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PREVALENCE AND DIVERSITY OF UREDINALES FUNGI AT URBAN GREENERIES IN LITHUANIA

Antanina Stankevičienė
Kaunas Botanical Garden of Vytautas Magnus University, Lithuania
antanina.stankeviciene@vdu.lt

Abstract
Woody plants at urban greeneries in Lithuania are injured by rust fungi of 13 genera, 28 species: *Coleosporium pulsatillae*, *C. tussilaginis*, *Cronartium flaccidum*, *C. ribicola*, *Cumminsiella mirabilissima*, *Gymnosporangium clavariiforme*, *G. confusum*, *G. cornutum*, *G. sabinae*, *G. tremelloides*, *Hyalopsora aspidiotus, M. allii-fragilis*, *M. allii-populina*, *M. caprearum, M. epitea*, *M. laricis-populina*, *M. populnea*, *Melampsora ribesii-viminalis*, *M. salicis-albae*, *Melampsorella caryophyllacearum*, *Melampsoridium betulinum*, *M. carpini*, *Ochropsora ariae*, *Phragmidium tuberculatum*, *Pucciniastrum areolatum*, *P. symphyti*, *Uromyces caraganicola*, *U. pisi-sativi*. During 2009 – 2017 *Gymnosporangium sabine* had the strongest damages (from 0.21 ± 0.00 to 2.43 ± 0.33 grades) on *Pyrus pyreaster,* the weakest damages had done *G. cornutum* on *Sorbus intermedia* and *S. x thuringiaca* 'Fastigiata' – 0 – 1 ± 0.58 grades.
Key words: woody plants, *Uredinales* fungi, urban greenery, Lithuania.

Introduction

Green areas are an important component of urban areas. The basic requirements for greeneries are durability and longevity. In order to achieve this, it is necessary to know the principles of greeneries design and choices of plant assortment (Januškevičius & Navys, 2012). For formation process, it is important not only to correctly assess plant compositions but also evaluate their ecological, biological properties (Jakovlevas-Mateckis, 2003). Since January 1st 2008 in Lithuania the law on Gardening came into force (2008.01.14, Nr.D1-31). In its program 'On monitoring the status of green areas and green plantations', there were provided tasks and solution tools for data and other information collection on green areas and plantations in the territories assigned to municipalities in order to properly assess, predict and manage their status (Order …, 2008). It is a part of the work to preserve and develop (introduce) new greeneries in cities, to maintain them as aesthetically, ecologically, historically important elements of the landscape, to form a full-fledged system of green areas (Grikevičius, 2009). These studies accumulate data on a spread of different groups of pathogens.

One of the most commonly occurring plant pathogens are obligately parasitic, host-specialized rust fungi of the order *Uredinales* in the *Basidiomycota*. They cause premature defoliation, sprouts deformation, ruin cone seeds (*Pucciniastrum areolatum* (Fr.) G.H. Otth.), provoke sprouts densification (*Melampsorella caryophyllaceaerum* (Link) Schroet), etc. Their cognition has a theoretical and practical significance (Minkevičius & Ignatavičiūtė, 1991). Studies on these fungi in Lithuania began at the beginning of the 19th century and consistently – 20th century (Minkevičius & Ignatavičiūtė, 1991). During 1937 – 1984 there were described 250 fungi species (Minkevičiaus & Ignatavičiūtė, 1991; 1993). Subsequently, additional researches were carried out and a monograph "Mycota Lithuania, Uredinales" (1, 2 parts) (Minkevičius & Ignatavičiūtė, 1991; 1993) prepared.

Evolution life cycles of *Uredinales* consist of several sporefication stages, which, for the most part, are passed through on plants belonging to two different taxonomic groups (pleomorphism). The complete sporefication cycle consists of five life stages, at which spores are formed: spermagonia (small spore deposits), aecia (aeciospores accumulation, dry, light yellow to orange, wind-dispersed), uredinia (uredioniospores accumulation, dry, orange to rust-colored or purplish, wind-dispersed), telia (teliospores accumulation, vary greatly in color, from dark brown and light brown, not dispersed or are dispersed only short distances), basidiospores (sprout after the rest period from teliospores). Some of rust fungi species pass all five stages – macrocyclic, if telia stage is missed – demicyclic etc. (Minkevičius & Ignatavičiūtė, 1991). Damp and warm climate intensifies rust fungi development.

Aim of the work: to describe the variety and damage intensity of *Uredinales* fungi in Lithuanian city urban greeneries.

Materials and Methods

In order to systematize previous studies of *Uredinales* fungi in Lithuania, a retrospective analysis of literature sources was performed: using an online access for accumulated literature in Phytopathology group in Kaunas Botanical Garden of Vytautas Magnus University.

In order to determine the prevalence of *Uredinales* fungi, in 2009 – 2017, the monitoring of plant status in recreational plantations in Lithuania was carried out, taking an example of Alytus and Kaunas cities. These cities have a rich plant variety in their greeneries: woody plants to be observed in Alytus – 4040 (57

genera, 98 species, 30 cultivars) and in Kaunas, the second largest city of Lithuania – 2 441 (52 genera, 79 species, 19 cultivars) (according http://aplinkosauga.alytus.lt/documents/78415/113236/Alytus_%20zeldynu%20stebesena_2017.pdf; www.kaunas.lt/wp-content/uploads/sites/13/2015/04/Kaunas_stebesena_2017-ATASKAITA.pdf,). The monitoring was carried out annually from July to August. The plant names were described according to M. Griffiths (1997). Rust has damaged 10 genera, 15 species and 2 cultivars plants in recreational urban greeneries.

Uredinales fungi were identified visually, according to disease symptoms and disease agents – fungi morphological features, using binocular lupus. Other species fungi were identified by microscoping in accordance to characterizers, according to descriptors: A. Minkevičius & M. Ignatavičiūtė (1991, 1993), W. A. Sinclair & H. H. Lyon (2005), L. Orlikowski & A. Wojdyla (2010). Fungal names are described in accordance with generally accepted (interactive) code *Index fungorum* (http://www.indexfungorum), the climate conditions in Lithuania are described according to: http://www.meteo.lt/, and optimal condition for fungi development – according to W. A. Sinclair & H. H. Lyon (2005).

Rust fungi damage intensity was evaluated in grades in a 0 – 4 grade system: 0 grades – injured less than 10% of plant leaves; 1 grade – injured 11 – 30% of leaves; 2 grades – injured 31 – 60%; 3 – injured 61 – 80%, plant dries noticeably; 4 grades – injured more than 81% of plant surface, plant dries (Juronis, Snieškienė & Žeimavičius, 1999).

Disease intensity (average grade of damage) calculated using the formula:

$$V = \frac{\Sigma(n \times b)}{N} \quad (1)$$

where V – average grade of damage, $\Sigma(n \cdot b)$ – the sum of multiplications of equally injured (in grades) plant numbers and injury value, N – the number of valuated plants.

Results and Discussion

Literature analysis ascertains woody plants in Lithuania to be injured by fungi of 13 genera, 28 species, among them fungi of 11 genera, 23 species of macrocyclic development stage and 1 genus, 5 species of demicyclic stage (Table 1)

During the years 2009 – 2017 status monitoring of urban greeneries ascertained the spread and

Table 1

***Uredinales* fungi diversity on woody plants in city greeneries in Lithuania, 2009 – 2017**

Rust fungi species, developmental cycle: * macrocyclic, ** demicyclic	Host plants (developmental stage: spermagonia, aecia)	Host plants (developmental stage: uredinia, telia)	References
Coleosporium pulsatillae (F. Strauss) Fr.*	*Pinus sylvestris, P. mugo*	*Pulsatilla* Mill.	Minkevičius & Ignatavičiūtė, 1991
C. tussilaginis (Pers.) Lév. *	*Pinus* L.	*Tussilago* L.	
	Pinus sylvestris L., *P. mugo* Turra	*Senecio* L.	
Cronartium flaccidum (Alb. et Schw.) Wint.*	*Pinus sylvestris* L.	*Paeonia* L., *Asclepias* L., *Pedicularis* L. ir kt.	Minkevičius & Ignatavičiūtė, 1991
C. ribicola J.C. Fisch. *	*Pinus strobus* L.	*Ribes* L.	Minkevičius & Ignatavičiūtė, 1991; Grigaliūnaitė, 2011; Snieškienė & Stankevičienė, 2013; Stankevičienė 2016; Žiogas *et al.*, 2008
Cumminsiella mirabilissima (Peck) Nannf.*	*Malonia aquifolium* Nutt.	*Malonia aquifolium* Nutt.	Minkevičius & Ignatavičiūtė, 1991
Gymnosporangium clavariiforme (Wulfen) DC **	*Amelancher* Medik., *Crataegus* L., *Pyrus* L., *Sorbus* L.	*Juniperus* L.	Minkevičius & Ignatavičiūtė, 1991
G. confusum Plowr. **	*Cotoneaster* Medik., *Crataegus* L., *Cydonia* Mill., *Pyrus* L.	*Juniperus* L.	Grigaliūnaitė, 2011
G. cornutum Arthur ex F. Kern (=*G. juniperi*) **	*Amelanchier* Medik., *Sorbus* L.	*Juniperus* L.	Minkevičius & Ignatavičiūtė, 1991; Grigaliūnaitė, Meškauskienė, & Matelis, 2006; Snieškienė & Stankevičienė, 2013

Rust fungi species, developmental cycle: * macrocyclic, ** demicyclic	Host plants (developmental stage: spermagonia, aecia)	Host plants (developmental stage: uredinia, telia)	References
G. sabine (Dicks.) G. Winter. **	*Pyrus* L.	*Juniperus sabina* L.	Minkevičius & Ignatavičiūtė, 1991; Grigaliūnaitė, 2011; Grigaliūnaitė & Matelis, 2014; Nekrošienė, 2006; Stankevičienė, 2016
G. tremelloides R. Hartig **	*Malus* Mill., *Pyrus* L., *Sorbus* L.	*Juniperus* L.	Minkevičius & Ignatavičiūtė, 1991
Hyalopsora aspidiotus (Peck) Magnus*	*Abies alba* Mill. *A. balsamea* (L.) Mill.	*Gymnocarpium dryopteris* (L.) New.	Minkevičius & Ignatavičiūtė, 1991
Melampsora allii-fragilis Kleb.*	*Allium* L.	*Salix fragilis* L., *S. pentandra* L.	Minkevičius & Ignatavičiūtė, 1991
M. allii-populina Kleb.*	*Allium* L.	*Populus balsaminifera* L., *P.*x *canadensis* Moench, *P. nigra* L.	Minkevičius & Ignatavičiūtė, 1991; Stankevičienė & Snieškienė, 2012
M. caprearum Thüm. * (=*M. larici-caprearum*)	*Larix* Mill.	*Salix* L., *S. caprea* L.	Minkevičius & Ignatavičiūtė, 1991
M. epitea Thüm. * (=*M. laricis-epitea*)	*Larix* Mill.	*Salix* L., *Salix fragilis* L.	Minkevičius & Ignatavičiūtė, 1991
M. laricis-populina Kleb. *	*Larix decidua* Mill.	*Populus nigra* L., *P.*x *canadensis* Moench, *P. suaveolens* Fisch.	Minkevičius & Ignatavičiūtė, 1991; Grigaliūnaitė, 2011; Grigaliūnaitė, Meškauskienė, & Matelis, 2007; Snieškienė & Stankevičienė, 2013; Stankevičienė, 2014
M. populnea (Pers.) P. Karst.* (=*M. laricis-tremulae*; *M. pinitorqua*)	*Larix decidua* Mill.	*Populus alba* L., *P. tremula* L., *P. balsaminifera* L.	Minkevičius & Ignatavičiūtė, 1991
	Pinus contorta, *P. mugo* Turra, *P. sylvestris* L.	*Populus alba* L., *P. tremula* L.	Žiogas *et al*., 2008, 2006
M. ribesii-viminalis Kleb.**	Ribes *L.*	*Salix viminalis* L.	Grigaliūnaitė, Matelis, & Stackevičienė, 2009
M. salicis-albae Kleb. *	*Allium* L.	*Salix alba* L., *S. fragilis* L.	Minkevičius & Ignatavičiūtė, 1991
Melampsorella caryophyllacearum (DC.) J. Schröt. *	*Abies* Mill.	*Cariophyllaceae*: *Agrostema* L., *Arenaria* L.	Minkevičius & Ignatavičiūtė, 1991
Melampsoridium betulinum (Pers.) Kleb.*	*Larix* Mill.	*Betula* L.	Minkevičius & Ignatavičiūtė, 1991
M. carpini (Nees) Dietel*	*Larix* Mill.	*Carpinus* L., *Corylus* L.	Minkevičius & Ignatavičiūtė, 1991
Ochropsora ariae (Fuckel) Ramsb.*	*Anemone* L.	*Malus* Mill., *Pyrus* L., *Sorbus* L.	Minkevičius & Ignatavičiūtė, 1991
Phragmidium tuberculatum J. Müll. *	*Rosa* cult.	*Rosa* L.	Minkevičius & Ignatavičiūtė, 1991; Grigaliūnaitė, 2011
Pucciniastrum areolatum (Fr.) G. H. Otth * (=*Thekopsora areolata*)	*Picea abies* (L.) H. Karst.	*Padus avium* Mill., *Prunus* L., *Cerasus* Mill.	Minkevičius & Ignatavičiūtė, 1991
P. symphyti (DC.) McKenzie & Padamsee (=*M. symphyti*)*	*Abies alba* Mill.	*Symphytum* L.	Minkevičius & Ignatavičiūtė, 1991
Uromyces caraganicola Henn.*	*Euphorbia* L.	*Caragana arborescens* Fabr.	Minkevičius & Ignatavičiūtė, 1991
U. pisi-sativi (Pers.) Liro (= *U. laburni*)*	*Euphorbia* L.	*Laburnum anagyroides* Med.	Minkevičius & Ignatavičiūtė, 1991

diversity of currently most prevalent rust fungi in urban greeneries (Table 2). During the monitoring of green plantations, it was determined that rust fungi belonging to 5 genera, 11 species in various intensity have injured woody plants of 10 genera, 15 species and 2 cultivars in recreational urban greeneries.

Fungi rust agents mostly common in Lithuania are *Gymnosporangium sabinae*, *G. cornutum*

Table 2

The diversity and violation intensity of rust fungi in urban greeneries in Lithuania, 2017

Rust fungi species / Host plants species, number of investigated plants								
Average damage grade / Years								
2009	2010	2011	2012	2013	2014	2015	2016	2017
Cronartium flaccidum (Alb. & Schwein.) G. Winter. / *Pinus sylvestris* L., 25								
						0.01±0.04	0	0
C. ribicola J. C. Fisch. / *Pinus strobus* L., 9								
	0	0	1±0.36	1.15±0.14	0	1.25±0.14	1±0.36	
Gymnosporangium clavariiforme Dietel. / *Crataegus monogyna* Jacq. 68								
0	0	0	0.56±0.06	0.9±0.38	2±0.3	1.18±0.49	1.18±0.49	2±0.17
G. confusum Plowr. / *Juniperus sabina* L., 43								
			0.03±0.1	0.03±0.1	0.03±0.1	0.03±0.1		
G. cornutum Arthur ex F. Kern. / *Sorbus intermedia* (Ehrh), 51								
0.09±0.58		0	0	1±0.58	0.01±0.5	1±0.58	0.01±0.5	
G. cornutum Arthur ex F. Kern. / *Sorbus x thuringiaca* 'Fastigiata', 12								
0	0	0	0	1±0.58	0	1±0.58		
G. sabine (Dicks.) G. Winter / *Pyrus pyraster* Rehder, 7								
0.21±0.00	2.11±0.0	0.5±0.00	1.5±0.00	1.03±0.00	1.03±0.00	2.43±0.33	1.1±0.0	1±0.00
Melampsora caprearum Thüm. / *Salix alba* 'Tristis', 98								
			1±0.00	1±0.24	0.5±0.25	1±0.00		
M. caprearum Thüm. / *Salix caprea* L., 57								
0.4±0.01	2±0.01	2±0.01	1±0.01	1.1±0.01	1.1±0.01	2±0.01	0.1±0.01	0.01±0.01
M. epitea Thüm. / *Salix fragilis* L., 2								
0.7±0.37	0.03±0.37	0.4±0.37	0.9±0.37	0±0.37	1±0.37	0.09±0.37	1±0.37	0
M. laricis-populina Kleb. / *Populus x berolinensis* Dipp. 10								
0	1.15±0.17	1.23±0.57	1±0.37	1±0.37	1±0.65	2.16±0.17	0.01±0.37	
M. laricis-populina Kleb. / *Populus* x *canadensis* Moench, 62								
2±0.48	2±0.48	0	0	1.13±0.24		0.01±0.14		
Melapsoridium betulinum (Pers.) Kleb. / *Betula pendula* Roth, 508.								
0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0	0.01±0.01	0,03±0.01	0	0
M. betulinum (Pers.) Kleb. / *Larix decidua* Mill., 68								
0.02±0.01	0.01±0.01	0.03±0.01	0.03±0.01	0.02±0.14	0.02±0.01	0	0.01±0.1	0.1±0.1
Phragmidium tuberculatum Jul. Müll. / *Rosa canina* L., 4								
0	2±0.10	0.85±0.10	1.14±0.27	1±1.12	0.01±0.29	0.01±0.04	0.01±0.29	

(=*G. juniperi*) and *G. clavariiforme*. Optimal development for fungi is wet weather in spring and wet, dry weather with temperatures of 18 – 21 °C in summers. During the research period, plants of 4 species were injured by various grades (from 0 to 2.43 ± 0.33 grades) (Table 2). *G. sabine* common in Lithuania, during all these years injured *Pyrus pyreaster*. Fungi of these species hibernate in the tissue of *Juniperus commmunis*, begins to develop in spring, when humidity occurs, at the temperature of 10 – 30° (Labanowski *et al.*, 2001). During the research period *Gymnosporangium cornutum* (=*G. juniperi*) had the smallest damage on *Sorbus intermedia*, *S. x thuringiaca* 'Fastigiata'. In 2010 and 2017, no injuries of this rust were located, and a stronger damage was noticed on *S.x thuringiaca* 'Fastigiata' in 2013, 2015 (1 ± 0.58) (Table 2).

Melampsora spp. is a fungus cosmopolitan (Sinclair & Lyon, 2005). About 27 species of *Melampsora* genus fungi is being taken into account in Lithuania. They are morphologically similar, and therefore host plants are often regarded for their identification (Minkevičius & Ignatavičiūtė, 1991). We managed to detect 3 species on plants of 5 species (Table 2). Young (up to 10 years) pine trees at arboretums are often injured by *M. populnea* (=*M. pinitorqua*). *Pinus contorta* is often injured but more rarely *P. sylvestris, P. mugo*. Their sprouts are distorted in "S" shape. Failed to detect this rust, as it is a disease spreading in arboretums, especially if *Populus* spp., *P. tremula* is

in vicinity, part of the development of fungus passes on it.

Cronartium ribicola is widespread in Lithuania on *Pinus flexilis* James, *P. strobus* L., *P. sibirica* (Rupr.) Mayer etc.). Fungus develops most favorably at the end of summer with wet weather, temperatures not exceeding 20 °C.

During the research period *P. strobus* was injured most in 2015 (1.25 ± 0.14 grades). In order to limit the spread of this dangerous disease, *P. flexilis*, *P. strobus*, *P. sibirica* should not be taken to grow near currants (*Ribes* L.), which are the only interim host plants of this rust. In 2015, on thickened, bumpy branches of *P. sylvestris* L. was detected *Cronartium flaccidum*. *Paeonia* L. plants were detected to be growing nearby, whose leaves have dried up yet in July (uredinia, telia develope on them).

Melampsoridium betulinum spread on *Larix decidua* aside them grow young *Betula pendula*. It carries a lot harm in arboretum. In spring on the bottom side of *Larix* spikes form orange in color aecia and *Betula* is spread over with aeciospores. In summer, orange urediniospores develop on the bottom side of birch leaves Uredinia developed within 13 – 14 days at 12 °C, and they were killed by exposure to 30 °C for 6 hours. In the hot, dry summer of 2015, this rust was hardly detected.

Disease damaged spikes dry, fall before time (Snieškienė, 2015). During research *Melampsoridium betulinum* was found on both plant species (Table 2).

Phragmidium tuberculatum had the strongest damage on *Rosa canina* in 2010 (2 ± 0.10). The most favorable conditions to spread are at frequent wet periods and temperatures of 18 – 21 °C in summer.

In order to limit the spread of fungus, a proper plant arrangement is required. Plants, which are common hosts of development of fungi – disease agents should be planted away from each other. Fallen leaves in autumn should be collected and together with damaged parts of the tree should be dug deep or burned.

Uredinales fungi develop more intensely under humid and warm weather condition (Sinclair & Lyon, 2005). As the development stages, development time and optimal condition for development of these fungi differ; therefore, we cannot determine the general conclusion for them all.

Conclusions

1. Woody plants in Lithuania in urban greeneries are injured by rust fungi of 13 genera, 28 species. The largest variety is of *Melampsora* genus (8 species): *M. allii-fragilis* Kleb., *M. allii-populina* Kleb., *M. caprearum* Thüm., *M. epitea* Thüm., *M. laricis-populina* Kleb., *M. populnea* (Pers.) P. Karst., *M. ribesii-viminalis* Kleb., *M. salicis-albae* Kleb. and *Gymnosporangium* (5): *G. clavariiforme* (Wulfen) DC, *G. confusum* Plowr., *G. cornutum* Arthur ex F. Kern., *G. sabinae* (Dicks.) G. Winter., *G. tremelloides* R. Hartig.
2. According to the data of monitoring during 2009 – 2017, woody plants in urban greeneries in Lithuania are injured by rust fungi of 5 genera, 11 species. They have injured plants of 10 genera, 15 species and 2 cultivars on various intensity. The strongest damage (from 0.21 ± 0.00 to 2.43 ± 0.33 grades) *Gymnosporangium sabine* (Dicks.) G. Winter) was on *Pyrus pyreaster* Rehder, the weakest influence had *Gymnosporangium cornutum* Arthur ex F. Kern on *Sorbus intermedia* (Ehrh) Pers.) and *S. x thuringiaca* 'Fastigiata' – 0 – 1 ± 0.58 grades.

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