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THE EFFECT OF EDAPHIC FACTORS ON THE SIMILARITY OF PARASITIC NEMATODES IN THE SOIL SAMPLED IN NURSERIES OF ORNAMENTAL TREES AND SHRUBS

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ABSTRACT

The largest faunistic similarity of nematodes was found in soils sampled in coniferous nurseries where arborvitae (*Thuja occidentalis* – Cupressaceae), spruces (*Picea* spp. – Pinaceae) and pines (*Pinus* spp. – Pinaceae) were grown. In soil sampled from deciduous tree and shrub nurseries, similar species composition of parasitic nematodes was found in stands of oaks (*Quercus* spp. – Fagaceae), black locusts (*Robinia pseudoacacia* – Fabaceae) and maples (*Acer* spp. – Sapindaceae). In soils, especially the light and medium, from stands of coniferous and deciduous trees and shrubs, *Aphelenchus avenae* was often isolated. *Bitylenchus dubius* occurred in both types of nurseries, particularly in light soils. The largest faunistic similarities between nematodes isolated from places of growth of coniferous and deciduous plants were recorded in soils of loamy sand and sandy loam. The most abundant nematode species and the greatest similarity in species of plant parasitic nematodes were observed in soils with neutral pH or slightly acidic. *Aphelenchus avenae* was found in soil samples collected from both coniferous and deciduous plants, with no relation to soil acidity.

Key words: plant parasitic nematodes, ornamental plants nurseries, faunistic similarity

INTRODUCTION

Nursery production of ornamental trees and shrubs in Poland is a relatively new branch of plant production started during the 1990s. Currently, the area occupied by trees and shrubs nurseries in Poland is about 55% of the whole area under ornamental crops (GUS 2012). Soil nematodes as parasites of ornamental plants in nurseries are poorly known group of pests.

In Poland, the study on the plant parasitic nematodes associated with woody plants began Wilski (1960), which reported that nematodes are pests of coniferous trees in forests. Since then, studies on plant parasitic nematodes in forests and forest nurseries were continued by Wasilewska (1969, 1970, 1971) and recently, by Dobies (2004) and Skwiercz (2012). Studies on the plant parasitic nematodes in the soil of nurseries producing trees for plantings in cities was presented by Wolny (1980).

The aim of this work was to evaluate faunistic similarity of plant parasitic nematode communities in soils under cultivation of various groups of trees and shrubs in ornamental nurseries.

MATERIALS AND METHODS

This research was conducted during 2007-2008 in 21 ornamental nurseries located throughout Poland (Table 1). Soil samples were collected from 16 coniferous and 15 deciduous trees and shrubs nurseries. Nomenclature of plant species was given according to the European Nurserystock Association (ENA) standards for the period 2010-2015 (Hoffman 2010). Among the sampled groups, 8 species of coniferous and 26 species of deciduous trees and shrubs were examined (Table 1). Samples were collected at each nursery once during the growing season using a soil core sampler with a diameter of 20 mm. Single soil

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sample taken for nematode analysis was a mixture of 200 g collected from 10 punctures (single puncture was made at a distance of about 50 cm from the trunk to a depth of about 20-30 cm). Procedures based on Flegg's and Baermann's technique, as well as centrifugal flotation method were used for the extraction of nematodes (Brzeski et al. 1976). Nematodes were conserved in a 4-6% formalin solution and permanent slides were made by the lactoglycerol method (Ryss 2003, modified). Specimens were identified using a compound microscope with Nomarski differential interference contrast at a power of up to 1000× magnification. Identified nematode species were classified according to the feeding types (Yeates et al. 1993).

Soil pH was measured according to the potentiometric method (Nowosielski 1988), and the acidity of the soil was classified according to 5-point scale (Starck 1997). To determine the content of sallow parts of the soil, areometric Casagrande method modified by Prószyński was used (Mercik 2002). On the basis of the content of each fraction, soil was classified into granulometric groups according to the BN-78/9180-11 elaborated by the Polish Society of Soil Science, which complies with the United States Department of Agriculture (USDA) classification.

Table 1. List of tree and shrub species grown in soil sampled for nematodes in 2007-2008

Plant name	Latin name of plant	Location (UTM code*)
Yew	*Taxus baccata* L.	DA14, DD75, CA41, CA62, DC96
Juniper	*Juniperus communis* L., *J. chinensis* L., *J. scopulorum* Sarg.	DF22, DA14, CB74, CD30, CC03, CA41, DD75
Arborvitae	*Thuja occidentalis* L.	CA41, CA62, CD30, DA14, XS74, CC28, CC27, CA53
Silver fir	*Abies koreana* Wils., *A. alba* Mill.	CB74, XS74, DD75
European larch	*Larix decidua* Mill.	XS73
Pine	*Pinus aristata* Engelm., *P. mugo* Turra, *P. nigra* Arn., *P. sylvestris* L.	CC27, DA14, CA53, CC28, CB63, CA62, DC94, DF22
Spruce	*Picea abies* (L.), *P. omorica* (Pančić) Purk., *P. pungens* Engelm	CC03, CC27, CD30, DD75, CA53, CB63, CA62,
Birch	*Betula pendula* Roth., *B. utilis*	XS73, XT49, DC96, DF22
Alder	*Alnus glutinosa* Gaertn.	XT49
Beech	*Fagus sylvatica* L.	DF22, CA53, XT49, DD75, DC96, CA41
Oak	*Quercus robur* L., *Q. rubra* L.	XT49, CA62, CD30
Hornbeam	*Carpinus betulus* L.	DF22, CA62, CD30, DF22
Gleditsia	*Gleditsia triacanthos* L.	CD30
Black locust	*Robinia pseudoacacia* L.	DC88, XT49, DC94, CD30, DF22, CA41
Ash	*Fraxinus excelsior* L.	XS73, DC88
Chestnut	*Aesculus hippocastanum* L.	CA62, XT49, EB79
Maple	*Acer negundo* L., *A. pseudoplatanus* L., *A. platanoides* L., *A. rubrum* L.	DF22, DC88, XT49, DD75, CA62, CD30, DF22, CA41
Lime	*Tilia* × *europaea* L., *T. cordata* Mill., *T. caucasica* Rupr., *T. platyphyllos* L., *T. tomentosa* Moench	DC88, XS73, XT49, DF22, CA41, DF22,
Plane tree	*Platanus* × *hispanica*	CA41, CA62
Elm	*Ulmus glabra*, *Ulmus* × *hollandica*	DC88, EB79, DC96, CA41
Willow	*Salix alba* L., *Salix* × *sepulcralis*	XT49, DC96
Rose	*Rosa canina* L.	CD15
prune	*Prunus cerasus* L., *P. pumila* L., *P. serrulata* L.	XS73, DF22, CA62
Ninebark	*Physocarpus opulifolius* L.	DC96
Rowan	*Sorbus aucuparia* L., *S.intermedia* (Ehrh.), *S.* × *thuringiaca* Fritsch	DC88, XT49, XS73, EB79, CA62, DC96

*Universal Transverse Mercator coordinate system

Analyses were based on 18402 individuals representing 139 species of plant parasitic nematodes, extracted from 291 soil samples. In samples taken from ornamental coniferous plants, 6082 individuals belonging to 105 species of nematodes were identified, whereas in samples taken from deciduous trees and shrubs – 12320 individuals belonging to 120 species were identified. The faunistic similarity of plant parasitic nematode communities was evaluated according to 5-point scale (Czachorowski 2006). To compare the nematode faunistic similarities and selected edaphic factors, qualitative data were analysed using Jaccard's formula (1912).

RESULTS

The similarity of parasitic nematode groups depending on the host plants

The coefficient of faunistic similarity of plant parasitic nematode species between the coniferous and deciduous trees and shrubs was 51% and indicated a very high affinity.

The composition of plant parasitic nematode species present in the soil taken from conifers was the most similar between pines and junipers, for which the coefficient of faunistic similarity was over 40%. *Pratylenchus neglectus*, *Rotylenchus robustus*, *Mesocriconema xenoplax* and *Trichodorus primitivus*, known as harmful species, were present in soil taken from rhizosphere of both these conifers. In addition, *P. fallax*, *Helicotylenchus pseudorobustus*, *Paratylenchus nanus* and *Bitylenchus dubius* were also found in large numbers. A similar nematode species composition was observed in the soil sampled from pines, spruces and arborvitae rhizosphere, and the coefficient of faunistic similarity for soils under these crops fluctuated between 32.0 and 37.7%. In the soil of those three coniferous species, the potentially harmful species of nematodes were *P. crenatus*, *R. robustus*, *P. projectus*, *Paratrichodorus pachydermus* and also *H. pseudorobustus*, *P. nanus* and *B. dubius*. Nematode species composition noted in the vicinity of arborvitae was similar to that found in soil sampled from the place of grow of yew and junipers, i.e. species of the genus *Rotylenchus*, such as *R. robustus* and *R. pumilus*. The most unspecific nematode composition was found in the soil from around European larch, for which faunistic similarity coefficients ranged from 10.2 to 12.2%, when compared with soil environments of other plants (Table 2).

In soils sampled from nurseries of deciduous trees and shrubs, the highest coefficient of faunistic similarity (above 35%) was found for maples and black locust as well as for chestnut and oaks rhizosphere (Table 4). Among nematode species known as harmful to plants, in soil sampled from around maples and black locust were found *P. penetrans*, *P. neglectus*, *H. digonicus*, *H. pseudorobustus*, *R. robustus*, *P. projectus*, *P. bukowinensis* and *T. viruliferus*. In soil samples taken from around maples and chestnut species, such nematodes as *P. crenatus*, *M. xenoplax*, *P. projectus* and *T. viruliferus* were present. Nematodes *P. penetrans*, *P. neglectus*, *H. digonicus* and *T. viruliferus* were noted in soil samples taken from rhizosphere of maples and oaks. In addition, *Cephalenchus hexalineatus* was recorded in samples of soil taken in the vicinity of maples, oaks and black locust.

The coefficient of faunistic similarity of nematodes was also high (above 30%) for samples of soil taken from around oaks and birches as well as rowans and hornbeam rhizosphere (Table 4). Nematode *M. curvatum*, were present in the soil sampled from around oaks and hornbeam. Near oaks and birches, *H. digonicus*, *P. fallax*, *P. thornei*, *C. hexalineatus* and *B. dubius* were found. Species such as *P. neglectus*, *H. digonicus*, *M. curvatum*, *Trichodorus* sp., *P. fallax*, *P. thornei*, *C. hexalineatus* and *B. dubius* were observed in soils sampled from the place of growth oaks and rowans. In soil sampled from black locust and rowans rhizosphere, *P. neglectus*, *P. flakkensis*, *P. thornei*, *H. digonicus* and *C. hexalineatus* were present (Table 4).

The most similar nematode species composition was recorded in the vicinity of black locust, maples, oaks and rowans (Table 4), even though these trees belongs to a different botanical family. *P. neglectus*, *P. thornei*, *H. hexalineatus* and *C. digonicus* were present in each sample taken from around these trees.

Table 2. Coefficients of nematodes faunistic similarity (%) in soils from coniferous nurseries, according to host plant genus

Plant	*Taxus*	*Juniperus*	*Abies*	*Larix*	*Pinus*	*Picea*
Juniperus	24.6*	-				
Abies	22.0	13.6	-			
Larix	10.8	12.2	11.1	-		
Pinus	29.3	43.5	19.3	10.2	-	
Picea	22.4	28.0	28.6	10.9	37.7	-
Thuja	30.4	36.8	25.3	11.3	32.0	37.5

*The coefficient of faunistic similarity value: very high >30%, high 25-30%, medium 20-25%, low 10-20%, very low <10%

Table 3. Coefficients of nematodes faunistic similarity (%) in soils from coniferous and deciduous plant nurseries, according to soil acidity (pH)

Soils	very acid (pH < 4.5)	acid (pH 4.5-5.5)		slightly acid (pH 5.6-6.5)	
	deciduous	coniferous	deciduous	coniferous	deciduous
acid (pH 4.6-5.5)	24.6*	-	-		
slightly acid (pH 5.6-6.5)	32.0	15.4*	41.0	-	-
neutral (pH 6.6-7.2)	28.8	13.2	38.1	8.6	32.9

*see explanation for Table 2

Table 4. Coefficients of nematodes faunistic similarity (%) in soils from rhizosphere of deciduous plants belonging to families: *Fabaceae*, *Fagaceae*, *Sapindaceae*, *Betulaceae*, *Rosaceae*, according to host plant

Plant	*Fabaceae*		*Sapindaceae*		*Fagaceae*		*Betulaceae*			*Rosaceae*		
	Robinia	*Gledit-sia*	*Acer*	*Aescu-lus*	*Quer-cus*	*Fagus*	*Alnus*	*Carpinus*	*Betula*	*Rosa*	*Physo-carpus*	*Sor-bus*
Gleditsia	13.0*	-										
Acer	35.5	22.4	-									
Aesculus	21.8	22.9	33.9	-								
Quercus	25.5	25.0	38.5	27.9	-							
Fagus	22.2	19.2	12.5	21.0	16.2	-						
Alnus	7.5	18.7	10.9	6.2	19.2	4.8	-					
Carpinus	21.6	15.1	22.8	23.3	38.9	24.2	11.5	-				
Betula	21.8	19.4	27.1	28.9	30.9	17.9	13.3	26.2	-			
Rosa	21.4	28.6	13.5	16.7	18.2	15.4	5.9	8.8	20.0	-		
Physocarpus	11.1	18.2	11.5	24.2	22.6	20.8	6.2	16.1	13.9	19.0	-	
Sorbus	31.1	21.7	29.4	26.8	33.3	20.4	9.3	22.2	26.8	17.0	22.7	-
Prunus	10.6	16.7	13.2	13.2	21.2	14.8	5.6	15.1	13.2	17.4	18.2	14.3

*see explanation for Table 2

Table 5. Coefficients of nematodes faunistic similarity (%) in soils from coniferous and deciduous plant nurseries, according to soil category

Soils	Sand			Loamy sand			Sandy loam			Sandy clay loam			Silt loam
	c/d**	c	d	c/d	c	d	c/d	c	d	c/d	c	d	c/d
Sand	14.7*	-	-	-									
Loamy sand	-	39.2	25.8	35.9	-	-	-	-	-	-	-	-	-
Sandy loam		28.7	29.1	-	31.3	52.9	36.4	-	-	-	-	-	-
Sandy clay loam		8.9	10.3	-	7.4	36.5	-	9.8	7.9	22.6	-	-	-
Silt loam		19.0	16.7	-	20.0	35.9	-	20.3	30.9	-	20.0	12.5	12.0

*The coefficient of faunistic similarity value: very high >30%, high 25-30%, medium 20-25%, low 10-20%, very low <10%
**c = coniferous plants; d = deciduous plants

The similarity of parasitic nematode groups, depending on the soil category

In samples from the same agronomic categories of soil, the coefficient of faunistic similarity of nematode communities between samples taken from rhizosphere of coniferous and deciduous trees and shrubs was high only in the case of loamy sand and sandy loam soils (Table 5).

In soil samples taken from around coniferous plants, the coefficient of faunistic similarity of nematodes was almost 40% between the sand and loamy sand soils (Table 5). Plant nematodes known as harmful, i.e. *P. neglectus*, *P. projectus*, *P. pachydermus* and *P. teres* were found in both types of the soil. In addition, *P. fallax*, *H. pseudorobustus*, *H. varicaudatus*, *P. nanus*, *C. hexalineatus* and *dubius* were also recorded in a large number. High similarity in species composition of parasitic nematodes was also found in sandy loam and loamy sand soils (Table 5). Equally, in these soil categories some species of nematodes known as harmful for plants were found: *P. neglectus*, *P. projectus* and *P. bukowinensis*, as well as species of nematodes, which affect plants when are present in large numbers, such as *P. fallax*, *H. pseudorobustus*, *H. varicaudatus*, *P. nanus*, *C. hexalineatus* and *B. dubius*.

The similarity of the nematode species composition in soils sampled from around trees and shrubs were very high, exceeding 50%, between sandy loam and loamy sand soils (Table 5). Among nematodes known as harmful to plants, in both types of these soils were species from the genus *Pratylenchus* (*i.e. P. crenatus*, *P. fallax*, *P. flakkensis*, *P. neglectus*, *P. penetrans*, *P. pratensis* and, *P. thornei*), as well as *H. digonicus*, *R. robustus*, *M. xenoplax*, *P. projectus*, *P. bukowinensis* and *Trichodorus* sp. In both soil categories *Longidorus leptocephalus*, *P. nanus*, *C. hexalineatus* and *B. dubius* were also recorded.

A high faunistic similarity coefficient was found in growth places of ornamental trees and shrubs in loamy sand, sandy clay loam and silt loam soils (Table 5). *P. crenatus*, *P. fallax*, *P. neglectus*, *P. penetrans*, *P. thornei*, *H. digonicus* and *R. robustus* were among economically most important species of nematodes, which were found in all of these three categories of soil.

The similarity of parasitic nematode groups, depending on the soil acidity

The similarity of the nematode communities from nurseries of coniferous and deciduous trees and shrubs, present in soils of the same pH was high only for acidic soils (40.3%) and significantly lower for slightly acidic (18.6%) and neutral (15.4%) soils (data not shown).

The coefficient of faunistic similarity of nematodes in the acidic, slightly acidic and neutral soil did not exceed 20%. For slightly acidic and neutral soils faunistic similarity coefficients of nematode species composition showed significant difference and its value was less than 9% (Table 3), which means that in coniferous nurseries, soil pH had a significant impact on the nematode species composition.

Faunistic similarity between all soils sampled from deciduous trees and shrubs nurseries with respect to the soil acidity was high. Most similar nematode species composition was found in the acidic and slightly acidic soils and was recorded at the level exceeding 40%. The most distinctive species composition occurred in very acidic soils (Table 3). Among the harmful plant nematodes, both for slightly acidic and acid soils *P. neglectus*, *M. curvatum*, *M. xenoplax*, *P. projectus*, *P. bukowinensis* and *T. viruliferus* were recorded. In addition, other parasitic species – *P. fallax*, *P. thornei*, *H. varicaudatus*, *C. hexalineatus* and *B. dubius* were found. *P. neglectus*, *P. thornei* and *C. hexalineatus* were recorded in soil samples collected from the place of growth of deciduous plants, independently from soil type and pH of the soil. *Aphelenchus avenae* was commonly observed in soil sampled from both coniferous and deciduous ornamental plants, regardless of the soil acidity.

DISCUSSION

Our results concerning *A. avenae* are in agreement with data obtained earlier. This nematode was present in the soil taken from rhizosphere of the same plant species growing in forests and ornamental nurseries (Dobies 2004), in nurseries producing trees for plantings in cities (Wolny 1980), and in nurseries of ornamental coniferous plants (Mancini et al. 1981).

Slightly less common than *A. avenae*, was *B. dubius* often observed in the circumference of both types of plants. Our results confirm data obtained in forest nurseries in Poland by Dobies (2004) and Skwiercz (2012).

In our study, *H. digonicus* was more strongly associated with deciduous plants than with conifers. This nematode has already been noted in nurseries producing trees for planting in cities (Wolny 1980) and in forestry nurseries (Wasilewska 1969). Studies of Skwiercz (2012) and Dobies (2004) show that in forestry nurseries *H. digonicus* does not occur frequently, however in fruit nurseries it was more numerous (Szczygieł & Zepp 2004).

Our results indicate that *R. robustus* was associated with coniferous plants. It is known as abundant in coniferous nurseries (Mancini et al. 1981; Dobies 2004; Skwiercz 2012), but also in the orchards (Szczygieł & Zepp 2004) and in nurseries producing trees for plantings in cities (Wolny 1980). A harmfulness of *R. robustus* to the root system of coniferous seedlings was documented by Boag (1982).

The majority of parasitic nematode species was noted in the environment of loamy sand and sandy loam, hence high similarity of nematode communities in a vicinity of coniferous and deciduous trees and shrubs grown in these soils were observed. A large number of nematode species was recorded in light soils and depended on the soil parameters. In sandy soils, empty spaces between particles allow for nematodes movement and water penetration which promotes their occurrence (Wallace 1963) and spread (Wallace 1971). However, *A. avenae* from rhizosphere of coniferous and deciduous plants often appeared in both loamy sand and sandy loam soils, whereas *B. dubius* often occurred in loamy sand soils only. *P. crenatus* and *P. bukowinensis* were often present in the coniferous nurseries on sandy soils, whereas *C. hexalineatus* was more frequent in deciduous trees and shrubs nurseries. In sandy loam soils where coniferous plants were grown, *H. pseudorobustus* and *R. robustus* were common, but in deciduous trees and shrubs nurseries *H. digonicus* was frequently found.

The association between the presence of nematodes and soil acidity was described by Burns (1971) and Norton and Hoffmann (1974). The slightly acidic and neutral soils were the richest in nematode species and the species composition was similar in soils of both levels of acidity. In soils of this acidity, *H. digonicus* was the most frequent species, mainly in deciduous trees and shrubs nurseries. In slightly acidic soils in coniferous nurseries the most frequent were *B. dubius* and *A. avenae*, and in neutral soil – *C. hexalineatus*. In slightly acidic and neutral soils more frequently occurred *H. digonicus*. This dependence was also reported by Szczygieł and Zepp (2004) as well as Brzeski (1969). Observations on the occurrence of *B. dubius* in lower acidity soils were in agreement with other research results (Szczygieł & Zepp 2004; Brzeski 1969), although this species was also observed in alkaline soils (Dmowska 2001).

In this study *A. avenae* was recorded in soils of both coniferous and deciduous tree and shrub nurseries of various pH, while in earlier studies it was found in the forests, where the soil was acidic

(Háněl 1996), in acidic soils in fruit plant nurseries (Szczygieł et al. 1969) and in the field, where soil pH ranged from 5.0-7.0 (Domurat 1970) or even in the ash dumps with the pH at the range of 7.8-8.9 (Dmowska 2001). The results of Dmowska (2001) study provide evidence that *A. avenae* is more tolerant for high pH than most of other nematodes and plays an important role in reclamation of degraded soils.

CONCLUSIONS

1. The largest similarity of plant parasitic nematodes is for arborvitae, spruce and pine rhizosphere in coniferous nurseries, and for oak, locust and maple rhizosphere in deciduous trees nurseries.
2. The most commonly nematode species in nurseries are *Aphelenchus avenae* independently of edaphic factors.
3. The most abundant plant parasitic nematodes are in the sandy loam and loamy sand, as well as in slightly acidic or neutral soils.

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