Seasonal fluctuations of the nematode communities in a hop garden soil

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Summary

A study on the seasonal fluctuation of nematode population was conducted during three vegetation periods (2005 – 2007), at 20 and 40 cm soil depth, from May to October, in a hop garden at Nemšová (Slovak Republic). The seasonal fluctuation of the nematode population was related to temperature and rainfall. At 20 cm soil depth of each year, the largest nematode population was recorded in July, and the smallest from July to October. At 40 cm soil depth, nematode abundance was not significantly different between the years 2006 and 2007. In general, at the same depth, a decrease of nematode abundance was observed from May to October. The soil nematode community was rich in bacterivorous nematodes, especially in the top 20 cm soil. The genus *Rhabditis* was the eudominant taxon at both soil depths. This genus with the genera *Cephalobus*, *Heterodera*, *Merlinius* and *Aglencus* represented the 50 % of the total nematode population at 20 cm soil depth and with the genera *Cephalobus*, *Helicotylenchus*, *Heterodera* and *Merlinius* represented the 52 % of total nematodes abundance at 40 cm depth.

Keywords: nematode community; seasonal fluctuation; trophic groups; hop garden; Slovak Republic

Introduction

Earlier investigations on nematodes in the hop gardens throughout the world were focused mostly on the cyst nematode *Heterodera humuli*. However, apart from information on *H. humuli* and some other plant parasitic nematodes species (Hay & Pethybridge, 2003), knowledge of nematode communities in hop gardens is scarce.

The seasonal or temporal dynamic of occurrence of soil nematodes has been documented previously in several ecosystems e.g. forest (Sohlenius *et al.*, 1987), sugar beet, cereals and lucerne (Renčo 2002), *Ambrosia trifida* and *Chenopodium serotinum* (Liang *et al.*, 2007). Neher *et al.*

(2004) stated that fluctuation of nematodes during vegetation is influenced by several biotic and abiotic factors such as temperature, annual rainfall, type of soil and plants, organic substances, microflora and management practices. As reported by Bakonyi and Nagy (2000), temperature is the main factor influencing nematode diversity although the nematode abundance is predominantly affected by the soil moisture content.

In Slovakia the structure of nematode communities in hop gardens was studied only during a single season (2004) (Lišková & Renčo, 2007), whereas information on the seasonal fluctuation of nematodes in a longer period is lacking. Such information would contribute to a better understanding of potential nematode problems and consequently, the adoption of appropriate measures to control phytoparasitic nematodes. Therefore, the objective of this investigation was to obtain information on the nematode population seasonal fluctuations in established hop gardens, and to determine the principal environmental factors affecting nematode population changes in a very important hop growing area of Slovakia.

Materials and methods

The study was undertaken in a hop garden at Nemšová in western region of Slovakia situated in a warm area with temperate and moderately humid winter. The locality is characterized by deep, permeable, clay sandy or sandy clay soils, soil type Luvisol or Fluvisol, with pH 6.6 – 7.8. The locality is at an elevation of 181 m a. s. l., characterized by annual isotherms during the years 2005-2007 of 9.4 – 10.7°C and with annual rainfall of 580 – 760 mm, while during the vegetation period (May – October) temperature was in the range 16.5 – 17.1°C and rainfall in the range 195 – 370 mm. The studied hop garden was 30 years old and it was fertilized every year with 50 – 70 t/ha of cattle manure.

Table 1. Dominance of nematode genera at each monthly sampling at 20 cm depth

Genus	TG	Dominance % (n=3)						Total
		V	VI	VII	VIII	IX	X	
<i>Acrobeles</i>	BF	0.04	0.03	-	0.14	0.21	-	0.08
<i>Alaimus</i>	BF	1.44	1.37	1.27	0.42	0.90	0.72	1.08
<i>Amphidelus</i>	BF	0.10	-	0.02	0.33	-	-	0.10
<i>Aulolaimus</i>	BF	-	0.18	-	0.20	0.07	-	0.07
<i>Cephalobus</i>	BF	4.16	5.04	7.54	9.04	12.13	10.91	7.67
<i>Eucephalobus</i>	BF	3.20	2.95	1.24	1.95	2.33	4.25	2.51
<i>Eumohohystera</i>	BF	-	0.23	0.16	0.31	0.14	-	0.18
<i>Chiloplacus</i>	BF	3.26	3.57	2.48	3.32	4.24	2.74	3.17
<i>Panagrolaimus</i>	BF	0.88	1.16	0.57	1.90	1.25	1.70	1.14
<i>Plectus</i>	BF	1.03	0.94	1.18	2.18	1.81	2.01	1.37
<i>Rhabditis</i>	BF	29.52	24.93	39.22	31.61	26.34	33.05	31.63
<i>Aphelenchoides</i>	FF	0.88	1.11	1.08	0.95	0.87	0.85	0.97
<i>Aphelenchus</i>	FF	4.00	3.10	4.26	3.07	2.40	3.52	3.54
<i>Diphtherophora</i>	FF	0.02	0.03	-	0.11	0.03	0.09	0.04
<i>Ditylenchus</i>	FF	0.16	0.10	0.16	0.47	0.31	0.16	0.21
<i>Nothotylenchus</i>	FF	0.82	1.40	1.10	1.98	1.67	0.63	1.22
<i>Seinura</i>	FF	0.31	-	0.25	-	0.52	0.25	0.28
<i>Bitylenchus</i>	PP	1.95	2.17	0.65	1.42	1.77	1.23	1.45
<i>Helicotylenchus</i>	PP	7.47	7.03	4.25	2.54	3.82	2.64	4.82
<i>Heterodera</i>	PP	10.36	12.46	8.45	6.22	2.57	3.30	7.78
<i>Merlinius</i>	PP	8.76	5.35	2.86	5.64	6.53	4.87	5.51
<i>Paratylenchus</i>	PP	2.38	1.47	2.21	0.39	1.49	2.14	1.77
<i>Pratylenchus</i>	PP	1.37	1.22	1.77	0.72	2.60	1.07	1.48
<i>Tylenchorhynchus</i>	PP	0.60	0.88	0.21	0.47	1.09	0.47	0.51
<i>Aglenchus</i>	RFF	3.43	4.63	5.52	5.13	6.15	6.48	5.11
<i>Boleodorus</i>	RFF	1.70	1.27	1.86	0.98	1.88	0.75	1.46
<i>Filenchus</i>	RFF	0.35	0.49	0.51	0.86	0.35	0.44	0.49
<i>Tylenchus</i>	RFF	3.20	4.97	2.18	2.26	3.30	2.23	2.96
<i>Campydora</i>	P	0.02	0.05	-	0.31	0.45	-	0.12
<i>Clarkus</i>	P	0.33	0.59	0.37	0.70	0.28	0.41	0.44
<i>Mononchus</i>	P	0.37	0.52	0.76	0.31	1.01	1.64	0.72
<i>Mylonchulus</i>	P	0.33	0.80	0.59	0.89	1.18	1.16	0.76
<i>Nygolaimus</i>	P	-	0.05	-	0.06	0.10	-	0.03
<i>Tripyla</i>	P	0.04	0.08	0.10	0.14	-	0.06	0.13
<i>Aporcelaimellus</i>	O	2.42	4.16	2.10	5.75	4.41	4.65	3.57
<i>Axonchium</i>	O	0.18	0.23	0.11	0.17	0.45	0.13	0.19
<i>Dorylaimoides</i>	O	-	0.13	0.08	0.06	0.14	-	0.06
<i>Ecumenicus</i>	O	0.41	1.14	0.89	1.34	0.66	1.04	0.89
<i>Eudorylaimus</i>	O	2.52	3.03	2.89	3.85	3.16	3.21	3.05
<i>Mesodorylaimus</i>	O	1.42	0.88	0.72	1.53	0.66	0.82	1.01
<i>Oxydirus</i>	O	0.10	0.10	0.22	0.06	0.35	0.13	0.16
<i>Steinernema</i>	IN	0.47	0.16	0.17	0.22	0.38	0.25	0.27

Fig. 1 Mean monthly temperature recorded from January to December in the years 2005, 2006 and 2007

The study was conducted during tree vegetation periods from 2005 to 2007. From May to October, soil samples were collected monthly from the rhizosphere of hop plants at depths of 20 and 40 cm. Nematodes were isolated from 500 g of mixed soil by using Cobb's flotation-sieving method (Cobb, 1918), fixed in FAA (80 parts distilled water, 16 parts 96 % ethanol, 2.4 parts formalin, 1.6 parts acetic acid) (Johansen, 1940) and identified to genus level. The nematodes were evaluated by dominance of individual genera within sampling dates at the two soil depths. It was calculated as proportion of number of specimens of individual genera and a total number of specimens in soil sample. Results are presented in Table 1 – 2. The nematode genera were eudominant at $D > 10$ %, dominant at $D = 5 - 10$ %, subdominant at $D = 2 - 5$ % (Losos *et al.*, 1984)

For statistical evaluation, the identified genera were allocated into seven trophic groups (TG) according to classification of Yeates *et al.* (1993); bacterial feeders (BF), fungal feeders (FF), plant feeders (PP), root fungal feeders (RFF), predators (P), omnivores (O) and insect parasites (IN). Data were analysed by analysis of variance (ANOVA) and means compared by Duncan's Multiple Range Test. All statistical analyses were performed using the PlotIT program v.3.2.

Results and Discussion

A total of 42 nematode genera, including 7 genera of plant parasites were identified during three vegetation periods (Table 1 – 2). This number of genera is less than that observed by Lišková (1980) in perennial ecosystems of vineyards (*Vitis vinifera* L.) in Slovakia, but it is similar to that

found by Deming *et al.* (2006) in perennial ecosystems of *Caragana microphylla* plantation.

The seasonal fluctuation of mean monthly temperature (Fig. 1), monthly precipitation (Fig. 2), and abundance of nematodes showed similarity during the three years. At the 20 cm soil depth (Fig. 3) nematodes were more abundant in May than in June in each year. In July the nematode abundance increased again and reached maximum in each year because of high occurrence of BF nematodes of the genus *Rhabditis*. These agree with finding by Venette & Ferris (1997) who observed an increase of bacteriovorous nematodes at higher temperatures. In August, September and October, the abundance of nematodes decreased while decrease being related to the decrease of temperatures at the end of vegetation period, and to the highest rainfall recorded in August 2005 and 2006 (Fig. 1 – 3).

At a depth of 40 cm (Figure 4) the seasonal variation in nematode abundance was similar between in 2006 and 2007, with a decrease of nematode population from May to October, although a moderate increase was observed during the summer months, probably caused by higher temperatures. A different situation was observed in 2005 when nematode abundance increased from May to July and decreased from July to October.

The mean abundance of nematodes at the 20 cm soil depth was higher than that to 40 cm (Table 3). Our results agree with Deming *et al.* (2006) and Zhang *et al.* (2007) who recorded a gradual decrease of total abundance of nematodes with an increase of soil depth in several ecosystems. A similar gradual reduction of abundance of nematodes with increase of soil depth was also observed in various types of soil (Valocká & Sabová 1997; Lazarova, 2004).

Fig. 2 Monthly precipitation recorded from January to December in the years 2005, 2006 and 2007

Table 2. Dominance of nematode genera within sampling dates in soil depth of 40 cm

Genus	TG	Dominance % (n=3)						Total
		V	VI	VII	VIII	IX	X	
<i>Acrobeles</i>	B	2.47	3.49	4.6	3.61	4.4	4.28	3.73
<i>Alaimus</i>	B	1.86	1.44	1.37	0.84	0.79	0.38	1.2
<i>Amphidelus</i>	B	0.35	0.46	-	0.38	0.56	0.27	0.33
<i>Aulolaimus</i>	B	0.13	0.03	-	-	0.09	-	0.05
<i>Cephalobus</i>	B	5.94	5.74	5.74	4.79	6.48	8.56	6.07
<i>Eucephalobus</i>	B	2.83	2.77	2.34	2.58	3.43	2	2.65
<i>Eumohohystera</i>	B	-	0.16	-	0.52	0.19	0.38	0.21
<i>Chiloplacus</i>	B	2.92	4.24	4.64	4.36	2.78	1.9	3.56
<i>Panagrolaimus</i>	B	1.32	2.28	1.3	0.94	1.3	1.3	1.44
<i>Plectus</i>	B	0.9	0.91	0.9	0.38	0.88	1.25	0.84
<i>Rhabditis</i>	B	17.8	16.58	16.04	19.94	15.01	15.93	16.81
<i>Aphelenchoides</i>	FF	1.06	0.55	1.37	1.78	2.55	1.79	1.41
<i>Aphelenchus</i>	FF	3.28	5.84	4.37	2.58	5.28	2.87	4.04
<i>Diphtherophora</i>	FF	0.16	-	0.23	-	0.14	0.54	0.18
<i>Ditylenchus</i>	FF	0.06	-	-	-	0.09	-	0.03
<i>Nothotylenchus</i>	FF	1.86	1.53	1.37	4.32	3.61	1.14	2.29
<i>Seinura</i>	FF	-	0.1	-	0.23	0.05	0.05	0.1
<i>Bitylenchus</i>	PP	1.35	1.24	1.56	1.22	2.55	1.41	1.52
<i>Helicotylenchus</i>	PP	13.58	11.36	10.21	4.36	7.5	6.77	9.47
<i>Heterodera</i>	PP	9.89	6.72	7.34	8.63	5.42	3.74	7.28
<i>Merlinius</i>	PP	12.72	13.54	13.81	9.29	11.58	9.32	12
<i>Paratylenchus</i>	PP	3.47	2.15	2.84	3.52	2.22	4.5	3.12
<i>Pratylenchus</i>	PP	1.54	1.73	1.5	4.27	2.32	4.12	2.44
<i>Tylenchorhynchus</i>	PP	0.19	0.82	0.83	2.39	1.81	1.08	1.08
<i>Aglenchus</i>	RFF	0.35	-	0.03	0.09	0.09	0.16	0.12
<i>Boleodorus</i>	RFF	1.09	1.7	0.63	2.82	1.25	1.25	1.4
<i>Filenchus</i>	RFF	0.29	0.49	0.47	0.84	0.09	0.49	0.41
<i>Tylenchus</i>	RFF	1.8	1.44	2.94	2.06	1.2	1.73	1.85
<i>Campydora</i>	P	0.1	-	0.07	-	0.37	0.16	0.14
<i>Clarkus</i>	P	0.45	0.39	0.7	0.44	1.61	1.39	0.75
<i>Mononchus</i>	P	0.29	0.42	0.43	0.89	0.28	2.28	0.78
<i>Mylonchulus</i>	P	0.64	0.69	1.23	0.84	1.07	1.03	0.9
<i>Nygolaimus</i>	P	0.06	0.1	-	0.14	0.28	-	0.09
<i>Tripyla</i>	P	0.55	0.62	0.4	0.47	0.51	0.7	0.53
<i>Aporcelaimellus</i>	O	2.92	3.46	4.54	3.43	4.12	7.8	4.16
<i>Axonchium</i>	O	-	0.07	0.23	0.09	0.26	0.49	0.15
<i>Dorylaimoides</i>	O	0.32	0.29	0.33	0.38	0.14	0.11	0.25
<i>Ecumenicus</i>	O	1.38	1.04	1.3	2.26	1.99	3.25	1.67
<i>Eudorylaimus</i>	O	3.18	4.11	2.84	2.58	4.51	4.28	3.61
<i>Mesodorylaimus</i>	O	0.58	1.01	1.07	0.8	0.79	0.7	0.83
<i>Oxydirus</i>	O	0.1	0.23	0.13	0.47	0.09	-	0.17
<i>Steinernema</i>	IN	0.22	0.26	0.3	0.47	0.32	0.6	0.34

Fig. 3 Nematode abundance from May to October in the years 2005, 2006 and 2007 at 20 cm soil depth

However, the total number of nematodes was larger in soil with perennial undisturbed natural pasture (Valocká & Sabová, 1997) or grass and lucerne stands (Sohlenius *et al.*, 1987) than in our hop gardens, characterized by perennial plants with a high level of disturbance agricultural practices such as tillage, cultivation and organic fertilization.

At 20 cm soil depth, the highest percentage of nematode was represented by BF followed by PP, RFF, O, FF, P and IN (Table 4). These findings agree with previous reports from Slovakian hop gardens (Lišková & Renčo, 2007) and are similar to those from sugar beet and cereals grown after sugar beet (Renčo 2003, 2004). However, in a study by Deming *et al.* (2006), the order of abundance of the trophic group was BF, O, P, PP and FF.

The trophic groups BF (Table 4) prevailed at the 20 cm soil depth in each sampling dates and it reached greater percentages during August, September and October. However, no significant difference in the proportions of BF within sampling dates, during three vegetation periods, was found ($P \leq 0.05$).

For PP, the second largest trophic group, a significant larger proportion was observed in May and June than in August, September and October, caused by high abun-

dance of juveniles and males of the species *Heterodera humuli*. The occurrence of this species in different Slovakian hop gardens was reported in a previous study (Lišková & Renčo, 2007). No significant differences were found ($P \leq 0.05$) among the percentages of PP recorded in May, June and July, thus confirming findings by Sabová *et al.* (1987) in cereal monocultures. Higher soil humidity in spring months in addition to new root flushes are favourable conditions for reproduction and invasion of plant parasitic nematodes. On the contrary, climatic conditions in summer months were characterized by lack rainfall and dried soil, which caused a decrease of plant parasitic nematode abundance. BF and PP nematodes together represented 69 – 77 % on total nematode abundance.

Of RFF a significant larger proportion was observed in September than in August (Table 4) with no statistical differences among different months. The FF reached a stable proportion and no significant differences were observed during individual sampling dates. For P and O trophic groups a significant smaller proportion was recorded in May than in September and August (Table 4).

At 40 cm soil depth, with fewer disturbances, the PP group prevailed and it was followed by O, RFF, FF, P and IN. Moreover, PP prevailed over BF in May, June, July and September sampling dates (Table 4). Maximum proportion of PP occurred in May and June and then decreased throughout October but there were no statistical differences among sampling dates ($P \leq 0.05$).

Fig. 4 Nematode abundance from May to October in the years 2005, 2006 and 2007 at 40 cm soil depth

Table 3. Mean nematode abundance withing different sampling dates

Nematode abundance	Month of investigation					
	V	VI	VII	VIII	IX	X
20 cm	698	467	1135	459	380	434
40 cm	540	442	462	416	303	276

BF was the second largest group with its maximum population density reached in August. However, no statistical differences in BF proportion were found ($P \leq 0.05$) during the three vegetation periods (Table 4).

For FF a significant smaller proportion was observed in May and October in comparison to September and no significant differences were found among other sampling dates ($P \leq 0.05$) (Table 4). Similarly, a significant lower proportion in May and June, in comparison to October, was found for P trophic group.

of BF, especially in the top 20 cm soil layer, regularly ploughed and fertilized by organic matter. The higher abundance of BF was also observed at the depth of 40 cm, although at this soil depth the PP slightly prevailed. The increasing number of BF after application of organic material into the soil was also observed by Liang *et al.* (2001) and Nahar *et al.* (2006) and also by Renčo (2003) in sugar beet fields where soil was regularly ploughed and amended with organic materials. The larger proportion of BF at 20 cm soil depth would indicate that nematodes of this trophic

Table 4. Proportion of nematode trophic group (%) in soil depth of 20 and 40 cm

Soil depth	Trophic group	Month of investigation											
		V		VI		VII		VIII		IX		X	
20 cm	BF	42.9*	a**	42.3	a	47.3	a	50.3	a	47.9	a	53.1	a
	FF	6.3	a	6.4	a	6.8	a	6.4	a	5.7	a	6.1	a
	PP	32.0	a	27.8	a	23.8	ab	18.6	b	19.6	b	18.0	b
	RFF	9.1	ab	10.5	ab	11.9	ab	8.4	a	13.3	b	9.5	ab
	P	1.3	a	2.6	ab	2.1	ab	2.5	ab	3.8	b	3.0	ab
	O	7.7	a	10.0	ab	8.8	ab	13.2	b	9.5	ab	9.9	ab
	IN	0.5	a	0.2	a	0.2	a	0.2	a	0.4	a	0.3	a
40 cm	BF	34.0	a	35.4	a	33.7	a	35.6	a	29.3	a	29.8	a
	FF	6.5	a	8.0	ab	7.3	ab	8.3	ab	11.6	b	6.7	a
	PP	40.3	a	36.3	a	35.8	a	31.4	a	33.0	a	28.7	a
	RFF	6.5	a	7.3	a	9.3	a	10.8	a	7.4	a	9.5	a
	P	2.2	a	2.0	a	3.1	ab	3.1	ab	4.2	ab	5.6	b
	O	9.7	a	10.5	a	10.6	a	10.5	a	13.5	ab	17.5	b
	IN	0.4	a	0.5	a	0.4	a	0.3	a	0.5	a	0.8	a

* Each data is proportion of nematode trophic group on total nematode fauna

** Data flanked in each row by the same letters are not statistically different according to Duncan's Multiple Range Test ($P=0.05$)

BF – bacterial feeders; F- fungal feeders; PP – plant parasite; RFF – root fungal feeders; P – predators; O – omnivores; IN – insect parasite

A significant larger proportion of O trophic group was observed in October in comparison to May, June, July and August, with an increasing tendency from May to October. A similar nematode community structure was recorded by Lišková and Čerevková (2005) in river banks and adjacent meadows, natural ecosystems in Slovak Republic. Freckman and Ettema (1993) recorded, that omnivorous nematodes are very sensitive to agricultural practices. As found by Dabur and Bajaj (2002), populations of omnivorous were significantly larger in non-ploughed than in conventionally ploughed fields. Sánchez-Moreno *et al.* (2006) recorded, that *Discolaimus*, *Prionchulus*, *Mylonchulus* and *Aporcelaimidae* were more abundant in intermittent fallow plots and in deeper soil layers. Similarly, López-Fando & Bello (1995) found that omnivores and predators had greater abundance and diversity in virgin ecosystems than in tilled soil. Although Gupta and Kumar (1998) and Okada and Harada (2007) observed the stimulation of predators by soil organic amendments, in our study the predators represented a small and stable proportion of nematode communities at both soil depths.

This evaluation of nematode trophic structure showed that community of nematodes in hop garden at Nemšová is rich

group contribute to decomposition of cattle manure. This is confirmed by the prevalence of PP on BF in soil with cereals without organic amendment reported by Valocká *et al.* (2001) and Renčo (2003, 2004), and also in soybean fields (Gomes *et al.*, 2003). A similar situation was recorded in ecosystems of vineyards in Austria, in which PP nematodes prevailed, followed by BF, F, O, P and IN (Hoschitz, 2004).

In our hop gardens BF were characterized by prevalence of genera *Rhabditis*, *Cephalobus*, *Eucephalobus* and *Chiloplacus*, PP by prevalence of genera *Heterodera*, *Helicotylenchus*, *Merlinius* and *Paratylenchus* (Table 1, 2). The other trophic groups were mainly represented by the genera *Aphelenchus* and *Nothotylenchus* (FF); *Aglenchus* and *Tylenchus* (RFF); *Aporcelaimellus* and *Eudorylaimus* (O). This situation was similar to that found by Renčo & Valocká (2002), Renčo (2004) and Liang *et al.* (2001) in soil with sugar beet plants; in rhizosphere of cereals grown after sugar beet or peanut fields. The genera *Rhabditis*, *Cephalobus*, *Heterodera*, *Merlinius* and *Aglenchus* at 20 cm soil depth and *Rhabditis*, *Cephalobus*, *Helicotylenchus*, *Heterodera* and *Merlinius* at 40 cm soil depth participated to 50 and 52 % on total nematode abundance, respectively.

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