Soil microarthropods (Acari and Collembola) in two crop rotations on a heavy marine clay soil

BY

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Synopsis: In 1983 and 1984 an inventory was made of the mites and springtails in crops of a six-year and a three-year rotation. Of the three-year rotation a disinfected and a non-disinfected half were sampled. The distribution of the mesofauna was examined by means of correspondence analysis and frequency tables. The mesofauna was indicative of factors related to year and climate, depth, crop, rotation and disinfection of the soil.

Keywords: soil mesofauna, microarthropods, Acari, Collembola, agro-ecosystem, crop rotation, correspondence analysis, soil disinfection.

INTRODUCTION

During 15 years of crop rotation experiments at the experimental farm “De Schreef”, yield losses up to 10% were recorded in potato crops of a three-year rotation as compared with a six-year rotation (Anon., 1984).

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Neither soil physical (bulk density, pore volume, macrostructure) nor soil chemical properties (in both rotations the uptake of nitrogen, phosphorus and potassium was proportional to dry weight production) of the three-year rotation could account for this yield depression (HOEKSTRA, 1981). Because treatment of the soil with methyl bromide (soil disinfection) reduced the yield loss even though there was no infestation with the potato cyst nematode, it was suggested that the yield reduction was caused by some hitherto unknown pest(s) or pathogen(s) or the cumulative effect of non-pathogenic rhizosphere organisms (SCHIPPERS *et al.*, 1985). An extensive biological research programme was carried out to investigate these phenomena and in this paper we report the results of investigations on edaphic mites and springtails to determine whether certain species or ecological feeding groups might indicate soil ecological differences between the six- and the three-year rotation.

I. − MATERIALS AND METHODS

1. Field site

Data were collected at the experimental farm “De Schreef” which is located near Dronten in the polder Oost-Flevoland. The soil is a heavy marine clay with approximately 3% humus and 10% CaC03, which has been in cultivation since 1963.

2. Sampling

Samples were taken in 1983 in all fields of the six-year rotation (R6) and in the non-disinfected (R3) and disinfected (R3*) halves of all fields of the three-year rotation. In 1984 only the potato crops of R6, R3 and R3* were sampled. The sampling scheme and in following order the different crops of each rotation and accompanying soil labour practices are given in table I. On each sampling occasion four samples were taken in the potato crop, and two samples in each of the other crops. The soil of R3* was disinfected every third year after the harvest of the potato crop with 330 kg/ha metamsodium (100%). Samples were taken in the row with the plants in the centre of the soil core, or immediately adjacent to the plants of potato and sugar beet, to a depth of 27.5 cm with a corer of 5.8 cm diameter. Only subsamples from the depths 0−2.5; 2.5−5; 7.5−10; 15−17.5 and 25−27.5cm were used for extraction of the mesofauna from soil by means of a Macfadyen-type high-gradient apparatus.

3. Data processing

The species composition of the soil fauna as related to depth, crop, rotation or year was examined by means of correspondence analysis. For a detailed explanation of correspondence analysis *see* GREENACRE (1984). The unit of measurement used in correspondence analysis was the number of animals of a certain taxon per sample (66 cm^3). Of the total of 35 taxa identified, 12 taxa occurring in less than fifteen samples were omitted from the analysis. These rare taxa are enumerated at the end of the appendix. Also samples with less than four species were omitted from correspondence analysis, resulting in a total of 268 samples representing 23 taxa. All 295 samples (5 samples were lost) were used for the analysis of quantitative aspects of the mesofauna. Interactions between mesofauna totals and depth, crop, rotation or soil disinfection were examined with the two-way test of independance using the ‘Chi-square’ statistic.

4. The weather

The years 1983 and 1984 were quite different with respect to temperature and rainfall (*Fig.* 1). The weather of 1983 was relatively warm and wet. The temperature of the soil at 10cm depth mostly stayed above 3°C in winter, while in July temperatures higher than 20°C were common. Heavy and prolonged rainfall was recorded between March and the end of June. For a long time the soil was water-logged and in many places in the fields puddles were formed. Due to these wet conditions, sowing or planting was delayed until late May (*Fig.* 1). In 1984, however, the weather was relatively cold with a dry spring. Soil temperature (at 10cm depth) frequently fell below 3°C during winter and in summer temperatures over 20°C were seldom measured. The growing season started with a dry spring followed by relatively much precipitation during the summer. All crops were sown or planted before May.

II. − RESULTS

A) Crop effects

The number of mites and springtails captured in a field during the year varied in close relation to the crop grown (*Fig.* 2 and Tab. II). In cereals (spring barley and winter wheat) the mesofauna was relatively numerous, especially pyemotid mites (*Pygmephorus blumentritti*) and springtails not belonging to the *Tullbergia krausbaueri* group. Also predatory mites (*Veigaia planicola*, rest-group predatory mites) appeared in high numbers. The mesofauna in cereals peaked at the end of the summer when the cereals ripened (Tab. III). The following species were especially abundant in the last two samplings: *V. planicola*, *Arctoseius cetratus*, *P. blumentritti*, *Pygmephorus selnicki*, *Tarsonemus talpae*, *Nanorchestes sp.*, *T. krausbaueri*, *Ceratophysella denticulata*, *Isotoma notabilis*, *Folsomia candida* and *Megalothorax minimus.*

Fewer animals were found in flax and peas. These crops grew very poorly in 1983 and the growth of a green manure crop in these crops probably affected the soil mesofauna more than the main crops flax and peas themselves.

In the root and tuber crops (potato and sugar beet) very few animals were captured in 1983, springtails of the *T. krausbaueri* group and cryptostigmatid mites being the most abundant.

In 1984 the potato crop of the three-year rotations (R3 and R3*) harboured more mites than in 1983. This did not hold for the potato crop of the six-year rotation.

***B*) Depth**

For each taxon the vertical distribution of mites and springtails in the soil, summarized for 1983 and 1984 for all crops, is shown in table IV. Mites and springtails show significant differences in depth distribution [d. f. = 4; $P(\chi^2>556) \ll 0{,}01$].

On average, mites were most numerous at depths of 0−5 cm, whereas springtails were most numerous at depths of 2.5−17.5 cm (Tab. IV). In cereals the number of mites and springtails inhabiting the soil near the surface was large in comparison to all other crops. This was especially true for springtails. In the root and tuber crops the number of mites and springtails in the surface layer was small, especially in potato. The potato crops planted as a second rotation after cereals showed higher numbers of mites and springtails at greater depth.

Some species of mites and springtails were particularly abundant near the soil surface (*A. cetratus*, *Tectocepheus velatus*, *P. selnicki*, *T. talpae*, *Eupodes sp.*, *Nanorchestes sp.*, *Isotoma viridis*) while other species were found most frequently in the deeper soil layers (*Veigaia agilis*, *O. minus*, *T. krausbaueri*, *M. minimus, F. candida* and *Folsomia sp.*). All other species were distributed according to the mean depth distribution (Tab. V).

C) Effects of crop rotation

Effects of crop rotation on the soil mesofauna should be visible as marked shifts in total numbers and abundance of certain taxa either in all crops of the rotations compared or in a corresponding crop that had the same previous crop(s) in all rotations. In 1983 larger numbers of mites appeared in crops of the six year rotation than in corresponding crops of the three-year rotation (Tab. II, IV, *Fig.* 2*a*). This effect was mainly accounted for by the cryptostigmatid mite *T. velatus*. The reverse was true for the potato crop of 1984.

The relation between rotational and year related effects was examined in the 1983 and 1984 potato crops. For mites, the effect of the year on the extracted numbers differed highly significantly for the six-year and the not-disinfected three-year potato crops [d. f. = 4; $P(\chi^2>123) \ll 0.01$]. In the six-year rotation more animals were caught in 1983 than in 1984, in the three-year rotation a reverse effect was observed.

For springtails, no association was found between year and rotation when comparing rotation R6 and R3.

In all rotations spring barley had the same preceding crop. Expression of effects of the rotation on the mesofauna was, however, hampered by the presence of Italian ryegrass (*Lolium multiflorum*) undersown in the three-year rotation spring barley only. Therefore, no unequivocal explanation exists for the selective abundance of *V. nemorensis, T. velatus, Oppia nova* and *F. candida* in spring barley of the six-year rotation and of *V. planicola*, *Hypoaspis similisetae*, *A. cetratus, P. blumentritti*, *Nanorchestes sp.* and *C. denticulata* in the three-year rotation of this crop.

D) Effects of soil disinfection

For the mesofauna in the corresponding potato, beet and barley crops a significant association existed between the effects of soil disinfection (R3, R3*) and the cultivated crops (mites [d. f. = 2; $P(\chi^2> 49) \ll 0.01$], springtails [d. f. = 2; $P(\chi2>26) \ll 0.01$]).

The mesofauna totals in potato and beet of the disinfected rotation R3 were consistently lower than in the non-disinfected rotation R3*. In barley, mites and springtails reacted differently, the largest mesofauna numbers being found in barley of the disinfected rotation.

Since in both years mites were less abundant in the R3* th an in the R3 potato crop, no significant association was found for mites of soil disinfection and year.

Springtails showed a significant association of rotation and year [d. f. = 1; $P(\chi^2>39) \ll 0.01$] with largest counts in 1983 in the R3 potato crop and in 1984 in the R3* potato crop.

The vertical distribution of the mesofauna in R3 and R3* was significantly associated only with soil disinfection in 1983 in beet (mites [d. f. = 4; $P(\chi^2>44) \ll 0.01$], springtails [d. f. = 4; $P(\chi^2>10) \ll 0.05$]) and barley (mites [d. f. = 4; $P(\chi^2>49) \ll 0.01$], springtails [d. f. = 4; $P(\chi^2>11) < 0.025$]) and in 1984 in potato (mites [d. f. = 4; $P(\chi^2>38) \ll 0.01$], springtails [d. f.=4; $P(\chi^2>25) \ll 0.01$]).

III. CORRESPONDENCE ANALYSIS

The first four axes resulting from correspondence analysis could be given a meaningful interpretation. Axes 1 to 4 accounted for respectively 12.0, 9.0, 8.6 and 5.7 percent of the total variance. Plots of axis 1 versus 3, 2 versus 3, again 2 versus 3 and 2 versus 4 are represented in figures 3, 4, 5 and 6.

Axis 1 (*Fig.* 3)

Along the first axis samples from near the soil surface of the six-year rotation oppose those from the deeper soil layers of the three year rotation especially in beet and potato.

This ordination of the samples along the first axis is in many ways characterized by *T. velatus* (TVE) and its nymph (NTV). *T. velatus* (TVE) was captured in largest numbers near the soil surface. In the six-year rotation *T. velatus* (TVE) was much more abundant than in the three-year rotation, in particular when compared with the disinfected half of the plot (Tab. II). Accordingly, samples and species from near the soil surface of the abovementioned crops, mostly of the six-year rotation are at the top of the first axis.

The species at the bottom of Figure 3 were abundant in the deeper soil layers and/or were mostly found in the crops of the three-year rotation. Species such as *F. sp.* (FSP), *O. minus* (OMI) and its nymph (NOM), *T. krausbaueri* (TKR), unidentified Heterostigmata (HET), *Nanorchestes sp.* (NAN), *Cryptopygus bipunctatuc* (CBI), *A. cetratus* (ACE), *C. denticulata* (CDE), the male of a *Pygmephorus sp.* (MPS), *F. candida* (FCA), *P. selnicki* (PSE) and *P. blumentritti* (PBL) belong to this group.

As a consequence of the combination of factors related to depth and rotation, surface-dwelling species that were most abundant in the three-layer rotation such as *A. cetratus* (ACE), *P. sellnicki* (PSE), *Nanorchestes sp.* (NAN) and *T. talpae* (TTA), have affinity along the first axis with the deeper soil layers.

Axis 2 (*Fig.* 4, 5 and 6)

Along axis 2 the potato crop of 1984 is opposed by all crops of 1983 (*Fig*. 4).

Apparently the soil fauna of both years was greatly influenced by some year-related factor(s). Because the potato crops were the only crops sampled in 1984, interpretation of the year effect along axis 2 is meaningful for the potato crops only.

Correspondence analysis demonstrated the relative importance of *T. krausbaueri* in characterizing the soil community of the potato crops in both years. This importance follows from the fact that in the 1983 potato crop *T. krausbaueri* (TKR) was about 5 times more numerous than in the potato crop of the following year. Together with *T. velatus* (TVE), *T. krausbaueri* was the only species abundant in potato in 1983. In 1984 the potato crop was inhabited by many different species. Some of these species were typically associated with this particular 1984 potato crop [Astigmata except Anoetidae (AST), Anoetidae (ANO), *V. agilis* (VAG), Entomobryinae (ENE), *M. Minimus* (MMI)]. Unlike the position of *V. agilis*, the Anoetidae and the Astigmata, the position of *F. candida* (FCA) is due to a highly clustered distribution in the field. The extreme position of this species along axis two is therefore of little importance in regard to the effects along this axis.

Other species lived in large numbers in the preceding gramineous crops (in 1983 Italian ryegrass was sown in the six-year rotation potato cr op after the cultivation of peas had failed) and were found in 1984 in small numbers in the potato crops [*I. notabilis* (INO), *C. denticulata* (CDE), *P. blumentritti* (PBL), unidentified Heterostigmata (HET), *P. selnicki* (PSE) and *V. planicola* (VPL)].

Axis 3 (*Fig.* 3, 4 and 5)

Ordination of the data along axis 3 showed that the species composition of the soil mesofauna strongly depended on the crops and associated agricultural practice (*Fig.* 5*a* and *b*).

Firstly, ignoring for a moment the results of 1984, a great difference existed between the species composition in cereals and the root and tuber crops. Data from the root and tuber crops are at the left of axis 3 (*Fig.* 5*a*). These crops were characterized by a relative abundance of species such as *O. minus* (OMI) and its nymph (NOM), *T. krausbaueri* (TKR), *M. minimus* (MMI), Astigmata except Anoetidae (AST), *O. nova* (ONO), Eupodina except *Eupodes sp.* (AEU), and *T. velatus* (TVE). Scattered along axis 3 are the core samples for flax and peas. Both these crops grew very poorly in 1983 and the soil mesofauna probably was influenced more by the green manure than by the crops themselves. For these reasons, flax and peas will not be mentioned hereafter. At the right of axis 3 are the data for cereals. The cereals, especially spring barley of the three-year rotation (undersown with Italian ryegrass), were characterized by species such as *Nanorchestes sp.* (NAN), *P. blumentritti* (PBL), the male of a *Pygmephorus sp.* (MPS), *A. cetratus* (ACE), *I. viridis* (IVI), *Pseudosinella alba* (PAL) and *T. talpae* (TTA).

Secondly, the effect of spring barley on the mesofauna of the following potato crop varied with the year (*Fig.* 4). The potato crops of the three-year rotation had the same previous crop and were subject to the same farm practices in 1983 and 1984. Therefore the year-related differences in species composition found in these crops were most likely caused by weather conditions or by the dates of sowing and planting, which in turn were also influenced by the weather.

Thirdly, the effect of spring barley on the species composition of the following potato crop was found to be most pronounced in spring or early summer, after which it slowly faded away (*Fig.* 5 *b*). This effect is demonstrated by the fact that the three-year potato samples from the first two sampling dates both in 1983 and 1984 are more at the cereal-associated side of axis 3 than those from the last two sampling dates. Species associated with this effect were *I. notabilis* (INO), *C. denticulata* (CDE), *P. blumentritti* (PBL), *Nanorchestes sp.* (NAN), unidentified Reterostigmata (RET), *Alliphis halleri* (ARA), *H. similisetae* (RSI), *P. selnicki* (PSE) and *V. planicola* (VPL). The mite *A. halleri* (ARA) shared all characteristics of the group of cereal-associated species mentioned above, except that it was extremely rare in the preceding spring barley crop. Its abundance in the

1984 potato crops of the three-year rotation therefore did not result from a large population in spring barley.

In combination with axis 1 (*Fig.* 3), axis 3 shows that in 1983 the composition of the mesofauna in cereals had a more equal vertical distribution than in root and tuber crops. In the latter crops, surface and deeper soil layers were inhabited by quite different species. In the 1984 potato crop, however, this vertical difference was almost absent.

Axis 4 (*Fig.* 6)

Besides the similarity in soil mesofauna of the cereals and the 1984 potato crop along axis 3 (*Fig.* 3), the 1984 potato crop also showed a characteristic fauna of its own, as illustrated by the opposite ordination of the data from the 1983 cereals and 1984 potato crop along axis 4 (*Fig.* 6). The potato crop of 1984 typically was inhabited by unidentified Heterostigmata (HET), *V. agilis* (VAG), *A. halleri* (AHA), Entomobryinae (ENE), *O. minus* (OMI) and its nymph (NOM), *I. notabilis* (INO), Anoetidae (ANO) and M. *minimus* (MMI). Conditions in 1983 must have been less favourable for the development of a species-rich fauna typical of potato since the potato crop of that year occupied an intermediary position. The cereals winter wheat and spring barley were characterized by the following taxa; *T. talpae* (TTA), *I. viridis* (IVI), *P. selnicki* (PSE), *P. alba* (PAL), *Nanorchestes sp.* (NAN), *A. cetratus* (ACE) and *F. sp.* (FSP).

IV. − DISCUSSION

The soil mesofauna provided information on the soil system as a whole, and in relation with the observed yield losses. This information will be discussed in relation to year, crop and rotation, followed by a paragraph on yield depression.

Year

Judging from the mesofauna in the 1983 and 1984 potato crop, the extremely different weather conditions in these years had a profound influence on the soil system.

Indicative of this influence was the massive appearance in the 1983 potato crop of springtails of the *T. krausbaueri* group when all other springtails occurred in small numbers only. The small size and worm-like body of *T. krausbaueri* and its adaptations to living at depth are most likely an advantage over other species when colonizing compact soils.

The high relative abundance of these springtails suggests that the wet and relatively warm conditions during winter and spring of 1983 resulted in a soil that had many small pores and a low content of fresh organic material (*see* Appendix). The mesofauna of the potato crop in 1984 differed substantially from that of the preceding year (*Fig.* 4). During the spring of 1984 in particular, many more species were present that were associated with the preceding spring barley crop than in 1983 (*Fig.* 5*b*). Partly this may be a consequence of the early sampling in 1984 but, more likely, it points to a slow decomposition of the barley straw in the relatively dry and cold winter of 1984. Apart from the cereal-associated species, the following taxa were typically found in the 1984 potato samples: *F. candida*, Astigmata, *V. agilis*, Anoetidae, Entomobryidae and *M. minimus.* Most of these species have a comparatively large body size and are indicative of a loose soil structure when found in the deeper soil layers. The abundance of anoetid mites in spring implies moist soil with abundant food (protozoa and bacteria).

Crop

Numbers as well as species composition of the mesofauna indicated large differences between the soil conditions under cereals compared with those under root and tuber crops.

Cereals had a very abundant mesodauna particularly *I. notabilis, C. denticulata, Lepidocyrtus spp.* and the group of rare or unidentified springtails, and the pyemotid mites *P. blumentritti*, *P. selnicki*, *T. talpae*. Since pyemotids and this group of springtails depend mainly on fungi for their nutrition (*see* Appendix), the abundance of these species suggests a rich fungus flora in soils under cereals. More specific information about the cereal soil system can be obtained by examining the biology of those species that were selectively associated with cereals (axes 3 and 4). These species can be divided into two groups.

The first group consists of species, such as *A. cetratus*, *I. viridis*, *P. selnicki* and *T. talpae*, which were present only in cereals. These species were mostly found near the soil surface. They belong to the fauna inhabiting the litter layer (*see* Appendix). Their high abundance is indicative of organic material in an early stage of decomposition (*A. cetratus*), the presence of algae (*I. viridis*), a rich fungal growth (*P. selnicki* and *T. talpae*) and humid conditions at the soil surface.

The species of the second group were found in large numbers in cereals, but not typically near the soil surface. They were also found in the following crop (potato) where their abundance diminished slowly (axis 3) (*I. notabilis*, *C. denticulata*, *Nanorchestes sp.*, *P. blumentritti*, *H. similisetae* and *V. planicola*). These species live on fungi (*I. notabilis,* C. *denticulata*), nematodes (*H. similisetae*) or springtails (*V. planicola*) and are an indication of fresh decomposing organic matter.

Accordingly, they were most abundant when the roots had died during the ripening of the cereals and in the deeper soil layers of the 1984 three-year potato crops, where undecomposed organic material from the preceding spring barley stubble that had been plowed down was still present.

A. halleri increased in numbers from a few specimens in spring barley to a high abundance on the first two sampling dates in the subsequent three-year potato crop. This pattern of increase was similar to that observed by BÜHLMANN (1984) in a potato crop that was planted after plowing up temporary grassland.

A. halleri is strictly nematophagous (*see* Appendix) and accordingly a rise in the population of *A. halleri* indicates a rise in the nematode population. The nematodes could have profited from the plowed-down stubble of spring barley or from the rotting seed potatoes.

The mesofauna of the root and tuber crops in 1983 consisted mainly of springtails of the *T. krausbaueri* group and cryptostigmatid mites, especially *T. velatus*. *T. krausbaueri* lives in the deeper soil layers and survives well, even when only small pores and decomposed organic matter are available. *T. velatus* is known to occur in a wide range of habitats; often habitats where other species are lacking (*see* Appendix). Species which require fresh organic matter or a constant microclimate in the topsoil, such as exists under a crop coyer, were absent from the bare soil between the rows of the root and tuber crops.

Soil compaction in the root and tuber crops, as indicated by large numbers of *T. krausbaueri*, may be the result of more severe tillage operations for seedbed preparation than in other crops.

Soil compaction will have been most severe in 1983 when the soil was still wet when tilled for seedbed preparation.

Rotation

A crop rotation effect on the mesofauna is indicated by the relatively low abundance of most taxa of mites in the three-year rotation in 1983. *T. velatus* in particular was negatively affected by the short rotation period and soil disinfection. *T. velatus* has a thick cuticle, resists desiccation well, feeds on fungi and is sensitive to many pesticides. However, even when this species was harmed by the application of metamsodium in the disinfected half of the three-year rotation, this does not explain its low abundance in the non disinfected half. Other factors, such as soil compaction or a different quality or quantity of the organic matter or fungal flora in the three-year rotation, may be involved.

The results presented here show that, apart from the factors weather and depth (which cannot be influenced by the farmer), the kind of crop and related crop management practices strongly affect the mesofauna of the agro-ecosystem investigated. Relations between the soil mesofauna and vegetation are best known from oligotrophic ecosystems such as blanket bog (BLACKITH, 1974) or steppe (STEBAEVA, 1963). Several factors may have led to the marked plant-mesofauna interaction that was found in the nutrient-rich agro-ecosystem investigated. High microbial activity of the calcic soil may have caused a rapid decomposition of the organic material, especially when the mean annual temperature and the humidity of the soil were high (as was the case in 1983). Under such conditions, species associated with organic material in an early stage of decomposition depend on the direct supply of organic material by a crop. The root system of cereals apparently added much suitable fresh organic material to the soil, as is demonstrated by the large number of species associated with such organic material that were recorded in cereals. In potato or sugar beet only species with low ecological specificity or species associated with the late stages of decomposition and small pores were abundant. In combination with a very low abundance of species associated with freshly decomposing organic material, the mesofauna indicated that the supply of organic matter in the root and tuber crops was low. It is therefore likely that rotation effects on the mesofauna are the result of a high percentage of root and tuber crops in the three-year rotation (66%) in comparison with the six-year rotation (33%).

In previous work correspondence analysis or related techniques have been used for analysing data of the soil mesofauna (PONGE, 1973, 1980, 1983; PARR, 1978; CURRY, 1978). During winter GERS (1982) studied the collembolan fauna of fields previously sown to wheat or maize and demonstrated that the species composition was influenced by factors related to soil depth and the preceding crop, and factors related to plowing, surface soil cultivation or no tillage. ANDRÉN and LAGERLÖF (1983) concluded from PCA (Principal Component Analysis) ordination of data on the soil fauna in Swedish cropping systems that "... the main factors are site dependent (climate, soil type, etc.) or time dependent (within year and between year variation)". They also found effects of soil tillage and of fertilization.

Yield depression

The indication by the mesofauna of small pores and decomposed organic material coincides with lower yields in the three year rotation potato crop. However, the yields in the metamsodium treated three year rotation potato crop were higher even though in this part the mesofauna was less abundant and comprised less species than in the not treated three year rotation. Therefore negative effects of the three year rotation on the soil system as indicated by the mesofauna caused less damage to the crop than unknown negative factors of which the influence is diminished by metamsodium treatment of the soil.

It is unlikely that after three years the N-flush which normally occurs following soil disinfection will have attributed to higher yields of potato in the three year rotation.

BEUTE and BENSON (1979) discussed the relation between small soil fauna and plant disease. Of the mesofauna, certain acarid mites (*Rhizoglyphus sp.*, *Rh. echinopus*, *Rhizophagus sp.* and *Caloglyphus sp.*), pyemotid mites (*Stenotarsonemus laticeps*, *Siteroptes spp.*) and certain springtails were reported to aggravate infections of plant tissue with pathogenic fungi which showed very limited pathogenicity in absence of these animals. Of the above mentioned taxa only acarid mites have been reported as secondary parasites in association with damage to potato (BAKER *et al.* 1954; KARG, 1962). Acarid mites have strong chelicerae which are capable of cutting fun gal material or plant tissue. They feed on a wide range of foods such as fungal material, fresh or decaying plant material, yeast or nematodes (WOODRING, 1963; MURAOKA & ISHIBASHI, 1976; STURHAN & HAMPEL, 1977). The number of acarids captured in the potato crops in this study was rather small (Tab. II). However, larger numbers of acarids were found in both years in the three-year than in the six-year rotation potato crop. They may have caused selectively more root damage in the three-year rotation potato crop, which would account for part of the yield reduction. This possibility needs further study.

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SUMMARY

In 1983 and 1984 an inventory was made of the edaphic mites and springtails in a six-year rotation, a three-year rotation and a three-year rotation in which the soil was disinfected with metamsodium after the potato crop was harvested. The aim was to find possible direct or indirect biological factors related to the yield loss observed in the three-year rotation potato crop. The test site was situated on a heavy marine clay soil. Samples were taken four times in the course of the growing season. The mesofauna was extracted by means of Macfadyen high-gradient extraction. The following depths were extracted: 0−2,5; 2.5−5; 7.5−10; 15−17. 5 and 25−27. 5 cm. The results were examined by analytical and synthetical procedures.

The mesofauna was much more abundant in cereals than in root and tuber crops. Most mites and springtails were found near the surface of the soil except in potato when it was preceded by a cereal crop that was plowed down. In 1983, a year with relatively heavy and prolonged rainfall, more mites were found in corresponding crops of the six-year rotation than of the three-year rotation. The short rotation reduced the abundance of *Tectocepheus velatus*, whereas the percentage of the *Tullbergia krausbaueri* group and the number of Heterostigmata were increased. In 1984, a year with colder and drier weather, more mites and springtails were found in the potato crop of the three-year rotation than in the potato crops of the six-year rotation.

Correspondence analysis resulted in four axes that could be given a meaningful interpretation. Ordination of the samples and species along the first axis was mainly due to the presence of *Tectocepheus velatus* and was related with depth, rotation and climatic factors. The second axis showed a year-effect for the 1983 and 1984 potato crops. The species composition of the mesofauna in many ways reflected crop effects as

shown by the ordination of the samples and species along axes 3 and 4.

There was a suggestion of a possible contribution of the Acaridae to the yield loss. This has to be subjected to further study. The mesofauna was indicative of a low content of fresh decomposing organic matter and a compacted soil structure in the root and tuber crops. The high percentage (66%) of root and tuber crops is the most probable cause of the low abundance and species richness of the mesofauna in the three-year rotation. Lower yields in the three year rotation potato crop coincided with the indication by the mesofauna of a more compact soil structure and less fresh decomposing organic matter, which was even more so in the disinfected three year rotation. Still, soil treatment with metamsodium partially reduced the yield depression.

RESUME

Les microarthropodes du sol (acariens et collemboles) de deux assolements culturaux sur sol argileux lourd d'origine marine

Un inventaire des acariens du sol et des collemboles a été réalisé en 1983 et 1984, dans des cultures avec assolement sur 6 années, 3 années sans désinfection du sol et 3 années avec désinfection au metamsodium après la culture des pommes de terre. Le but de cette étude est de trouver des indications biologiques directes ou indirectes relatives au déficit de production observé chez les pommes de terre de l'assolement triennal. Des échantillons ont été prélevés à quatre dates différentes pendant la période de croissance végétale. La mésofaune a été extraite à l'aide du système à haut gradient de Macfadyen. Les profondeurs suivantes ont été échantillonnées: 0−2,5cm; 2,5−5cm; 7,5−10cm; 15−17,5cm; 25−27,5cm. Les résultats ont été analysés à l'aide de techniques analytiques et synthétiques (analyse des correspondances).

La mésofaune est beaucoup plus abondante dans les céréales que dans les cultures de racines ou de tubercules. La plupart des acariens et des collemboles se rencontrent près de la surface du sol sauf dans le cas où la pomme de terre a été précédée par une céréale, enfouie après la culture. En 1983, année où les chutes de pluie ont été abondantes et de longue durée, les acariens ont été récoltés en plus grand nombre dans les cultures de l'assolement sur 6 années par rapport aux cultures correspondantes de l'assolement triennal. Les rotations rapides affectent négativement l'abondance de *Tectocepheus velatus* tandis que *Tullbergia* groupe *krausbaueri* et les Heterostigmata sont au contraire favorisés. En 1984, année où le temps a été plus froid et plus sec, les acariens et

les collemboles ont été trouvés en plus grande abondance dans les cultures de pommes de terre de l'assolement triennal que dans celles de l'assolement sur 8 ans.

L'analyse des correspondances a fourni 4 axes interprétables. Le classement des relevés et des espèces le long du premier axe correspond essentiellement à la présence de *Tectocepheus velatus* et est lié à la profondeur, au type d'assolement et aux facteurs climatiques. Le second axe montre un effet de l'année de culture pour ce qui concerne la pomme de terre. Le classement des relevés et des espèces le long des axes 3 et 4 indique de différentes manières l'influence du type de culture.

Les résultats suggèrent une contribution possible des Acaridiés au déficit de production. Ceci doit faire l'objet d'une prochaine étude. La mésofaune s'avère indicatrice de la faible teneur en matière organique fraiche et de la compacité du sol sous les cultures de racines et de tubercules. Le fort pourcentage (66 %) occupé par ces cultures dans l'assolement triennal est probablement responsable de la faible abondance et du faible nombre d'espèces de la mésofaune qui le caractérisent.

APPENDIX

SPECIES LIST AND ECOLOGICAL DATA

(In alphabetic order)

Acari

Mesostigmata

ACE − *Arctoseius cetratus* (Sellnick, 1940)

A. cetratus is phoretic on sciarid flies and feeds on sciarid eggs or larvae, on caecid larvae, on *Tyrophagus myceliophagus* and on rhabditid nematodes (BINNS, 1973), on *T. krausbaueri*, *Folsomia fimetaria*, nymphs of oribatid mites and on *Tyrophagus spp.* (KARG, 1960). SARDAR (1980) observed that *A. cetratus* consumed *Liebstadia similis*, but that *Tyrophagus putrescentiae*, collembola, tribolium eggs and larvae of Ceratozetes were not eaten. It was found in high numbers after application of 550 t cattle slurry per ha (BOLGER & CURRY, 1980) and was more numerous in two-or four-year ley than in permanent pasture (WHELAN, 1986).

ARA − *Alliphis halleri* G. and R. Canestrini, 1981. (= *Alliphis siculus*, Oudemans, 1905)

This species is one of the early colonizers of substrate (LAGERLÖF & ANDRÉN, 1985) and was found in the soil, but also in the herbage of grassland (WHELAN, 1986). It is phoretic on *Geotrupus spp.* (GÖTZ, 1952) and possibly also *Copris hispanus* (COSTA, 1963) and feeds selectively on nematodes (KARG, 1960, KARG & GROSSE, 1983; SARDAR, 1980). In potato it was distributed throughout the soil profile. In winter wheat it lived near the soil surface. Its abundance depended more on application of manure than on the kind of crop (BÜHLMANN, 1984).

A female *A. halleri* lives about 90 days and produces in that period about 110 eggs (at 15°C). When fed with *Nematospiroides dubuis* or *Pelodera strongyloides*, reproduction and survival of *A. halleri* was much better than when fed with *Globodera rostochiensis* larvae (SARDAR, 1980).

HSI − *Hypoaspis similisetae* (Karg, 1965)

After sewage sludge application this species became numerous (HÖLLER, 1959) and was considered indicative of the early rotting stage. According to KARG (1971), *H. similisetae* is normally found in moist soil in humus between roots. It is associated with nematodes (VAN DE BUND, pers. comm.).

RPR − Unidentified nymphal stages or adults of mesostigmatid mites

VAG − *Veigaia agilis* Berlese.

This species feeds on collembola (KARG, 1969). In two- or four-year ley it was less frequently found than in permanent pasture (WHELAN, 1986).

VPL − *Veigaia planicola* (Berlese, 1892)

Little is known about this species except that it is more common in arable land than in woodland soil (KARG, 1971).

Astigmata

ANO − Anoetidae

These mites feed on bacteria and protozoa that are filtered out of the matrix water (HUGHES, 1959). They were the first inhabitants of fresh sewage sludge (HÖLLER, 1959) and survive submersed situations very well (pers. obs.). The adults and nymphs are slow-moving creatures that are sensitive to desiccation. Under dry conditions the deutonymph can develop to the phoretic and drought resistant hypopus stage. It takes 7−12 days for Anoetidae to complete their life cycle (WOODRING, 1963). Anoetids were also found in the herbage or on grasses (WHELAN, 1986).

AST − All Astigmata except the Anoetidae.

Prostigmata

AEU − All Eupodina except *Eupodes sp.* and *Nanorchestes sp.*

EUP − *Eupodes sp.*

HET − All unidentified Heterostigmata.

MPS − Male of an unidentified *Pygmephorus* sp. probably *P. blumentritti.*

NAN − *Nanorchestes sp.*

Nanorchestidae were found abundantly in manured fields (KARG, 1969; HÖLLER-LAND, 1962) or in fields heavily infested with potato cyst nematodes (KARG, 1962).

PBL − *Pygmephorus blumentritti* n. sp. Krczal

PSE − *P. selnicki* (Krczal, 1958).

Pyemotidae

In general, the Pyemotidae feed on fungi. They pierce the fungal hyphae with their sticking mouthparts and suck up the contents. Except for *Siteroptes graminis* no specific information was found about the Pyemotidae captured in this study. *Siteroptes graminis* has been found in association with fungal infections of grasses (KRCZAL, 1959). Adults of some Pyemotidae can practice phoresy on insects or in sect larva.

SCU − *Scutacarus spp.*

TTA − *Tarsonemus talpae* n. sp. Schaarsmidt.

Cryptostigmata

OMI − *Oppia minus* (Paoli, 1908).

NOM = nymph of O. *minus*

ALEJNIKOVA and UTROBINA (1975) found this small species in large numbers in continuous rye and wheat. It is found more in the deeper soil layers than near the soil surface (KARG, 1961; VANNIER, 1970) and, like *Oppia nova,* it was less abundant in nematode infested soil of a potato field (KARG, 1961).

ONO − *Oppia nova* (Oudemans, 1970).

NON = nymph of *O. nova*.

Oppia nova has been reared on lichens or mushrooms. It feeds in all its nymphal stages and in the adult stage, it is parthenogenetic and lives at 25°C about 30 days (WOODRING, 1963). HARTENSTEIN (1962) concluded that this species is strictly fungivorous, but according to LUXTON (1981) *O. nova* is a microbial feeder. In permanent grassland it was more abundant than in two- or four-year ley (WHELAN, 1986) and it was less abundant in potato soil heavily infested with cyst nematodes than in soil that was almost free of infection (KARG, 1962).

TVE − Adult of *Tectocepheus velatus* (Michael, 1880).

NTV = nymph of *T. velatus*.

This large species was reared on “skeletonized leaves from the litter layer of broadleaved woodland”, is parthenogenetic, has small eggs and produces two generations a year (MURPHY & JALIL 1963: SCHENKER, 1986). It feeds on fungi (MITTMANN, 1983). It lives near the soil surface (WEIS-FOGH, 1947; KARG, 1961) and is sensitive to application of urea in woodland soil (MARSHALL, 1977) and to the pesticides endosulfan, lindane, methomyl, aldicarb, oxamyl and DBCP (HEUNGENS & VAN DAELE, 1979). It resists desiccation better than *O. nova* (RIHA, 1951), was found in soils with a wide range of pH (CHISTYAKOV, 1972) and is sensitive to frost (LEBRUN, 1964). SCHALK (1968) states that this species survives a broad spectrum of ecological conditions and will be found where other species are lacking.

Rare species: *Veigaia cerva* (KRAMER, 1876) (VCE), *Veigaia exigua* (BERLESE, 1917) (VEX), *Saprosecans baloghi* Karg 1964 (SBA), *Antennoseius sp.* (ASP), *Prozercon triighardi* (HALBERT, 1923) (PTR), *Pygmephorus ursulae* n. sp. Krczal (PUR).

Collembola

CBI − *Cryptopygus bipunctatus* (AXELSON, 1903).

CDE − *Ceratophysella denticulata* (BAGNALL, 1941).

BOLGER and CURRY (1980) always found increased numbers after application of cattle slurry on grassland. It profits strongly from fresh organic material (PIART and DUVIART, 1985) and is an early species in decomposition (BECKMANN, pers. comm., HÖLLER-LAND, 1959). It was most abundant in the top 5 cm of the soil, and suffered from plowing (GERS, 1982). When reared in microcosms in competition with *Onychiurus gr. armatus* it was less successful at 16°C (constant temperature) but it had a better development at 23°C (fluctuating temperature) (LONGSTAFF, 1976).

COL − All other springtails.

ENE − Entomobryinae

FCA − *Folsomia candida* (Willem, 1902).

This parthenogenetic species feeds on fungi such as *Rhizoctonia*, *Pythium*, *Fusarium* or the mycorrhizal fungi of leek (*Allium porrum*) (KARG, 1969, WARNOCK and FITTER, 1982) of which it prefers newly grown hyphae (LEONARD and BRADBURY, 1984), but can be reared also on yeast (SNIDER, 1973). At 21°C (constant temperature) a female *F. candida* produced on average 63 eggs during her life, “l” was 20.3 and r. day^{-1} was 0.15 (GREGOIRE-WIBO, 1977). At temperatures of 15, 21 or 26°C representants of this species lived respectively 240, 136 or 72 days producing in that period on average 1344, 1011 or 130 eggs (SNIDER and BUTCHER 1973).

GERS (1982) found this species associated with deeper soil layers and with plowing, especially when maize rather than wheat was the previous crop.

FSP − *Folsomia sp.*

INO − *Isotoma notabilis* Schaffer, 1896.

This parthenogenetic species (PETERSEN, 1971) lives in the litter layer or in the soil just beneath it (KARG, 1962) and was also found on snow by PIART and DUVIART (1985). The juveniles penetrate the soil more deeply and are found in the soil surrounding the roots (MÜLLER, 1959; ULBER, 1978). It was found as early colonizer of decomposing organic matter (HÖLLER-LAND, 1959). GERS (1982) found relatively many *I. notabilis* in the deeper soil layers. Soil tillage affected this species relatively little.

IVI − *Isotoma viridis* Bourlet, 1839.

This large species lives at the soil surface or just in the soil [especially the juveniles (KARG, 1961)]. It produced twice as much eggs when fed with algae instead of "Tetramin".

LSP − *Lepidocyrtus spp.*

MMI − *Megalothorax minimus* Willem, 1900.

M. minimus is a late successional species (PARR, 1978) which shows little vertical movement (HÖLLER-LAND, 1962).

PAL − *Pseudosinella alba* (Packard, 1873).

P. alba lives in neutral or alkaline soils (PONGE, 1980). It eats specifically from fungi, of which it likes the spores the best, followed by conidiophores or hyphae (ARPIN *et al.*, 1980; PONGE and CHARPENTIÉ, 1981). It is an early species in succession (PARR, 1978).

TKR − *Tullbergia krausbaueri* s.l. Börner, 1901. [A group of species until recently not separated in literature (Rusek, 1979)].

This parthenogenetic species (PETERSEN, 1971) probably has only one generation per year (LEINAAS, 1976). *T. krausbaueri* inhabits small pores (HAARLÖV, 1955) of deeper soil layers (KARG, 1961; GERS, 1982) and feeds most probably on fungi (KARG, 1969). They are not bound to rhizosphere soil or to a particular crop (MÜLLER, 1959; ULBER, 1978). As one of the very few springtails, they survive continuo us fallow very well (VAN DE BUND 1970). Furthermore, they are associated with late stages of decomposition of organic material

(ANDRÉN, 1984), and devour mineral fractions of the soil together with organic material (BOCKEMÜHL, 1966). *T. krausbaueri* is sensitive to high nitrogen gifts (LEINAAS, 1976; BOLGER, 1980).

Rare species: *Lepidocyrtus cyaneus* Tullberg, 1871 (LCY), *L. lignorum* (Fabricius, 1781) (LLI), *Proisotoma minuta* (Tullberg, 1871) (PMI), *P. brevidens* Stach, 1917 (PBR), *Isotomurus palustris* (Müller, 1776) (IPA), *Sminthurides stachi* Jeannenot, 1955 (SST).

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Legends of figures

FIG. 1. − Soil temperature at 10cm depth and rainfall during 1982, 1983 and 1984, mean values for 10-day periods. Arrows (↓) indicate sampling dates.

FIG. 2. − (*a*) Total number of mites in 40 samples taken in each crop of the six and three-year rotation. (Approximation of the number of animals per m^2 to a depth of 27.5 cm on a given day can be obtained by multiplication of the data by 100.) (*b*) Total number of springtails in 40 samples taken in each crop of the six and three-year rotation. (Approximation of the number of animals per m^2 to a depth of 27.5cm on a given day can be obtained by multiplication of the data by 100.)

FIG. 3. − Ordination of the data according to axes 1 and 3; effects along the first axis are mainly related to the presence or absence of TVE. Depths 0−2.5 and 2.5−5; ○ = potato and sugar beet (1983), "−" = potato (1984), □ =spring barley. Depths 7.5−10, 15−17.5, 22.5−25; ● = potato and sugar beet (1983), "=" = potato (1984), ■ = spring barley, "•" = all other samples.

FIG. 4. − Ordination of the data according to axes 2 and 3; separate ordination of the 1983 and 1984 potato samples along axis 2 and 3 due to year related effects. ○ = 1983 potato samples, ● = 1984 potato samples, "•" = all other samples.

FIG. 5. − (*a*) Ordination of the data according to axes 2 and 3; crop effects. ▲ = sugar beet, ○ = potato (1983), ◙ = spring barley (R6), □ = spring barley (R3 and R3*), "•" = all other samples.

FIG. 5. − (*b*) Ordination of the data according to axes 2 and 3; effects of season and previous crop. Only samples of the three-year rotation potato crop (that had spring barley as previous crop) are shown. 1983 R3 and R3* potato crops; △ =first two sampling dates, ● =last two sampling dates. 1984 R3 and R3* potato crops; ⊕ = first two sampling dates, ○ = last two sampling dates. "•" = all other samples.

FIG. 6. − Ordination of the data according to axes 3 and 4; axis four shows a contrast in effects on the edaphic microarthropods of cereals and root and tuber crops. □ = spring barley, △ = potato (1983), ● = potato (1984), "•" = all other samples.

TAB. I. − Sampling scheme for the crops of the six-year and the three-year rotation (PO =potato [mesofauna extracted of four samples]; WW = winter wheat, FL = flax, BE = sugar beet, BA = spring barley, PE=peas [mesofauna extracted of two samples]). [1]The sampling on 1-XI took place after harvest of the potato crop and after plowing. [2]Flax was undersown with white clover (*Trifolium repens*). [3]The sampling on 1-XI took place after harvest of the beets. [4]Spring barley in R3 and R3* was undersown with Italian ryegrass (*Lolium multiflorum*).

Year		1983						1984
Sampling dates		15-VI 18-VII 23-IX 1-XI						26-IV 14-VI 7-VIII 18-IX
Rotation		CROP						
6 year (R6)		PO[1]	WW	FL[2]	BE[3]	BA	PE	PO
3 year (R3)		PO[1]	−	−	BE[3]	BA[4]	−	PO
3 year (R3*) (disinfected)		PO[1]	−	−	BE[3]	BA[4]	−	PO
Soil labour practices								
PO	R6	OH, Harvest						
	R3	OH, Harvest						
	R3*	OH, Harvest, FTC, Metamsodium treatment						
WW	R6	FTC						
FL	R6	Plowing, Leveling (2 times)						
BE	R6	Plowing, OH (2 times), Harvest						
	R3	FTC, Plowing, OH (2 times), Harvest						
	R3*	TFC, Plowing, OH (2 times), Harvest						
BA	R6	OH						
	R3	OH						
	R3*	OH						
PE	R6	Plowing, OH						

FTC = Fixed-tine cultivator.
OH = Oscillating harrow.

TAB. II. − **Distribution of the most numerous mites and springtails in the different rotations as affected by the crops.** (Approximation of the number of animals per m^2 to a depth of 27.5 cm on a given day can be obtained by multiplication of the data by 100.)

Crop	year:				1983									1984	
	Potato			WW	FL	Sugarbeet			Spring barley			PE	Potato		
	R6	R3	R3*			R6	R3	R3*	R6	R3	R3*		R6	R3	R3*
Taxon:															
Acari															
Mesostigmata															
V. planicola	1	3	0	44	41	2	4	4	23	30	40	26	26	6	21
Restgroup	3	4	1	10	8	6	0	7	46	36	23	7	7	48	32
H. similisetae	7	12	0	0	5	2	0	1	1	5	15	9	5	5	6
A. halleri	0	10	3	0	0	1	0	1	1	0	1	0	3	6	18
Cryptostigmata															
T. velatus (nymph+adult)	212	39	39	15	49	165	75	18	190	10	2	98	19	64	20
O. minus (nymph+adult)	16	9	3	5	36	22	19	33	4	16	8	20	16	30	17
O. nova (nymph+adult)	17	10	6	33	15	11	12	13	32	9	7	1	14	15	9
Prostigmata															
Eupodes sp	6	10	12	25	44	4	19	14	38	31	44	8	17	17	26
Nanorchestes sp	0	0	0	0	0	0	0	1	1	43	54	1	6	11	9
P. blumentritti	3	24	5	26	2	5	3	6	205	237	365	7	14	26	28
P. selnicki	11	1	1	94	3	3	11	9	24	69	16	4	1	8	10
Restgroup	0	1	1	17	0	13	1	0	33	4	64	2	4	27	50
T. talpae	1	2	1	84	8	1	5	2	15	7	16	14	0	0	0
Astigmata															
Acaridae	1	8	2	1	50	15	3	1	19	35	2	3	2	108	28
Anoetidae	2	3	3	0	2	5	3	3	19	6	3	51	38	32	19
Collembola															
T. krausbaueri	142	277	149	224	151	199	198	120	132	123	170	102	34	32	40
C. denticulata	0	1	0	14	0	2	0	1	4	33	42	0	1	29	32
I. notabilis	0	13	4	49	0	11	0	0	174	20	82	1	37	80	182
F. candida	0	1	1	2	0	0	1	9	35	9	0	6	3	47	0
Lepidocyrtus sp.	3	5	1	22	25	4	5	3	13	5	6	15	3	5	2
P. alba	4	0	1	22	8	5	9	5	18	14	18	5	1	0	1
Folsomia sp.	0	1	1	5	0	6	0	8	24	19	7	2	0	0	0
M. minimus	2	1	2	5	15	10	8	12	10	20	0	12	41	15	7
TOTAL ACARI	289	147	106	388	304	275	163	120	735	587	725	279	199	451	353
TOTAL COLLEMBOLA	150	304	158	373	234	246	228	161	440	292	354	149	127	228	270

TAB. III. − **Seasonal variation in the abundance of mesofauna species in cereal and potato crops. Values given are sums of the first two samplings (spring) or the last two samplings (late summer) for cereals (winter wheat and three spring barley crops) and potato (two thirds of the summarized data of the six potato crops).** (Approximation of the number of animals per m^2 to a depth of 27.5 cm on a given day can be obtained by multiplication of the data by 50. Abbreviations of species names are explained in the appendix.)

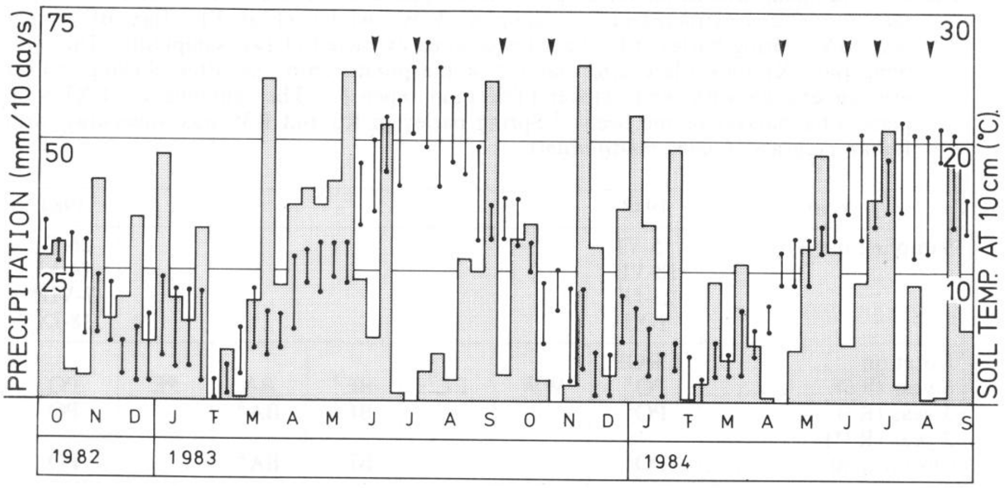
	Cereal		Potato			Cereal		Potato	
	spring	late summer	spring	late summer		spring	late summer	spring	late summer
Taxon:					Taxons:				
Mesostigmata					*Astigmata*				
VPL	26	111	31	9	AST	12	45	29	71
RPR	20	95	41	15	ANO	10	17	40	25
HSI	9	12	15	2	*Prostigmata* (excl. Heterostigmata)				
AHA	0	2	24	5	EUP	82	64	20	39
VAG	0	0	8	19	NAN	0	98	14	3
ACE	4	21	2	1					
VNE	6	13	1	4					
Cryptostigmata					*Collembola*				
NTV	65	112	118	48	TKR	175	476	97	353
TVE	7	33	15	11	INO	52	273	189	19
NOM	2	1	1	15	CDE	20	73	39	4
OMI	9	21	30	17	MMI	8	27	27	18
NON	20	6	8	11	COL	11	33	5	1
ONO	30	25	15	14	FCA	2	44	1	41
Heterostigmata					LSP	24	24	8	6
PBL	301	532	53	16	PAL	23	49	2	2
PSE	1	206	12	11	FSP	6	49	0	1
HET	79	39	49	7	IVI	14	24	1	0
TTA	20	102	2	4	CBI	18	8	6	0
MPS	41	29	4	4	ENE	0	0	2	10
SCU	18	8	8	7					

TAB. IV. − **Vertical distribution of mites and springtails in relation to crop and rotation. Solid lines separate crops which are not in sequence in the crop rotation. Dashed lines separate crops which are in sequence in the crop rotation but were sampled on different fields in the same year. No lines are drawn between crops that were grown on the same field in two successive years.** (Approximation of the number of animals per m^2 for each layer on a given day can be obtained by multiplication of the data by 50.)

		Mites					Springtails			
		1983			1984		1983			1984
Rot.	depth	PO	BE	BA	PO		PO	BE	BA	PO
R6	0−2.5	46	110	351	38		4	19	94	25
	2.5−5	116	98	187	66		16	44	148	26
	7.5−10	42	18	97	25		60	73	77	17
	15−17.5	56	30	79	39		38	58	86	34
	25−27.5	30	18	21	31		33	52	35	26
R3	0−2.5	27	96	340	85		21	23	112	18
	2.5−5	48	29	81	63		25	43	65	35
	7.5−10	19	5	42	80		112	56	42	42
	15−17.5	30	13	68	120		100	50	24	85
	25−27.5	25	20	56	103		48	56	49	49
R3*	0−2.5	14	39	333	41		5	18	135	25
	2.5−5	38	18	160	58		8	23	95	51
	7.5−10	21	33	118	87		70	61	46	90
	15−17.5	26	17	66	133		47	32	44	78
	25−27.5	8	13	48	35		30	27	34	27

TAB. V. − **Vertical distribution of mesofauna, summarized for all samples.** (Approximation of the number of animals per m^2 at a given day and for each layer can be obtained by multiplication of the values with 3. Abbreviations of species names are explained in appendix.)

	Depth (cm) and numbers						Depth (cm) and numbers				
Taxon	0−2.5	2.5−5	7.5−10	15−17.5	25−27.5	Taxon	0−2.5	2.5−5	7.5−10	15−17.5	25−27.5
Mesostigmata						*Astigmata*					
VPL	80	74	59	31	25	AST	54	39	46	123	15
RPR	55	37	42	51	53	ANO	82	46	19	27	14
RSI	15	18	16	10	4	*Prostigmata*	(exc . Heterostigmata)				
ARA	11	5	13	10	6	EUP	135	103	39	27	21
VAG	4	6	8	10	10	NAN	72	24	12	4	15
ACE	20	3	3	4	3						
VNE	5	8	8	4	3						
Cryptostigmata						*Collembola*					
NTV	518	245	42	46	19	TSL	252	349	574	525	391
TVE	66	55	15	3	4	INO	128	274	150	73	28
NOM	1	1	7	11	21	CDE	46	41	26	37	9
OMI	4	11	19	73	107	MMI	26	18	41	37	38
NON	13	20	20	13	2	COL	69	15	24	10	9
ONO	19	38	30	33	15	FCA	5	10	8	88	13
Heterostigmata						LSP	51	32	15	8	10
PBL	408	233	108	124	82	PAL	39	38	11	14	9
PSE	158	42	24	27	14	FSP	2	4	25	12	29
RET	15	32	69	81	20	IVI	31	7	3	1	2
TTA	121	28	2	2	3	CBI	8	5	11	11	8
MPS	26	33	19	4	4	ENE	5	5	4	3	2
SCU	13	16	12	12	10	Total mites	1977	1186	685	784	487
						Total collembola	658	801	891	817	547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50
25
30
20
10
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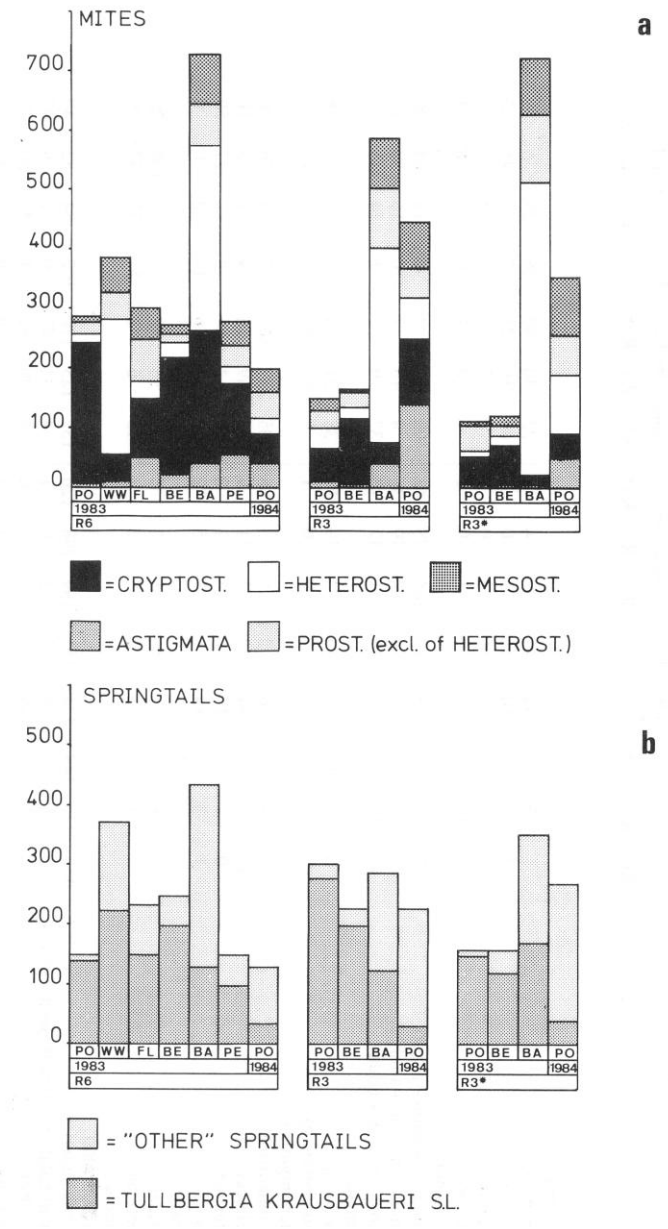
1982
1983
1984

Fig. 1


MITES
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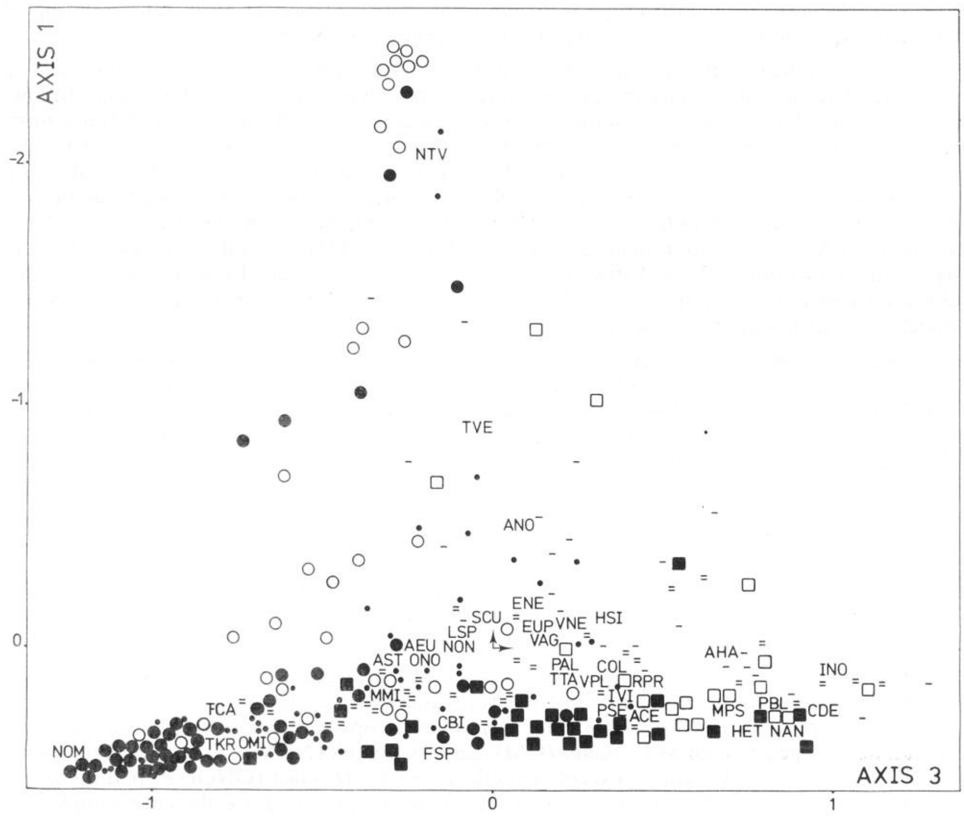
600
500
400
300
200
100
0
PO WW FL BE BA PE PO
1983 1984
R6
PO BE BA PO
1983 1984
R3
PO BE BA PO
1983 1984
R3*
=CRYPTOST.
=HETEROST.
=MESOST.
=ASTIGMATA
=PROST. (excl. of HETEROST.)
SPRINGTAILS
b
500
400
300
200
100
0
PO WW FL BE BA PE PO
1983 1984
R6
PO BE BA PO
1983 1984
R3
PO BE BA PO
1983 1984
R3*
= "OTHER" SPRINGTAILS
= TULLBERGIA KRAUSBAUERI S.L.

Fig. 2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VPL
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AHA
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Fig. 3

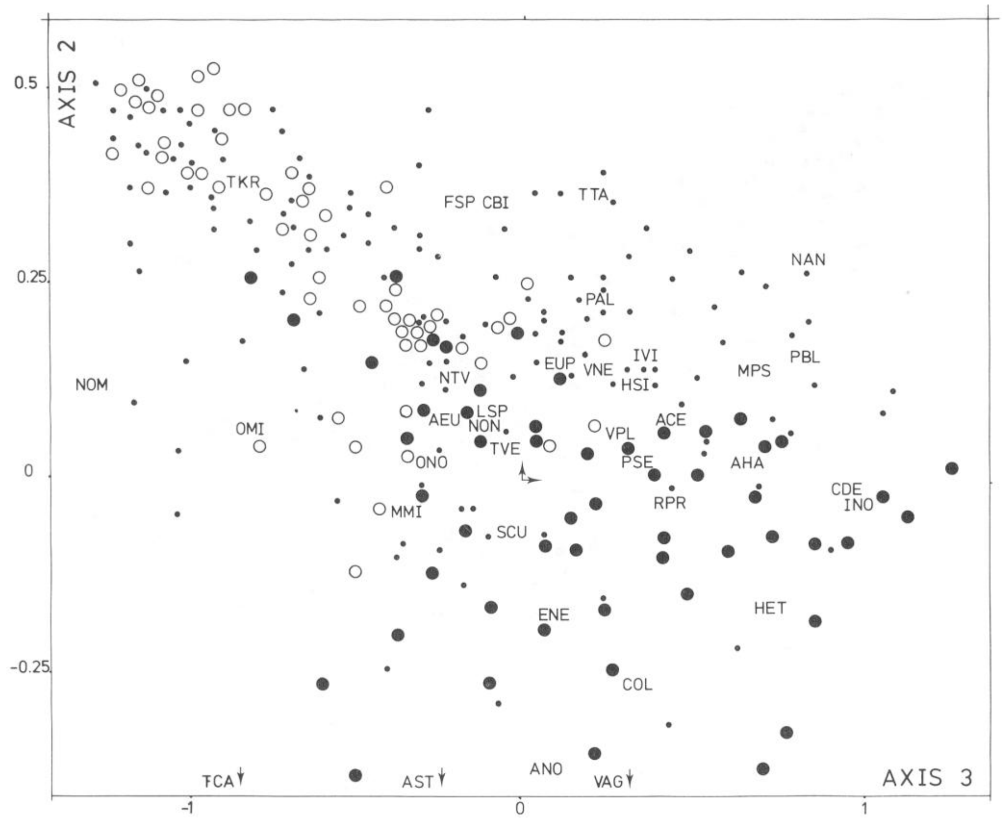
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Fig. 4

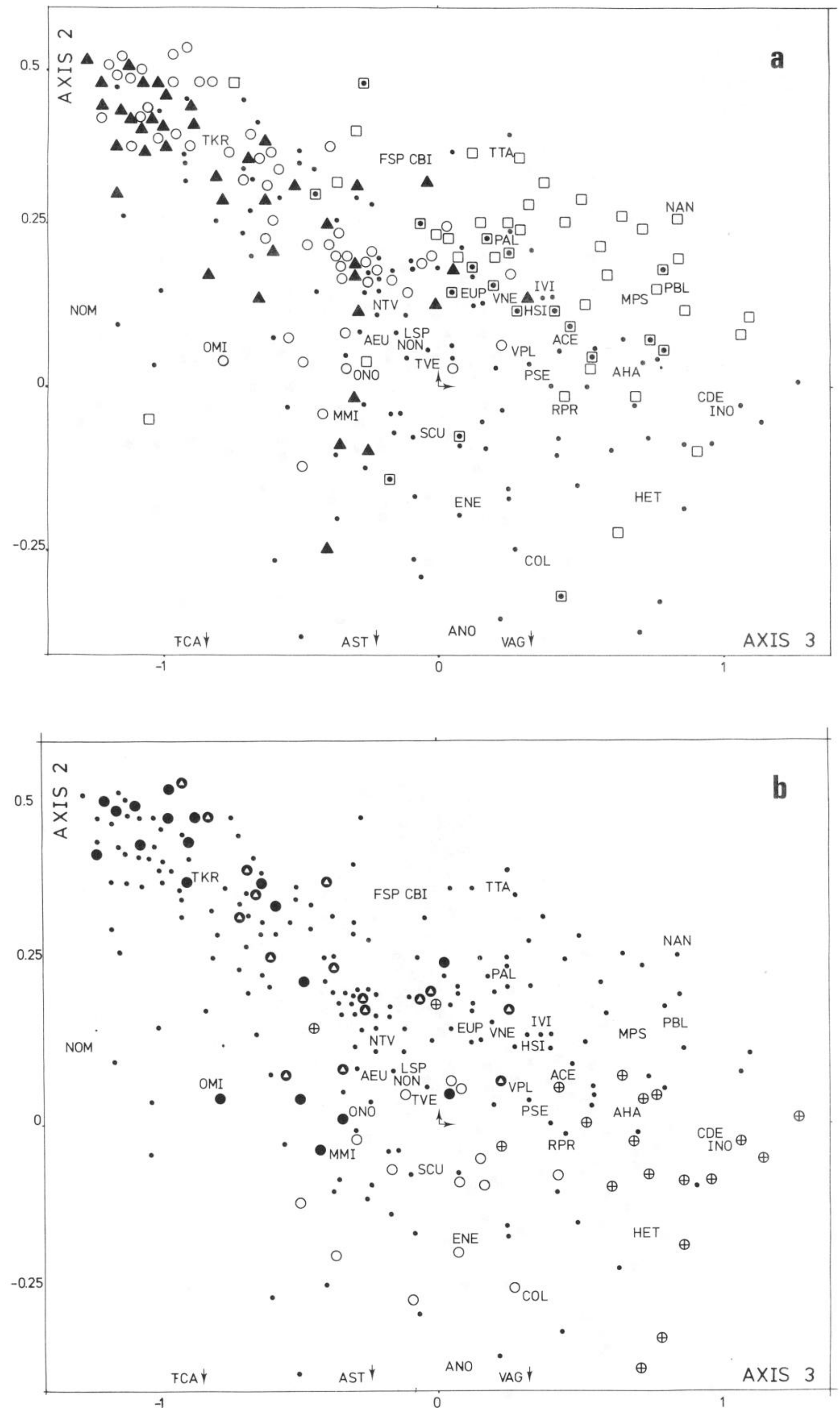
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Fig. 5

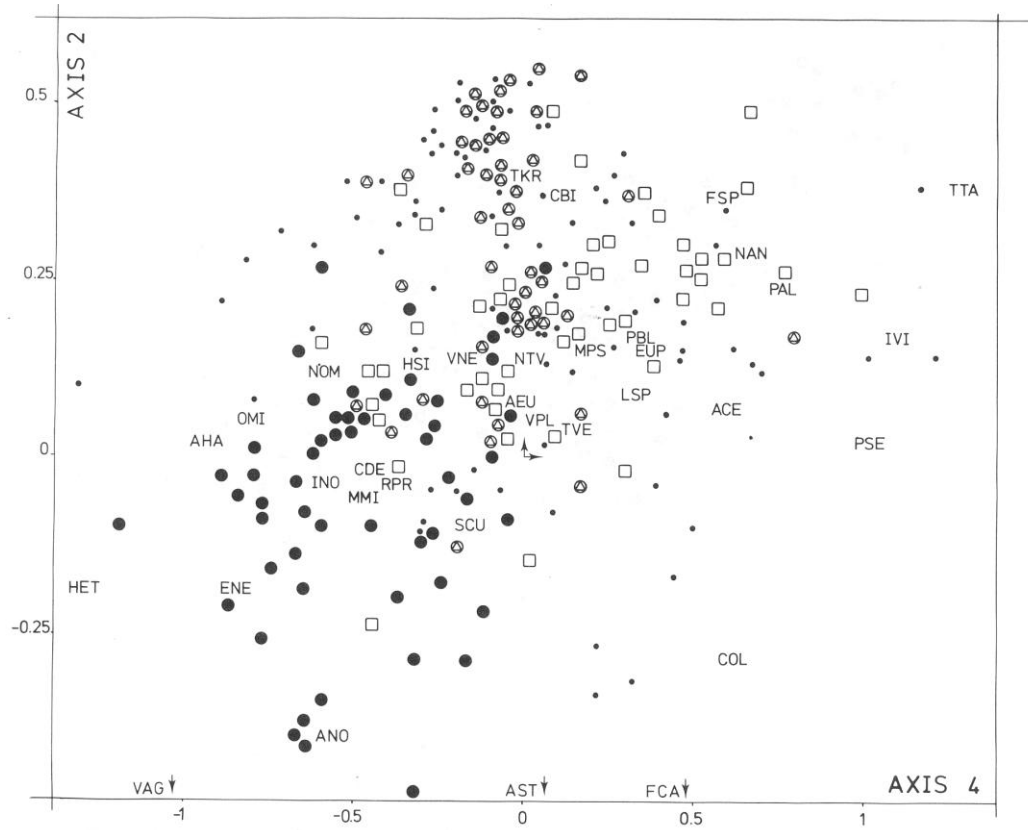
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Fig. 6