Neth. J. Pl. Path. 88 (1982) 1-17

The influence of some agricultural practices on soil organisms and plant establishment of sugar beet

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Accepted 19 May 1981

Abstract

In a long term field experiment the influence of crop rotation and the application of insecticides and herbicides on soil arthropods (mesofauna), nematodes, soil fungi and weeds was investigated. Possible changes in numbers of not only pathogenic organisms, but also of predators or parasites of pathogens, could affect seedling establishment and/or yield of sugar beet. In soil samples taken during the spring, high populations of the springtail *Onychiurus armatus* were detected which caused considerable damage in the first two years. Later also rather severe infestations by *Atomaria linearis* occurred, probably caused by frequent sugar beet cropping.

No significant influence of crop rotation on damage caused by soil arthropods could be detected yet, but in the 1/3 sugar beet and 2/3 winter wheat rotation more micro-arthropods and a higher diversity of species were found than in the blocks with continuous sugar beet growing. In the latter ones the numbers of *Heterodera schachtii* increased and in 1980 the tolerance level was exceeded. On the contrary in the 1/3 sugar beet blocks *Pratylenchus spp.* were dominant. Since a number of perennial weeds cannot be controlled sufficiently in sugar beet, some of them created a problem in the 1/1 sugar beet blocks.

In the plots not treated with a soil herbicide large numbers of annual weeds provided alternative food for *O. armatus,* which resulted in less plant damage. No significant effect of chloridazon on the micro-arthropod fauna could be detected.

The insecticides lindane and aldicarb controlled *O. armatus* and *A. linearis* partially, and improved seedling emergence and to a lesser extent yield. Both insecticides had a variable effect on the relative abundancy of *Collembola* and in addition lindane suppressed numbers of *Acariformes* and aldicarb those of *Parasitiformes.* No negative influence on the species diversity could be detected. All effects did not last long and varied considerably from year to year.

Indications were found that, if species of *Collembola,* which could act as predators of nematodes, were suppressed, the numbers of *Pratylenchus spp.* and *H. schachtii* increased.

Additional keywords: Onychiurus armatus, Atomaria linearis, soil arthropods, *Heterodera schachtii, Pratylenchus spp.,* perennial weeds, *Stellaria media,* soil fungi, crop rotation, lindane, aldicarb, chloridazon.

Introduction

Cultural practices in sugar beet growing have changed drastically. The seed-spacing in the rows has increased and developed into planting to a stand on a large part of the sugar beet area. Weed control has improved by application of soil herbicides at drilling. In this way less food for soil arthropods (some of which are very polyphagous) is available, so that pest concentration around sugar beet seedlings and riscs of severe damage increase.

The use of insecticides as a seed dressing, seed furrow treatment or overall soil treatment for control of infestations by pygmy beetles *(Atomaria linearis)* and springtails *(Onychiurus spp.)* has become widespread now. Overall treatments can have serious implications, because predators are also killed, and soil and crops become contaminated with pesticides. Possibilities of an integrated approach were therefore investigated. We aimed at a combination of local chemical control or seed treatment and biological methods like creating alternative food supply between the rows of sugar beet or modification of seed-bed preparation.

Soil samples from some arable fields showed that *Onychiurus armatus* (Fig. 1) hibernate in deep layers. When soil temperatures rise above 5°C in early spring, they will become active and can migrate to the seed-bed. *O. armatus* is highly sensitive to desiccation and therefore its presence in the seed-bed is largely dependent on moisture content. If the water content of the seed-bed increases, many *O. armatus* migrate to the surface near the seedlings. So damage is considerable in a spring with periods of cool and rainy weather (Heijbroek, 1972). It also migrates over a short distance

Fig. 1. Scanning electronmicrograph of *Onychiurus armatus* Tullb.; magnification 84× (Laboratory for Electron Microscopy, University of Amsterdam).

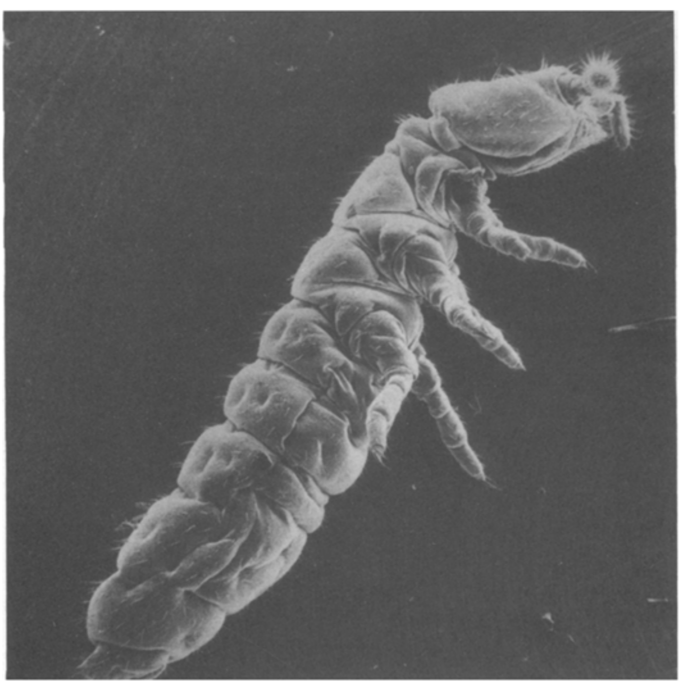

Fig. 1. Raster elektronenmicroscopische foto van Onychiurus armatus Tullb.; vergroting 84× (Laboratorium voor Elektronenmicroscopie, Universiteit van Amsterdam).

horizontally if weeds offer an alternative food supply between the sugar beet rows (Heijbroek et al., 1980).

Apart from causing damage, *Onychiurus spp.* can also be beneficial by preying on noxious nematodes.

A 'long term' trial on the effects of crop rotation, application of aldicarb and lindane and soil herbicides on *Onychiurus spp., A. linearis* and, more generally, on the composition of the soil fauna and the interrelations between predators and preys was laid down on an experimental farm. The results of the first four year period are presented.

Materials and methods

The trial was laid in two replicates at Westmaas in the SW part of the Netherlands on a clay soil. Each replicate consisted of two blocks with different crop rotations (Table 1), divided into six plots of 12 rows of sugar beet (at 50 cm) of 18 m each. The distance between the blocks was 9 m.

In 1978 the trial was expanded to 4 replicates to facilitate yield determinations but, because of differences in cropping history and springtail populations, most results of this additional part are not mentioned in this report.

Crop rotation before trial: 1975 pernnial ryegrass, 1974 potatoes, 1973 spring barley, 1972 sugar beet.

Soil analyses: silt 28%; pH-KCl 7.3; Pw 18; org. matter 2.6%; $CaCO_3$ 7.3%; K-HCl 16 mg/100 g.

Sugar beet varieties: Kawemegamono or Monohil.

Treatments, applied at or before drilling:

1. No insecticide — herbicide chloradizon 2.6 kg a.i./ha.
2. lindane, 1 kg a.i./ha — herbicide chloradizon 2.6 kg a.i./ha.
3. aldicarb, 1 kg a.i./ha in seedrurrow — herbicide chloridazon 2.6 kg a.i./ha.

Table 1. Scheme for crop rotation in the trialfield and drilling dates of sugar beets.

Year	Crops		Drilling dates of sugar beet
	rotation 1/1 SB	rotation 1/3 SB	
1976	SB	WW	5/3
1977	SB	WW	10/3
1978	SB	SB	7/4
1979	SB	WW	17/4
1980	SB	WW	24/3

SB = sugar beet; WW = winter wheat.

Tabel 1. Schema voor de vruchtopvolging in het proefveld en de data waarop de suikerbieten werden gezaaid.

4. no insecticide	no soil herbicide, weeds removed at singling.
5. lindane, 1 kg a.i./ha	no soil herbicide, weeds removed at singling
6. aldicarb, 1 kg a.i./ha in seedfurrow	no soil herbicide, weeds removed at singling.

In the blocks with winter wheat normal cultural practices were followed, but no soil insecticides were used. To control weeds methabenzthiazuron (4.5 kg/ha) and MCPA 25% a.i. (4 l/ha) were applied. Fungal diseases and aphids were controlled by carbendazim + maneb (4 kg/ha) and pirimicarb 50% a.i. (0.5 kg/ha) if necessary.

All seedlings of the 3 centre rows were counted twice and at harvest root weight and sucrose content were determined according to standard procedures.

Soil arthropods, nematodes and soil fungi. From the 2 centre rows of each plot 4 samples of 62.5 ml were taken to a depth of 10 cm with a sugar beet seedling in the center and analysed by means of the modified Tullgren extraction apparatus as described by Van de Bund (1965). The diameter of the cores was 5.7 cm. The very poor emergence in 1977 forced us to take samples next to the seedlings.

For the determination of numbers of *Onychiurus spp.* and *A. linearis,* and their relation to damage, these organisms were extracted from soil samples by flotation on water. A part of the organic debris was removed by pouring the suspension over a 1.4 m sieve.

Nematodes were analysed in soil samples of 20 cores per plot, taken to depth of 20 cm. Cysts were extracted from 2 × 100 ml of dried soil by sieving (0.25 mm) with a water jet and consecutive separation on alcohol, according to Seinhorst (1970). Migratory nematodes were extracted from 2 × 100 ml of wet soil by means of the Oostenbrink elutriator (Oostenbrink, 1960).

Soil fungi were isolated and identified from 50 randomly sampled seedlings per plot and adhering rhizosphere soil.

Changes in the arthropod soil fauna. Changes in the composition of the arthropod soil fauna, caused by cultural measures, application of herbicides, pesticides etc., were determined by using the following criteria:

1. The number of individuals of the large (orders and suborders) and the small taxa (genera and species);
2. The relative abundance of the different taxa;
3. The total numbers of species;
4. The extent of mutual similarity of the ranges of the occurring species obtained by:

a. Jaccard index = $j(a+b-j)$, in which j = the number of species occurring in common in the plots being compared; a and b are the total number of species in theseplots. The highest possible value which can be reached is 1 (complete similarity), but this is a very rare exception. Since the majority of the species was represented by a few individuals only, most samples did not contain all species. Therefore a restricted part of the occurring species is in common in two series of samples of the same plot. Apart from that, the Jaccard index is also dependent on sample size.

b. the dominance identity (Renkonen value), which represents a percentage of mutual similarity, is calculated by using the Jaccard index, but here the numbers of individuals of each species are incorporated. In this case $j = d_1 + d_2 + \ldots d_n$, as d = the number of individuals of the species which occur in common; a and b are the total numbers of individuals in the samples being compared. This index is multiplied by 100 to obtain percentages.

Weeds. Annual and perennial weeds were counted in between two rows over the whole length of the plots in a total of 9 m^2. Because of the high densities in 1978 the incidence of annual weeds was estimated by applying the index of abundance/distribution according to the following scales:

Abundance:
0. none
1. very few
2. few
3. moderate
4. many
5. very many

Distribution:
1. very regular
2. small groups
3. rather big groups
4. big groups
5. very big groups

Results

Plant counts, infestations and yield of the sugar beet crop. In het first year of the trial (1976) high populations of *O. armatus* were detected and serious damage to sugar beet seedlings was caused. As can be seen in Table 2 the insecticides, applied in the plots treated with chloridazon, enhanced seedling establisment. They could not prevent damage completely, however. On the root system of sampled plants severe damage could be detected regularly. Generally in the plots not treated with herbi-

Table 2. Plant establishment and numbers of *Onychiurus armatus* and *Atomaria linearis* in the blocks with continuous sugar beet growing during 4 years.

Treatment	Number of plants per ha × 1000 before singling			
	1976	1977	1978	1979
1. no insecticide + chloridazon	44	4	126	76
2. lindane + chloridazon	89	54	149	110
3. aldicarb + chloridazon	102	40	149	123
4. no insecticide – no herbicide	83	17	123	90
5. lindane no herbicide	95	74	171	120
6. aldicarb no herbicide	73	39	145	121
Seedling pests	Average numbers of soil pests per l of soil in all treatments			
Onychiurus armatus	95	33	11	26
Atomaria linearis	0	10	8	25

Tabel 2. Plantbestand voor opéénzetten en aantallen Onychiurus armatus en Atomaria linearis in de blokken met een continuteelt van suikerbieten gedurende 4 jaar.

Table 3. Plant numbers and yields of sugar beet, as a function of different rotations and insecticide treatments (1978 and 1979).

Treatments	Plants/ha (× 1000)		Root weight (1000 kg/ha)		Sucrose content (%)		Sugar yield (10 kg/ha)	
	1978	1979	1978	1979	1978	1979	1978	1979
1/1 sugar beet no insecticide	81	56	57.7	41.3	16.4	14.7	946	609
1/1 sugar beet lindane	85	68	59.4	42.4	16.6	14.8	982	630
1/1 sugar beet aldicarb	83	69	60.4	43.6	16.4	15.1	987	664
1/3 sugar beet no insecticide	88	–	57.9	–	16.6	–	961	–
1/3 sugar beet lindane	88	–	60.0	–	16.7	–	1002	–
1/3 sugar beet aldicarb	85	–	58.8	–	16.6	–	976	–

Tabel 3. Aantallen planten en opbrengst van suikerbieten in relatie tot rotatie en behandelingen met insecticiden (1978 en 1979).

cides a better seedling establishment could be detected. In 1977 lower numbers of *O. armatus* were found, but for the first time *A. linearis* was extracted from the soil samples. Both seedling pests, but also frost and pheasants caused damage and contributed to a very poor seedling establishment. Therefore, samples had to be taken next to the seedlings and, later, the whole field was resown. In 1978 the emergence was rapid and only little damage was caused; a slight effect of insecticides, but no influence of weed control on plant numbers could be detected. Damage by both seedling pests occurred in 1979. These results referred only to the blocks with continuous sugar beet.

In 1978 sugar beet was also grown in the blocks with two previous crops of winter wheat, but no statistically significant differences in the numbers of soil pests or seedlings could be detected, as compared to the blocks with 1/1 sugar.

Yields were first determined in 1978 (Table 3). A significant difference (at $P = 0.05$) in root weight and sugar yield could be detected only between insecticide treated and untreated plots. This was repeated in 1979 for 1/1 sugar beet with similar results. That year the differences in root weight could be attributed to low plant numbers in the untreated plots, but this was not true for 1978.

Micro-arthropods in the soil. From 1976-1979 an average of 149 micro-arthropods per l of top soil were extracted. Their numbers varied from 89 (in 1977) to 289 (in 1979). From these totals 60-75% were springtails and the others were mites; 19 springtail and 57 mite species were identified (see Cheklist). A restricted number of species could be observed regularly; in most cases only 4-6 springtail species and 5-7 mite species were found in large numbers.

The influence of the crops and their rotation. In 1976 a small influence of the crops (wheat and sugar beet) on the total numbers of micro-arthropods could be detected (Table 4); this was enlarged considerably the next year. From the beginning the numbers of mites in the plots with sugar beet were significantly less than in the plots with winter wheat.

Table 4. The influence of crops and rotations on the composition of the micro-arthropod soil fauna in three consecutive years.

	1976		1977		1978	
Previous crops	ryegrass	ryegrass	ryegrass sugar beet	ryegrass w.wheat	ryegrass sugar beet sugar beet	ryegrass w.wheat w.wheat
Crops	sugar beet	w.wheat	sugar beet	w.wheat	sugar beet	sugar beet
mean number of all micro-arthropods/l of soil	94 (± 39)	117 (± 31)	62 (± 16)	143 (± 31)	68 (± 33)	99 (± 30)
Collembola/l of soil	55 (± 30)	33 (± 25)	38 (± 9)	76 (± 25)	44 (± 25)	61 (± 29)
Parasitiformes/l of soil	13 (± 3)	25 (± 6)	10 (± 2)	25 (± 15)	12 (± 7)	19 (± 7)
Acariformes/l of soil	19 (± 9)	60 (± 27)	14 (± 5)	43 (± 17)	11 (± 11)	18 (± 12)
Total number of species	28	32	39	33	37	35
Extent of similarity:	sugar beet-w.wheat		sugar beet-w.wheat		s.beet 1/1-s.beet 1/3	
The individuals of all micro-arthropods as percentages	80%		43%		69%	
Dominance identity as percentages	46%		33%		50%	
Jaccard index	0.62		0.53		0.73	

Tabel 4. De invloed van gewassen en rotaties op de samenstelling van de micro-arthropoden-bodemfauna in drie opéénvolgende jaren.

At first the diversity of species in the winter wheat and sugar beet plots was about the same and the extent of similarity between the series of occurring species (Jaccard index) was high. This can be expected between more or less similar plots in the same field. In 1977 the diversity in the sugar beet plots increased and at the same time the extent of similarity between sugar beet and winter wheat decreased. This tendency was detected with respect to the individuals of all micro-arthropods in the dominance identity (Renkonen value), as well as in the Jaccard index. The numbers of springtails extracted from the soil samples of the sugar beet plots in 1977 were considerably less than in 1976, which was mainly caused by a decrease of the relative abundance of *O. armatus*.

In 1978 when sugar beets were grown in all plots, differences in the total numbers of micro-arthropods *(Collembola* as well as *Parasitiformes* and *Acariformes)* between the plots with the different previous crops were found, but they did not prove to be significant. The extent of similarity expressed in the different ways was relatively high and did not differ much from that in 1976. *A. linearis* which had already been present previously in the 1/1 SB blocks occurred in the 1/3 SB blocks at the same densities (resp. 7.8 and 7.5/l).

The influence of weed control. Any significant differences in the total numbers of *Collembola* and *Acarina* could not be detected between plots treated with chloridazon and those where mechanical weed control was applied. At the same time the dominance identities, expressed as percentages of similarity, were large and varied in the period 1976-1979 from 60-80%. In 1976 a significant effect of weed control on the numbers of *O. armatus* and consequently on plant establishment was detected (Table 5). In the other years the population levels of this springtail were far lower which resulted in less damage so that eventual differences between the two treatments could not be established. Nevertheless, if we calculate the average plant numbers over the four years period the differences between chloridazon and no herbicide treatments are still significant, if we only take into account the plots, in which no insecticides were applied. This is not significantly correlated with the extracted numbers of *O. armatus.*

The effect of insecticides. The applied insecticides, lindane and aldicarb, had some negative influence on the numbers of individuals but not at all on the species diversity of micro-arthropods. In many cases the detected effects were not significant, short-lasting and varying considerably from year to year. Apart from the influence of many unknown factors, it is very probable that the amount of rainfall had a considerable effect on the mode of action of the two insecticides in different ways.

As a consequence of the very dry weather conditions in 1976 no effect of aldicarb on the numbers of mirco-arthropods and the species diversity could be detected

Tabel 5. The effect of chemical weed control with chloridazon (65%, 4 kg per ha) on the numbers *Onychiurus armatus* and plant establishment in 1976.

Soil herbicide	Insecticide	Average number of *O. armatus*/l of soil	Plants per ha before singling relative to 100
chloridazon	none	116	100
chloridazon	lindane 21%	42	200
chloridazon	aldicarb 10%	106	230
none	none	61	186
none	lindane 21%	37	214
none	aldicarb 10%	65	164

Tabel 5. Het effect van chemische onkruidbestrijding met chloridazon (65%, 4 kg per ha) op de aantallen Onychiurus armatus en het plantbestand voor opéénzetten in 1976.

(Table 6). On the contrary application of lindane suppressed *Collembola* and *Acariformes* considerably, but not the *Parasitiformes*. The extent of similarity given by the dominance identities (Renkonen values) was very small, particularly when compared with the high Jaccard index of similarity (Table 6). This phenomenon was caused by differences in the relative abundancy of a number of species like *Isotoma notabilis* and *Arctoseius cetratus*.

The low numbers of micro-arthropods found in 1977 could have been caused by high mortality during the extremely dry summer of 1976; no significant differences between the treatments could be detected. The extents of similarity varied from normal to high and only some changes in the relative abundancy of some species, a.o. *Tullbergia krausbaueri, Hypogastrura manubrialis* and *Veigaia nemorensis,* was apparent.

In 1978 the populations of *Collembola* seemed to recover and some, although insignificant, effects of lindane and aldicarb on their numbers was found. However,

Table 6. The influence of insecticide application on three groups of micro-arthropods, extracted from soil samples under sugar beet from 1976-1979.

	1976	1977	1978	1979
Collembola per l of soil:				
untreated	97 (± 61)	38 (± 29)	89 (± 38)	291 (± 296)
lindane	27 (± 19)	33 (± 13)	55 (± 27)	184 (± 66)
aldicarb	87 (± 43)	45 (± 22)	60 (± 39)	175 (± 122)
Parasitiformes per l of soil:				
untreated	16 (± 8)	11 (± 9)	24 (± 6)	49 (± 26)
lindane	14 (± 8)	11 (± 7)	20 (± 7)	55 (± 19)
aldicarb	12 (± 7)	7 (± 4)	9 (± 2)	10 (± 10)
Acariformes per l of soil:				
untreated	30 (± 14)	15 (± 12)	16 (± 7)	51 (± 16)
lindane	13 (± 9)	9 (± 7)	14 (± 8)	29 (± 25)
aldicarb	49 (± 26)	17 (± 11)	12 (± 13)	42 (± 28)
Total number of species:				
untreated	23	33	40	33
lindane	20	29	46	37
aldicarb	23	28	34	30
Extent of similarity by dominance identity:				
untreated-lindane	33%	63%	62%	53%
untreated-aldicarb	34%	56%	58%	40%
lindane-aldicarb	34%	55%	62%	40%
Extent of similarity by Jaccard Index:				
untreated-lindane	0.79	0.60	0.63	0.67
untreated-aldicarb	0.77	0.59	0.51	0.66
lindane-aldicarb	0.95	0.61	0.58	0.68

Tabel 6. De invloed van behandelingen met insecticiden op drie groepen micro-arthropoden, geëxtraheerd uit grondmonsters onder suikerbieten van 1976-1979.

little difference in the diversity of the species was present and the extents of similarity between treated and untreated varied from normal to rather high. Probably differences in the relative abundance of *Isotoma notabilis* and *O. armatus* had been responsible for this effect. The *Parasitiformes* in the aldicarb treated plots were significantly less numerous than in the lindane and untreated plots.

The wet spring of 1979 created a situation which differed considerably from that in the preceding years. The numbers of *Collembola* were much larger, but *O. armatus* was no longer the most abundant species in the untreated plots. The high relative abundance of *Hypogastrura manubrialis* was strongly decreased by the application of either insecticide. This, and other differences in relative abundances of some other species, was reflected in a relative low dominance identity as percentage of similarity, between all treatments. Just as in the preceding year a significantly lower number of *Parasitiformes* were found in the aldicarb treated plots. The extent of similarity of all micro-arthropods between the lindane and aldicarb treated plots was relatively high.

Soil fungi. Although many seedlings were attacked by *Collembola* no serious primary damage caused by pathogenic fungi could be established.

From the roots low numbers of fungal species were isolated and among them incidentally *Alternaria alternata, Phoma betae, Rhizoctonia* spp. and *Pythium* spp. occurred.

In 1976 more *Phycomycetes* were found in the aldicarb treated plots as compared to untreated and lindane, but in the next year this could not be confirmed.

Several times *Cylindrocarpon destructans,* a parasite of cyst nematode eggs (Tribe, 1977), was found.

This investigation was stopped in 1979.

Nematodes. From the 1/1 sugar beet blocks every year soil samples were taken for cyst forming nematodes in winter, and for migratory nematodes in spring at the two-leaf stage. The only cyst nematode species present was *Heterodera schachtii* and its numbers increased in successive years (Table 7). In 1980 the tolerance level was exceeded and damage could be expected in the blocks where sugar beet were grown continuously.

Tabel 7. Average numbers of eggs of *Heterodera schachtii* in 100 ml air dried soil in the plots with 1/1 sugar beet.

Treatment		1976	1977	1978	1979	1980
1. no insecticide	+ chloridazon	0	0	0	550	290
2. lindane	+ chloridazon	0	0	45	470	1875
3. aldicarb	+ chloridazon	0	60	75	190	1070
4. no insecticide	+ no herbicide	10	0	0	430	1025
5. lindane	+ no herbicide	0	110	15	480	1740
6. aldicarb	+ no herbicide	0	0	0	220	75

Tabel 7. De gemiddelde aantallen eieren van Heterodera schachtii in 100 ml luchtdroge grond, in de veldjes met een continuteelt van suikerbieten.

Table 8. Average numbers of migratory nematodes in 100 ml soil.

	Frequency of beet growing			
	1978		1979	
	1/1	1/3	1/1	1/3
Pratylenchus (P)	214	870	84	154
Tylenchorhynchinae (T)	5	45	1	1
Helicotylenchus (H)	30	43	12	10
Heterodera larvae (Hl)	0	0	14	5
Other nematodes (O)	1365	775	2445	3250

Tabel 8. De gemiddelde aantallen vrijbewegende nematoden in 100 ml grond.

Because of many samples, even in 1980, contained no or only a few cysts, distribution of the nematode was not homogeneous enough to demonstrate effects of treatments. In the blocks with 1/3 sugar beet no cysts of *H. schachtii* were found.

Among migratory plant parasitic nematodes *Pratylenchus neglectus* and *P. thornei* were predominant. In Table 8 an effect of crop rotation on *Pratylenchus* is evident. In 1978 the population of these nematodes was higher after wheat than after sugar beet and had decreased after sugar beet on the whole field in the samples in 1979.

In 1979 after sugar beet no effect of herbicide or lindane on migratory nematodes was found, but aldicarb showed some effect on *Pratylenchus* (Table 9).

Although not significant, more migratory plant parasitic nematodes (including *Heterodera* larvae) were found in the lindane treated plots than in untreated ones in 1979 and the same was true for eggs of *H. schachtii* before the sugar beet crop in 1980.

Table 9. Average numbers of migratory nematodes in 100 ml of soil after different treatments in sugar beet (1979).

Treatment	Nematodes (for abbreviations see Table 8)				
	P	T	H	Hl	O
1. no insecticide + chloridazon	125	0	8	8	2804
2. lindane + chloridazon	151	0	12	15	3224
3. aldicarb + chloridazon	71	0	6	6	2865
4. no insecticide + no herbicide	129	5	14	6	3266
5. lindane + no herbicide	175	0	20	20	2445
6. aldicarb + no herbicide	56	0	6	5	2805

Tabel 9. De gemiddelde aantallen vrijbewegende nematoden in 100 ml grond na de verschillende behandelingen in suikerbieten (1979).
Voor afkortingen zie Tabel 8.

Table 10. The occurrence of the different kinds of weeds in 1978, as related to treatments and crop rotations (1/1 SB and 1/3 SB).

Treatment	Perennial weeds index abundance/ distribution (0-5 scale)		Annual weeds numbers/10 m²)		*Stellaria media* (numbers/10 m²)	
	1/3 SB	1/1 SB	1/3 SB	1/1 SB	1/3 SB	1/1 SB
1. no insecticide + chloridazon	0/0	4/4	1	6	0	1
2. lindane + chloridazon	1/1	5/3	8	26	1	6
3. aldicarb + chloridazon	1/1	3/2	9	1	1	4
4. no insecticide + no herbicide	1/1	4/4	53	57	3	29
5. lindane – no herbicide	1/1	3/4	65	85	12	39
6. aldicarb – no herbicide	1/1	2/3	44	59	13	23

Tabel 10. Het voorkomen van de verschillende soorten onkruiden in verhouding tot de behandelingen en vruchtopvolging (1/1 SB en 1/3 SB).

Weeds. In the trial initially *Polygonum convolvulus* was dominant, but later also the numbers of *Cirsium arvense* and *Sonchus arvensis* increased rapidly in the blocks with 1/1 sugar beet. Both perennial weeds formed a serious threat for the beet after two years (Table 10), so that in 1978 counting could not be done anymore and an estimation of the index abundance/distribution (from 0-5) was made. In the blocks continuously grown with sugar beet *C. arvense* and *S. arvensis* increased rapidly, as these weeds could be controlled only in the wheat crop by application of MCPA, and not in sugar beet.

Stellaria media could be controlled by methabenzthiazuron in winter wheat and reasonably by chloridazon in sugar beet (Table 11).

In the plots treated with lindane often more seedlings of *S. media* were counted than in the untreated ones.

Table 11. The influence of chloridazon on *Stellaria media* in 1/1 sugar beet blocks.

Treatments	Numbers of *Stellaria media*/10 m²			
	1976	1977	1978	1979
1. no insecticide + chloridazon	0	1.0	0.6	4.4
2. lindane + chloridazon	0.2	2.3	5.6	1.3
3. aldicarb + chloridazon	0.1	1.2	3.8	3.8
4. no insecticide – no herbicide	0.1	6.4	29.0	5.0
5. lindane – no herbicide	0.5	12.2	39.4	11.9
6. aldicarb – no herbicide	0.1	6.5	23.4	8.8

Tabel 11. De invloed van chloridazon op Stellaria media in de blokken met een continue suikerbietenteelt.

Discussion and conclusions

In the field at Westmaas where the trial was made a high population of *O. armatus* was already present, built up in a previous crop of perennial ryegrass, which is a good environment for this springtail species. Relatively severe damage to the seedlings was caused in the first and to a lesser extent in the following years. Often the amount of damage caused by *O. armatus* is dependent on a number of external factors like moisture content and compaction of the seed bed, the amount of young organic material in the soil (green manure crop) and the number of emerging annual weeds. From 1977 onwards also infestations by *A. linearis* occurred which only in 1979 resulted in a more or less severe damage and poor plant establishment.

Crop rotation. In the winter wheat blocks an increase of the total number of micro-arthropods was found, particularly *Acariformes* and to a lesser extent also *Collembola* and *Parasitiformes*. In the sugar beet blocks with two previous crops of winter wheat (1978), *O. armatus* was less dominant and far more *I. notabilis* were found than in the 1/1 sugar beet blocks. This could be an indication for a more stable situation caused by rotation. On the other hand continuous sugar beet growing did not stimulate the expected multiplication of *A. linearis* to such extent that differences in damage between the two cropping systems could be detected. Possibly early spring migration of *A. linearis* out of the relatively small crop rotation blocks has counteracted this effect.

As expected beet cyst nematode infestations increased slowly in the 1/1 sugar beet blocks until in 1980 the tolerance level of 500 eggs and larvae per 100 ml of soil was exceeded. Of the migratory plant parasitic nematodes in 1978 *Pratylenchus spp.* were dominant in the 1/3 sugar beet blocks, favoured by previous crops of wheat, which is a good host for these nematodes.

The perennial weeds *C. arvense* and *S. arvensis* were strongly enhanced in the 1/1 sugar beet blocks, since they could not be controlled in sugar beet. This is only indirectly a crop rotation problem and will be solved largely, if more selective herbicides for the control of perennial weeds are developed.

The effect of soil herbicides. Annual weeds were partially controlled by the application of chloridazon (4 kg per ha), but no influence of this chemical on the perennial weeds was detected. In the long term the spread of *S. media* in the 1/1 sugar beet blocks was hampered by chloridazon application. High population densities of annual weeds in the non-treated plots provided alternative food for *O. armatus,* which resulted in less plant damage. When the Onychiurids were suppressed by lindane more *S. media* seedlings were detected, which suggests some kind of weed control caused by these springtails. There was no significant effect of chloridazon on the total numbers of *Collembola* and *Acarina* in this four year period.

The effect of insecticides. Lindane and aldicarb controlled *O. armatus* and *A. linearis* partially. There was a beneficial effect on seedling emergence, particularly in 1976 and 1977. In the two years yield determinations were done (1978 and 1979) root weight was significantly improved by the application of insecticides. This could not always be explained by differences in plant numbers and must be caused also by differences in plant development. The efficacy was variable; particularly in the dry year 1976 the action of aldicarb was insufficient and this was caused by the fact that drought influences the release pattern of the active ingredient from the granules.

Both insecticides, if effective, had a variable and temporary effect of not more than half a year on the numbers of *Collembola*. In addition to that, lindane suppressed the numbers of *Acariformes* a little, and aldicarb had some negative effect on the *Parasitiformes*. It can be concluded that the side effects of these chemicals on the soil mesofauna are tolerable and, if applied carefully and at low dosages, they will not interfere seriously with the application of a programme for integrated control of soil pests.

As aldicarb also acts as a nematicide, one could expect control of *H. schachtii* and *Pratylenchus spp.* With respect to *Pratylenchus* this was found indeed, but it could not always be established for *H. schachtii,* presumably because of the irregular spread of the infestation.

More *Pratylenchus spp.* and *H. schachtii* were found in 1979 after treatment with lindane than in untreated soil. This could be caused by the partial elimination of *Collembola,* which act as predators of nematodes. However these differences were not signigicant and more evidence is needed before any conclusions can be drawn.

Acknowledgement

This multidisciplinary research could be realized thanks to the valuable contributions of the following investigators:
dr ir J.A. Bunt (Department of Nematology, AU Wageningen): Soil sample analysis for migratory nematodes.
ir P.W.Th. Maas (Plant Protection Service, Wageningen): Soil sample analysis for migratory nematodes.
ir C.A.A. Maenhout and ir H.F.M. Aarts (Research Station for Arable Farming and Field Production of Vegetables, Lelystad): Determination of weed populations.
G.M. Tichelaar (Research Institute for Plant Protection, Wageningen): Analysis of plant samples for soil fungi.

Samenvatting

De invloed van enige cultuurmaatregelen op bodemorganismen en het plantbestand van suikerbieten

In een veeljarig proefveld (1976-1979) werd de invloed van de vruchtopvolging en toepassing van insecticiden en herbiciden op bodemarthropoden (mesofauna), nematoden, bodemschimmels en onkruiden onderzocht. Niet alleen mogelijke veranderingen in de aantallen schadeverwekkers, maar ook in de aantallen predatoren en pathogenen van bodemplagen zouden het plantbestand en/of de opbrengst van suikerbieten kunnen beïnvloeden.

Gedurende de eerste twee jaar van de proef werden in grondmonsters, die gedurende het voorjaar werden genomen, grote aantallen springstaarten *(Onychiurus armatus)* aangetroffen, die aanzienlijke schade veroorzaakten. Later kwamen eveneens aantastingen door het bietekevertje *(Atomaria linearis)* voor, waardoor in meerdere of mindere mate planten wegvielen.

Er kon nog geen duidelijke invloed van de vruchtopvolging op de schade door bodemarthropoden worden vastgesteld, maar in de rotatie met 1/3 suikerbieten en 2/3 wintertarwe werden meer micro-arthropoden en een grotere soortenrijkdom gevonden dan in de gedeelten met een continuteelt van suikerbieten. In laatstgenoemde veldjes zijn de aantallen bietecystenaaltjes *(Heterodera schachtii)* toegenomen, waarbij in 1980 de tolerantiegrens werd overschreden. Daarentegen vond in de veldjes met 1/3 suikerbieten in de rotatie een sterkere vermeerdering van *Pratylenchus spp.* plaats dan in de continuteelt. Aangezien een aantal wortelonkruiden in suikerbieten niet voldoende kan worden bestreden, veroorzaakten enkele na enige jaren een probleem in de continue bietenteelt.

In de veldjes die niet met een bodemherbicide waren behandeld vormden grote aantallen zaadonkruiden een alternatieve voedselbron voor *Onychiurus armatus,* wat een geringere aantasting van kiemplanten tot gevolg had. Er werd geen aantoonbaar effect van chloridazon op de micro-arthropoden vastgesteld.

De insecticiden lindaan en aldicarb konden schade door *Onychiurus armatus* en *Atomaria linearis* slechts gedeeltelijk voorkomen; er werd een duidelijk betere opkomst en soms ook een hogere opbrengst verkregen. Beide insecticiden hadden een wisselende invloed op de relatieve talrijkheid van *Collembola* en bovendien onderdrukte lindaan de aantallen *Acariformes* en aldicarb de *Parasitiformes.* Er kon geen negatieve invloed op de soortenrijkdom worden vastgesteld. Al deze effecten waren niet van langdurige aard en verschilden sterk van jaar tot jaar.

Er werden aanwijzingen gevonden dat, indien bepaalde soorten *Collembola,* die als predatoren van nematoden kunnen optreden, werden onderdrukt, de aantallen *Pratylenchus spp.* en *Heterodera schachtii* toenamen.

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Tribe, H.T., 1977. Pathology of cyst-nematodes. Biol. Rev. 52: 477-507.

Checklist of *Collembola* and *Acarina* species occuring in the soil of the trial farm at Westmaas.

* = Common spp. occuring in at least 10% of all soil samples.

Collembola Lubbock, 1870

Hypogastruridae
Hypogastrura manubrialis (Tullberg, 1869)
Ceratophysella bentssoni (Agren, 1904)
Friesea mirabilis (Tullberg, 1871)

Onychiuridae, Börner, 1901
*Protaphorura armatus (Tullberg, 1869)
Stenaphorura quadrispina (Börner, 1901)
*Mesaphorura krausbaueri (Börner, 1901)

Isotomidae Börner, 1913
Folsomia candida Willem, 1902
Folsomia fimetaria (Linnaeus, 1758)
Isotomiella minor (Schäffer, 1896)
Isotomina bipunctata (Axelson, 1903)
*isotoma notabilis Schäffer, 1896
Isotoma olivacea Tullberg, 1871
Isotoma viridis Bourlet, 1839
Isotomurus palustris (Müller, 1776)

Entomobryidae Börner, 1913
Entomobrya nivalis (Linnaeus, 1758)
Lepidocyrtus cyaneus Tullberg, 1871
Pseudosinella alba (Packard, 1873)

Neelidae rolsom, 1896
*Megalothorax minimus (Willem, 1900)

Sminthuridae Lubbock, 1870
Sminthurinus indet. juv.

ACARINA

Gamasida (= Mesostigmata)

Veigaiaidae
*Veigaia nemorensis (Koch, 1839)
Veigaia cervus (Kramer, 1876)
Veigaia planicola (Berlese, 1892)

Parasitidae
Parasitus indet juv.
*Pergamasus runcatellus Berlese, 1903
Pergamasus quisquiliarum (G. et E. Can., 1882)
Pergamasus longicornis (Berlese, 1903)
Gamasodes spiniger (Trägardh, 1910)

Pachylaelaptidae
Pachylaelaps magnus Halbert, 1915

Rhodacaridae
Rhodacarus elbius Karg, 1971
*Rhodacarellus silesiacus Willmann, 1936

Digamasellidae
Dendrolaelaps fimetarius Karg, 1965

Ascidae
Arctoseius semiscissus (Berlese, 1892)
Arctoseius minutus (Halbert, 1915)
Arctoseius cetratus (Sellnick, 1940)
Leioseius bicolor (Berlese, 1918)

Halolaelapidae
Halolaelaps communis (Gutz, 1952)

Phytoseiidae
Amblyseius sp. indet.

Hypoaspididae
Hypoaspis aculeifer (Canestrini, 1883)

Marochelidae
Geholaspis mandibularis (Berlese, 1904)

Eviphididae
Eviphis ostrinus (Koch, 1836)
Alliphis siculus (Oudemans, 1905)

Uropodidae
Nenteria elimata (Berlese, 1917)

Acaridida (= Astigmata)

Anoetidae
*Histiostoma feronarium (Dufour, 1839)

Acaridae
Tyrophagus palmarum (Oudemans, 1924)
Tyrophagus dimidiatus (Hermann, 1804)
Tyrophagus putrescentiae (Schrank, 1781)
Rhizoglyphus robini (Claparède, 1869)
Caloglyphus berlesei (Michael, 1903)

Oribatida (= Cryptostigmata)

Hypochthoniidae
Hypochthonius luteus Oudemans, 1917
Brachychthonius sellnicki Thor, 1930

Eremaeidae
Oppia nova (Oudemans, 1902)
*Oppia clavipectinata (Michael, 1885)
Oppia subpectinata (Oudemans, 1900)
Oppia minus (Paoli, 1908)
Oribella paolii (Oudemans, 1913)
Oribella lanceolata (Michael, 1885)

Carabodidae
Tectocepheus velatus (Michael, 1880)

Oribatulidae
Zygoribatula propinguus Oudemans, 1902

Ceratozetidae
Trichoribates trimaculatus (C.L. Koch, 1836)
Punctoribates punctum (C.L. Koch, 1839)

Actinedida (= Prostigmata)

Eupodidae
Eupodes Koch 1836, sp. indet

Bdellidae
Bdella Lateille, 1795, sp. indet.

Rhagidiidae
Rhagidia Thorell, 1871, sp. indet.

Tydeidae
Tydaeolus Berlese, 1910, sp. indet
Microtydeus Thor, 1931, sp. indet

Nanorchestidae
Nanorchestes Topsent and Trouessart, 1890, sp. indet
Speleorchestes Trägardh, 1909, sp. indet

Tarsonemida (= Tarsonemini)

Tarsonemidae
Tarsonemus Canestrini and Fanzago, 1876, sp. indet
Siteroptes Kirchner, 1864, sp. indet.

Pyemotidae
Pygmephorus sellnicki Krczal, 1958
Pygmephorus blumentritti Krczal, 1959
Pygmephorus tarsalis Hirst, 1921
Pygmephorus silvestris Jacot, 1936

Scutacaridae
Scutacarus Gros, 1845 sp. indet
Variatipes quandrangularis (Paoli, 1911)
Variatipes eucomus (Berlese, 1908)

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