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OCCURRENCE OF *PHYTOPHTHORA* SPP. IN DECIDUOUS TREES IN LITHUANIA: FIRST RESULTS

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The occurrence of alien invasive species of *Phytophthora* genus on deciduous trees was surveyed in 17 districts of Lithuania. 261 trees from 14 genus and 22 species with typical to *Phytophthora* genus disturbance symptoms in city greeneries, parks, and forests were documented. The highest percentage of disturbed trees was observed between *Acer* (52%) and *Alnus* (16%), while *Tilia* was acknowledged as the most resistant deciduous genus in Lithuania. More than a half of documented trees were young individuals (52%). The young trees typically grow nearby the water sources, while the number of premature and mature diseased trees is stable or tend to increase altogether with the distance to water source. The small bleeding spots on stem is the typical disturbance symptom of young trees, while the large bleeding spots and bark cracks are the characteristic symptoms of premature and mature trees ($p<0.00$).

Key words: alien invasive species, bleeding cancer, deciduous trees, Lithuania, *Phytophthora* genus.

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INTRODUCTION

Phytophthora is a genus of plant-damaging Oomycetes fungi, which are capable of causing enormous economic losses on crops, as well as environmental damage in natural ecosystems. The *Phytophthora* became widely known after 1875, when the new pathogen – agent of potato blight disease was identified (Bourke 1991). In response to the Irish potato famine the plant pathology was birthed (Erwin & Ribeiro 2005).

So far, more than 100 *Phytophthora* species have been described, and it is likely that worldwide 200-600 species exist being still unknown to science (Brasier 2009). In 1999, eleven of ca. 55 known species (20%) were considered to be damaging to forests and natural ecosystems. However, this proportion changed drastically after the year 2000 and the number of recognized potentially tree damaging species increased up to 60% (Brasier 2009). It was proven that decline and die-off of many forest tree species in Europe and other continents was connected with pathogenic *Phytophthora* spp. activity as a primary factor (Erwin & Ribeiro 2005, Jung et al. 2009a). Therefore, it is an urgent need to assess the spread of *Phytophthora* species on the spatial scale and among different host trees

in Lithuania. Three *Phytophthora* species have been identified on rhododendrons in Lithuania: *P. citricola* in 2002, *P. cactorum* in 2004, and *P. ramorum* (Jovaišienė 2004, Jovaišienė & 2006). However, the spatial spread of identified *Phytophthora* species was not assessed at all. The authors are not aware on any investigations concerning *Phytopohthora* in natural ecosystems in Lithuania.

The aim of the study was to assess the occurrence of alien invasive genus *Phytophthora* on deciduous trees in city greeneries, parks, and forests in Lithuania. Moreover, the most sensitive and resistant tree genus was determined and the occurrence of *Phytophthora* spp. disturbed trees in different regions of Lithuania was analysed.

MATERIAL AND METHODS

Territory of Lithuania is located between maritime and continental climate zones of middle latitude. Average year temperature in Lithuania is +6.1°C (-4.9°C in January and +17.0°C in July) (Bukantis 1994). Territory of Lithuania, according to the differences in climate character, is divided into four main regions: Western, Northern, Southern, and Eastern Lithuania (Fig. 1).

Western region is characterized with the mildest maritime climate conditions: highest amount of precipitation per year (up to 930 mm), warmest winters (temperature of January -2.8°C). The smallest amount of precipitation (520-620 mm per year) is typical for the North Lithuania. Warmer winters and summers than those in the North and East are characteristic for the South Lithuania. The most continental climate conditions with the shortest period of vegetation (185-192 days) and coldest winters (-5.0 to -6.8°C) are characteristic for the East Lithuania.

Deciduous trees infected by *Phytophthora* spp. were surveyed in 17 districts of Lithuania: city parks and greeneries altogether with natural ecosystems in forests, floodplain and riverbank sites. The fieldwork was carried out during summers and autumns of 2011-2014; several sites were surveyed at least two times. Trees in each

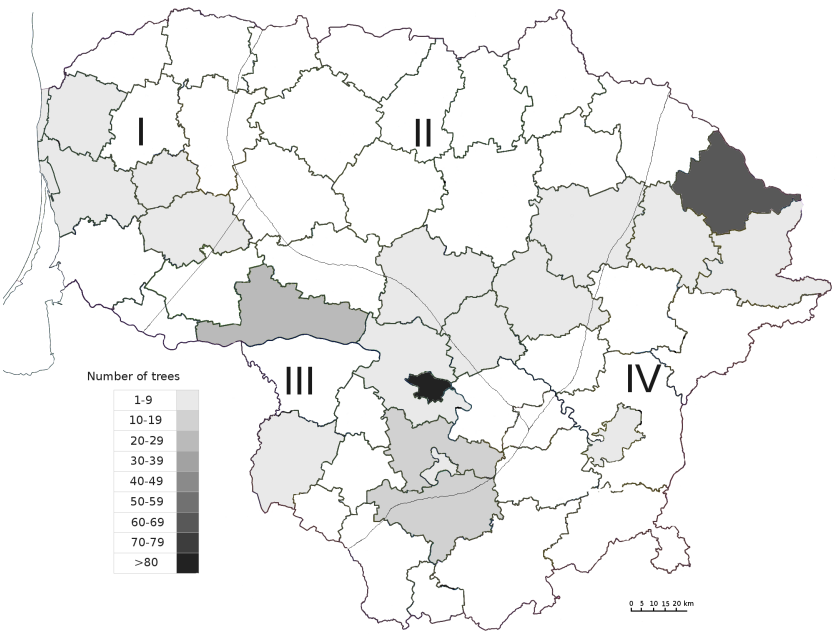

Fig. 1. The number of *Phytophthora* spp. disturbed trees in different districts and climate regions of Lithuania, 2010–2014. I – Western, II – Northern, III – Southern, and IV – Eastern. The white colour indicates the districts, which were not surveyed.

Table 1. The list of disturbed tree genera by *Phytophthora* spp. in surveyed districts in Lithuania, 2010–2014

District	No. of sites	Tree genus	No of trees
Alytus	4	Ac, Ae, Al, Be, Po, Qu, Sa	13
Anykščiai	2	Ae, Po, Ul	4
Birštonas	1	Ac	4
Ignalina	3	Al, Be, Qu	4
Jonava	1	Ac	3
Jurbarkas	5	Ac, Ae, Be, Fr, Qu, Sa, Ti	24
Kėdainiai	1	Al	8
Kaunas	13	Ac, Ae, Al, Be, Ca, Mo, Po, Pr, Qu, Sa, Ti	88
Klaipėda	3	Ac, Be	5
Kretinga	1	Ac	7
Palanga	2	Ac, Ae	4
Prienai	2	Ac, Al, Pr	18
Ukmergė	1	Be	1
Rietavas	1	Ac	1
Šilalė	1	Ac	2
Šventoji	1	Al	6
Utena	3	Ac, Al, Be, Sa	6
Vilkaviškis	1	Al	1
Vilnius	1	Ae	1
Zarasai	4	Ac, Ae, Al, Co, Po, Ul	61

site were examined for symptoms of bleeding cancer: tarry or rusty spots on the surface of bark, exudates in bark cracks or fissures with characteristic lesions, and flame-shaped necrosis on collars (Černy & Strnadova 2010). The sites with excessive soil moisture, which are favourable to genus of *Phytophthora* were observed in thoroughly. The following characteristics for disturbed trees were documented: tree genus and species, visual age of trees (young, premature, and mature), distance to water source (>10 m, 11-50 m, and >51 m), and disturbance symptoms (number and size of rusty and necrosis, bark cracks or fissures). GPS coordinates for each tree, whenever available, were determined using a Magellan Triton 1500 unit, equipped with external antenna (data available under request). The statistical calculations and significance tests (t-test for independent samples) were performed using Statistica 6 (Statsoft Inc., Tulsa).

RESULTS

The number of trees disturbed by genus of *Phytophthora* in surveyed districts of Lithuania altogether with climate regions are shown in Fig. 1 and Table 1.

Four districts, Jurbarkas, Prienai, Alytus, Zarasai districts and Kaunas City, are characterized by the highest number of disturbed trees (from 13 to 88). These regions belong to the Southern and Eastern regions of Lithuania. In 51 sites, trees with infection signs to *Phytophthora* genus fungi were documented; disturbance was not observed in six sites (not included into Table 1, comprising 88% and 12% respectively). The number of studied sites in each district varied from one to 13 and the documented number of disturbed trees from one to 88. Each site yielded on average 13 disturbed trees. At most, 11 host tree genera were found in one district.

Table 2. The percentage of disturbed deciduous trees by *Phytophthora* spp. within different age categories and distance to water source

Age of trees	Distance to water source, meters		
	<10	11-50	>51
Young	61	45	37
Premature	6	14	29
Mature	32	40	34

Table 3. The percentage of disturbed deciduous trees according to age categories and type of disturbance

Age of trees	Type of disturbance		
	Small bleeding spots	Large bleeding spots	Bleeding stem cracks
Young	76	29	22
Premature	12	14	31
Mature	12	57	47

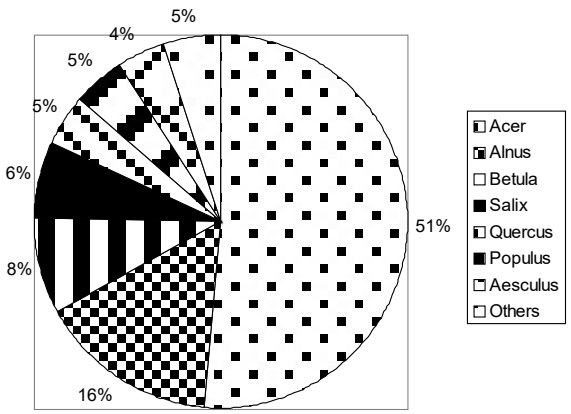

Fig. 2. The host deciduous tree genera of *Phytophthora* spp. in Lithuania, 2010–2014.

The percentage of disturbed trees by *Phytophthora* spp in each genus is presented in Fig. 2.

Totally, 261 trees from 14 genus and 22 species with typical disturbance symptoms to *Phytophthora* genus (bleeding bark cancers) were documented: *Acer* (*A. ginalla*, *A. platanoides*, *A. pseudoplatanus*) – 52%, *Alnus glutinosa* – 16%, *Betula pendula* – 8%, *Salix* (*S. alba*, *S. caprea*) – 5%, *Quercus* (*Q. robur*, *Q. rubra*) – 5%, *Populus* (*P.* x *canescens*, *P. nigra*, *P. tremula*) – 5%, *Aesculus hippocastanum* – 4%, *Prunus* (*P. avium*, *P. serotina*) – 1%, *Morus nigra* – 1%, *Tilia* (*T. cordata*, *T. platyphyllos*) – 1%, *Ulmus glabra* – 1%, and *Carpinus betulus, Fraxinus excelsior*, *Corylus avellana* <1%).

The young, premature, and mature trees comprise to 52%, 14% and 33%, respectively. More than a half of trees in less than 10 m distances from the water source were young individuals, and their number decreases, while the distance from the water source increases (Table 2).

The inverse tendency is typical for premature trees, while the number of mature trees was not related to the distance to water source. The differences between the number of young vs premature and mature trees within 10 meters distance from the water source were statistically significant (p=0.00-0.05). The differences in 11-50 and >51 m distance to water source are significant only between young and mature trees (p=0.00). The following bark disturbance symptoms were documented: tarry or rusty spots of exudates on bark, flame-shaped collar necrosis, bleeding bark cracks and fissure usually several metres length. The rusty spots are of variable size. The small bleeding spots on stem are the typical disturbance symptom of young trees (Table 3) in comparison to premature and mature trees (p<0.00).

The bleeding bark cracks are the most typical symptom of premature trees, while large bleeding spots and bleeding stem cracks predominated among mature trees. However, the differences

are not statistically significant due to a smaller number of documented trees (p=0.10-0.67).

Several sites were tested twice, and the rapid spread of *Phytophthora* infection among trees growing besides from summers to autumns of 2011-2014 was documented. For example, in Kaunas Vydūno av. one diseased maple was documented on 25th of May and other five maples growing beside started to demonstrate the infection on bark on 31st of October. The similar results were obtained also in Balbieriškis and Jurbarkas Parks.

DISCUSSION

The number of disturbed trees by *Phytophthora* spp. is variable across Lithuania (Figure 1, Table 1). The districts with the highest number of diseased trees are located in Southern and Eastern regions of Lithuania. The excess soil moisture and abundant precipitation are acknowledged to be the most important natural factors increasing severity and spread of *Phytophthora* diseases (Erwin & Ribeiro 2005). Hence, the highest spread of *Phytophthora* spp. infection in trees in Southern and Eastern Lithuania cannot be explained by favourable climatic conditions because the highest amount of precipitation is characteristic for Western Lithuania. It is evident that the second half of summers in 2011, which favoured the spread of *Phytophthora* spp. The amount of precipitation felt in Kaunas during July-September exceeded the long-term average for 72%, 81%, and 34% respectively.

The cardinal temperatures favourable to the growth of invasive alien *Phytophthora* spp. ranges from +3-4°C to +30°C and above, and is species-specific (Erwin & Ribeiro 2005). Hence, the global climate change by extending the length of the vegetation period increases the spread of *Phytophthora* genus (Thorain et al. 2007, Brasier 2003).

The study has shown that the young deciduous trees are more vulnerable to infection of *Phytophthora* genus, and they develop the visual symptoms of infection quicker in comparison to premature and mature trees. This is in accordance to (Tsao 1990), who stated that even decades are needed until a mature tree produces the visible disturbance symptoms.

The symptoms of *Phytophthora* genus infection were documented on 14 deciduous tree genera in Lithuania (Fig. 2). The most common host genera are *Acer* and *Alnus*, comprising 67% from the all diseased trees. The *Tilia* genus is common in greeneries in Lithuania. However, only two trees were documented with infection of *Phytophthora* spp. Hence, it could be considered as comparatively resistant deciduous tree genera to the infection of *Phytophthora* genus in Lithuania at present.

The disturbed trees were found in the majority of investigated sites (88%), indicating that infection of *Phytophthora* genus is spread across Lithuania disturbing trees in sites with water flooding and increased soil moisture. The number of disturbed trees in each site is variable, even if the favourable conditions for fungi altogether with sensitive tree genera exist. We hypothesize, that it could be because of the infection caused by different *Phytophthora* species, the different amount of pathogen in rhizosphere or invasion time into an investigated site. The first assumption cannot be validated because the identification of *Phytophthora* species was not performed in Lithuania. On the other hand, it is obvious that the *Phytophthora* alien fungi have invaded into Lithuania at least decades ago because the long time is needed until a mature tree produce the visible declining symptoms (Tsao 1990).

The list of *Phytophthora* species observed in Europe on a host tree genera documented in Lithuania is given below.

P. alni ssp. *Alni – Alnus* (Černy & Strnadova 2010, Cerny et al. 2007).
P. alni ssp. *multiformis – Alnus* (Jung et al. 2009b).
P. cactorum – Acer, *Aesculus*, *Alnus*, *Betula*, *Corylus*, *Fraxinus*, *Populus*, *Prunus*, *Quercus*, and *Tilia* (Erwin & Ribeiro 2005, Jung et al.

2009a, Jung et al. 2009b, Rytkonen et al. 2009, Cerny et al. 2008, Orlikowski et al. 2011).
P. cambivora – Acer, *Aesculus*, *Alnus*, *Quercus*, and *Tilia* (Erwin & Ribeiro 2005, Brasier 2003, Jung et al. 2009b, Orlikowski et al. 2002, Stepniewska et al. 2008).
P. cinnamomi – Quercus (Brasier 2003).
P. citricola – Acer, *Aesculus*, *Alnus*, *Betula*, *Corylus*, *Fraxinus*, *Quercus*, and *Tilia* (Erwin & Ribeiro 2005, Jung et al. 2009a, Jung et al. 2009b, Brasier 2003, Orlikowski et al. 2011, Szabo & Lakatos 2009, Orlikowski et al. 2004).
P. europae – Quercus (Jung et al. 2002).
P. gonapodyides – Acer, *Alnus*, *Betula*, *Fraxinus*, *Quercus*, and *Tilia* (Erwin & Ribeiro 2005, Jung et al. 2009a, Jung et al. 2009b, Orlikowski et al. 2011, Szabo & Lakatos 2009).
P. hungarica – Alnus (Szabo & Lakatos 2009).
P. innundata – Alnus, *Aesculus*, and *Salix* (Szabo & Lakatos 2009, Brasier & Jung 2003).
P. kernoviae – Aesculus and *Quercus* (Fera … 2010a, Brasier et al. 2005).
P. polonica – Alnus (Belbahri et al. 2006).
P. megasperma – Aesculus and *Alnus* (Erwin & Ribeiro 2005, Szabo & Lakatos 2009).
P. pluvivora – Fraxinus and *Quercus* (Orlikowski et al. 2011, Jung et al. 1999).
P. pseudosyringae – Alnus, *Carpinus*, *Quercus*, and *Tilia* (Jung et al. 2009a, Jung et al. 2003, Denman et al. 2009).
P. psychrophila – Quercus (Jung et al. 2002).
P. quercina – Alnus and *Quercus* (Jung et al. 2002, Jung et al. 1999, Jönsson et al. 2005).
P. ramorum – Acer, *Aesculus*, *Betula*, *Fraxinus*, *Quercus*, and *Salix* (Jung et al. 2009a, Fera … 2010b, Orlikowski 2005).
P. syringae – Acer, *Aesculus*, *Alnus*, *Prunus*, *Quercus*, and *Tilia* (Erwin & Ribeiro 2005, Jung et al. 2009a, Jung et al. 2009b).
P. uliginosa – Quercus (Jung et al. 2002).

In Europe, the highest number of *Phytophthora* species was observed on *Quercus* and *Alnus* genera – 12–14 species; *Acer*, *Betula*, *Aesculus*, *Tilia*, and *Fraxinus* were infected by 4-8 species; *Salix*, *Populus*, *Prunus*, *Carpinus*, and *Corylus* – 1-2 taxa, respectively. For genus of *Ulmus* and *Morus* no data of documented species of *Phytophthora* in Europe are available. In Lithuania, alder is one of the most sensitive to *Phytophthora* spp. tree genera at present. Hence, it might be supposed that *P. alni* – the main parasite of alder trees is overspread in riparian ecosystems of Lithuania.

In Poland, at least 17 species of *Phytophthora* genus have been recorded until 2009 (Ptaszek et al. 2009). At least, eleven invasive species have been documented on trees: *P. quercina* in *Quercus* (Jung et al. 2002), *P. cambivora – Acer*, *Quercus*, and *Fagus* (Orlikowski et al. 2002, Stepniewska et al. 2008, Jung et al. 1999), *P. citricola – Fraxinus* (Orlikowski et al. 2004), *P. cactorum – Fraxinus* and *Quercus* (Orlikowski et al. 2011, Jung et al. 1999), *P. plurivora – Fraxinus*, *Fagus*, and *Quercus* (Orlikowski et al. 2011, Jung et al. 1999), *P. gonapodyides – Fraxinus* (Orlikowski et al. 2011), *P. uliginosa – Quercus* and *Fagus* (Jung et al. 2002), *P. alni* subs. *alni* and *P. alni* subsp. *multiformis – Alnus* (Jung et al. 2011, Evans & Oszako 2007), *P. polonica – Alnus* (Belbahri et al. 2006), *P. hungarica – Alnus* (Jung et al. 2011).

Assuming the similar climate conditions in Poland and in Lithuania and intensive trade of plants between both countries, which allows the spread of alien pathogens over the long distances (Jung et al. 2009a, Evans & Ribeiro 2007), it could be supposed that at least 5–10 *Phytophthora* species are widespread in trees in natural ecosystems of Lithuania. Therefore, it is an urgent need to identify the up most spread *Phytophthora* species in Lithuania. This will enable to answer the several questions: (i) why *Tilia* genus is comparatively resistant to *Phytophthora* fungi infection in Lithuania. The finding not supported in other countries and (i) to forecast the further spreading of the infection of *Phytophthora* alien species in natural ecosystems.

CONCLUSIONS

261 deciduous trees representing 14 genus and 22 species with symptoms of *Phytophthora* spp. infection have been documented in Lithuania during year 2011–2014. More than a half of documented trees were young individuals

(52%) growing nearby the water sources, while the number of premature and mature hosts increases altogether with the distance to water source. The highest percentage of disturbed trees was observed between *Acer* (52%) and *Alnus* (16%) genus. *Tilia* is widespread in greeneries in Lithuania, but was acknowledged to be the most resistant deciduous tree genus. The typical disturbance symptom of young trees is small bleeding spots on stem in comparison to premature and mature trees, where large bleeding spots and bark cracks predominate.

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