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*Erika MÄGI*

# INFLUENCE OF CEREAL CROPS ON THE MULTIPLICATION RATE OF THE CEREAL CYST NEMATODE *HETERODERA AVENAE* WOLLENWEBER

Abundant research by several authors has been conducted into the biology and ecology of the cereal cyst nematode, the main agricultural pest in permanent cereal growing districts (Gair et al., 1968; Kerry, Hague, 1974; Meagher, 1977; Rivoal, 1979, 1983; Brown, 1984; et al.). Most of the effort has been directed to population studies in field conditions and multiplication investigations of the nematode in glasshouse experiments (Meagher, Brown, 1974; Graham, Stone, 1975; Kerry, Jenkinson, 1976; Cook, 1977; Spaull, Hague, 1978; Seinhorst, 1981; et al.).

The purpose of this study is to investigate the reproduction of the cereal cyst nematode in the Estonian SSR. It is evident that increasing the cereal growing areas leads to the distribution of the nematode. Nevertheless, in the Estonian SSR, the pest has been observed in light sandy soils, but not in heavy, poorly structured ones.

The results of our observations in a severely damaged cereal field and a pot experiment with *H. avenae* are presented here.

## Material and methods

The investigations on the reproduction rate of the cereal cyst nematode were carried out in a field of the collective farm Paistu at Sultsi, Viljandi District. Twenty-five one-kilogramme soil samples, each containing 20 subsamples, were taken from the infested foci measuring 5—50 m², twice a season: in spring after sowing and in summer before harvesting.

The cysts were extracted from air-dried soil. The egg contents and free larvae in cysts were counted after crushing the cysts under a binocular microscope.

The relationships between the initial ($P_i$) and final ($P_f$) population levels per each season give information about the multiplication rate of the nematode. The mean densities of the eggs and larvae per 1 kg of soil in the infested field were calculated. The minimal and maximal amounts of eggs and larvae per cyst content were plotted against the cereal vegetation in 1978—1983.

A pot experiment was carried out in an unheated glasshouse where the diurnal temperature ranged from 10—25 °C. Five pots per crop, each containing 150 g of soil with 18 cysts, were sown with a single seed. The pots, including five unplanted controls, were placed in the glasshouse at the end of April. After two months of growing, the plants were removed in June in order to estimate the number of the white females on the roots. At the end of the experiment the proportion of hatched larvae and the multiplication rate of the nematode were calculated.

At the same time in spring, batches of 5 cysts of an approximately equal size, with root diffusates or soil water in five replicates, were tested

in laboratory so as to assess the number of the hatched larvae. The diffusates were obtained by diurnal leaching of cereal plants with intact roots in distilled water. The hatched larvae were counted at three-day intervals during 1.5 months.

## Results

The results presented in Fig. 1 show that in a field where cereal crops were grown in six successive seasons the multiplication rate of *Heterodera avenae* increases in the fifth season to the maximal value (point 5). $E_q$ is the logistic equilibrium point, showing neither an increase nor a decrease in population density. The fluctuation of the relation $P_f/P_i$ about the equilibrium level is evident after permanent cultivation of barley. Winter rye (point 4) shows the minimal value of the multiplication rate; however, an appreciable increase of the $P_f/P_i$ values was indicated in 1979, 1980 and especially in 1982, the first season after the cultivation of rye.

The sloping of the straight line N 1 drawn through the points of data under an angle of 33° (tan 0.649) shows slight fluctuations and indicates an approach to the equilibrium. The angle of the slope of the second line — 78° (tan 4.705) shows considerable fluctuations in comparison with the equilibrium level.

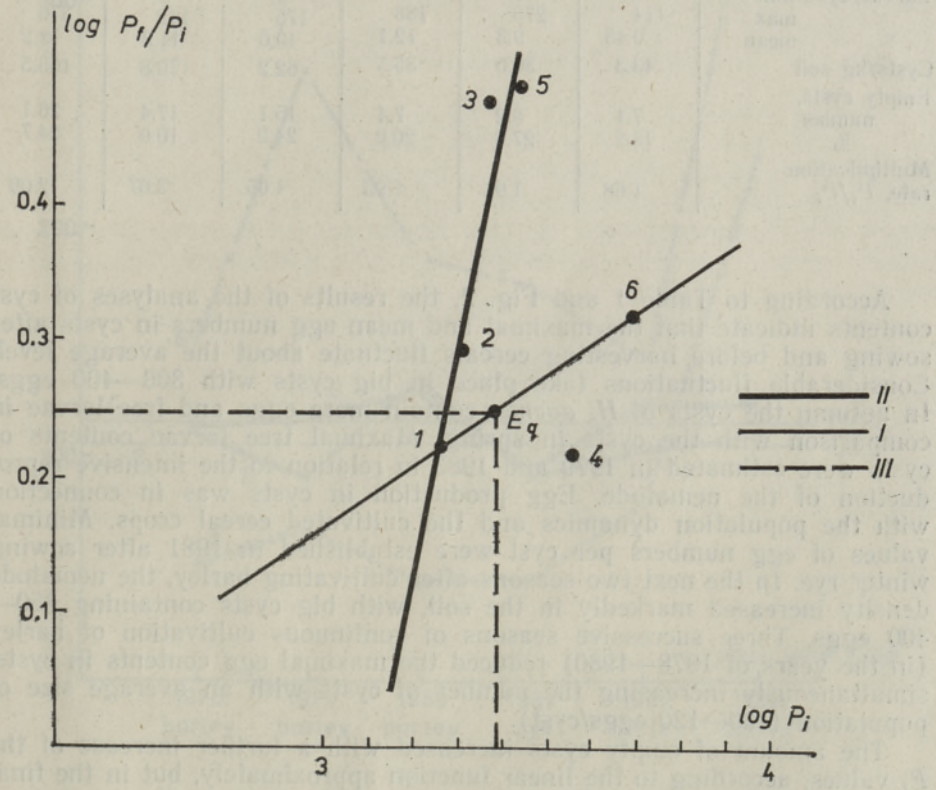


Fig. 1. Multiplication rate of *Heterodera avenae* in relation to initial population level after sowing. I — multiplication rate in 1978 and 1983, II — data in 1979, 1980 and 1982, III — coordinates of the $E_q$ — point; $E_q$ — logistic equilibrium point. Multiplication rates: *1* — in 1978, *2* — in 1979, *3* — in 1980, *4* — in 1981, *5* — in 1982, *6* — in 1983.

*Table 1*

**Average rates of egg and cyst production by *Heterodera avenae* per kg of soil and the contents of cysts in relation to cereal growing years**

| Multiplication of the nematode | Years and crop | | | | | |
|---|---|---|---|---|---|---|
| | 1978, barley | 1979, barley | 1980, barley | 1981, rye | 1982, barley | 1983, barley |
| **Initial** population (eggs/kg soil) | 1825± 85.2 | 2038± 90.2 | 2415± 100.2 | 3574± 119.4 | 2716± 108.1 | 4910± 140.1 |
| Eggs/cyst, min | 4 | 2 | 12 | 2 | 4 | 7 |
| max | 398 | 430 | 320 | 314 | 319 | 400 |
| mean | 109.3 | 92.4 | 135.5 | 89.4 | 101.7 | 108.6 |
| Larvae/cyst, min | 0 | 0 | 0 | 0 | 0 | 0 |
| max | 53 | 68 | 43 | 43 | 78 | 230 |
| mean | 2.3 | 4.7 | 2.5 | 10.0 | 14.4 | 27.5 |
| Cysts/kg soil | 30±7 | 24±5 | 32±3 | 44±7 | 38±5 | 57±4 |
| Empty cysts, number | 6.6 | 5.1 | 18.3 | 19.0 | 11.4 | 24.5 |
| % | 20.0 | 20.0 | 56.2 | 43.2 | 30.0 | 42.1 |
| **Final** population (eggs/kg soil) | 3081± 111.0 | 4046± 127.0 | 7140± 168.4 | 3762± 121.0 | 8360± 182.8 | 10269± 202.0 |
| Eggs/cyst, min | 7 | 8 | 2 | 5 | 3 | 7 |
| max | 452 | 411 | 376 | 315 | 413 | 423 |
| mean | 111.5 | 112.3 | 129.1 | 90.0 | 122.1 | 121.5 |
| Larvae/cyst, min | 0 | 0 | 0 | 0 | 0 | 0 |
| max | 114 | 270 | 188 | 175 | 142 | 370 |
| mean | 0.45 | 9.3 | 12.1 | 10.0 | 11.3 | 19.2 |
| Cysts/kg soil | 43.3 | 30.0 | 35.5 | 62.2 | 170.8 | 105.5 |
| Empty cysts, number | 7.1 | 8.2 | 7.4 | 15.1 | 17.4 | 26.1 |
| % | 18.2 | 27.6 | 20.0 | 24.2 | 10.0 | 24.7 |
| Multiplication rate, $P_f/P_i$ | 1.68 | 1.98 | 2.95 | 1.05 | 3.07 | 2.09 |

According to Table 1 and Fig. 2, the results of the analyses of cyst contents indicate that the maximal and mean egg numbers in cysts after sowing and before harvesting cereals fluctuate about the average level. Considerable fluctuations take place in big cysts with 300—400 eggs. In autumn the cysts of *H. avenae* contain more eggs and free larvae in comparison with the cysts in spring. Maximal free larvae contents of cysts were estimated in 1979 and 1983 in relation to the intensive reproduction of the nematode. Egg production in cysts was in connection with the population dynamics and the cultivated cereal crops. Minimal values of egg numbers per cyst were established in 1981 after sowing winter rye. In the next two seasons after cultivating barley, the nematode density increased markedly in the soil, with big cysts containing 350—400 eggs. Three successive seasons of continuous cultivation of barley (in the years of 1978—1980) reduced the maximal egg contents in cysts, simultaneously increasing the number of cysts with an average size of population (100—120 eggs/cyst).

The amount of empty cysts increased with a further increase of the $P_i$ values, according to the linear function approximately, but in the final populations of the last years the quantity of empty cysts was proportionally smaller.

The multiplication rate of *H. avenae* increased gradually to the figure in the year of 1980 but in 1981, after growing rye, it diminished to 1.05, and the maximal value was estimated after growing barley in 1982

(3.07). Nevertheless, the observed maximal nematode density in 1983 ($P_f$=10269) and the multiplication rate of the nematode decreased again to 2.09.

For determining the multiplication rate of the nematode in glasshouse conditions, a pot experiment with six cereal cultivars and maize was carried out. Table 2 demonstrates a high susceptibility of the tested cereal cultivars to *H. avenae*. On the roots of maize we estimated seven cysts

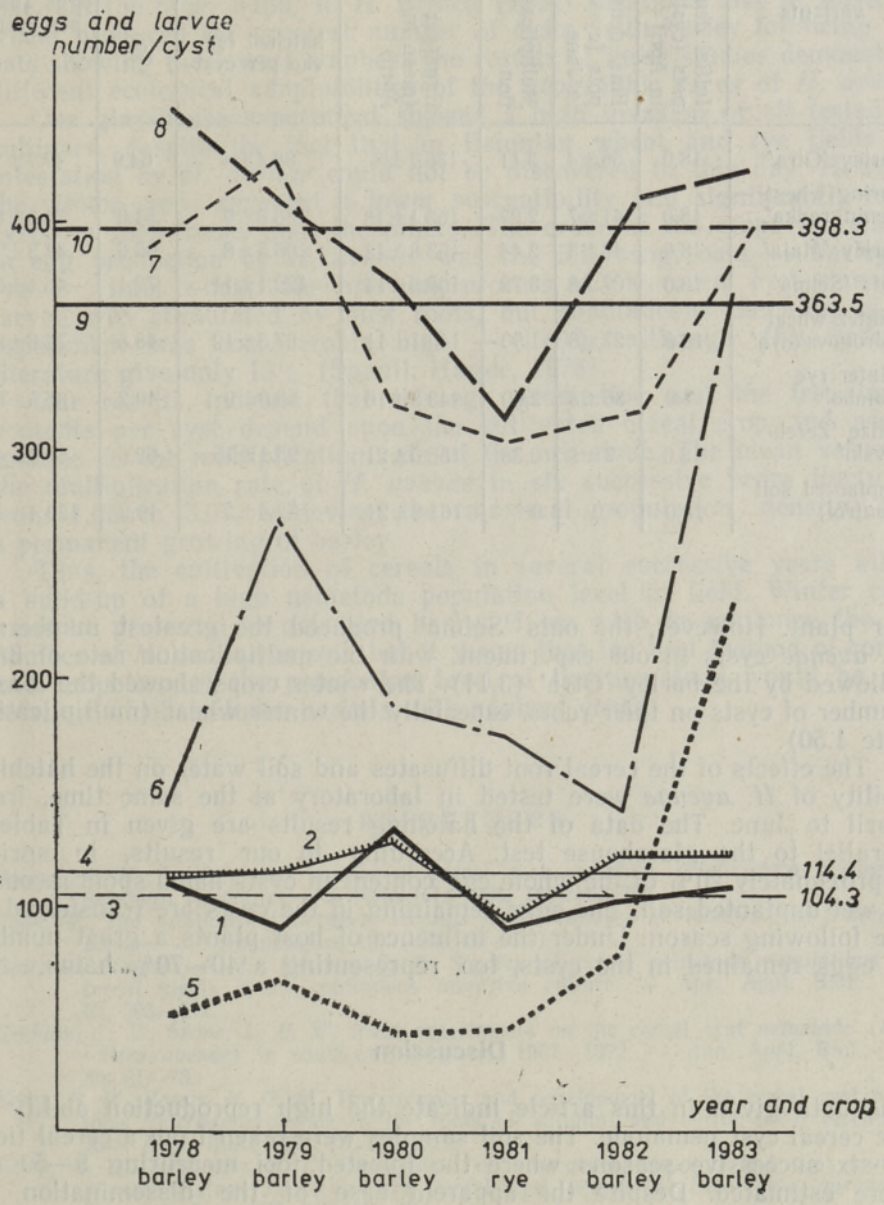


Fig. 2. *Heterodera avenae* cyst contents in 1978—1983. *1* — average egg number in spring ($P_i$), *2* — average egg number in cysts before harvesting ($P_f$), *3* — mean value of eggs/cyst in spring per 6 seasons ($P_i$), *4* — mean value of eggs/cyst before harvesting per 6 seasons ($P_f$), *5* — maximal larval number in cysts ($P_i$), *6* — maximal larval number in cysts ($P_f$), *7* — maximal egg number in cysts ($P_i$), *8* — maximal egg number in cysts ($P_f$), *9* — mean maximal value of egg number per 6 seasons ($P_i$), *10* — mean maximal value of egg number per 6 seasons ($P_f$).

*Table 2*

**Reproduction and emergence of *Heterodera avenae* on six cereal cultivars and maize grown in Estonia**

| Experiment variants | Initial density in pots (cysts/plant) in April | Final density in pots (cysts/plant) in June | Multiplication | Eggs per cyst (mean in April) | Emergence of larvae (laboratory test) | | Remaining eggs (mean per cyst) |
|---|---|---|---|---|---|---|---|
| | | | | | hatched larvae per cyst | % | |
| Barley 'Otra' | 18.0 | 56±4 | 3.11 | 136.1±8 | 88.4±4 | 64.9 | 47.7±7 |
| Spring wheat 'Leningradka' | 18.0 | 41±7 | 2.27 | 163.1±18 | 88.8±9 | 54.0 | 74.3±6 |
| Barley 'Maja' | 18.0 | 44±3 | 2.44 | 153.8±13 | 106.5±8 | 68.6 | 47.3±3 |
| Oats 'Selma' | 18.0 | 67±8 | 3.72 | 168.5±14 | 122.1±11 | 72.1 | 46.4±3 |
| Winter wheat 'Mironovskaya' | 18.0 | 27±3 | 1.50 | 140.1±11 | 67.5±12 | 48.5 | 72.6±8 |
| Winter rye 'Vambo' | 18.0 | 36±3 | 2.00 | 143.5±16 | 58.0±9 | 40.2 | 85.5±5 |
| Maize 'Zerebnovski' | 18.0 | 7±1 | 0.38 | 150.0±21 | 93.1±15 | 62.0 | 56.9±4 |
| Unplanted soil (control) | 18.0 | 0 | 0 | 161.8±21 | 32.4±2 | 19.9 | 129.4±12 |

per plant. However, the oats 'Selma' produced the greatest number of *H. avenae* cysts in our experiment, with the multiplication rate of 3.72, followed by the barley 'Otra' (3.11). The winter crops showed the lowest number of cysts on their roots, especially the winter wheat (multiplication rate 1.50).

The effects of the cereal root diffusates and soil water on the hatching ability of *H. avenae* were tested in laboratory at the same time, from April to June. The data of the hatching results are given in Table 2 parallel to the glasshouse test. According to our results, in spring approximately 20% of the whole egg content in cysts hatch spontaneously in wet unplanted soil. The eggs remaining in the cysts are transferred to the following season. Under the influence of host plants a great number of eggs remained in the cysts, too, representing a 40—70% hatch.

## Discussion

The data given in this article indicate the high reproduction ability of the cereal cyst nematode. The soil samples were taken from a cereal field in six successive seasons where the infested foci measuring 5—50 m² were estimated. Despite the apparent ease of the dissemination of *Heterodera avenae* by wind and agricultural implements, the areas adjacent to the diseased foci (even in the same field) did not get infested. As marked by J. W. Meagher (1968) and R. H. Brown (1984), the distribution of the nematode is mainly influenced by the soil type. The disease acquires a serious form in lighter soils.

The data of R. Cook (1977) indicate that in glasshouse experiments a minimum of 28 days of growing on the host plant was necessary

before egg production. Nevertheless, the females that were allowed to feed longer produced more eggs and formed larger cysts. Our results show that the optimal time for pot experiments was up to seven weeks.

According to B. R. Kerry and S. C. Jenkinson (1976), in England the oats were attacked most severely, followed by wheat and barley. A. M. Spaull and N. G. Hague (1978) agree that the early invasion was heavy in most of the oats cultivars, whereas barleys usually contained fewer nematodes. The differences in the invasions were not related to root size. On the other hand, R. H. Brown (1984) mentions that in Australia wheat produced the greatest number of cysts, with barley following and oats showing the lowest number. The results of those studies demonstrate different ecological adaptabilities of the geographic races of *H. avenae*.

Our glasshouse experiment showed a high invasion of all tested six cultivars, despite the fact that in Estonian wheat and rye fields the infestation by *H. avenae* could not be discovered to this day. However, the winter crops revealed a lower susceptibility and significantly fewer cysts on their roots than the others. The order of the crops in relation to egg production by *H. avenae* was the following: oats — barley — rye — winter wheat. The hatching process of the cereal cyst nematode larvae was stimulated by host roots, but spontaneous hatching in the experiment was considerably high — 19.9%, although the data of literature give only 13% (Spaull, Hague, 1978).

Our results indicate that the egg production and the free larvae contents per cyst depend upon the cultivated cereal crop and are in relation to the multiplication rate of the nematode. The mean values of the multiplication rate of *H. avenae* in six successive years fluctuated from 1.05 to 3.07, achieving the maximal population density after a permanent growing of barley.

Thus, the cultivation of cereals in several successive years allows a build-up of a high nematode population level in field. Winter crops must be preferred to oats and barley if we wish to minimize the egg number of *H. avenae* in soil, but it seems that the best method of control and reduction of the population level of the nematode would be crop rotation which includes periods with nonhost crops.

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*Academy of Sciences of the Estonian SSR,*
*Institute of Zoology and Botany*

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*Erika MÄGI*

## TERAVILJADE MÕJUST KAERA-KIDUUSSI *HETERODERA AVENAE* WOLLENWEBER PALJUNEMISMÄÄRALE

On esitatud andmed aastail 1978—1983 teraviljapõllul tehtud vaatluste ja mullaproovide analüüsi tulemuste kohta. Samuti esitatakse vegetatsioonikatse tulemused Eesti NSV-s rajoonitavate teraviljade mõju kohta kaera-kiduussi paljunemismäärale kasvuhoonetingimustes.

Selgitati, et kaera-kiduussi paljunemismäär teraviljade iga-aastasel kasvatamisel kõigub põllul kultuurist olenevalt 1,05 ja 3,07 vahel, nõukatses 1,50 ja 3,72 vahel. Nematoodide arvukuse absoluutväärtus mullas tõuseb odrakülvi järel pidevalt, saavutades kuuenda aasta lõpuks maksimumi. Seega kujunevad külvikordadeta põllul soodsad tingimused parasiidi populatsiooni järjekindlaks suurenemiseks.

Katsetingimustes nakatusid nii suvi- kui taliviljad, kuid viimaste puhul oli parasiidi paljunemismäär 1,5—2 korda väiksem. Parimaks peremeestaimeks kaera-kiduussile osutus kaer, sellele järgnesid oder, rukis ja talinisu.

*Эрика МЯГИ*

## ВЛИЯНИЕ ЗЕРНОВЫХ КУЛЬТУР НА СТЕПЕНЬ РАЗМНОЖЕНИЯ ОВСЯНОЙ ЦИСТООБРАЗУЮЩЕЙ НЕМАТОДЫ *HETERODERA AVENAE* WOLLENWEBER

Изучение динамики степени размножения овсяной нематоды проводили в 1978—1983 гг. на зараженном поле в Вильяндийском районе, где зерновые культуры возделывались без севооборота. Результаты анализа почвенных проб показали, что средний уровень степени размножения овсяной нематоды колебался в зависимости от культивируемого растения-хозяина: 1,68 — ячмень (1978), 1,98 — ячмень (1979), 2,95 — ячмень (1980), 1,05 — рожь (1981), 3,07 — ячмень (1982) и 2,09 — ячмень (1983). Степень размножения нематоды при посеве ячменя постепенно увеличивалась, после возделывания ржи — резко уменьшалась до минимума, а после возделывания ячменя достигала максимального уровня.

Данные вегетационного опыта показали, что наилучшим растением-хозяином для овсяной нематоды в условиях эксперимента оказался овес (степень размножения 3,72) и ячмень (3,11). Результаты опыта подтвердили, что после возделывания озимых культур (рожь, пшеница) численность популяции овсяной нематоды возросла не больше чем в 1,5—2 раза, т. е. практически в 2 раза меньше, чем после яровых (овес, ячмень).

Процент вылупившихся личинок по отношению к их общему числу в цистах также показывал аналогичную корреляцию с возделываемыми видами зерновых. Так, у овса 'Селма' процент вылупившихся личинок — 72,1, ячменя 'Отра' — 64,9, озимой пшеницы 'Мироновская' — 48,5 и ржи 'Вамбо' — 40,2. Вылупление личинок в зараженной почве без растений (контроль) в конце эксперимента составляло около 20%.