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THE INFLUENCE OF SELECTED CLIMATOLOGICAL CHARACTERISTICS ON ANTRACNOSE DISEASE DEVELOPMENT IN PLANE TREES

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Abstract

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The plane tree (*Platanus* sp.) is one of frequently used ornamental trees in Slovak urban areas. The population of London plane in the Slovak Republic has not been affected so far by important dangerous pathogens common to warmer regions of Europe. However, in recent years the health state of plane trees has been significantly deteriorating. During 2004–2008, reappearances of anthracnose on *Platanus* × *hispanica* Münchh. were recorded. The causal agens of the disease, microscopical fungi of genus *Apiognomonia* [*A. veneta* (Sacc. & Speg.) Höhn.], were isolated from symptomatic leaves and twigs, with characteristic spots and lesions sampled from affected host trees growing in the urban environment at the selected localities (Nitra, Komárno, Piešťany). The spreading of fungi basically depends on meteorological conditions, for example air humidity and precipitation, active solar radiation and air temperature. In this study, climatological parameters, air temperature and annual precipitation with their influence on the incidence of *Apiognomonia* anthracnose on plane trees growing in urban settings are presented. Our results show that plane population damage can be irreversible and very considerable in consequence of repeated climatically unfavourable years, resulting in the subsequent development of *A. veneta* infection.

Key words: air temperature, *Apiognomonia veneta*, *Discula platani*, ecological conditions, *Platanus* × *hispanica*, precipitation

Introduction

Changed ecological conditions reflect also on open-grown greenery health states. Changes are especially pronounced in urban environments. Besides climate changes that form the conditions for cultivation of new plant species, in these conditions woody plants are affected negatively by other injurious factors, e.g. air pollutants, emissions, etc.

New hosts, as well as new pathogens appear. Eventually less important harmful agents are activated and adapted to new conditions and new host spectrums. This new incoming imbalance creates conditions for mass expansion of plant diseases atypical for a specific area (Černá, 2004).

Tree plantings able to store significant quantities of impurities are of great importance to improving the environment toward a cleaner atmosphere. Their filter effect depends on the resistance of individual woody plants to industrial air pollutants, on the structure of tree settings, as well as the nature of air pollution. Some tree genera and species such as spruce, larch, Douglas fir, small-leaved linden and sycamore maple are so sensitive that it may be heavily damaged or even destroyed by air pollutants. By contrast, black locust, oak, ash, plane and poplar show significant resistance in this respect. From this range, the plane tree (*Platanus* × *hispanica* M ü n c h h.)– used primarily in Slovakia as an ornamental tree in large urban parks and many streets - was chosen as a model tree species. Plane trees (*Platanus* sp.) are among the most abundant urban trees in Slovakia, used primarily in linear plantings along streets but also in public and private parks and gardens. They are native to regions with warm summers. Summer droughts do not seem to be a problem for established trees, though they probably slow down their growth. These trees do not do so well in regions with cooler summers. The trees survive strong, hot summers well and, unlike other species in the same areas, show no desiccated shoot tips due to high temperatures. This is partly owing to the effects of anthracnose, which is much worse in damper and cooler climatic conditions and can overwhelm some trees.

The activation of diseases up to the present of peripheral importance comes up as a result of the impact of climatic changes on woody plant species growing in Central Europe. Changed ecological conditions reflect on the decline in the health state of open-growing greenery in urban environments. Temperature increases, longer growing seasons and higher humidity, in connection with the predisposition of woody plants, contribute substantially to the activation of causal agents of numerous leaf diseases, where besides powdery mildew and rust, various leaf spots play an important role (Jankovský, 2002).

Although the incidence of fungal pathogens causing leaf škvrnitosti was known earlier, since 2002 significantly increased expansion was recorded.

Although the occurrence of fungal pathogen-caused leaf spots was already known previously (Juhásová, 1988; Juhásová, Ivanová, 1999), since 2002 a markedly increased expansion of many fungal species contributing to the formation of leaf spots was noticed on beeches – *Apiognomonia errabunda* (R o b e r g e ex D e s m.) H ö h n . (Kapitola et al., 2002), plane trees – *Apiognomonia veneta* (S a c c. & S p e g.) H ö h n. (Kapitola et al., 2002; Ivanová et al., 2007; Pastirčáková et al., 2008; Bernadovičová et al., 2009), linden trees – *Apiognomonia tiliae* (R e h m.) H ö h n. (Kapitola et al., 2002; Jankovský, 2002; Ivanová, Bernadovičová, 2006), horse chestnuts – *Guignardia aesculi* (P e c k) V. B . S t e w a r t (Zimmermannová, 2001; Kapitola et al., 2002; Zimmermannová-Pastirčáková, 2003; Pastirčáková, 2004; Pastirčáková et al., 2009) and willows – *Marssonina salicicola* (B r e s.) P. M a g n. (Kapitola et al., 2002).

Anthracnose is caused by a group of fungal pathogens that created typical symptoms on trees: twig and branch dieback and necrotic lesions delineated by leaf veins. The most conspicuous symptom of the disease in early spring is the dying of twigs and new shoots. Small black fruiting structures of the fungus break through the dead bark of blighted, one-year-old shoots. After the buds break, trees show scorching and wilting new shoots and leaves. Later, fully expanded leaves develop elongated tan to brown lesions parallel to the midrib and veins. Infected leaves scorch and shed. In general, anthracnose is mostly primarily an aesthetic problem, but some diseases can seriously disfigure trees, while others are lethal. In exceptionally cool, wet springs, trees leaf out and then can defoliate heavily. Repeated defoliation may weaken trees and lead to death.

Each species of the anthracnose fungus attacks only a limited number of tree species. Other anthracnose-causing fungi have similar life cycles, but require slightly different moisture and temperature conditions for infection. Anthracnose is not uniformly defined, but these diseases tend to produce: irregular-shaped necrotic areas (often along veins), acervuli that overwinter in small twig lesions, and possibly twig blight in case of severe infection. Anthracnose may cause partial or complete defoliation of seedlings, resulting in a decrease in growth and vigor. The mortality of infected plants is rare (Sinclair, Johnson, 1997; Stipes, Hansen, 2000).

The present study was undertaken to examine the influence of climatological characteristics, in particular air temperatures and changes in precipitation, and in the frequency and seriousness of extreme climatic events, on the incidence and severity of plane anthracnose in trees growing in urban landscape settings.

Material and methods

Plane trees (*Platanus* × *hispanica* M ü n c h h.) in Slovakia, growing primarily in linear plantings along streets and in large public parks and gardens, were chosen as the model tree species for the observation of the health state with regard to plane anthracnose, in close with selected climatic characteristics.

The causal agent of the disease, fungus *Apiognomonia veneta*, was isolated and identified using standard phytopathological techniques from symptomatic leaves and twigs with characteristic spots and lesions, sampled during the growing seasons (from April to August 2004–2008) from affected plane trees growing in urban plantings at the selected localities (Nitra, Komárno, Piešťany). The material was sampled from the lower parts of tree crowns. The age of the evaluated trees varied from 20 to 150 years.

Meteo-data on selected climatic characteristics, air temperature (°C) and precipitation (mm) at the monitored sites were provided to us continually during the study period by the Slovak Hydrometeorological Institute (SHMI) Bratislava.

Results and discussion

Apiognomonia veneta (syn. *A. errabunda*, *Gnomonia veneta, G. platani*) rarely causes more than minor damage to plane trees. Leaves are disfigured, and shoots and twigs sometimes disappear. Park ground can be covered with a thin layer of infected plane leaves or leaf litter from early June onwards. The disease is promoted by damp weather during shoot extension in spring and early summer. It is, or it used to be, reduced by pollution in cities. The fungus overwinters in fallen leaves, and also on the tree bark (Swift, 2001).

The causal agent of plane tree anthracnose is a stem colonising fungus *Apiognomonia veneta* (the asexual stage *Discula platani,* syn. *Gloeosporium platani*) that causes defoliation, twig dieback and a ragged appearance in the attacked trees. The seriousness of this disease is dependent on the health state of the infected tree. Healthy trees can resist many years of defoliation, while trees in stressed conditions can experience severe dieback and decline.

Microscopical identification of *Gloeosporiu*m D e s m. et M o n t. isolates, according to Woodward (2001), confirmed the presence of conidia produced in an acervulus, spores that rupture through the host tissue at maturity. The conidia are one-celled, hyaline (colourless) or cream, or pink-coloured in mass, ovoid, cylindrical or slightly curved in shape (Ivanová et al., 2007), (Fig. 1).

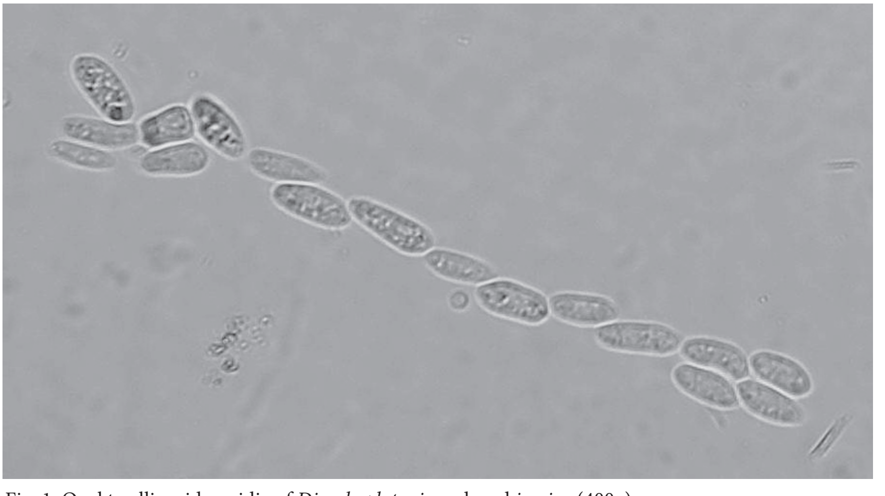

Fig. 1. Oval to ellipsoid conidia of *Discula platani* produced *in vivo* (400x).

The anthracnose fungi attack plane trees early in the spring, causing a rapid wilt of newly emerging leaves. This rapid wilting is frequently misidentified as frost damage. Larger, more mature leaves develop a brown growth along the main veins, often in V-shaped patterns (Terrell, 2004). Infected leaves often curl and eventually fall, littering the ground.

Anthracnose infection occurs at budbreak and during leaf expansion. Besides defoliation, symptoms include a brown leaf blotch associated with the leaf veins (Fig. 2). The disease moves from the leaf to the twig where it produces a canker and causes dieback. Repeated annual killing of twigs results in clusters of old dead twigs and live branches, "witches' brooms" (Pilotti et al., 2002; Terrell, 2004; Nameth, Chatfield, 2007). On heavily infected trees, dieback can be extensive leading to the gradual decline and death of the tree.

Fig. 2. Symptoms of anthracnose on affected mature plane leaf.

Anthracnose fungi overwinter in leaf debris on the ground and/or dead areas of the bark on the tree, called cankers. In early spring, spores of the fungus are produced in fruiting structures and are dispersed by splashing rain. The expanding leaf buds, shoots, or in some cases young leaves, are infected by the spores. Acervules are formed on the leaves with ovoid to elliptical unicellular conidia. During the next spring, the perithecia with ascospores developing on fallen leaves transfer the primary infection to young leaves.

Disease severity changes from year to year and it is dependent on temperature. Cool springs are more conductive to severe plane anthracnose outbreaks. The infection process is favoured by relatively cool temperatures and prolonged periods of leaf wetness. Therefore, the disease tends to be more severe during wet, cool springs. After infection, the anthracnose fungus colonizes leaf tissues and begins to produce new fruiting structures and spores capable of reinfecting expanding leaf tissue. Disease development may continue throughout the spring and into early summer if appropriate weather conditions persist. These diseases tend to be less of a problem during hot, dry summer weather. As temperatures increase, the disease becomes less active and the trees releaf.

The intensity of this disease is generally determined by the weather conditions during the last two weeks of April and the first week of May. If temperatures are not higher than 10 °C and moderate to heavy rain occurs, defoliation to plane trees will be noticeable varying from light to heavy. This will mean that planes will not develop full foliage until June. Weather determines the severity of anthracnose. Frequent rains and cool temperatures promote the disease. If the average temperature during the two-week period, following the emergence of the first leaves, is below 12 °C, the shoot-blight phase of the disease will be serious. Disease intensity decreases as the average temperature increases from 12 to 15 °C. Little or no anthracnose will occur if average temperatures during this vulnerable stage are above 15 °C (Hitchcock, Cole, 1980; Berry, 1985; Leininger et al., 1999; Swift, 2001; Jurc, 2006).

In general, mild winter and the following late frosts with longer cool and wet weather in spring during sprout budding and prolongation initiate plane anthracnose disease caused by the fungus *Apiognomonia veneta*. Recurring infection year after year gradually weakenes woody plants, so these are more predisposed to other fungal diseases and damage by insect pests. Reccurence of infection caused by *A. veneta* was observed at selected localities in Slovakia from 2004–2008. These observations correspond to the data of SHMI (2004–2008). In comparison with the long-term average values (1959–1980), the average monthly air temperatures in the from 2004–2008 in the observed area were higher, but in the months decisive for origin of infection (a period from 17 April to 7 May) in the evaluated years 2004–2008, the temperatures ranged between 11.59 °C (Piešťany, 2008) and 14.82 °C (Komárno, 2004), (Table 1). Since significant progress of infection caused by the fungus

T a b l e 1. Average air temperature (°C) in the observed period, 2004–2008, at selected localities within Slovakia and in Slovakia entirely.

Year	Period	Localities			Slovakia
		Nitra	Piešťany	Komárno	
2004	17 April–7 May	14.22	14.04	14.82	11.849
	Summer	20.09	19.28	20.59	17.534
2005	17 April–7 May	12.60	12.05	13.19	10.657
	Summer	20.03	19.08	20.32	17.980
2006	17 April–7 May	14.11	13.14	14.19	12.506
	Summer	21.14	20.42	21.62	18.918
2007	17 April–7 May	12.69	12.19	13.95	12.300
	Summer	19.61	19.69	20.48	18.989
2008	17 April–7 May	12.64	11.59	13.45	10.925
	Summer	19.88	18.88	19.18	17.425

A. veneta can be noticed at temperatures lower than 12–13 °C and at higher rainfall in the growing season (above 350 mm), the progress of infection did not induce general withering and tree dieback, but only certain weakening of the trees. Average temperatures recorded at selected localities in all observed critical periods (17.4.–7.5) varied from 11.59 to 14.82 °C, and they did not exceed 15 °C, representing the value for remission of infection. Rainfall in the critical 2004-2008 period varied noticeably from 0.66 mm (Nitra, 2004) to 7.25 mm (Komárno, 2007), (Table 2).

According to Gregorová et al. (2009), the health state of the London plane during the 11-year survey (1992–2002) was negatively and most importantly influenced by various

T a b l e 2. Average rainfall (mm) in the observed period, 2004–2008, at selected localities within Slovakia and in Slovakia entirely.

Year	Period	Localities			Slovakia
		Nitra	Piešťany	Komárno	
2004	17 April–7 May	0.66	1.01	1.37	147.57
	Summer	2.38	2.16	5.43	475.52
2005	17 April–7 May	2.93	7.15	4.09	148.27
	Summer	1.57	4.86	4.06	579.51
2006	17 April–7 May	1.44	6.54	3.00	160.28
	Summer	1.82	5.68	4.12	477.39
2007	17 April–7 May	1.24	2.79	7.25	63.28
	Summer	4.67	4.85	6.07	384.00
2008	17 April–7 May	1.86	1.63	2.94	123.00
	Summer	4.59	4.91	6.10	384.00

environmental factors. Results of multiple regression analysis showed a highly significant regression model: the average temperatures in January and May explained together 84% variability of population damage. The coincidence of climatic factors favourable for pathogen *A. veneta* and unfavourable for London plane may intensity the damage. Results show that changes in the London plane population can be irreversible and very considerably damaged in consequence of repeated climatically unfavourable years with subsequent development of *A. veneta* infection.

According to Sury and Flückiger (1991), who compared the leaf infections on *Platanus* × *hispanica* over two years, while leaf necroses were widespread after the 1987 infection, they appeared only sparsely in 1988. This striking contrast might have been caused by differing climatic conditions. In Basel, for instance, the mean temperature 10.8 °C in May 1987 compared to 15.0 °C one year later indicated correlation between the severity of *Apiognomonia* blight and low temperatures in spring. According to Swart et al. (1990), all symptoms (bud blight, twig blight, shoot blight) except leaf blight disappeared during the summer months in each year. This observation is consistent with the view of Neely (1976) that anthracnose infection of *Platanus* occurs mainly in early spring. This view corresponds to observations in our conditions. It is further supported by the fact that the severity of shoot-blight is determined by the mean daily temperature during the 2-week period immediately following the emergence of the first leaves in spring – the optimum temperature for disease development ranging from 10–13 °C (Neely, Himelick, 1963).

According to Hitchcock, Cole (1980), Berry (1985), Leininger et al. (1999), Swift (2001), Jurc (2006) disease intensity decreases as the average temperature increases from 12 to 15 °C. This fact corresponded with our five-year observations of leaf infection of *P.* × *hispanica*. In the months decisive for the origin of infection (period from 17 April to 7 May) on selected localities in the evaluated years 2004–2008, the temperatures ranged between 11.59 and 14.82 °C, and they did not exceed 15 °C, representing the value for remission of infection (Table 1).

According to date of SHMI the temperature on all territory of Slovakia during the period from 17 April to 7 May in 2004-2008, did not exceed a limit of 15 °C. The temperature ranged from 10.657 to 12.506 °C (Table 1), and the mean precipitations ranged from 63.28 to 160.28 mm (Table 2). Annual air temperature mean on selected localities did not exceed 10 °C; it ranged from 9.2 to 9.8 °C. Mean annual areal precipitation total ranged from 540 to 608 mm (Table 3).

T a b l e 3. Average annual air temperatures (°C) and average annual rainfalls (mm) at selected localities within Slovakia.

Localities	Geographical coordinate	Altitude m a.s.	Average annual air temperatures (°C)	Average annual rainfalls (mm)
Nitra	48°18′25″ N 18°05′11″ E	138–587	9.8	540
Piešťany	48°35′31″ N 17°49′23″ E	162	9.2	608
Komárno	47°45′48″ N 18°07′42″ E	112	9.7	550–600

According to Gregorová et al. (2009), plane health state is negatively affected primarily by long-term high rainfall, a higher rainfall in May, a greater number of frosty days in winter and higher concentrations of nitrogen oxides. By contrast, higher average temperatures especially in January and May, and higher precipitations in autumn have positive effects. According to the authors conclusions, the development of plane damage is most likely affected by the inter-relationship between climatic factors favourable for pathogen, and at the same time unfavourable for plane trees. They note that the damage of *Platanus* is probably connected with the stress induced due to high temperatures and low rainfall during the previous summer period. In this context, the positive effects of autumn precipitations, which partially eliminate the rainfall deficit in summer, is mentioned. Higher average temperatures in January and May positively affect not only the development of plane trees but also *Apiognomonia* fungus. Lower temperatures in May inhibit sprout development and increase the importance of damage by pathogen. The results indicate that adverse climate for several years resulting in subsequent severe expansion of pathogen can lead to significant irreversible damage to a large part of *Platanus* × *hispanica* population.

The data of SHMI (Table 4) correspond with conclusions obtained by Gregorová et al. (2009). The annual precipitation total in all Slovakia (SR) in 2004–2008 ranged from 740 mm in 2006 to 938 mm in 2005 (normal mean is 762.0 mm). During summer the mean areal precipitation totals in SR ranged from 315 mm (in 2006) to 407 mm (in 2005), and during the growing season the mean areal precipitation totals in SR ranged from 92 mm (in 2007) to 188 mm (in 2006). Annual air temperature means in SR during 2007–2008 was 9.2 °C. The summer air temperature mean in SR during the 2004–2008 period ranged from 17.425 °C (in 2008) to 18.989 °C (in 2007), and the air temperature mean during the growing season varied from 10.657 °C (in 2005) to 12.506 °C (in 2006).

T a b l e 4. Mean areal precipitations totals (mm) and air temperature in Slovakia (°C) in the period, 2004–2008.

Selected climatological characteristics	Year				
	2004	2005	2006	2007	2008
Mean areal precipitation totals (mm)	851	938	740	894	873
Mean summer areal precipitation totals (mm)	355	407	315	384	384
Mean summer areal precipitation totals (mm)	142	170	188	92	123
Annual air temperature mean (°C)	-	-	-	9.2	9.2
Summer air temperature mean (°C)	17.534	17.980	18.918	18.989	17.425
Growing season air temperature mean (°C)	11.849	10.657	12.506	12.300	10.925

*Normal mean areal precipitation totals in SR is 762.0 mm and annual air temperature mean in SR is 8.7 °C.

In Slovakia the trend in decline of the annual rainfall is attributed in the long-term view as a consequence of industrialization. In the 20th century, annual rainfall decreased by 5.6 %. This means that on the territory of Slovakia, in the long-term, there has been an average fall in volume of about 2 billion m^3 less rain than at the beginning of the 20th century. Another important connection in Slovakia at the present time is more uneven distribution of precipitation than in the past. In the mountains, precipitation is more profuse and more intensive and in the lowlands it rains less in volume than in the past (Kravčík, 2006).

According to SHMI observations, 2007 was the second warmest since 1871 in Slovakia. The year 2007 had the warmest January, the warmest winter period and cold half-year (October–March) from the beginning of observations. Even the temperature in spring 2007 was about 2.7 to 3.7 °C and in summer 2.1 to 3.1 °C above the long-term average. The period from September 2006 to August 2007 was 3.06 °C above the long-term average which is an unparalleled record for a 12-month period. The year 2008 was similar in climatology. Spring 2008 in Slovakia was 1.4 to 1.7 °C above the long-term average. Summer 2008, as confirmed by climatological analysis, was abnormal in its high temperature with an average air temperature 1.7 to 2.0 °C above the long-term average. In terms of rainfall, summer 2008 was abnormal (317 mm, which is 123% of long-term average), but rainfall was lower than in 2005 when it was 325 mm on average in Slovakia (Lapin, 2008, 2009).

These findings correspond with the prognoses up to 2075, which were given by members of Prof. Lapin's team (Lapin et al., 1995). In subsequent periods in Slovakia, one may expect average annual growth in air temperature of 2–4 °C (especially in winter), a slight increase in rainfall in winter and a slight decrease in summer. These changes will also relate to a series of other changes in the incidence of pathogens, diseases and pests.

Also our observations show that the negative development of the health state of *Platanus* is induced by stress due to the impact of high temperatures and decreasing rainfall during the previous summer period. Higher temperatures in January and temperatures below 12 °C, at a critical time for the disease development (April 17 to May 7), cause an increased incidence of *Apiognomonia veneta* infection. Higher temperatures in this critical period inhibit the infection incidence and also temperatures above 15 °C cause disease remission.

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