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Communities of free living and plant parasitic nematodes in hop gardens in Slovakia

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Summary

A total of 61 nematode species belonging into 48 genera was identified in soil of nine localities of hop gardens in Slovakia. From free living soil nematodes the most abundant were the genus *Rhabditis* - eudominant taxon, species *Aphelenchus avenae* – dominant taxon, the species *Cephalobus persegnis*, *Chiloplacus propinquus, Aglenchus agricola, Nothotylenchus acris, Aporcelaimellus obtusicaudatus* and genus *Eudorylaimus* were subdominant taxa. Only ten species of plant parasitic nematodes were observed – *Ditylenchus dipsaci*, *Bitylenchus dubius*, *Merlinius brevidens*, *Rotylenchus robustus*, *Helicotylenchus canadensis*, *H. digonicus*, *Pratylenchus penetrans*, *P. pratensis*, *Heterodera humuli*, and *Paratylenchus bukowinensis*. *Bitylenchus dubius* and *Merlinius brevidens* belonged to dominant taxa, the species *Heterodera humuli* and *Helicotylenchus digonicus* to subdominant taxa. The occurrence of *Heterodera humuli* cysts was recorded at all localities studied, and the occurrence of *H. humuli* larvae in soil during autumn indicates that possibly more than one generation of the parasite have developed within one vegetation period. The proportion of individual trophic groups in nematode communities of hop gardens was characterised by the prevalence of bacterial feeders followed by plant parasites. The ecological characteristics used for ecological evaluation, especially Maturity Index and Plant Parasitic Index/ Maturity Index, indicate a more disturbed environment. Although hop is a perennial plant, the structure and ecology of its nematode communities is more similar to the agricultural ecosystems with a higher level of agricultural practices.

Key words: nematode communities; hop gardens; Slovakia

Introduction

The wild hop, *Humulus lupulus* L., can be found freely in nature; commercial hop cultivars used for beer production are grown in suitable climatic and soil conditions throughout the world. The first records of nematodes in soil of hop fields were associated with the occurrence of *Heterodera humuli* in Germany Voigt (1894) and, subsequently, in England (Percival, 1895). To date, research on nematodes linked with hops had focused mainly on this species - considered to be the dominant parasite of hop. Previous investigations studied the geographical distribution of *H. humuli* e.g. in the Czech Republic (Šály & Kříž, 1961), in Switzerland (Hogger, 1988), in Spain Lopez – Robles (1995), in England (Mende & McNamara (1995a), in Germany (Eppler, 1999), explored the biology and a life cycle of *H. humuli* (Mende & McNamara (1995a,b), pathological effect of *H. humuli* on hop plants connected with different varieties (Mende & Mc. Namara, 1995b; Hafez *et al*., 1999), and nematodes as vectors of plant viruses by e.g. Valdez *et al*. (1974) and Barbez (1982). The other nematodes of the rhizosphere of hop gardens were investigated by Malan *et al*. (1991), Eppler (1999), and Hay and Pethybridge (2003) and others.
In spite of the substantial investigation of communities of free living and plant parasitic nematodes of various agroecosystems and natural ecosystems in Slovakia, no data from hop gardens are available – with the exception of the reports on the occurrence of *H. humuli* in Slovakia by Šály (1983), but with no closer reference to the habitat. Recently, Sturhan and Lišková (2004) observed *H. humuli* on a grassy slope at the edge of a forest with the occurrence of *Urtica* species, known as the host of this nematode species. The objective of the presented work was to determine the structure of nematode communities in specific agroecosystem of hop gardens in Slovakia, focusing on the occurrence of *H. humuli*.

Materials and Methods

The first recorded hop gardens in Slovakia were set up in

1920. In 2001, their area covered 1210 ha (Sasin, 2002). However, hop production during the last five years has been dramatically reduced, and at present, hop gardens cover only 350 ha, concentrated at 13 localities in West Slovakia (Fig. 1). Research on nematode communities has been carried out at 9 localities.

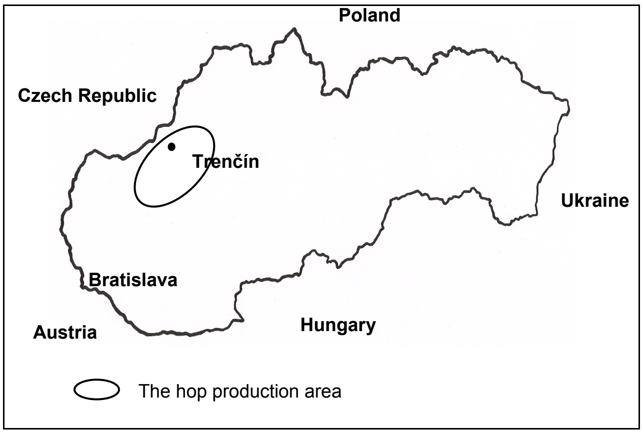

Fig. 1. The hop production area in the Slovak Republic

Climatic and soil characteristics of areas with hop gardens in Slovakia

All nine hop gardens studied are situated in orographic units Trnavská and Nitrianska pahorkatina (upland) and Považské podolie (vale), in warm areas with temperate and moderately humid winters, fog- and wind-free areas, with deep, permeable, loamy, clay loamy or loamy sandy soils, soil type Orthic Luvisol or Eutric Fluvisol with pH 6.5 – 7.5, the level of pH being maintained by regular liming (20t $CaCO_3$/ha) every four years. Hop garden soils are manured every two years (50 – 70t of cattle manure/ha) and fertilised regulary each year - with fertilizer being applied directly to the soil or onto the leaves during vegetation. The investigated localities are at the altitude of 170 – 210 m a.s.l., characterised by annual isotherms of 8.5 – 9.5°C, annual rainfalls of 610 – 680 mm, during the vegetation period with temperatures of 15.5 – 16.0°C and with rainfalls of 350 – 370 mm.

The average soil samples were collected from the rhizosphere of ten hop plants from each locality, from the depth of 20 – 40 cm in July and October 2004. Two sampling dates were used in order to obtain more records of species

Table 1. Specific structure of nematode communities in hop gardens of the Slovak Republic, mean value of taxon abundance in 500 g of soil, dominance and frequency

Nematode species	Mean value X ± S.D	D %	F %
Monhysterida			
Eumonhystera filiformis (Bastian, 1965)	10.2 ± 0.6	0.04	22.2
Araeolaimida			
Anaplectus granulosus (Bastian, 1865)	0.1 ± 0.5	0.02	11.1
Plectus acuminatus Bastian, 1865	1.9 ± 3.6	0.26	44.4
Plectus parietinus Bastian, 1865	1.5 ± 2.9	0.29	33.3
Plectus parvus Bastian, 1865	0.4 ± 1.4	0.08	22.2
Plectus submersus Hirschmann, 1952	0.4 ± 1.6	0.07	11.1
Rhabditida			
Acrobeloides nanus de Man, 1880	7.4 ± 6.8	1.38	88.9
Cephalobus persegnis Bastian, 1865	18.1 ± 11.1	3.34	100.0
Cephalobus parvus Thorne, 1937	1.4 ± 3.0	0.20	22.2
Eucephalobus mucronatus (Kozlowska et Roguska-Wasilewska, 1963)	3.7 ± 5.8	0.68	66.7
Eucephalobus oxyuroides (de Man, 1876)	8.2 ± 8.3	1.51	100.0
Eucephalobus striatus (Bastian, 1865)	9.5 ± 8.4	1.75	100.0
Acrobeles ciliatus Linstow, 1877	1.9 ± 4.6	0.35	44.4
Acrolobus emarginatus (de Man, 1880)	0.8 ± 2.6	0.15	22.2
Chiloplacus propinquus (de Man, 1921)	20.1 ± 21.5	3.71	77.8
Chiloplacus symmetricus (Thorne, 1925)	7.3 ± 13.0	1.35	66.7
Panagrolaimus rigidus (Schneider, 1866)	8.5 ± 9.0	1.57	100.0
Rhabditis juvs.	131.2 ± 206.3	24.21	100.0
Steinernema juvs.	5.9 ± 9.0	1.10	77.8
Aphelenchida			
Aphelenchus avenae Bastian, 1865	33.4 ± 27.3	6.17	100.0
Paraphelenchus pseudoparietinus Micoletzky, 1922	0.7 ± 1.8	0.13	33.3
Aphelenchoides composticola Franklin, 1957	0.6 ± 2.6	0.11	11.1
Aphelenchoides parietinus (Bastian, 1865)	8.0 ± 5.7	1.49	100.0
Aphelenchoides saprophilus Franklin, 1957	1.1 ± 1.8	0.22	44.4
Seinura celeris Hechler in Hechler et Taylor, 1965	1.1 ± 3.2	0.08	11.1

Seinura oxyura (Paesler, 1957)	8.0 ± 13.5	1.49	88.9
Tylenchida			
Psilenchus hilarulus de Man, 1921	1.2 ± 2.7	0.11	44.4
Basiria gracilis (Thorne, 1949)	3.5 ± 6.9	0.65	66.7
Boleodorus thylactus (Thorne, 1941)	1.4 ± 1.8	0.20	88.9
Tylenchus davainei Bastian, 1865	1.5 ± 3.3	0.29	55.6
Malenchus bryophilus (Steiner, 1914)	9.4 ± 9.9	1.73	100.0
Malenchus exiguus (Massey, 1969)	2.7 ± 5.6	0.50	44.4
Aglenchus agricola (de Man, 1884)	16.8 ± 16.7	3.10	100.0
Ditylenchus dipsaci (Kühn, 1857)	0.2 ± 0.5	0.04	22.2
Nothotylenchus acris Thorne, 1941	26.4 ± 35.2	4.67	100.0
Bitylenchus dubius (Bütschli, 1873)	38.9 ± 42.0	7.17	88.9
Merlinius brevidens Siddiqi, 1970	51.9 ± 77.3	9.57	88.9
Rotylenchus robustus (de Man, 1876)	0.3 ± 1.2	0.05	11.1
Helicotylenchus canadensis Waseem, 1961	1.2 ± 3.6	0.23	22.2
Helicotylenchus digonicus Perry in Perry et Darling & Thorne, 1959	11.3 ± 28.7	2.08	77.8
Pratylenchus penetrans (Cobb, 1917) Filipjev et Schuurmans Stekhoven, 1941	1.0 ± 2.3	0.18	55.6
Pratylenchus pratensis (de Man, 1880)	0.7 ± 1.44	0.13	33.3
Heterodera humuli Filipjev, 1934 (juvs. + males)	18.7 ± 22.1	3.44	88.9
Paratylenchus bukowinensis Micoletzky, 1922	5.7 ± 10.6	1.05	88.9
Enoplida			
Prismatolaimus intermedius (Bütschli, 1873)	0.2 ± 0.9	0.04	11.1
Amphidelus coronatus Andrássy, 1957	0.1 ± 0.5	0.02	11.1
Aulolaimus juvs.	0.2 ± 0.7	0.03	11.1
Alaimida			
Alaimus primitivus de Man, 1880	1.7 ± 1.6	0.32	100.0
Mononchida			
Clarkus papillatus (Bastian, 1865)	1.9 ± 4.5	0.36	44.4
Coomansus parvus (de Man, 1880)	0.4 ± 0.8	0.08	55.6
Mononchus juvs.	2.0 ± 3.6	0.26	55.6
Mylonchulus brachyuris (Bütschli, 1873)	2.1 ± 3.7	0.39	55.6
Mylonchulus micrurus (Cobb, 1917) Andrássy, 1958	0.2 ± 0.9	0.04	11.1
Dorylaimida			
Mesodorylaimus bastiani (Bütschli, 1873)	1.8 ± 3.2	0.18	22.2
Aporcelaimellus obtusicaudatus (Bastian, 1865)	20.4 ± 22.7	3.71	88.9
Eudorylaimus leucarti (Bütschli, 1973)	0.3 ± 0.9	0.05	22.2
Eudorylaimus monohystera de Man, 1880	3.8 ± 7.1	1.00	44.4
Eudorylaimus opistohystera (Altherr, 1953)	4.1 ± 10.1	0.61	11.1
Eudorylaimus vulvostriatus (Stefanski, 1924)	1.2 ± 2.9	0.23	22.2
Eudorylaimus juvs.	25.8 ± 16.0	4.76	100.0
Microdorylaimus parvus (de Man, 1880)	0.3 ± 1.2	0.05	11.1
Longidorella microdorus (de Man, 1880)	0.3 ± 1.4	0.06	11.1
Axonchium juvs.	0.3 ± 0.9	0.05	22.2
Oxydirus oxycephalus (de Man, 1885)	0.3 ± 0.7	0.05	33.3
Dorylaimoides micoletzkyi (de Man, 1921)	2.8 ± 4.9	0.52	77.8
Paravulvus hartingii (de Man, 1880)	1.3 ± 3.9	0.19	22.2
Triplonchida			
Diphtherophora communis de Man, 1880	0.5 ± 1.4	0.05	22.2

diversity of nematode communities. Nematodes were isolated from 500 g of mixed soil by using a flotation-sieving method (Cobb, 1918), fixed in FAA (80 parts distilled water, 60 parts 96 % ethanol, 2.4 parts formalin, 1.6 parts acetic acid) (Johansen, 1940) and determined microscopically in permanent glycerine slides. From the soil samples collected in October, the cysts of *Heterodera humuli* were isolated by using the flotation method of Sabová and Valocká, (1980).

The list of identified species, their mean abundance from all nine localities investigated (X ± S.D), dominance (D %) and frequency of the occurrence (F %) is given in Table 1.

The indices used for ecological evaluation of nematode communities are given in Table 2, and they are as follows: number of nematode species, number of nematode genera, Shannon Index of diversity for species (H´spp) and for genera (H´gen) (Shannon & Weaver, 1949), Maturity Index (MI) for nonparasitic nematodes and Plant Parasitic Index (PPI) for plant parasitic nematodes (Bongers, 1990), PPI/MI ratio: Proportion of Plant Parasitic Index to Maturity Index (Bongers & Korthals, 1995), B/F ratio: Proportion of Bacterial Feeders to Fungal Feeders (Wasilewska, 1997). The identified genera were allocated into five trophic groups according to classification of Yeates *et al*. (1993) - bacterial feeders, fungal feeders, plant feeders, omnivores and predators. Besides plant feeders as obligate plant parasites, the other group of root fungal feeders was distinguished as a group which included *Tylenchus* spp. and related species. In addition to these trophic groups, nematodes *Steinernema* spp. - insect parasites were observed.

Table 2. Nematode cummunity structure of hop gardens in the Slovak Republic

Nematodes	Localities									
	Čachtice	Hôrka nad Váhom	Chocholná	Kočovce	Nemšová	Soblahov	Trenčianske Stankovce	Trenčianska Turná	Vrbové	Mean value x ± S.D.
Number of species	25	44	24	38	28	31	34	30	26	31.1 ± 6.6
Number of genera	25	39	24	32	26	29	28	28	25	28.4 ± 4.7
Total abundance	186	692	309	530	1077	609	571	666	236	507.9 ± 321.9
Bacterial feeders %	40.3	28.1	38.0	42.3	65.0	34.4	41.1	28.4	31.1	38.7 ± 11.2
Fungal feeders %	16.1	14.3	13.7	10.7	6.3	11.3	16.4	27.6	25.4	15.8 ± 6.8
Root-fungal feeders %	4.3	4.9	15.5	7.4	6.3	9.3	6.4	4.1	1.7	6.6 ± 4.0
Plant parasitites %	10.5	39.8	19.1	30.2	15.3	27.2	14.5	29.3	19.5	22.8 ± 9.4
Omnivores %	24.2	10.5	13.2	5.7	6.5	13.4	19.1	10.1	21.6	13.8 ± 6.5
Predators %	3.8	0.9	0.5	1.3	0.5	3.7	1.5	0.5	0.2	1.4 ± 1.4
Insect parasites %	0.8	1.1	-	2.5	0.5	0.7	1.0	-	0.6	0.8 ± 0.7
H´spp	2.30	2.65	2.25	2.69	2.66	2.78	2.82	2.45	2.07	2.51 ± 0.26
H´gen	2.34	2.60	2.37	2.43	1.91	2.70	2.63	2.42	2.20	2.40 ± 0.24
MI	2.42	2.29	2.56	1.97	1.49	2.30	2.33	2.12	2.34	2.20 ± 0.31
PPI	2.98	2.81	2.97	2.89	2.91	3.01	2.91	2.93	2.90	2.82 ± 0.43
PPI/MI ratio	1.23	1.22	1.16	1.46	1.95	1.30	1.24	1.38	1.25	1.35 ± 0.30
B/F ratio	2.50	1.96	2.77	3.95	10.31	3.04	2.50	1.01	1.22	3.25 ± 2.79

Results

A total of 61 nematode species from 48 genera were observed in hop gardens in Slovakia. The number of the species varied (24 – 44), genera (24 – 39), abundance of nematodes 186 – 1077 individuals in 500 g of soil within investigated localities. The genus *Rhabditis* is the eudominant taxon, species *Aphelenchus avenae, Bitylenchus dubius* and *Merlinius brevidens* are dominant taxa, species *Cephalobus persegnis*, *Chiloplacus propinguus*, *Aglenchus agricola*, *Nothotylenchus acris, Helicotylenchus digonicus, Heterodera humuli*, *Aporcelaimellus obtusicaudatus* and genus *Eudorylaimus* are subdominant taxa, recendent taxa are the species *Acrobeloides nanus*, *Eucephalobus oxyuroides, E. striatus, Chiloplacus symmetricus, Panagrolaimus rigidus, Aphelenchoides parietinus, Seinura oxyura, Malenchus bryophilus, Paratylenchus bukowinensis, Eudorylaimus monohystera* and genus *Steinernema.* The species *Cephalobus persegnis, Eucephalobus oxyuroides, E. striatus, Panagrolaimus rigidus, Aphelenchus avenae, Aphelenchoides parietinus, Malenchus bryophilus, Aglenchus agricola, Alaimus primitivus* and juveniles of the genus *Rhabditis* and juveniles of the genus *Eudorylaimu*s were observed at all localities investigated.

Nematode communities of hop gardens in Slovakia are characterised by a low number of plant parasitic species, only ten species (16 % from a total number of species) were recorded; *Ditylenchus dipsaci*, *Bitylenchus dubius*, *Merlinius brevidens*, *Rotylenchus robustus*, *Helicotylenchus canadensis*, *H. digonicus*, *Pratylenchus penetrans*, *P. pratensis*, *Heterodera humuli*, and *Paratylenchus bukowinensis*. In spite of the low number of species, the proportion of plant parasitic nematodes within localities was 10 – 40 %, and the species *Bitylenchus dubius* and *Merlinius brevidens* belonged to the most frequent and dominant species of all, followed by free living nematodes of the genus *Rhabditis*. The attention of the investigation was payed to the species *Heterodera humuli* as well. In soil samples collected in July, males were observed at seven localities, with an abundance of 2 – 22 specimens in 500 g of soil and at one locality, besides males, one juvenile (J2) was recorded as well. In October, juveniles occurred (19 – 78 specimens in 500 g of soil), and hereby the cysts of *H. humuli* at all localities were recovered. The number of cysts varied within localities (11 – 33 cysts in 100 g of soil). From other plant parasitic species, *Helicotylenchus digonicus* and *Paratylenchus bukowinensis* were frequent, but both species with fluctuating low population density

within localities. The other plant parasitic species occurred more rarely; longidorid and trichodorid nematodes as potential vectors of plant viruses were not recorded at all.
The dominant trophic group in hop gardens was bacterial feeders. The most abundant was the genus *Rhabditis* followed by the genera *Chiloplacus*, *Cephalobus* and *Eucephalobus.* The proportion of fungal feeders and root fungal feeders varied within localities, most frequent and abundant were the genera *Aphelenchus* and *Nothotylenchus* followed by genus *Aphelenchoides*. From root fungal feeders, most abundant was the genus *Aglenchus.* Besides bacterial feeders, the plant feeders were a group with the highest proportion of all trophic groups. The most abundant were the genera *Merlinius,* and *Bitylenchus.* The proportion of omnivores varied within localities as well and the most frequent and abundant genera were *Eudorylaimus* and *Aporcelaimellus.* A very low proportion of predators was ssociated with a very low abundance at all localities studied.
The H´spp mean value indicated a low species diversity in nematode communities within localities. Similarly, H´gen was compounded with the exception of one locality (Nemšová) only, where H´gen was lower. The Maturity Index MI varied within localities and its lowest value at locality Nemšová reflected a very low proportion of taxa with a high c-p value (persisters) – predators and omnivores and a high proportion of taxa with low c-p value (colonizers), mostly bacterial feeders. The PPI value and ratio PPI/MI was relatively balanced within localities. A substantial variation of B/F ratio has been recorded within localities. The lower B/F ratio value is influenced by the higher proportion of fungal feeders (e.g. localities Trenčianska Turná and Vrbové), the highest BF ratio value e.g at locality Nemšová is inluenced by very high proportion of bacterial feeders in comparison with the other localities.

Discussion

The communities of free living and plant parasitic nematodes of investigated hop gardens are characterised by a lower number of identified taxa, including a lower number of plant parasitic species (10) in comparison with other ecosystems studied in Slovakia. For instance Sabová and Valocká (1977) identified in cereal fields 30 plant parasitic species, Lišková (1977) in vineyards 21 and Lišková and Čerevková (2005) in natural river banks 41 species of plant parasitic nematodes. Hop gardens were characterised by a fluctuating number of identified taxa as well as by fluctuating total abundance of nematodes within localities. Results of the structure of nematode communities from hop gardens resembled the results from sugar beet fields (Renčo & Valocká, 2002), where, similarly, such taxa as *Cephalobus persegnis*, *Chiloplacus symmetricus*, *Rhabditis* spp., *Aphelenchus avenae*, *Bitylenchus dubius*, *Merlinius brevidens, Nothotylenchus acris*, *Aporcelaimellus obtusecaudatus* and *Eudorylaimus* spp. also belonged to the most abundant and the most frequent nematodes. A considerable dissimilartity between sugar beet fields and hop gardens was in a high population density and frequency of *Pratylenchus* spp. in soil with sugar beet; in hop gardens these nematodes were very rare. An entirely different structure of nematode communities has been observed in natural ecosystems in Slovakia, e.g. ecosystem of the river banks vegetation (Lišková & Čerevková, 2005) and natural meadows (Háňel & Čerevková, 2006) in comparison to hop gardens.
The record of the occurrence of *Heterodera humuli* from all localities studied is the first report on this species in Slovak hop gardens. From the occurrence of juveniles in October, it is possible to assume the presence of more than one generation of the parasite during a vegetation period. This is in agreement with the assumption of the development of two or three generations of *H. humuli* in England (Mende & McNamara, 1995a). According to Brown *et al.* (1993) and Hay and Pethybridge (2003), hop has a solid capacity to tolerate nematode feeding, but research by Mende and McNamara (1995b), Hafez *et al.* (1999) and by Hay and Pethybridge (2003) has shown that at high population density of *H. humuli*, when infested plants are under stress from drought or from other pathogens, the high population density can adversely affect losses of hop production. In spite of a low number of plant parasitic species observed in Slovakian hop gardens, population density and frequency of the species *Bitylenchus dubius* and *Merlinius brevidens* was high nearly at all localities and, together with *H. humuli,* these nematodes can be a potential factor negatively influencing hop growing in Slovakia.
The following order of trophic groups was observed – bacterial feeders > plant feeders > fungal feeders > root fungal feeders > omnivores > predators. The dominant trophic group were bacterial feeders with the exception of one locality Hôrka and Váhom, where plant parasites were dominant. The high proportion of bacterial feeders indicates an increase in microbial activity of soil, first of all an increase in nematodes of the genus *Rhabditis*, which are able to multiply in a short time when organic matter is added to the soil (Wasilewska, 1997). Hop gardens investigated were regularly manured with high doses of cattle manure (50 – 70t/ha each second year) and fertilised regularly every year. Similarly, the high proportion of bacterial feeders in sugar beet fields observed by Renčo and Valocká (2002) may also be a result of a high cattle manure supply. The second most abundant trophic group were plant parasites, despite the low number of occurring species. The high proportion of plant parasites is symptomatic for agroecosystems growing one specific host plant for more years, e.g., for *Ditylenchus dipsaci* associated with lucerne (Valocká, 1975), or longidorids with grapevine, fruit, or forest trees (Lišková & Brown, 2003). A higher proportion of fungal feeders was observed in Trenčianska Turná and Vrbové, where slower decomposting processes in heavier clay-loamy soils can be supposed. The proportion of omnivores fluctuated within localities. After Ferris and Ferris (1974) and Wasilewska (1979) this trophic group is considered to be sensitive to management prac-

tices, and the relatively high proportion of omnivores at some localities (indicating more stable ecosystem) is in the contrary with high proportion of plant parasites in hop gardens, because plant parasites indicate more disturbed ecosystem. Similarly, a low proportion of predators indicates a disturbed environment (Yeates & Bird, 1994, Freckman & Ettema, 1993).

The values of H´spp and H´gen indices, are characterised by a low fluctuation within localities, that suggests similar environmental conditions within localities. The low MI value is a reflection of a high proportion of bacterial feeders with c-p value 1 and 2 and a very low proportion of predators with higher c-p value and a higher MI reflects a less disturbed ecosystem (Freckman & Ettema, 1993). Therefore, hop fields with MI 1.5 – 2.6 can be considered as a more disturbed ecosystem than e.g. permanent meadows and pastures with MI 3.4, resp. 3.5 (Čerevková, 2006). According to Bongers *et al.* (1997), the PPI/MI ratio increases gradually from natural undisturbed ecosystems to intensively managed agricultural ecosystems, and in natural habitats, where higher plants make optimal use of nutrient resources, the ratio does not exceed 0.9. Therefore, the PPI/MI ratio with value >1.20 at all localities indicates a more disturbed ecosystem influenced by intensive agricultural practices. The B/F ratio provides information on the dominant way in which the breakdown of organic matter proceeds, i.e. with the participation of bacteria or fungi (Wasilewska, 1997) and a higher value indicates prevalence of decomposting processes. In hop gardens the B/F ratio has a large fluctuation, that considerably depends again on the manure of soil.

This first information about the structure of nematode communities of Slovak hop gardens was based on the current continual investigation of seasonal dynamics of nematodes with particular attention paid to the life cycle and the phytopathological importance of *Heterodera humuli*. The accumulated knowledge extends the understanding of the interactions within nematode communities and soil biota in this specific agroecosystem.

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References

BARBEZ, D. (1982): Bestrijding en controle van brandnetelblad bij hop. *Agricontact,* 118: 1 – 4

BONGERS, T. (1990): The maturity index: an ecological measure of environmental disturbance based on nematode species composition. *Oecologia*, 83: 14 – 19

BONGERS, T., KORTHALS, G. (1995): The behavior of maturity index and plant parasite index under enriched conditions. *Nematologica*, 41: 286

BONGERS, T., VAN DER MEULEN, H., KORTHALS, G. (1997): Inverse relationships between the nematode maturity index and plant parasite index under enriched nutrient conditions. *Appl. Soil Ecol.*, 6: 195 – 199

BROWN, D. J. F., DALMASSO, A., TRUDGILL, D. L. (1993): Nematode Pests of Soft Fruits and Vines. In EVANS, K., TRUDGILL, D.L. & WEBSTER, J.M. (Eds.): *Plant Parasitic Nematodes in Temperate Agriculture*. CAB International, Wallingford, 427 – 462

COBB, N. A. (1918): Estimating the nema population of the soil. *Agric. Tech. Circ. Bur. Pl. Ind. U.S. Dep. Agric*., 1.

ČEREVKOVÁ, A. (2006): Nematode communities in three types of grassland in the Slovak Republic. *Helminthologia*, 43: 171 – 176

EPPLER, A. (1999): Die Fauna des Hopfens. Proceedings 51st international symposium on crop protection, Gent, Belgium. *Universiteit Gent*, 64: 133 – 147

FERRIS, V. R., FERRIS, J. M. (1974): Inter-relationships between nematode and plant communities in agricultural ecosystems. *Agroecosystems*, 1: 275 – 299

FRECKMAN, D.W., ETTEMA, CH.H. (1993): Assessing nematode communities in agroecosystems of varying human intervention. *Agriculture, Ecosystems and Environment*, 45: 239 – 261

HÁŇEL, L., ČEREVKOVÁ, A. (2006): Diversity of soil nematodes in meadows of the White Carpathians. *Helminthologia*, 43: 109 – 116

HAFEZ, S. L., SUNDARARAJ, P., BARBOUR, J. (1999): Impact of *Heterodera humuli* on growth and mineral nutrition composition of hops *Humulus lupulus* cv. Cascade. *Intern. J. Nematol.*, 9: 23 – 26

HAY, F., PETHYBRIDGE, S. (2003): Plant-Parasitic Nematodes Associated with Hop Production in Tasmania, Australia. *J. Phytopathol.*, 151: 369 – 375

HOGGER, C. H. (1988): Plant parasitic nematodes in Swiss hop yeards. *Hopfenrundschau*, 39: 127 – 130

JOHANSEN, D. A. (1940): *Plant microtechnique*. New York & London, McGrow Hill Book Co.

LIŠKOVÁ, M. (1977): *Helminthocenoses of grapevine in East-slovak vineyard areas.* Helmintological Institute of SAS, Košice

LIŠKOVÁ, M., BROWN, D.J.F. (2003): Longidoridae (Nematoda: Dorylaimida) in the Slovak Republic. *Helminthologia*, 40: 165 – 172

LIŠKOVÁ, M., ČEREVKOVÁ, A. (2005): Nematode communities of river banks and adjacent meadows in the Slovak Republic. *Helminthologia*, 42: 223 – 232

LOPEZ-ROBLES, J. (1995): Distribution of *Heterodera humuli* in Spain. *Nematol. medit.*, 23: 73 – 75

MALAN, A. P., PIETERSE, W., BRITIS, G. (1991): Plant-parasitic nematodes associated with hops (*Humulus lupulus* L.) in South Africa. *Phytopathologica*, 23: 173 – 175

MENDE, N. VON, MCNAMARA, D.G. (1995a): Biology of the hop cyst nematode *Heterodera humuli* I. Life cycle and survival. *Ann. Appl. Biol.*, 126: 505 – 516

MENDE, N. VON, MCNAMARA, D.G. (1995b): Biology of the hop cyst nematode *Heterodera humuli* II. Host-parasite relationship of the nematode and its interaction with *Verticillium alboatrum*. *Ann. Appl. Biol.,* 126: 517 – 526

PERCIVAL, J. (1895): An eelworm disease of hops. *Nat.*

Sci, 5: 187 – 197
RENČO, M., VALOCKÁ, B. (2002): Communities of soil and plant nematodes in sugar beet growing areas of the Slovak Republic. *Biologia,* Bratislava, 57: 569 – 573
SABOVÁ, M., VALOCKÁ, B. (1977): *Free living and plant parasitic nematodes from cereal areas of SSR.* Helminthological Institute of SAS, Košice
SABOVÁ, M., VALOCKÁ, B. (1980): Plant parasitic nematodes of cerals in Slovakia. *Poľnohospodárstvo,* 26: 278 – 285
SASIN, A. (2002): *Hop production in Slovakia. 2,* Slovchmeľ Horná Streda, Piešťany
SHANNON, C. E., WEAVER, W. (1949): *The Mathematical Theory of Communication*. Urbana, University of Illinois Press.
STURHAN, D., LIŠKOVÁ, M. (2004): Cyst nematodes in the Slovak Republic. *Helminthologia*, 41: 217 – 219
ŠÁLY, A. (1983): *Free living nematodes in the Slovak Republic. VEDA,* Publishing House of SAS, Bratislava
ŠÁLY, A, KŘÍŽ, J. (1961): Hop cyst nematode – pest of hop. *Chmelařství*, 34: 43
VALDEZ, R. B., MCNAMARA, D. G., ORMEROD, P. J., PITCHER, R. S., TRESH, J. M. (1974): Transmission of the hop strain of arabis mosaic virus by *Xiphinema diversicaudatum. Ann. Appl. Biol.*, 76, 113 – 122
VALOCKÁ, B. (1975): *Helmintocenoses of alfalfa*. Helminthological Institute of SAS, Košice
VOIGT, W. (1894): Neue Varietät des Rübennematoden (*Heterodera schachtii*) S.B. niederrhein. *Ges. Nat. Heilk.*, 51: 94 – 97
WASILEWSKA, L. (1979): The structure and function of soil nematode communities in natural ecosystems and agrocenoses. *Pol. ecol. Stud.*, 5: 97 – 145
WASILEWSKA, L. (1997): Soil invertebrates as bioindicators, with special reference to soil-inhabiting nematodes. *Russ. J. Nematol*., 5: 113 – 126
YEATES, G. W., BONGERS, T., DE GOEDE, R. G. M., FRECKMAN, D. W., GEORGIEVA, S.S. (1993): Feeding habits in soil nematode families and genera – An outline for soil ecologists. *J. Nematol*., 25: 315 – 331
YEATES, G. W., BIRD, A. F. (1994): Some observation on the influence of agricultural practices on the nematode faunae of some South Australian soils. *Fund. Appl. Nematol.*, 17: 133 – 145

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