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Review

GYMNOSPORANGIUM SPECIES — AN IMPORTANT ISSUE OF PLANT PROTECTION

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*Rusts (*Fungi, Basidiomycota, Pucciniomycotina, Pucciniomycetes, Pucciniales*) are one of the most important causal agents of diseases and they are infecting many plants including cereals and field crops, vegetables, trees and many ornamentals. They have been studied for a long time and have economic importance among the plant diseases caused by agents of different species of fungi. In Europe, thirteen rust genera have been reported, of which the genus* Gymnosporangium *is the second largest after genus* Phragmidium*. The most significant fruit tree rust pathogen is the genus* Gymnosporangium*. The literature review shows quite limited scientific information about this genus and its species. Studies have mainly focused on some stages of the pathogen development cycle, which are significant for the spread of diseases — uredo and teleito stages. Special attention of the review was paid to European pear rust (caused by* G. sabinae *(Dicks.) G. Winter), the distribution of which has increased during the last ten years, especially in organic pear orchards. Currently there is a limited number of scientific publications about European pear rust, and they are mainly based only on observations* in vitro *without trials in the field, despite the fact that it has become one of the most devastating diseases. Therefore, the presented review analyses the rust exploration history, diversity and distribution of species, life cycle, development biology and plant protection issues.*

Key words: *plant disease, rusts, pear, species, life cycle.*

INTRODUCTION

Rusts (*Fungi, Basidiomycota, Pucciniomycotina, Pucciniomycetes, Pucciniales*) are one of the most important causal agents of diseases and are infecting many plants including grain and field crops, vegetables, fruit trees and many ornamentals (Cummins and Hiratsuka, 2003). Rusts as plant diseases have been studied for a long time and they have economical importance among the plant diseases caused by agents of different species of fungi. The rust fungi belong to one of the largest groups of *Basidiomycota* — the order *Pucciniales*, family *Pucciniaceae.* Worldwide are described nearly 8000 species, 150 genera and 13 families of rust fungi (Aime, 2006; Toome and Aime, 2012). Rust causing pathogens are biotrophic fungi or obligate parasites of plants (for successful development of their life cycle they need only a living plant) (Deacon, 2006). In contrast to saprophytic pathogens, rusts pathogens feed and develop on plants without killing them.

The rust pathogens significant for fruit trees belong to genus *Gymnosporangium* (Helfer, 2005), which mostly affects the plants of *Cupressaceae* — cypress (*Cupressus*) and junipers (*Juniperus*) and *Rosaceae* — hawthorns (*Crataegus*), apples (*Malus*), pears (*Pyrus*), quinces (*Cydonia*), shadberries (*Amelanchier*) and rowan (*Sorbus*) (Kern, 1911; Dodge, 1915). More than a half (54%) of *Rosaceae* species plants are highly susceptibile to rust fungi (Helfer, 2005).

Gymnosporangium are unique rust fungi, which telia stage developes only on the gymnosperms (Aime, 2006). Pathogens of *Gymnosporangium* develop the aecia stage on the *Rosaceae* host (secondary or alternate host) and the telia stage on cedars and junipers (primary or telia host) (Kern, 1911; Helfer, 2005). The most common worldwide distributed diseases caused by *Gymnosporangium* species are cedar apple rust (caused by *G. juniperi-virginianae* Schwein.), Japanese pear rust (*G. asiaticum* Miyabe ex G. Yamada) (Cummins and Hiratsuka, 2003) and European pear rust (*G. sabinae* (Dicks.) G. Winter), the distribution of which has significantly increased during the last years, especially in organic pear orchards (Fillip *et al.*, 2012; Kellerhals *et al.*, 2012).

RESEARCH HISTORY

Different rust diseases have been mentioned already in documents of the ancient world. In the notes of Aristotle (384–322 BC) and Theophrastus (371–287 BC) the rust of cereals was mentioned, and the ancient Romans adored rust God Robigo (Kolmer *et al.*, 2009; Sharma, 2014). They were recognised as plant diseases and pathogens only in 1767, by Italian natural scientists Felice Fontana and Targioni-Tozzetti, who investigated and described the morphology of teliospores and urediniospores (Ainsworth, 1981). The name of rust fungi was introduced due to the orange color of spore masses, which can be observed on the infected plants (Kolmer *et al.*, 2009).

The genus *Gymnosporangium* also has been studied for a very long time, e.g. already in the 18th century scientists payed attention to fungal diseases on junipers. The first study about the genus *Gymnosporangium* focused on the telia stage on *Juniperus communis* and it was published by C. Linnaeus (Linnaeus, 1753). In 1785, J. J. Dickson published description of *Tremella sabinae* (the synonym of *Gymnosporangium sabinae*) (Belomesyatseva, 2004), while A. P. De Kandolle (1805) in the mycological literature described the *Gymnosporangium* genus, reporting three species — *G. fuscum* DC., *G. conicum* Hedw. and *G. clavariaeforme* Jacq. Only in 1865, during experiments by A. S. Oersted it was discovered that the telia stage on juniper and aecial stage on the pear are different development stages of the same pathogen life cycle. Oersted's experiment was an important starting point for more detailed studies on the genus *Gymnosporangium,* and all the most significant *Gymnosporangium* species were identified during the 20th century. The first results on *Gymnosporangium* spore morphology appeared at the end of the 19th century. Several studies focused on the determination of host plants for various species of the genus *Gymnosporangium* (Thaxter, 1886; 1889; 1891). Variation of morphology in different stages of spore development was observed during study of the gelatinous mass of *Gymnosporangium clavariaeforme*, assuming presence of the uredo stage (Richards, 1889). However, later in 1908, F. D. Kern (1908) described *Gymnosporangium* as heteroecious rusts with absent uredo stage in all known species of the genus. Significant contribution to the investigation of the genus *Gymnosporangium* was given by Professor F. D. Kern (1883–1973). Already in his doctoral thesis, he summarised results of studies on *Gymnosporangium* since 1906, and published one of his the most notable works "A biologic and taxonomic study of the genus *Gymnosporangium*" (1911). F. D. Kern devoted his whole life to studies of the genus *Gymnosporangium* and in 1973 published the monograph *A revised taxonomic account of* Gymnosporangium (Boyle *et al.*, 1974). Although the rust diseases have been studied for a long time, there are still unclear questions on the *Gymnosporangium* genus and its species.

DISTRIBUTION

Rusts are distributed worldwide, while most rust species are found in temperate regions of the northern hemisphere, as well as in tropical and subtropical regions, where new genera and species of rusts are still identified (Hiratsuka and Sato, 1982; Horst, 2013). In Europe 13 rust genera are reported, of which the genus *Gymnosporangium* is the second largest after genus *Phragmidium* (represented by 15 species) and the most significant rust pathogens for fruit trees belong to this genus. At the beginning of the 21st century, nine species of *Gymnosporangium* were described in Europe — *G. fusisporum, G. torminali-juniperinum, G. amelanchieris, G. confusum, G. tremelloides, G. gracile, G. clavariiforme, G. sabinae* and *G. cornutum* (Table 1, according to Helfer, 2005).

In Turkey seven species of this genus were found: *G. amelanchieris, G. clavariiforme, G. confusum, G. cornutum, G. dobrozrakovae, G. sabinae,* and *G. tremelloides* (Dinē and Yilmaz, 1978; Hüseyinov, 2000; Bahçecioğlu, 2001; Hüseyinov and Selçuk, 2001; Erdoğdu *et al.*, 2010; Dervis *et al.*, 2010). Studies on distribution of the genus *Gymnosporangium* have been mainly performed in different regions of North America, where more species have been identified (Cummins and Hiratsuka, 2003). At the beginning of the 20th century, in total 27 species of *Gymnosporangium* (according to the telia host) and 45 species (according to the aecia host) were identified, including only 8 species (according to the telia host) and 14 species (according to the aecia host) in Europe (Kern, 1911). Currently about 60 species of *Gymnosporangium* are known and they are distributed worldwide (Kern, 1973; Cummins and Hiratsuka, 1984; Farr *et al.*, 1995).

Table 1

SPECIES OF GENUS *GYMNOSPORANGIUM* IN EUROPE*

Species	Primary hosts	Secondary hosts
G. fusisporum	*Juniperus sabina*	*Cotoneaster*
G. torminali-juniperinum	*Juniperus*	*Sorbus*
G. amelanchieris	*Juniperus oxycedrus*	*Amelanchier, Pyracantha*
G. confusum	*J. oxycedrus, J. sabina*	*Cotoneaster, Crataegus, Cydonia oblonga, Mespilus germanica, Pyracantha coccinea* ***Pyrus communis* L.,** *Sorbus aucuparia,*
G. tremelloides	*J. oxycedrus*	*Cydonia oblonga, Malus, Sorbus*
G. gracile	*Juniperus*	*Amelanchier ovalis, Crataegus monogyna, Cydonia oblonga*
G. clavariiforme	*J. communis*	*Amelanchier, Crataegus, Cydonia oblonga, Malus,* ***Pyrus,*** *Sorbus,*
G. sabinae	*J. communis, J. sabina*	***Pyrus***
G. cornutum	*J. oxycedrus*	*Sorbus*

* According to Helfer, 2005

Gathering information from the European herbariums, databases and local flora, Helfer (2005) reported that in the Baltic region (including Estonia, Latvia, Lithuania and the Kaliningrad region of Russia), there are four species — *G. tremelloides*, *G. clavariiforme*, *G. sabinae*, *G. cornutum*. Since the hosts of these *Gymnosporangium* species, junipers *J. communis* and *J. sabina* are commonly found also in Latvia (Enescu *et al.*, 2016), only the spread of species *G. sabinae* and *G. clavariiforme* is likely possible in Latvia. Since *J. oxycedrus* is distributed only in the Mediterranean regions (Vilar *et al.*, 2016), the species *G. tremelloides* and *G. cornutum* theoretically can not occur in Latvia, which contradicts Helfer's (2005) published information.

LIFE CYCLE

The life cycle of rust fungi is very complicated and plastic — at least 17 different development cycles are known around the world (Figueiredo, 2000). The most common are macrocyclic and heteroeciouis life cycles. The fungus develops five types of spore — spermagonia produces spermatia and receptive hyphae (stage 0), aecium produce aeciospores (stage 1), uredium — urediospores (stage 2), telium — teliospores (stage 3) and basidium — basidiospores (stage 4) and therefore two hosts are necessary for the complete life cycle. In the demicyclic life cycle the uredia stage is absent, but rust misses also the aecia stage in the microcyclic life cycle. Some rust species can complete their life cycle on one host — the autoecious rusts (Cummins and Hiratsuka, 2003; Kolmer *et al.*, 2009).

Usually fungi of *Gymnosporangium* have four different types of spores in the development cycle (Juhasova and Praslieka, 2002; Aime, 2006; Börner, 2009). J. C. Arthur in 1916 described the uredial stage of *G. nootkatense* Arthur (Arthur, 1916). Later in 1949, the uredial stage was found on *Juniperus nana* (*G. gaeumannii* H. Zogg) in Switzerland by Zogg Hanss, and in 1960 on leaves of *Calocedrus macrolepis* Kurz in Vietnam (*G. paraphysatum* Vienn.-Bourg). In contrast, *Gymnosporangium sabinae* is obligate parasite on plants and represents a heteroecious, demicyclic (with absent uredinia) rust, which overwinters in juniper twigs (Cummins and Hiratsuka, 2003; Börner, 2009). *Gymnosporangium* is the only genus of the rust fungi having a teleito stage that developes on gymnosperms (Aime, 2006).

EUROPEAN PEAR RUST CAUSED BY *GYMNOSPORANGIUM SABINAE*

Pears are the secondary host for species *G. confusum*, *G. clavariiforme,* and *G. sabinae* (Kern, 1973; Helfer, 2005); however, *G. sabinae* is economically the most important and disastrous among all *Gymnosporangium* species and the most devasting for pears (Helfer, 2005). European pear rust caused by *G. sabinae* is widespread in Europe. In the 1970s, in Sweden, due to the popularity of junipers European pear rust spread in the southern part of country, but during recent years it has spread also further north (Karlsson, 2008; Ivarsson, 2011). In the autumn of 2005, European pear rust symptoms were identified on pears in home gardens in Norway and in spring 2006 the telial stage was observed on junipers (Gjærum *et al.*, 2008).

The development of European pear rust starts in early spring on junipers (normally *Juniperus sabina, J. virginia, J. chinensis*). There appear fusiform conical or laterally compressed gelatinous swellings (2–3 × 4–6 mm in size) in dark brown, later orange colour, in which develop two celled, ellipsoid to oblong nearly colourless to dark brown, teliospores (28–72 × 16–39 μm in size) with 1–3 μm in size thick walls. During futher development, basidiospores are produced, which later infect pear leaves, shoots and fruits (Cummins and Hiratsuka, 2003). The first symptoms on pear may occur one month after infection. It appears at the top of the leaves as yellow-orange spots, which gradually become larger (5–10 mm). Later spermogonia develop in the middle of the spots, the structure of which conforms to group V (type 4) (Hiratsuka and Hiratsuka, 1980). At the end of summer until leaf fall, dark brown aeciospores (21–27 × 24–30 μm in size) with wall thickness 3–4.5 μm develop in globoid to ellipsoid roestelioid, hypophyllous aecia (0.5–1 mm diameter, 2–5 mm length), (Cummins and Hiratsuka, 2003). The peridium tear, releasing aeciospores by wind to the junipers, where they hibernate (Hilber and Siegfried, 1989).

In various parts of the world, teliospore formation starts at different times — in Slovakia at the end of April, beginning of May (Juhasova and Praslieka, 2002), in Switzerland in early April (Hilber *et al.*, 1990), and in Germany (Berlin — Brandenburg region) the end of March (Gebauer *et al.*, 2001). High relative humidity and water droplets on leaves promote formation of teliospores and basidiospores (Hilber and Siegfried, 1989). Studies on *Gymnosporangium sabinae* infection biology (Hilber *et al.*, 1990) revealed the optimal conditions for spore germination and distribution *in vitro*, but systematic studies in field conditions have not been performed.

A large number of basidiospores are distributed from infected junipers, but not all of them can infect pears; however even relatively poor spore material can cause rust epidemics. Formation and distribution of basidiospores have impact on the severity of rust, which is influenced also by ability of spores to penetrate plant tissue, wind speed and direction (Hau and De Vallavieille-Pope, 2006). Each of these factors can be modified by certain weather conditions (Mitrofanova, 1970; Pearson *et al.*, 1980). Although viability of basidiospores is low and they can not overpass long distances by wind (Agrios, 1997), mycologists R. Thaxter (1891) and H. Hughes (1958) reported that basidiospores can cause low infection of pears even 60 km away from the source of infection (Mitrofanova, 1970). Basidiospores of *G. juniper-virginianae* (causes apple — cedar rust) are able to overcome distances of 3–5 km (Agrios, 1997). Strong infection occurs when the pear trees and junipers grow near, not further than 300 to 500 m (Mitrofanova, 1970; De Ryck, 2001). A study on the severity of European pear rust in relation to the location of junipers found that when pears were located at 30 m distance from the juniper, 100% pear leaves were infected, 150 m away — 50% of the leaves, and 300 m — no symptoms of disease was observed on leaves (Ormrod, *et al.,* 1984).

Temperature and relative humidity has impact on the sporulation intensity of the pathogen (Hau and De Vallavieille-Pope, 2006). The range for germination of basidiospores is wide, and can take place at temperatures from 5 to 20 °C, with optimal temperature of germination 15 °C (Hilber *et al.*, 1990; Dong *et al.*, 2006). The optimal relative humidity (RH) is 84–91%, whereas at RH 97% the ability of spores to infect leaves decreases (Mitrofanova, 1970). Basidiospores are very sensitive to drying out, insufficient moisture and direct sunlight can affect their viability (Gold and Mendgen, 1991). The period of basidiospore release depends on weather conditions, but generally it coincides with the phenological stage of pome fruit — "wollen bud" (Meier, 2001). Basidiospore release occurs 4–6 hours after rain (average air temperature 8 °C) and it can last for 14 hours (Mitrofanova, 1970). An early and wet spring is not necessary for sporulation and every year the number of sporulations differs, for example, in Crimea sporulation occurred between 4–9 times (Mitrofanova, 1970), in Switzerland — three times (Hilber *et al.*, 1990a). The most critical period is when the average temperature rises rapidly and heavy rains occur in pear orchards. The primary, main infection takes place usually once in spring, when the average temperature is 13–15 °C. The next sporulations do not have significant impact on pear orchards (Mitrofanova, 1970; Hilber *et al.*, 1990a). A late and dry spring is not favorable for development and release of basidiospores. The period of infection can be from mid-April until the end of May (Mitrofanova, 1970). The infection is dependent on the age of pears leaves, especially susceptible are 10 days old leaves (Mitrofanova, 1970). A study on related a species (*G. juniper-virginianae*) showed that 4-, 6- and 8-day-old apple leaves were more susceptibile than the 10- and 12-day-old leaves (Aldwinckle *et al.*, 1980).

Basidiospores can infect only the secondary host — pear (Schildberger, 2011). Spores enter through the parenchyma of plant green parts and after some time the first symptoms of disease appear — spots (Hilber *et al.*, 1990a; Schildberger, 2011). Symptoms occur on the leaves, fruits and branches. Small dark dots develop in the middle of these spots — spermagonia, where single mating type spermatia are developing (Agrios, 1997; Schildberger, 2011). Spermatia produce a sweet liquid, which is food for insects and helps to distribute spermatia to others with a different mating type. Both spermatia of one mating type and spermatia of the opposite mating types interflow with receptive hyphae. By this time, dikaryotic mycelium has been developed and it produces an aecium containing aeciospores (Mitrofanova, 1970; Agrios, 1997). Aecium develop on the bottom of leaves and it grows for 140 days after infection. When aeciospores are mature (usually during 20 days), horns of aecium burst and spores release (Mitrofanova, 1970). Aeciospores of *G. sabinae* can be spread by wind over long distances up to defoliation. Aeciospores can infect only junipers. They return to the junipers, infect and hipernate in branches, completing the life cycle (Börner, 2009; Hilber and Siegfried, 1989; Schildberger, 2011).

EUROPEAN PEAR RUST IN LATVIA

In Latvia European pear rust for the first time was mentioned in 1938 by M. Eglītis (Eglītis, 1938), where it was characterised as widespread and a damaging disease only in Western Europe, but which is not found in Latvia. Later this disease was not mentioned for pears at all. Some sporadic information about European pear rust appeared only in popular publications and online resources, which associated the distribution of the disease in Latvia with popularity of junipers in late 1990s (Eihe, 2004). Scientific studies on severity of European pear rust in Latvia were started in 2007, when symptoms of the disease were found in more than half of 33 surveyed pear orchards. The disease was found throughout the whole territory of the country and the highest severity was observed in the middle part — Zemgale (Rancane *et al.*, 2012). In 2013, distribution of disease increased also in the western part — Kurzeme.

Pear orchards of different regions of Latvia were screened for incidence of European pear rust, and disease development was investigated for three years at the pear collection of the Institute of Horticulture, Latvia University of Agriculture (former Latvia State Institute of Fruit-Growing). Severity of pear rust was scored using scale of points (0–5) indicating average number of infected leaves per tree. European pear rust severity results showed significant difference over the years of evaluation. The incidence and spread of the disease was higher during more humid growth periods (Rancane *et al.*, 2012). Like in other studies (Kellerhals *et al.*, 2012) completely resistant cultivars were not found among the tested ones, but susceptibility was variable (Lāce and Bankina, 2013). This study also discovered dependence of disease severity on the tree location in the orchard. More infected trees were located at the edges of the trial block, but in the middle of orchard the infection was lower, regardless of the cultivar (Lāce and Lācis, 2015). High severity of European pear rust infection showed significant influence on pear yield (Prokopova, 2011; Rancane *et al.*, 2012).

EUROPEAN PEAR RUST CONTROL OPTIONS

Successful fruit crop growing should be based on a complex system, which includes agro-technical, biological and chemical plant growing and protection measures, resistant plant material. Traditionally, worldwide European pear rust is controlled by fungicide applications, like other diseases caused by fungi (Ormrod *et al.*, 1984; Agrios, 1997; Fischer and Weber, 2005). For example, in apple-growing regions the control of scab (caused by *Venturia inaequalis*), globally the economically most important disease, 12 to 30 sprays need to be applied during the growing season (Soufflet-Freslon *et al*., 2008; Soriano *et al*., 2009), and the control overlaps with other fungal diseases, including rust control (Holb, 2013). Although the distribution of European pear rust can be limited by application of pesticides (Ormrod *et al*., 1984), pesticide use in home gardens and organic orchards is not supported.

The task of agro-technical methods is ensuring favorable conditions for fruit crop growing, but which are unfavorable for pest development and spread. It is known that a balanced use of fertilisers, proper tillage, and seasonable thinning of the tree crown increases resistance to various pathogens and reduces to a minimum the applications of chemical plant protection products (Mitrofanova, 1970; Agrios, 1997). Pear orchards should be planted as far as possible away from the sources of infection (at least 3 km) and they should be enclosed by windbreaks. Crown thinning and illuminating have and essential role, which ensures quick drying of leaves after rain and causing unfavorable conditions for the growth of pathogen (Mitrofanovą, 1970). During the winter period of tree dormancy, pear and juniper branches infected with rust can be cut and wounds treated with disinfectants (Mitrofanova, 1970; Hunt and O'Reilly, 1978). Similarly, the disease severity can be controlled by removal of gelatinous teleito horn colonies from infected juniper branches before release of basidia spores (Hilbers and Siegfried, 1989). Some authors recommend the destruction of one of the host species in the case of disease appearence (Fischer and Weber, 2005). The possible, application of net covers during the infection period also has been shown to limit European pear rust, but positive effect was observed only for new trees or trees on dwarfing rootstocks, and covers should be removed timely to prevent twists in young shoot growth and spoilage of leaves (Ivarsson, 2011). Plant supply with sufficient quantities of nutrients essential for development is one of the most important requirements for high and stable yields; however, fertiliser doses must be balanced. High concentration of nitrogen in leaves promotes favorable conditions for the development of many pathogens, including European pear rust agent (Agrios, 1997; Hau and De Vallavieille-Pope, 2006).

Use of resistant plant material is one of the sustainable fruit growing options. Different defence mechanisms exist both in plants and pathogens, which could be used successfully in plant protection systems against biotrophic pathogens (Dangl *et al*., 1996; Govrin and Levine, 2000; Iakimova *et al*., 2005; Jones and Dangl, 2006; Boyd *et al*., 2013). Hypersensitive response (HR) is one of the most characteristic plant defense mechanisms, when plant cells die around the infection point thus preventing its further spread. It is a protective response against pathogenic infection and appears in case of interaction between a resistant plant genotype and avirulent pathogen (Heath, 2000; Shirasu and Schulze-Lefert, 2000). HR mechanism is blocking development of pathogen haustoria before its entrance into the plant cell, by activating the mechanisms of plant tissue death, thereby destroying the pathogen (Bennett *et al*., 1996; Naton *et al*., 1996). Research on HR in fruit crops is limited — mainly studies are focused on molecular mechanisms of resistance and biotechnology of resistant cultivars, but the physiological and biochemical mechanisms of HR are still insufficiently studied (Iakimova *et al*., 2005). Identification and growing of pear cultivars characterised by HR reaction to European pear rust infection can limit the spread of disease, since completely immune *P. communis* cultivars do not occur naturally. Typically, they are more or less susceptible cultivars, and evaluation results can be contradictionary, e.g. in Crimea cultivars 'Fondante des Bois' and 'Beurre Bosc' were highly susceptible, but the cultivar 'Clapp's Favourite' — less susceptible (Mitrofanova, 1970). In the Netherlands during 60 pear cultivar screening for resistance to certain fungal diseases, some symptoms of European pear rust were observed only on cultivar 'Erika' (Kemp and van Dieren, 2000), whereas no resistant cultivars were identified during the five-year study in a Belgian cultivar collection (Kellerhals *et al*., 2012). Resistance of different *Pyrus* species to European pear rust was studied by Fitzner and Fischer (2005) and species *Pyrus korzhinskyi, P. betulifolia, P. cordata* and hybrid *P. salicifolia* 'Pendula' were selected as resistant and recommended for use in landscaping as well as donors in breeding.

Sustainable fruit growing accepts and promotes application of biological control means. Several studies showing positive and successful results in rust biological control using pathogenic fungi were identified. Dolinska and Schollenberger (2011) in Poland found twisting and death of *Gymnosporangium* spp. aecial spores caused by conidia and conidia spores of the pathogen *Cladosporium uredinicola*. According to published information, there are over 150 species of parasitic fungi (from 15 genera) that hamper the development cycle of rust fungus. The most common fungus, natural parasite of rust aecidial stage *Tuberculina persicina* Ditm. Sacc. was mentioned for the first time at the beginning of the 19th century under the name *Tubercularia persicina* (Ditmar, 1817), the fungus acquired its current name at the end of the same century (Saccardo, 1880). Fungi of the genus *Tuberculina* are mitosporic parasites of rust fungi. Only three of thirty seven *Tuberculina* species are widely described and studied — *T. maxima*, *T. persicina*, *T. sbrozzii* (Wicker, 1981; Lutz *et al*., 2004b; Shamsi and Naher, 2010). *Tuberculina* is an anamorph stage of *Helicobasidium* genus rust parasites (according to Lutz *et al*., 2004a). Dominic Begerov studied genes of *Tuberculina* and rust fungi and found close relatedness, despite species differences (Lutz *et al*., 2004b). In Crimea during the appearance of rust spots on leaves, pears were sprayed with spore suspensions of *T. persicina*, which stopped the growth of spots (Mitrofanova, 1970). During contact of the suspension with infected leaves, *T. persicina* hyphae grew into the aecial spores, hampering their development (Bartkowska, 2007), whereas spots on nontreated leaves continued to grow, increasing 35 times. Sprays of the same spore suspension during occurence of aecia sets did not show differences bewteen sprayed and unsprayed leaves (Mitrofanova, 1970).

T. persicina spore suspension can be applied effectively only when the first symptoms of rust appear on leaves. This control method can be used, when fungicide sprays will not protect the plant under several conditions, like rain, heavy wind (Mitrofanova, 1970). In Latvia, *Tuberculina maxima* was found in Ādaži parish and identified in 1951 (Smarods, 1951), and *T. persicina* — in 1947, but there are no reports on their use in rust control (Smarods, 1947).

CONCLUSIONS

Some *Gymnosporangium* species, especially important fruit crop pathogens, are known for a long time, however many aspects of their distribution and life cycle are still not well understood. Special attention should be paid to the plant-pathogen interaction mechanisms, and their use in the sustainable plant protection systems. More detailed information on climate condition impact on pathogen development, and its pathogenicity, would be necessary in context of possible climate changes and forecasting of potential disease outbreaks. Implementation of biological control means for pathogens of genus *Gymnosporangium* is an important challenge for sustainable fruit growing, which requires detailed knowledge on possible control agents, and their interaction with pathogens.

Currently, an Integated Pest Managment system for this pear disease has not been established, but fungicide sprays on the basis of the pathogen life cycle is the beginning of the development of an integrated disease control system.

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GYMNOSPORANGIUM SPP. — NOZĪMĪGA PROBLĒMA AUGU AIZSARDZĪBĀ

Rūsas (*Fungi, Basidiomycota, Pucciniomycotina, Pucciniomycetes, Pucciniales*) ir patogēnās sēnes, kuras ir vienas no ekonomiski nozīmīgākās augu slimības ierosinātājiem. Tās var inficēt gan laukaugus, gan dārzaugus, gan dekoratīvos augus un kā augu slimību izraisītājas tās pētītas jau ļoti sen. Eiropā uz rožu dzimtas augiem aprakstītas 13 rūsas sēņu ģintis, no kurām augļu kokiem nozīmīgie patogēni pieder pie *Gymnosporangium* ģints, kas ir otra lielākā aiz *Phragmidium* ģints. Par augļaugiem nozīmīgām rūsu slimībām, tai skaitā bumbieru-kadiķu rūsu (ierosinātājs *Gymnosporangium sabinae* (Dicks.) G. Winter), zinātniskajā literatūrā pieejams ierobežots skaits publikāciju. Galvenokārt pētījumi par rūsu slimībām un to ierosinātājiem koncentrējas uz attīstības cikla atsevišķām stadijām, visbiežāk uz tām, kas nozīmīgas slimības izplatībā — uredo un teleito stadijām. To attīstība pētīta tikai optimālos apstākļos *in vitro* bez ilggadīgiem lauka pētījumiem. Literatūras apskatā apkopota pieejamā informācija par *Gymnosporangium* ģinti, tās izpētes vēsturi, daudzveidību, sugu izplatību, t.sk. Latvijā, dzīves ciklu, patogēnu bioloģiju un ierobežošanas iespējām.