Danish Research Service for Soil and Plant Sciences
The State Plant Pathology Institute (H. Ing. Petersen)
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Report No. 1437

Migratory nematodes in Danish barley fields

Migrerende rodnematoder i danske bygmarker

II. Population dynamics in relation to continuous barley growing
Populationsdynamik i relation til ensidig bygdyrkning

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Resumé
I tre forsøg med ensidig bygdyrkning på forskellige jordtyper er nematodfaunaens struktur og dynamik fulgt ved månedlige prøvetagninger gennem 1973 og 1974.

Migrerende rodnematoder og mikrobivore (bakteriophage) nematoder var to omtrent lige store grupper, der tilsammen oftest udgjorde omkring 90 pct. af hele nematodfaunaen. Mycophage nematoder udgjorde i gennemsnit ca. 10 pct. og sjældent over 20 pct. af den samlede fauna.

De dominerende migrerende rodnematodarter var *Tylenchorhynchus dubius, Merlinius brevidens* og *M. microdorus* samt *Pratylenchus neglectus* og *P. crenatus*. *Paratylenchus microdorus* var i nogle parceller tilstede i betydelige tætheder, men oftest var tæthederne af Paratylenchus spp. små.

Gruppen af microbivore nematoder domineres totalt af repræsentanter for ordenen *Rhabditida*. Blandt de mycophage nematoder var *Aphelenchus avenae* og *Aphelenchoides spp.* sammen med mycophage *Tylenchus* dominerende.

De enkelte gruppers tætheder varierede betydeligt mellem de tre forsøg. Variationen mellem parceller inden for samme forsøg kunne dog være af samme størrelsesorden.

For såvel den totale fauna som for de enkelte grupper var der tale om en udpræget sæsonvariation, der stort set fulgte samme mønster. Populationstæthederne aftog noget om foråret med et minimum i april-maj. Maximum forekom oftest i juli eller senere på sommeren. I perioden efter vækstsæsonen var der aftagende tætheder, mens der vinteren igennem ikke skete de store ændringer.

For ingen art eller gruppe er der fundet en fuldstændig overensstemmelse mellem de tre lokaliteter i relation til ensidig bygdyrkning. Den bedste overensstemmelse findes hos *Pratylenchus neglectus* og *P. crenatus*, hvor der er registreret relativt større tætheder hos 1.–3. års byg end hos 7. og 8. års byg. Med hensyn til migrerende rodnematoders skadevirkning hos ensidig dyrket byg tyder de foreliggende data på, at deres eventuelle direkte skadevirkning ikke forøges i relation til byg i et sædskifte.

Nøgleord: Migrerende rodnematoder, populationsdynamik, byg.

Summary
In three barley monoculture experiments placed at sites with different soil types, the structure and dynamics of the nematode fauna were investigated by monthly sampling of soil and roots through 1973 and 1974.

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Both migratory and microbivore nematodes were found to constitute about 45 per cent of the total number of nematodes. Mycophage nematodes most often contributed to the total fauna with about 10 per cent and seldom exceeded 20 per cent.

The dominating species of migratory nematodes were *Tylenchorhynchus dubius, Merlinius brevidens* and *M. microdorus* together *with Pratylenchus neglectus* and *P. crenatus*. *Paratylenchus microdorus* has in some plots been found in considerable numbers, but most often the densities of *Paratylenchus spp*. were small.

The density of a single species or group varied between the sites; however, the variation between plots within each site could be of the same order.

For the total nematode fauna as for the single groups there was a marked seasonal variation, generally following the same pattern when the population in roots was included. The densities were declining in springtime, reaching a minimum in April-May. Maximum densities were usually found in July or later in the summer. In early autumn the densities decreased and were stable throughout the winter.

In relation to continuous barley growing there was for no species or groups found a complete agreement between the different sites. The best agreement was found for *P. neglectus* and *P. crenatus*. These species had relatively greater densities in barley grown 1 to 3 years than in barley grown 7 to 8 years in succession. With such results there is no reason to think that possible damage caused by migratory nematodes will be aggravated with continuous barley growing under Danish conditions.

Key words: Migratory nematodes, population dynamics, barley.

Introduction

Compared with other main crops, only few studies have been carried out on the population biology of migratory nematodes in barley.

Investigations from Northern Europe (*Gair* et al. 1969, *Corbett* 1970, *Kemper* 1967 and 1970, *Fischer* 1968 and *Heide* 1975) are restricted mainly to *Pratylenchus spp.*, and population dynamic is not the main object. The results from the mentioned investigations show that barley must be considered to be a good host for *Pratylenchus neglectus* and *P. crenatus*. *Kemper* (1967) found that the population density of *Pratylenchus* in spring barley had increased about 150 per cent from April to September, and *Kemper* (1970) reports an increase up to 390 per cent in barley (250–1225 per 250 ml og soil) in a single growth season.

Fischer (1968) found that crop rotations mainly with cereals lead to higher densities of *Pratylenchus* populations. In a crop rotation experiment was found a density of *Pratylenchus* of 4,300 individuals per g of root after 4 years with cereal crops.

On another site with winter barley were found 4,000 *Pratylenchus* per 100 ml of soil after 5 years with cereal crops. Compared with this only a density of 400 *Pratylenchus* per 100 ml of soil was found in a nearby field with a crop rotation.

Fischer (1968) and *Heide* (1975) found that there was a correlation between high *Pratylenchus* densities and yield losses in spring barley. They also found that yield reductions seemed to be correlated with low pH-values and other unfavourable soil conditions.

Although the mentioned findings cannot directly be translated to Danish conditions, they at least suggest that other plant parasitic nematodes than *Heterodera avenae* could be a contributing factor to yield reductions in continuous barley growing.

The present investigation was carried out in order to evaluate the seasonal fluctuations and population development of migratory- and other main groups of nematodes in relation to continuous barley growing under Danish conditions.

Materials and methods

a) *Sampling sites and sampling programme*

The samples were taken from existing experiments with continuous barley growing at the Roskilde and Studsgård State Experimental Sta-

Table 1. Texture and pH at the sampling localities.
(Jordens tekstur og pH på prøvetagningslokaliteterne).

	% clay	3 silt	3 fine sand	3 coarse sand	3 humus	pH
Studsgård:						
Barley 2nd year 1974	5	8	36	46	5.6	6.9
Barley 3rd year 1974	7	7	32	49	5.4	6.6
Barley 8th year 1974	6	7	60	23	4.4	5.9
Lyngby:						
Barley 2nd year 1974	9	16	48	25	2.7	7.4
Barley 3rd year 1974	9	17	45	27	2.4	7.5
Barley 8th year 1974	9	17	50	22	2.5	7.0
Roskilde:						
Barley 2nd year 1974	12	19	46	20	2.7	7.0
Barley 3rd year 1974	11	20	43	23	2.7	7.4
Barley 8th year 1974	12	21	42	23	2.7	7.2

tions and at the State Plant Pathology Institute, Lyngby. At Studsgård the plots in the experiment are combined with plots situated in nearby fields. Soil samples from the barley plots have been analyzed for texture, humus and pH.

The first sampling programme was carried into effect in the period from January, 1973 to February, 1974 with monthly sampling in three plots at each site. In the three plots were grown barley 1st year, barley 7th year, and another crop: pea, lucerne and rye at Roskilde, Lyngby and Studsgård, respectively. In the months of May, June and July the soil samples were supplemented with root samples from the barley plots.

In the second period from February, 1974 to December, 1974 the sampling in other crops than barley was replaced by sampling in plots with 3rd year barley in order to get a better picture of the population development in relation to continuous barley growing.

b) *Sampling methods and extraction*

The soil sampling methods are described by *Andersen* (1978). After extraction 20 per cent (5 × 2 ml) of the final nematode suspension (50 ml) was examined. Each root sample was composed of the roots from about 10 plants. After cleaning the roots were cut into 2 mm pieces, and after blending 2 g were extracted with a modified Baermann funnel method. The results obtained in 1973 with the described method were so heterogeneous that it was necessary to change both sampling- and extraction methods in 1974.

The sampling in 1974 at Lyngby and Roskilde was done with a special soil auger which had a total volume of 1400 ccm. The auger was most often only filled partly, and the mean total volume of 4 samplings was reduced to 4000 ccm. The sampling at Studsgård was carried out with a planting fork and the sample, composed of 4 subsamples, included the roots from about 2000 ccm of soil.

The extraction of the roots was made by a modified method after *Coolen & d'Herde* (1972) whose principle is not based on the actice movement of the nematodes. 5 g of the sample (2 mm pieces) were extracted, and if the total sample was less than 5 g, the whole sample was extracted.

The sample was macerated in a Waring blender for 35 seconds by 20,000 rev/min. The most coarse root fraction was removed by a water jet over a 1 mm mesh sieve. The final suspension, 500 ml, was homogenized, and from 100 ml 5 × 2 ml were used for counting of nematodes.

c) *Reproduction of results*

In order to test the reproducibility of the single results,one double sampling was carried out at each of the sites. Each pair of samples was extracted at the same time, and from one plot at each site two extractions were made at the same time.

The standard error SEM was calculated by: SEM = $(S_u^2 : n_u) + (S_e^2 : n_e \cdot n_u)$ per cent, where S_u^2 and S_e^2 are the components of variance for sampling and extraction, respectively.

Table 2 gives SEM in per cent of the mean number for some values of n_u and n_e together with the contribution of sampling to the total SEM.

With one extraction per sample the per cent SEM varied between 6 per cent for *Tylenchorhynchus* + *Merlinius* to 20 per cent for *Aphelenchus*. Table 2 shows that the SEM can be reduced by more samples and by more extractions per sample.

In groups with many specimens the sampling error is dominating, opposed by groups with few specimens where the extraction error is dominating.

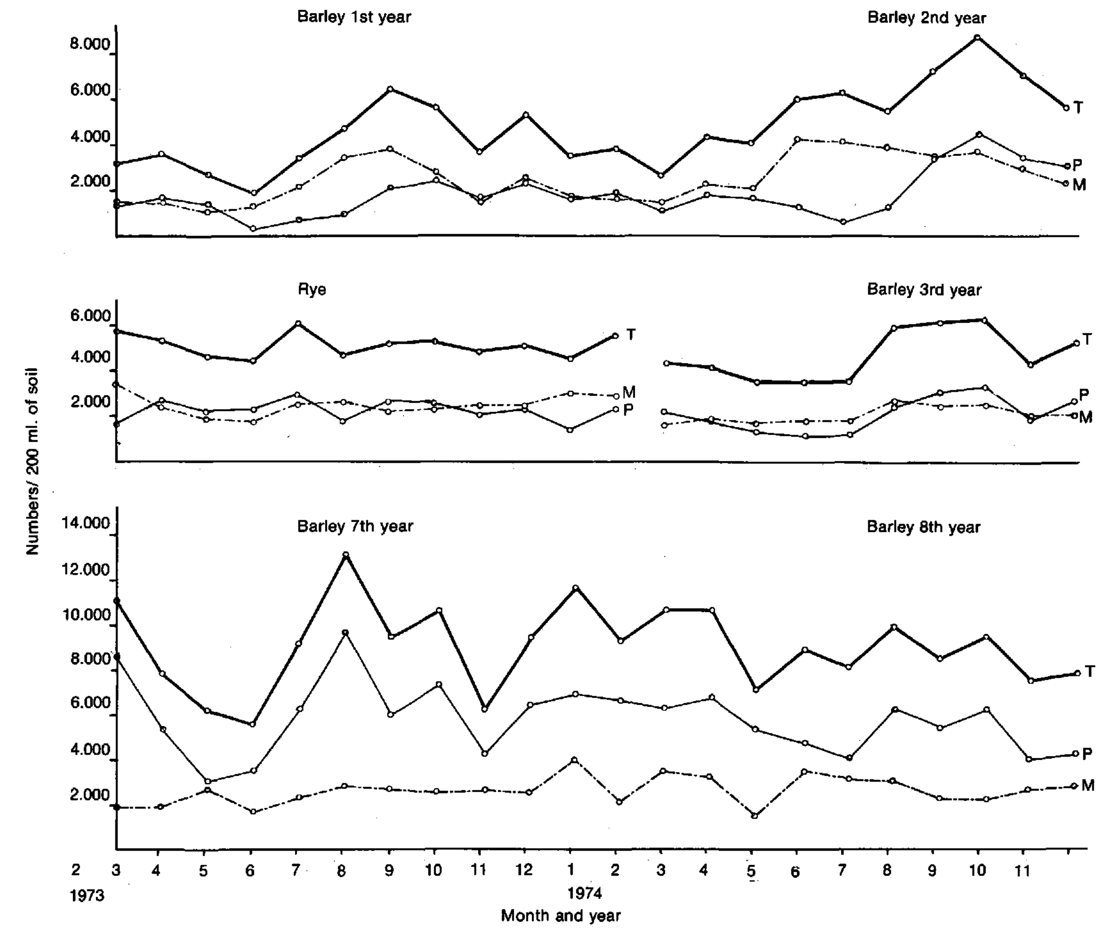

Fig. 1. Seasonal fluctuations in numbers of total nematodes (T), phytoparasites (P) and microbivore nematodes (M) at Studsgård in barley 1st, 2nd, 3rd, 7th and 8th year and in rye.

Svingninger i total antal nematoder (T), planteparasitter (P) og mikrobivore nematoder (M) i Studsgård hos byg 1., 2., 3., 7. og 8. år samt hos rug.

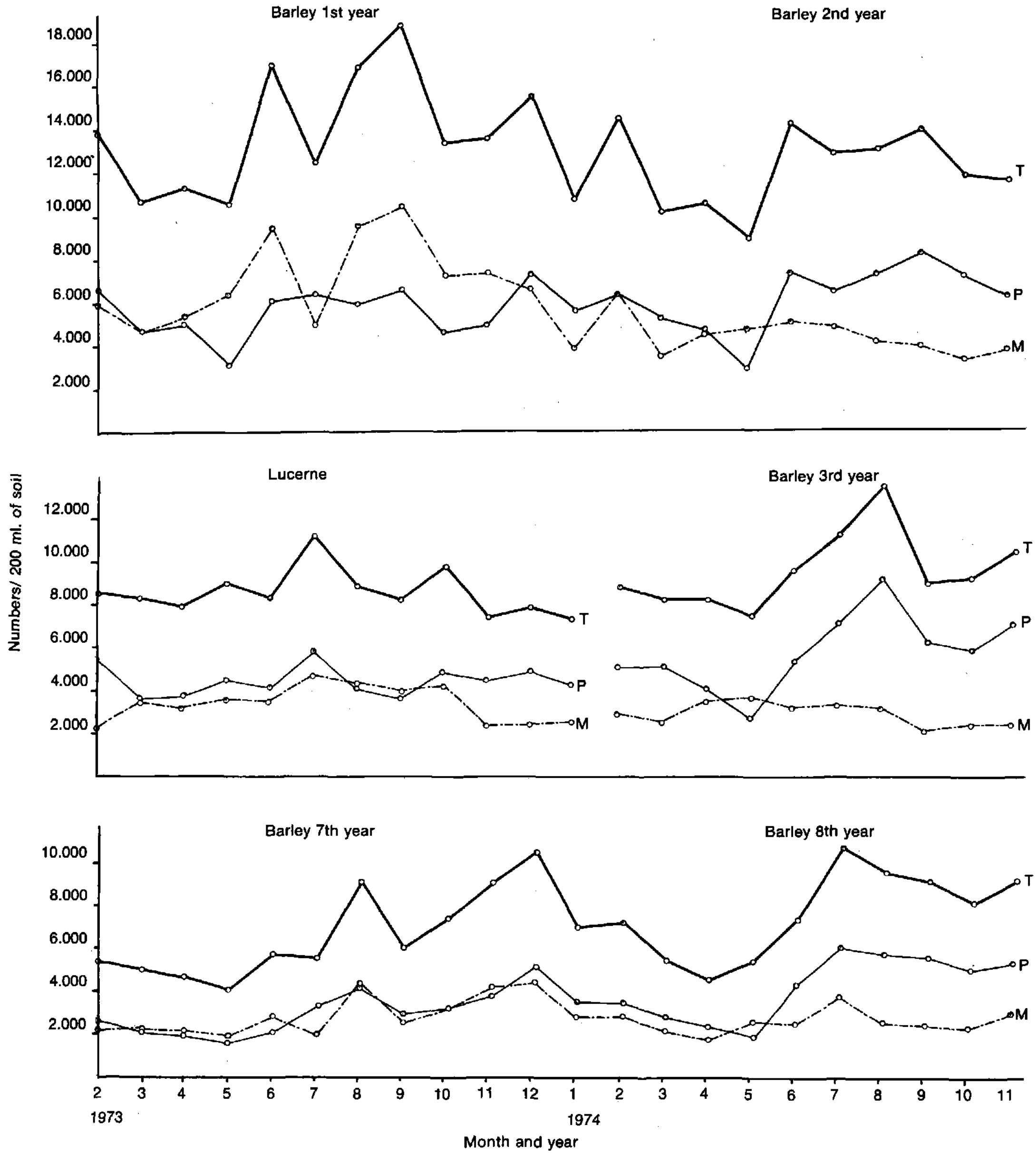

Fig. 2. Seasonal fluctuations in numbers of total nematodes (T), phytoparasites (P) and microbivore nematodes (M) at Lyngby in barley 1st, 2nd, 3rd, 7th and 8th year and in lucerne.

Svingninger i total antal nematoder (T), planteparasitter (P) og mikrobivore nematoder (M) i Lyngby hos byg 1., 2., 3., 7. og 8. år, samt hos lucerne.

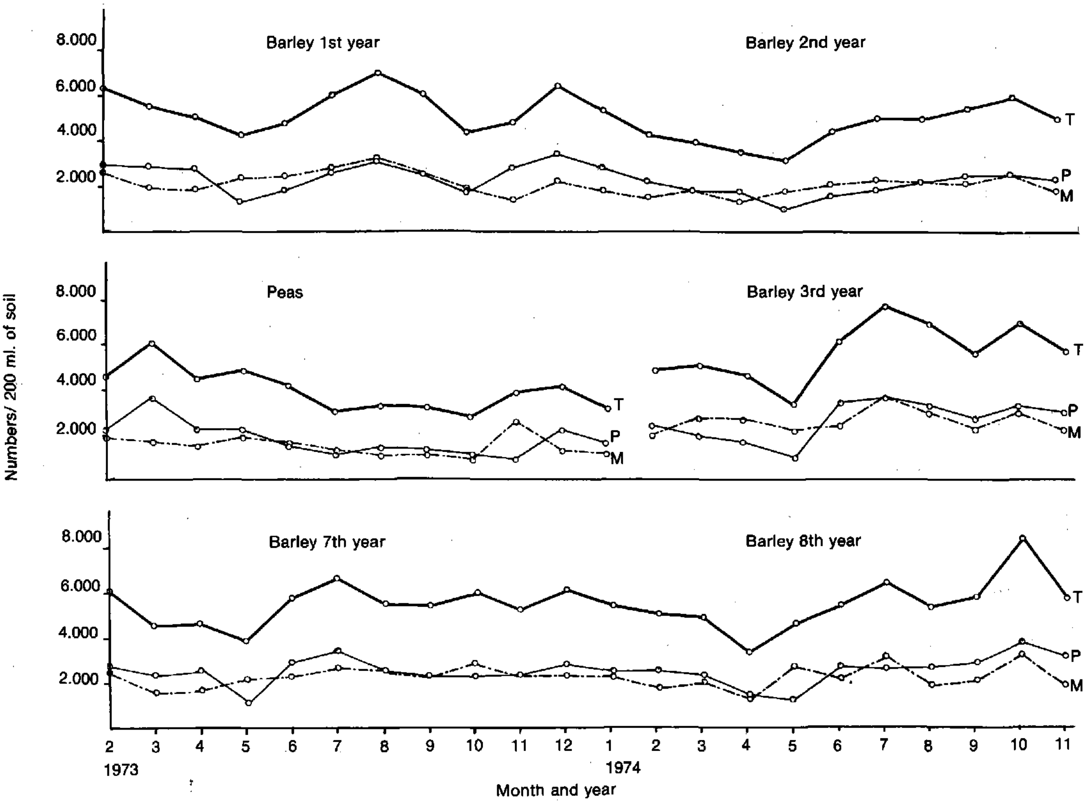

Fig. 3. Seasonal fluctuations in numbers of total nematodes (T), phytoparasites (P) and microbivore nematodes (M) at Roskilde in barley 1st, 2nd, 3rd, 7th and 8th year and in peas.

Svingninger i total antal nematoder (T), planteparasitter (P) og mikrobivore nematoder (M) i Roskilde hos byg 1., 2., 3., 7. og 8. år, samt hos ærter.

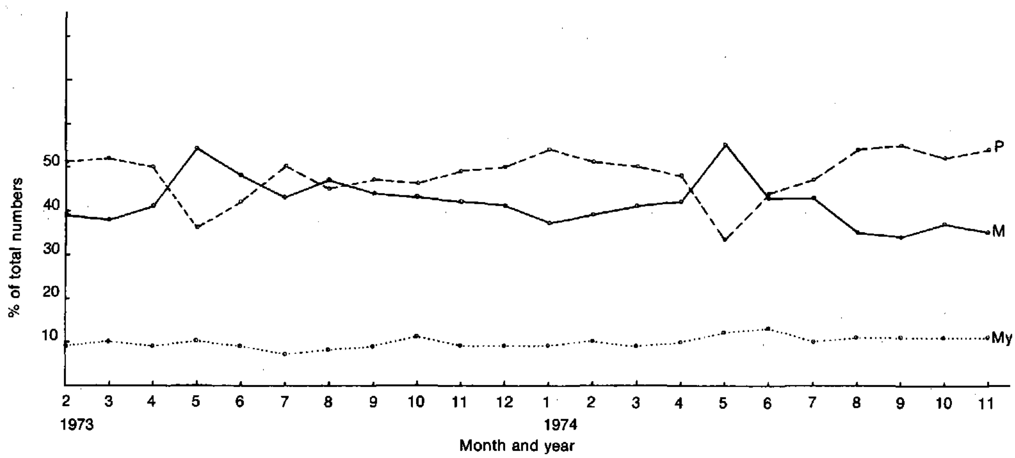

Fig. 4. The structure of the nematode fauna. Means from 9 plots at 3 sites. (P) phytoparasites, (M) microbivore nematodes and (My) mycophage nematodes.

Nematodfaunastruktur. Gennemsnittet af 9 parceller på 3 lokaliteter. (P) planteparasitter, (M) mikrobivore nematoder og (My) mykofage nematoder.

Results

a. *Grouping and seasonal variation*

Fig. 1–3 show the seasonal variation of the total nematode fauna as well as the phytoparasites and microbivore nematodes in the uppermost 20 cm of soil at Studsgård, Lyngby and Roskilde. Fig. 4 shows the relative seasonal variation between the mean numbers of the mentioned two groups and the mycophage nematodes.

Table 2. Standard error in per cent (SEM) and the contribution to SEM from sampling with varying number of samples, n_u and varying number of extractions, n_e per sample.

Standardafvigelsen i procent af middeltal (SEM) ved varierende antal udtagninger, n_u og antal ekstraktioner, n_e, samt udtagningens bidrag til samlet usikkerhed.

Nematode-group	Mean numbers	SEM $n_u=1$ $n_e=1$	SEM $n_u=1$ $n_e=2$	SEM $n_u=2$ $n_e=1$	SEM $n_u=2$ $n_e=2$	SEM $n_u=3$ $n_e=1$	Per cent of SEM from sampling
Pratylenchus	1184	17	16	12	12	10	85
Tylrh. + Merl.	2163	6	5	4	4	3	59
Aphelenchus	179	20	15	14	10	12	10
Tylenchus	501	11	8	8	6	7	0
Rhabditida	2522	14	12	10	8	8	51
Others	899	14	12	10	9	8	42
Total	7448	7	6	5	4	4	60

The found genera and higher groups belong to 4 ecological main groups: Phytoparasites, mycophage, carnivore and microbivore nematodes:

1. Phytoparasites:
   Pratylenchus
   Tylenchorhynchus
   Merlinius
   Paratylenchus
   Heterodera
   Trichodorus
   Paratrichodorus
   Longidorus
   Tylenchus

2. Mycophage:
   Aphelenchus
   Aphelenchoides
   Ditylenchus
   Tylenchus
   Hexatylus
   Diptherophora
   Other Dorylaimida

3. Carnivore:
   Seinura
   Mononchidae

4. Microbivore:
   Rhabditida
   Bastiania
   Alaimus
   Others

The classification is arbitrary because the feeding habits of all the groups are not yet fully explored. *Tylenchus*, which here shall be regarded as representing more than one genus, is supposed to be a facultative phytoparasitic group (*Decker*, 1969), but results from some investigations indicate that more species are obligate phytoparasites (*Khera & Zuckerman*, 1962 and 1963, and *Sutherland*, 1967). Half the numbers of the genus is here placed in phytoparasites and the other half in mycophage nematodes.

The genera *Ditylenchus* and *Aphelenchoides* are here placed in the mycophage group. None of the plant parasitic species of *Ditylenchus* and *Aphelenchoides* have been found here. The group 'other *Dorylaimida*' is listed under the mycophages, which is not true for all species. Some of them also take up food from algae and mosses and occasionally prey on other nematodes (*Wood*, 1973). In accordance with this, *Wasilewska* (1975) uses the term omnivor for the group. Most often the group has contributed with less than 1 per cent to the total nematode numbers, so the error here is not great.

The total nematode fauna has a characteristic seasonal variation. Most often there is a minimum in May. A maximum density is reached in the course of the summer. About October there is a new minimum, and after the following rise the densities are decreasing to the mentioned minimum in May.

The dominating main groups, Phytoparasites and microbivore nematodes (fig. 4), represent about 90 per cent of the total nematode numbers in the soil, and mycophages about 10 per cent. The variation between the different sites and plots was great, but with exception of the month of May the phytoparasites were dominating.

b) *Phytoparasites*

With the exception of the *Heterodera* group the found genera of phytoparasites belong to the migratory nematodes.

The dominating species at all three sites belong to the endoparasitic genus *Pratylenchus* and the ectoparasitic genera *Tylenchorhynchus* and *Merlinius*. *Paratylenchus* may occur in considerable densities in some plots, but most often they are present in only insignificant densities.

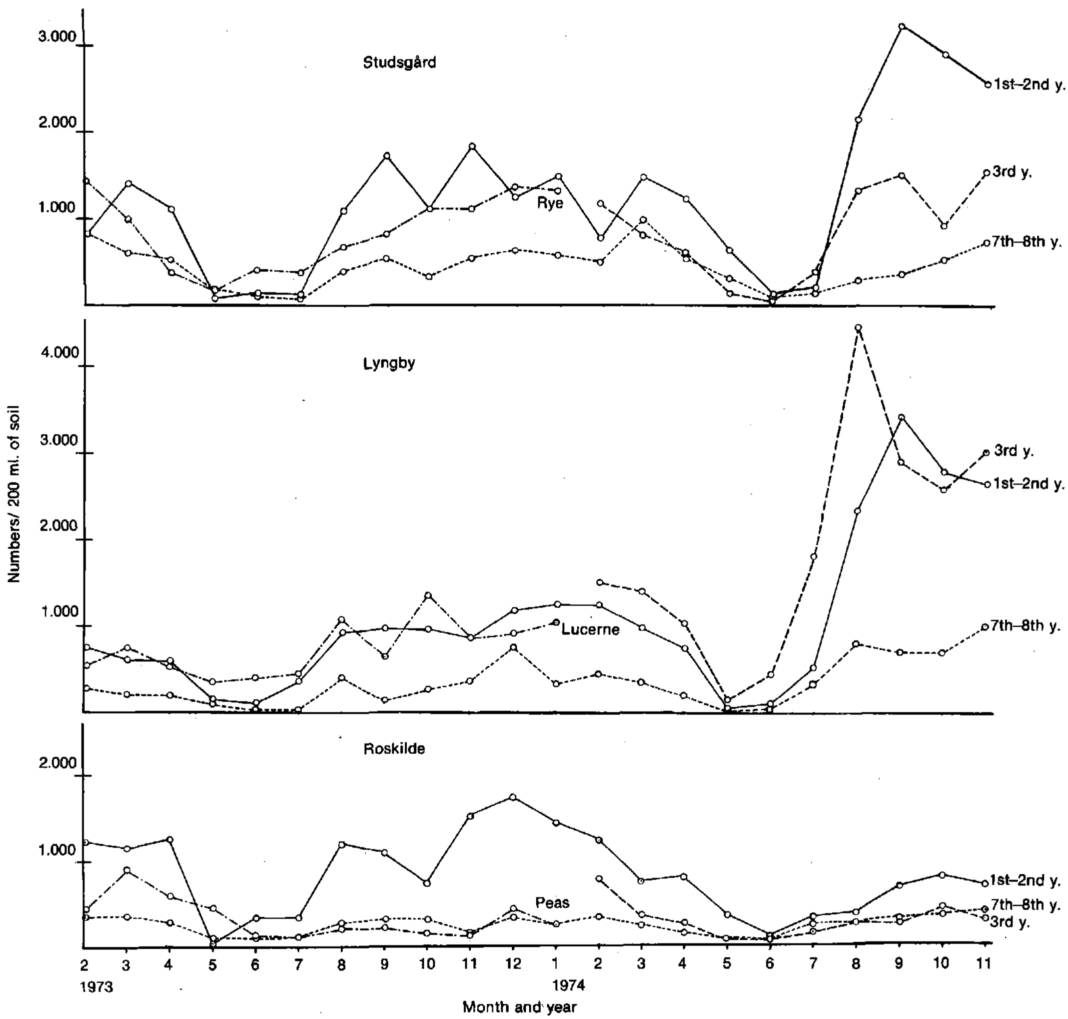

Fig. 5. Seasonal fluctuations of *Pratylenchus* populations at Studsgård, Lyngby and Roskilde in barley 1st, 2nd, 3rd, 7th and 8th year and in another crop.

Populationssvingninger af Pratylenchus i Studsgård, Lyngby og Roskilde hos byg 1., 2., 3., 7. og 8. år, samt i en anden afgrøde.

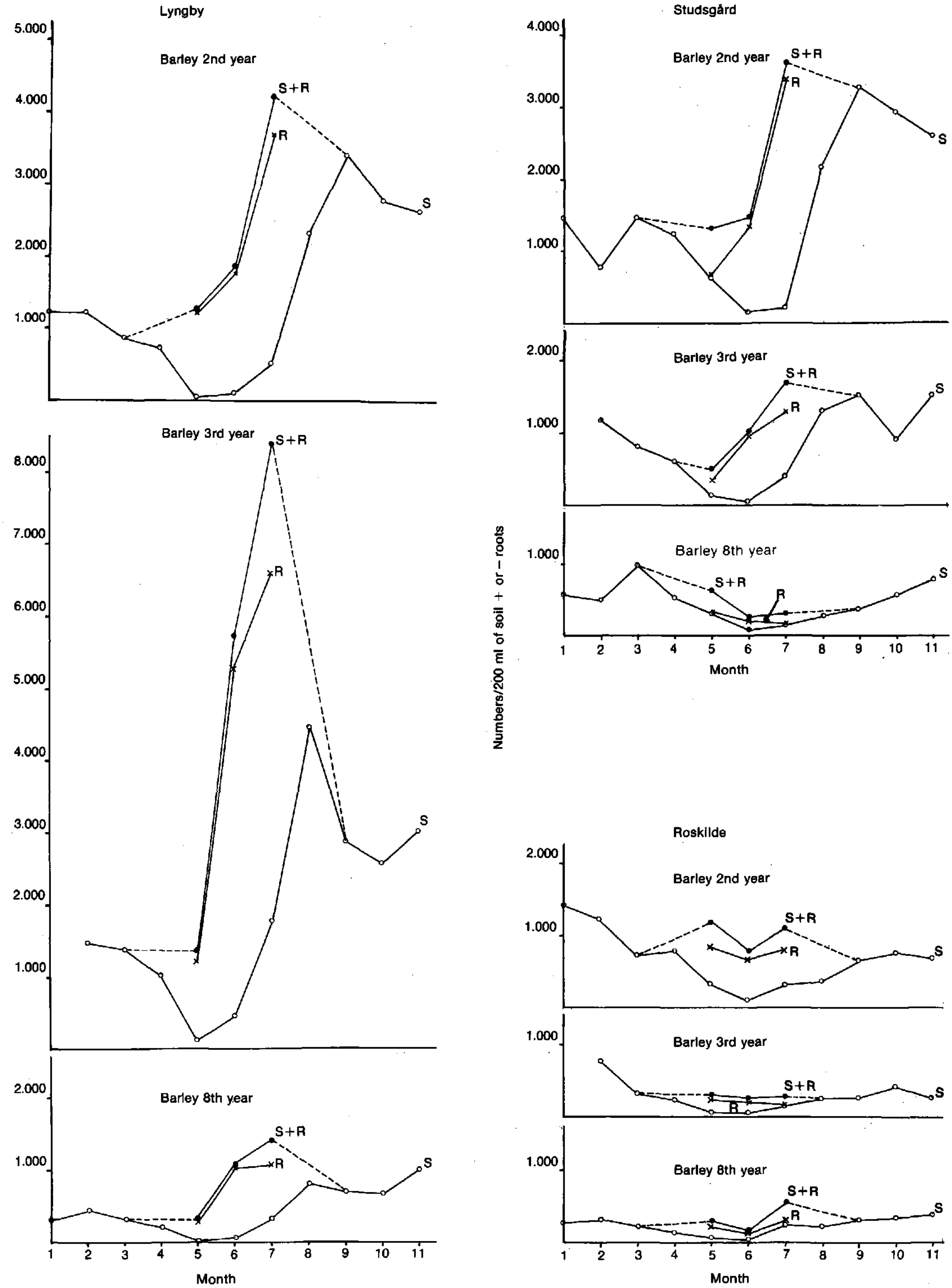

Fig. 6. Seasonal fluctuations of Pratylenchus populations in soil (S), roots (R) and in soil + roots (S+R) in 1974 at Lyngby, Studsgård and Roskilde in barley 2nd, 3rd and 8th year.

Populationssvingninger af Pratylenchus i jord (S), rødder (R) og i jord + rødder (S+R) i Lyngby, Studsgård og Roskilde i 1974.

b 1) *Pratylenchus*

Totally 5 Pratylenchus species have been found. In Roskilde was found only the species *P. neglectus*. Also in Lyngby *P. neglectus* was dominating. Moreover, small *P. penetrans* populations were present. The highest density of the latter was found in lucerne, in which approx. 10–15 per cent of the total *Pratylenchus* populations beling to *P. penetrans*. After several years with subsequent barley growing, the relative number of the populations was reduced considerably. At Studsgård were found 3 *Pratylenchus* species, *P. crenatus, P. neglecus* and *P. fallax*. *P. fallax* was found in all plots, but it usually constituted less than 10 per cent of the total population. In 7th and 8th year barley *P. crenatus* was dominating, whereas *P. neglectus* had this position in 1st, 2nd and 3rd year barley.

b 2) *Seasonal variation*

Fig. 5 shows the results from soil samples from the experimental sites. All plots with barley displayed a distinct seasonal fluctuation. The overwintering part of the populations was considerably reduced during spring and reached a minimum in May-June. From approx. July the density in the soil increased again, and usually maximum was reached in September. In the early autumn, October, a slight depression may set in, and a new maximum was reached in most plots around December.

The population in rye at Studsgård, 1973, showed a similar seasonal fluctuation as in barley. The crop was sown in the autumn, and the results do not indicate any great parasitic attack on the roots in the autumn.

The perennial crop lucerne in Lyngby, 1973, displayed a somewhat less distinct seasonal fluctuation, and in peas in Roskilde, 1973, the population at harvest was reduced in relation to the density at the sowing.

When comparing the curves of the barley plots (fig. 5) it will be noted as a characteristic feature that the population densities concordantly are higher in barley of 1st, 2nd and 3rd year than in barley of 7th and 8th year.

b 3) *Pratylenchus in roots*

Pratylenchus spp. are endoparasitic migratory nematodes. On the preceding pages the population development has been described on the basis of results of the extractions from soil, but if a complete picture of the seasonal fluctuation shal be obtained, it will be necessary in the growth period to consider the part of the population which is found in the roots.

The results of the extractions from the root samples for 1973 are so heterogeneous that the single results cannot be attached any greater importance. Therefore, in the following only the results from 1974 with the changed methods will be accounted for.

Fig. 6 shows the *Pratylenchus* populations in the barley plots for 1974. The densities in soil and roots are shown separately as well as totally. The curves indicating the total populations are almost complete, only the densities in the roots in April and August are missing. In April there will be a beginning invasion of roots, and the emigration will not be finished in August. Minimum will be found mainly in April-May. From the month of May increasing densities were noted, with maximum in July. In the same period was seen an increasing emigration from the roots into the soil, and the death-rate in the period from July to Sep-

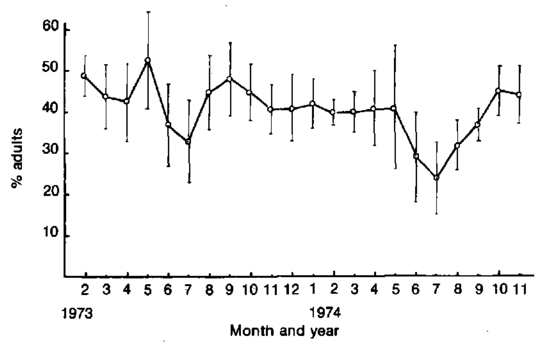

Fig. 7. The percentage numbers of adults in *Pratylenchus* populations in barley plots at Studsgård, Lyngby and Roskilde. The bars indicate the standard deviation. *Voksenandele af Pratylenchus populationer i bygparceller i Studsgård, Lyngby og Roskilde. Standardafvigelsen er angivet ved lodrette streger.*

tember when the emigration is most intense, may be great. After a depression around October, the densities are stabilized, and they fall towards the mentioned spring minimum.

b 4) *The population structure of Pratylenchus*
The males, females and juvenile nematodes are counted separately. The outlined curve (fig. 7), which combines the mean values of the adults in the total population, does not reach above 50 per cent, with the exception of one single month. In the period November to May, the adults constitute almost constantly 40 per cent. From May the share of the adults falls to a minimum in July, whereupon it increases until around November. The displacement in favour of juvenile nematodes, which is characteristic for populations in growth, thus coincides with the most vigorous growth of the plants.

Pratylenchus – and migratory nematodes on the whole – do not have separated generations, as is the case for sedentary nematodes as f.inst. *Heterodera spp.* At the start of the growth season of the plants, all stage and development groups are present, of which 40–50 per cent are adult nematodes. This fact hampers a measurement of number of generations or life cycles developing throughout a growth period. At a previous examination (*H. J. Andersen,* unpublished) of the life cycle of *Pratylenchus penetrans,* the cycle length was found to last approx. 35 days at about 22°C. Such high temperatures are not ordinary in the roots under Danish conditions. Other examinations have shown that the cycle length is greatly dependent on temperature. *Mamiya* (1971) found that the life cycle for *P. penetrans* at 15°, 20°, 24° and 30°C had a duration of 86, 42–44, 35 and 30–31 days, respectively.

Due to several factors, such as temperature fluctuations and various factors dependent on densities, the results cannot directly be compared with field conditions, but a conservative estimate may be that *Pratylenchus* will not be able to complete more than 1–2 life cycles in an annual crop as barley.

c) *Tylenchorhynchus and Merlinius*
Tylenchorhynchus and *Merlinius* are two closely related genera, and at 50 times magnification by stereo microscope a separation can only be made of the adults with a reasonable certainty. That is the reason why they are treated partly as a whole in this paper.

c 1) *Species*
Tylenchorhynchus dubius was present in all plots at the experimeltal sites. At the Studsgård plots also *T. maximum* populations were found. Two *Merlinius* species were common. I n Lyngby and Roskilde, *M. brevidens* was dominant. In Lyngby moreover *M. microdorus* was ordinarily present. This species was also represented in small densities in Roskilde, but was the only *Merlinius* species in the Studsgård plots.

c 2) *Seasonal variation*
Tylenchorhynchus and *Merlinius* are ectoparasitic migratory nematodes, and their densities can be determined by examining extractions from soil samples only.

Fig. 8 shows the seasonal fluctuations for 1973 and 1974. Apparently there is a fairly concordant seasonal fluctuation in the lucerne, rye and barley plots. The variation pattern does not differ much from that of *Pratylenchus*. During the spring months the densities fall towards a minimum in May. In June-July the population densities culminate, whereafter there is a decreasing tendency. In September and October a depression has often been observed; this may perhaps have a connection with the cultivation of the soil. The same situation has been observed in England (*Winslow,* 1964) and in Holland (*Sharma,* 1971).

The population densities display very large differences, both on and between the single sites. In 7th year barley, 1973 at Studsgård a maximum of 9,315 nematodes per 200 ml soil was found; this corresponds to 9 million per m^2, whereas maximum in 1st year barley in August at the same locality was determined to 1,065 per 200 ml soil (approx. 1 million per m^2).

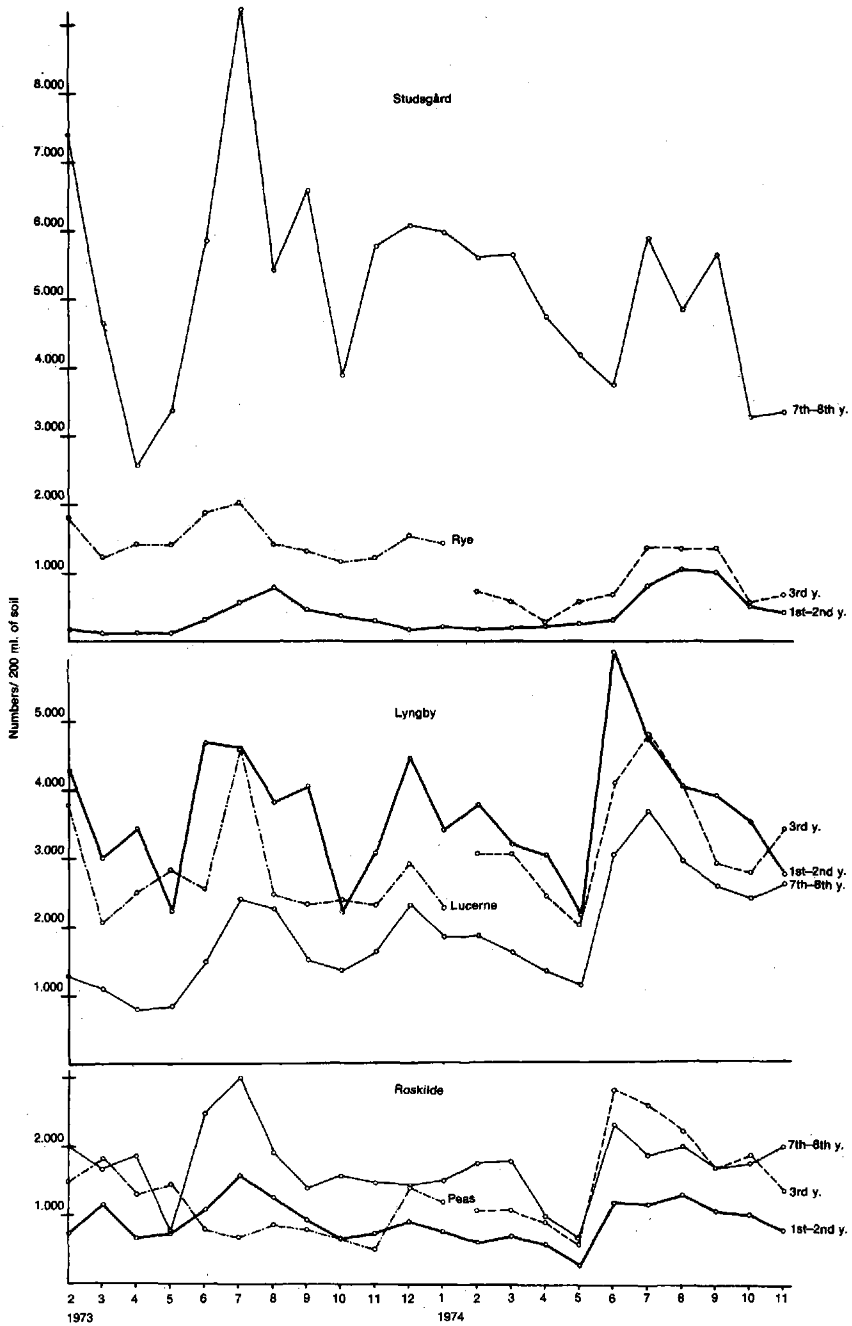

Fig. 8. Seasonal fluctuations of *Tylenchorhynchus-Merlinius* populations at Studsgård, Lyngby and Roskilde in barley 1st, 2nd, 3rd, 7th and 8th year and in another crop.

Populationssvingninger af Tylenchorhynchus-Merlinius i Studsgård, Lyngby og Roskilde hos byg 1., 2., 3., 7. og 8. år, samt hos en anden afgrøde.

At Studsgård and Roskilde the population densities were positively correlated with the number of years the barley had been grown, whereas the opposite was the case in Lyngby.

c 3) *Population structure*

As it was done with *Pratylenchus,* juvenile nematodes and adult nematodes were counted separately. As it will be noted from fig. 9, the variance is smaller here, and the adults constituted a smaller percentage of the population than was the case for *Pratylenchus*. Beyond this, the variation pattern was the same. In the summer months May-July the juveniles have the predominance, and in July 1973 and 1974 the adults represented 14 per cent and 16 per cent, respectively. From July to October the percentage of adults increased to approx. 33 per cent, and in winter 1973–74 it remained nearly constant until May.

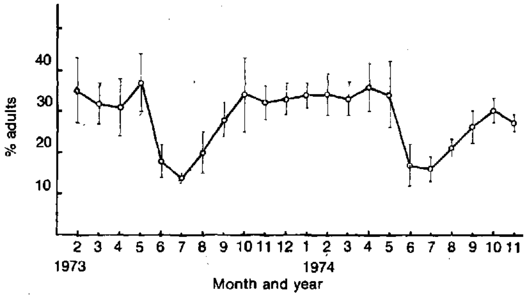

Fig. 9. The persentage numbers of adults in *Tylenchorhynchus+Merlinius* populations in barley plots at Studsgård, Lyngby and Roskilde. The bars indicate the standard deviation.
Voksenandele af Tylenchorhynchus+Merlinius populationer i bygparceller i Studsgård, Lyngby og Roskilde. Standardafvigelsen er angivet ved lodrette streger.

d) *Paratylenchus*

Fig. 10 shows the seasonal variations of the *Paratylenchus* populations. At Studsgård the populations were insignificant. In Lyngby, 1st year barley, 1973, and 2nd year as well as 3rd year barley, 1974, showed small populations. The largest populations were found in 7th and 8th year barley. The greatest density – 2000 per 200 ml soil – was observed in 8th year barley in September, 1974. This plot showed a concordant seasonal variation both years. As was the case with *Pratylenchus* and *Tylenchorhynchus,* the densities decreased in the spring months towards a minimum in May, whereas maximum was reached in September or later, that is to say somewhat later

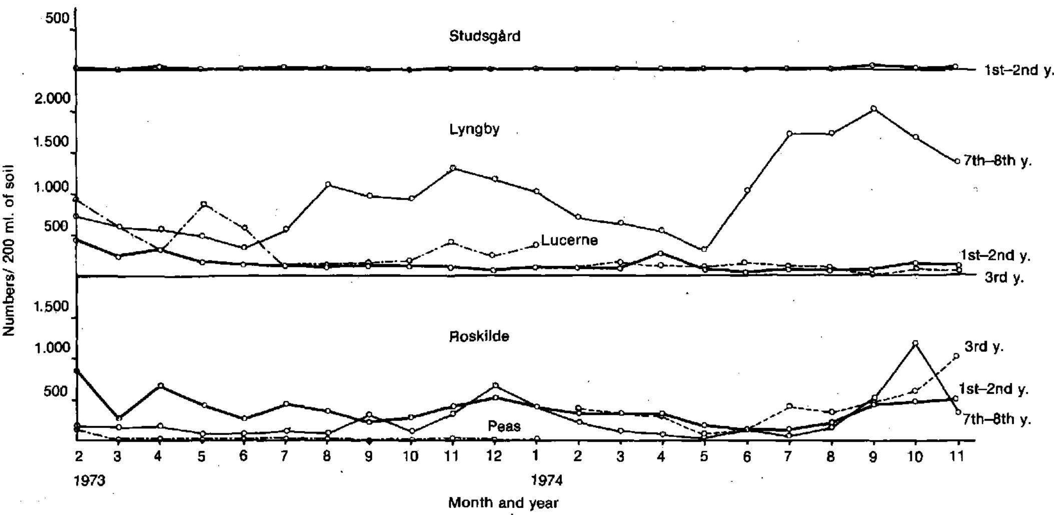

Fig. 10. Seasonal fluctuations of *Paratylenchus* populations at Studsgård, Lyngby and Roskilde in barley 1st, 2nd, 3rd, 7th and 8th year and in another crop.

Populationssvingninger af Paratylenchus i Studsgård, Lyngby og Roskilde hos byg 1., 2., 3., 7. og 8. år, samt i en anden afgrøde.

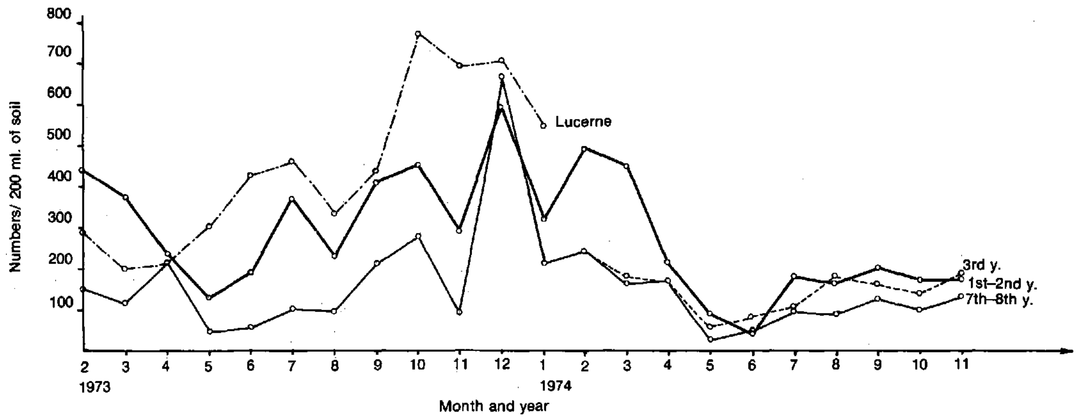

Fig. 11. Seasonal fluctuations of *Trichodorus primitivus* populations at Lyngby in barley 1st, 2nd, 3rd, 7th and 8th year and in lucerne.

Populationssvingninger af Trichodorus primitivus i Lyngby hos byg 1., 2., 3., 7. og 8. år, samt hos lucerne.

than for the mentioned groups, where maximum was reached in July. In Roskilde the densities were relatively small, but the seasonal variation was in accordance with the results obtained in Lyngby.

The dominant species in Lyngby and Roskilde was *P. microdorus*.

e) *Trichodorus*

The Lyngby populations of *Trichodorus* can be seen from fig. 11. *Trichodorus* was not found in Roskilde, and at Studsgård the populations were only small. The Lyngby populations consisted of *T. primitivus*, and the population at Studsgård was *T. pachydermus* syn. *Paratrichodorus pachydermus*.

As will be seen from fig. 11, the greatest densities were found in lucerne, where the maximum density in October 1973 was determined to 770 per 200 ml soil. In barley 1st year after lucerne the densities are still relatively great, whereas the populations in 2nd, 3rd, 7th and 8th year barley are reduced. The densities in 1973 displayed great variations, whereas only small fluctuations were observed in 1974.

f) *Tylenchus*

In the ecological division, this group is distributed with equal parts on migratory nematodes and mycophage nematodes. In taxonomical respect *Tylenchus* shall here be considered as a group including several genera. It is extremely difficult and time-consuming to make a determination of species. In Lyngby several species were found, among others *Tylenchus costatus* and *T. bastiania*. In Roskilde most of the group was *Tylenchus vulgaris*. At Studsgård it was impossible to determine the populations to any described species.

The population densities and the seasonal variation appear from fig. 12. The greatest densities were found in Lyngby in 1st and 2nd year barley, the greatest density was here 2,350 per 200 ml soil, determined in June 1974. The other plots in Lyngby and the plots in Roskilde and Studsgård showed smaller densities, and only one sampling had a greater density than 1,000 per 200 ml soil.

The seasonal fluctuations were not so distinct and concordant as was the case in genera with only migratory nematodes. However, the smallest densities tended to appear in March-April, and the greatest in June-July or in the early autumn.

g) *Heterodera*

No methods were used to extract *Heterodera* cysts. Therefore the registration of *Heterodera* populations was based only on the presence of juvenile and adult male nematodes in the soil.

In the barley plots in Lyngby no *Heterodera* was found, but in May 1973 some juveniles were found in lucerne.

With the exception of one single sampling, no juvenile nematodes were found in the barley plots in Roskilde, whereas a relatively large population was observed in peas 1973, where oats had been the preceding crop. The largest densities were determined in the spring months with maximum obtained in March when a density of 680 per 200 ml soil was found.

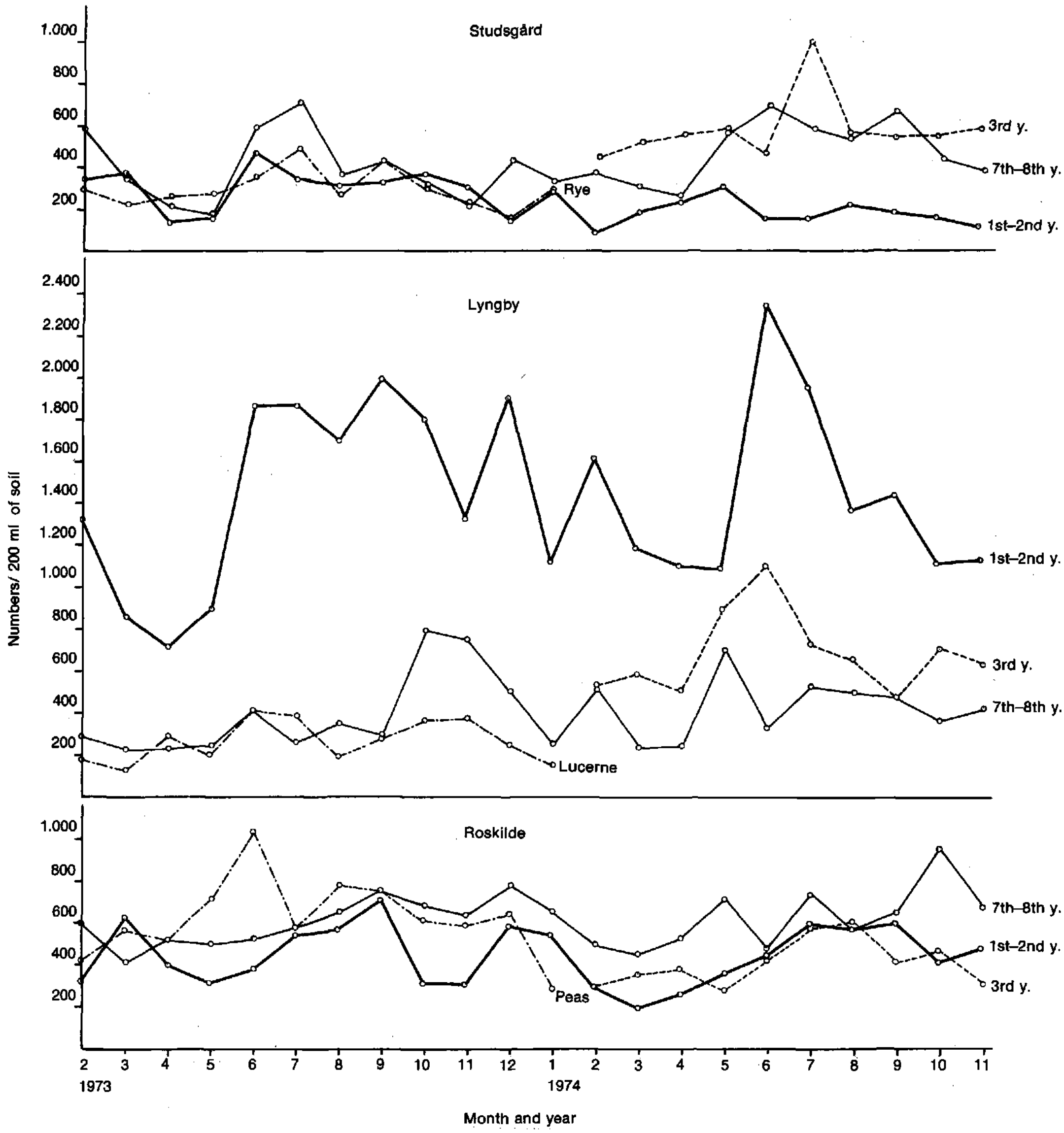

Fig. 12. Seasonal fluctuations of *Tylenchus* populations at Studsgård, Lyngby and Roskilde in barley 1st, 2nd, 3rd, 7th and 8th and in another crop.

Populationssvingninger af Tylenchus i Studsgård, Lyngby og Roskilde hos byg 1., 2., 3., 7. og 8. år, samt hos en anden afgrøde.

At Studsgård only a few juvenile nematodes were found in 7th-8th year barley, whereas the plot with 1st and 2nd year barley had a population under development. In may 1973 the density was determined to 30 per 200 ml soil, and in May 1974 to 180 per 200 ml soil.

The occurrence of *H. avenae* in the barley plots was then in concordance with the growth of resistant and susceptible barley varieties. 1st and 2nd year barley plots at Studsgård is thus the only place where a susceptible barley species was grown. The results confirm that the use of resistant barley varieties is a good protection against this serious plant parasite.

h) *Mycophage nematodes*
Together with *Tylenchus, Aphelenchus* and *Aphelenchoides* constitute the largest group of mycophage nematodes.

Aphelenchus avenae is the only *Aphelenchus* species observed. Its seasonal variation is shown in fig. 13. The lucerne plot in Lyngby displayed the largest densities with 900 nematodes per 200 ml soil. The densities on the single sites revealed no great differences between the barley plots. The seasonal variation of the *Aphelenchoides* populations is depicted in fig. 14. The densities were generally small. Considerable fluctuations were observed in some plots, f.inst. Lyngby and

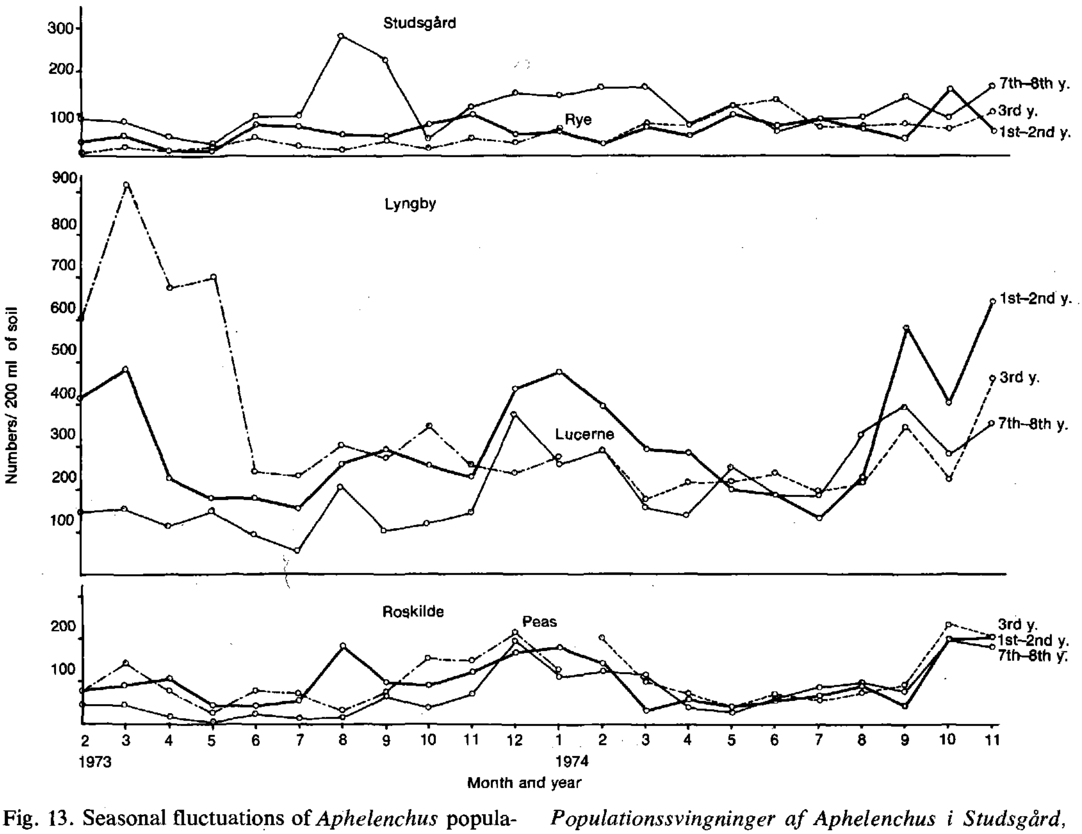

Fig. 13. Seasonal fluctuations of *Aphelenchus* populations at Studsgård, Lyngby and Roskilde in barley 1st, 2nd, 3rd, 7th and 8th year and in another crop.

Populationssvingninger af Aphelenchus i Studsgård, Lyngby og Roskilde hos byg 1., 2., 3., 7. og 8. år, samt hos en anden afgrøde.

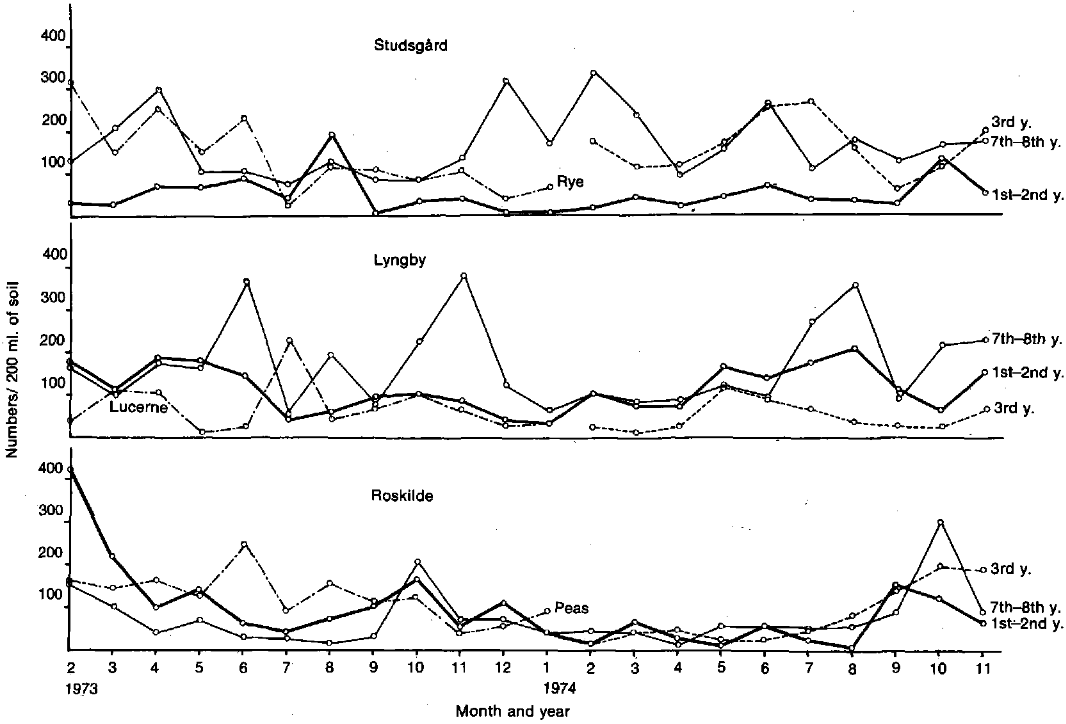

Fig. 14. Seasonal fluctuations of *Aphelenchoides* populations at Studsgård, Lyngby and Roskilde in barley 1st, 2nd, 3rd, 7th and 8th year and in another crop.

Populationssvingninger af Aphelenchoides i Studsgård, Lyngby og Roskilde hos byg 1., 2., 3., 7. og 8. år, samt hos en anden afgrøde.

Studsgård in 7th and 8th year barley, whereas other plots showed a more harmonious seasonal variation.

i) *Carnivore nematodes*

The group of carnivore nematodes most often constitutes less than 1 per cent of the total nematode fauna in barley.

The genus *Mononchus,* which is an exclusive carnivore group in the order *Dorylaimida,* has been represented in most of the plots. Only in a few cases they have, however, exceeded 50 per 200 ml soil.

In the Lyngby experiment were moreover found populations of *Seinura demani. Seinura* is a Tylenchid genus, and like other *Tylenchida* the species have a stylet. The species was most often observed in 7th and 8th year barley, where it occurred in 50 per cent of the samples. At Studsgård and Roskilde it was only just traced in a few of the samples.

j) *Microbivore nematodes*

As will be seen from fig. 4, this group – together with the migratory nematodes – constitutes approx. 90 per cent on average of the nematode fauna in the sites examined.

The greater part is by far the order *Rhabditida,* whereas a small part, represented by the genera *Plectus* and *Alaimus* and others, belong to the order *Araeolaimida.* The food of the group is predominantly bacteria (*Overgaard Nielsen,* 1949), (*Wood,* 1973).

The greatest density was found in Lyngby, in 1st year barley 1973, where a density of 10,260 Rhabditides per 200 ml soil was determined. The lowest density, 810 Rhabditides per 200 ml soil, was observed in October in peas, Roskilde 1973.

Fluctuation in densities from month to month may be very great, as seen in fig. 1. to 3. However, the densities most often reach a minimum in March or April in most plots. Maxima of the year were in most cases found in one of the summer months May-August.

Discussion and conclusion

The pattern of the seasonal variation observed for the various migratory nematodes is generally concordant, although the amplitudes and population densities may vary considerably. Moreover the pattern is generally in accordance with the results obtained in other Western European examinations of cultivated soil, *Winslow* (1964), *Maykuhs* (1969) and *Sharma* (1971) from England, Germany (Holstein) and Holland, respectively.

The pattern of the seasonal variation may be explained on the basis of the temperature development of the year and the fluctuating humidity conditions, and not at least on the basis of the growth active period of the plants. Throughout winter when the activity of the nematodes is greatly reduced, the population densities are rather constant. The rising temperatures in spring cause an activity in the nematodes, their predators, parasites etc., but the food obtainable is still very limited. The death-rate is therefore great. Not until germination of the new plants and the rise of temperature does the reproduction of the nematodes take place, and the densities will increase and culminate towards the end of the growth period. After harvest the food supply will again be limited, and until the low soil temperatures in winter reduce the biological activity, the densities may be cut down by the enemies of the nematodes.

A practical consequence of the seasonal fluctuation is that the time of sampling must be taken into consideration when the quantitative determination of a nematode population is made.

No complete agreement has been found for any species or group in the population development in relation to continuous barley growing. The best agreement was found in populations of *Pratylenchus neglectus* and *P. crenatus* where 1st–3rd year barley displayed relatively larger densities than 7th–8th year barley. The *Tylenchorhynchus-Merlinius* group showed no convincing tendency in relation to number of years with barley. The same applies to the other ectoparasitic species.

However, examinations in only 2 seasons and of very few localities cannot give a sufficient elucidation of the *Pratylenchus* populations in relation to continuous barley growing, although the results indicate that it does not especially favour the development of the *Pratylenchus* populations towards increasing densities under Danish conditions.

Rhabditides, which by far constitute the greater part of the microbivore nematodes, have a relatively much greater reproduction potential and a shorter lifetime than migratory nematodes (*Paramanov,* 1968). That may contribute to the explanation of the considerable and rapid fluctuations observed. These fluctuations may be dependent on physical factors, temperature and humidity, either with direct influence on the activity of the nematodes, or indirectly through the bacteria populations. The greatest density was found in barley 1st year after lucerne. After a lucerne crop the soil has a large organic content which is advantageous for a great microbial activity under favourable temperature and humidity conditions.

The population densities were not found to be correlated with the number of years the barley had been grown, and this may indirectly indicate that the bacterial activity is quantitatively rather unaffected by continuous barley growing.

The results of the dynamic trends of the populations of migratory nematodes do not seem to imply that a possible harmful effect on barley of some of the species will be aggravated with continuous barley growing under Danish conditions.

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