stay alive in the periphery of the soil sample. This is probably the reason for the high numbers of collembola which have sometimes been found in the treated plots compared with the controls.

The number of plants per plot are in most cases higher in comparison with the controls. In no case is it significant lower.

The results of the experiments generally show increased yields with all the granulates used. This also seems to apply in the cases where the collembola index was very low. These increases cannot always be explained by differences in the number of plants but may also be explained by differences in plant development.

However, increases in yield do not necessarily justify expenditure on chemical treatment. The increases should be so considerable that they cover the costs connected with chemical control.

The three insecticides in the recommended doses cost (including application) from 5–600 Dkr. per ha (1983 prices). The beets are sold for about 33 Dkr./100 kgs. During the last 4 years, the sugar yield (16 per cent) has been about 6.8 t/ha (*Danmarks Statistik,* 1983). Consequently an increase in yield of 4–5% is necessary to make a treatment with aldicarb profitable.

From Table 2, it appears that the economic damage threshold for collembola in sugar beets can be put at a collembola index between 5.9 and 9.6. Considering the S.E. the threshold index is 8–10. It appears as if there is a peak for index 9.6, but it may be a coincidence due to the small number of experiments. By way of comparison

Feeney (1979) describes cases where numbers of collembola as low as 7 per plant meant that only half of the plants developed.

Aldicarb gives statistically reliable increases in yield for collembola index higher than 9. Table 2 shows that the average increase is 9.2% for the three experiments. Thiofanox also gives significant increases in yield for index higher than 9. The average increase is 9.0%. Carbofuran apparently has the smallest effect, increases in yield are in most cases insignificant and the average of the increase is only 5.4%.

Unfortunately granulated insecticides can only be applied at the time of sowing, i.e. when the collembola density is still very low. Therefore soil samples taken at this time will not indicate whether the populations will reach the economic damage threshold later on. Further investigations are being conducted at The Institute of Plant Pathology, Lyngby. The aim is to set up a prognosis for the number of collembola in the spring based on the density of collembola in the previous autumn.

Conclusion

Of the three granulated insecticides that were tested, aldicarb and thiofanox turned out to be the most effective. To pay for the chemical control, the increases in yield must be at least 4–5%. On this basis the economic damage threshold was put at 8–10 in the collembola index.

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