REVIEW ARTICLE

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A review of *Sphaeropsis sapinea* occurrence on *Pinus* species in Bulgaria

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ABSTRACT
Sphaeropsis sapinea (Fr.) Dyko & Sutton causes shoot blight and canker disease throughout the world on conifers predisposed by stress. The disease is most important to *Pinus* species that are affected from the seedling stage in nurseries to mature trees in ornamental planting, forest plantations and natural stands. In Bulgaria, the first findings of the disease were noted in 1989 on *Pinus nigra* plantations in the North-eastern part of the country. Over the past few years, new emergency and severe damages have developed rapidly as a consequence of the prolonged drought periods during the last growing seasons. The high existence of *S. sapinea* outbreaks contributed considerably to the physiological weakness of pine trees that become more susceptible to attack by aggressive xylophages and other fungal pathogens. Disease occurrence and its pathogenicity are economically important affecting a number of pine trees from all ages. In Bulgaria, *S. sapinea* has been obtained on six pine species *P. nigra*, *P. strobus*, *P. radiata*, *P. ponderosa, P. pinaster* and *P. halepensis*. The aim of this review is to present the available knowledge on distribution, host specificity, biology, ecology, management of the disease, and to discuss its current prevalence and pathogenicity effect on pine species in Bulgaria.

Key words: *Sphaeropsis sapinea*, shoot blight disease, *Pinus*, Bulgaria

Distribution

Sphaeropsis sapinea (Fr.:Fr.) Dyko & Sutton (syn. *Diplodia sapinea* (Fr.) Fuckel, *Diplodia pinea* (Desm.) Kickx.) causes shoot blight and canker disease throughout the world on conifers predisposed by stress (Blodgett et al., 2005). Disease occurrence and its pathogenicity are economically important, affecting a number of coniferous species, in particular pine trees (*Pinus* spp.) from seedlings to mature trees (Chou, 1976; Gibson, 1979; Stanosz & Cummings Carlson, 1996). The pathogen is one of the most common fungal agents in more than 65 countries in Asia, Africa, Europe, Oceania, North and South America (CABI, 2017). *S. sapinea* was first reported in 1842 in France on *Pinus sylvestris* trees (Swart & Wingfield, 1991) and now is known to be widely distributed in the natural ranges of pines in the Northern Hemisphere and where these trees have been introduced in the Southern Hemisphere (Smith & Stanosz, 2006). A recent study has shown that the fungus causes significant die-back on *Pinus nigra* and *P. sylvestris* stands of almost all European countries (Zlatković et al., 2017).

In Bulgaria, *S. sapinea* was observed for first time in 1989 on *P. nigra* plantations in the North-east part of the country at the territory of Regional Directorate of Forestry (RDF) Shumen and Varna (Petkov, 1990). Over the last decade, an enlargement of areas severely damaged by the pathogen has been reported in native and exotic pine plantations throughout the whole territory of the country (Dobreva et al., 2016; EFA, 2006-2016). A trend of apparent increase of the disease throughout *P. nigra* plantations was detected in the period 2013-2016 due to the combination of the presence of large areas with susceptible stand conditions (mature trees in dense stands) and trees stressed by prolonged drought period. The most affected areas were assessed in the south part of the country – RDF Kardzhali, Plovdiv, Stara Zagora, Pazardzhik, Smoljan, where evidence of droughts is relatively common (Dobreva et al., 2016) and along Black see cost where climate conditions are most favorable for fungus development (Georgiev et al., 2017). It is probable that the known distribution of the fungus will continue to expand as it is further spread or detected in areas, where it has not been confirmed yet.

Host specificity

Sphaeropsis sapinea has spread all over the world on coniferous trees (Swart & Wingfield, 1991). The list of its host plants is extensive including the genera: *Abies*, *Arucaria*, *Cedrus*, *Chamaecyparis*, *Cupressus*, *Juniperus*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Thuja*, *Sequoiadendron* etc. (Palmer et al., 1987; Sinclair & Lyon, 2005; Zlatković et al., 2017).

In Bulgaria, the pathogen has been firstly found on *Pinus nigra* (Petkov, 1990). Later, it has been obtained on native and

introduced pines grown in Bulgaria – *P. sylvestris*, *P. radiata, P. strobus* (Rossnev & Petkov, 1993; Petkov, 2000), on *P. ponderosa* planted in 'Vrana' park, Sofia (Pencheva et al., 2009). In 2016 severe damages of *S. sapinea* were detected on *P. halepensis* on ornamental trees grown in the city parks of Sandanski and Gotse Delchev, South-west Bulgaria as well as on *P. pinaster* cultivated along Black see coast (Georgiev et al., 2017). The fungus should be considered likely to colonize any pine growing under unfavorable conditions in the country or among highly susceptible species as *P. nigra* and *P. radiata*. Among other genera damages caused by *S. sapinea* were determined on *Cedrus* sp. in the region of Varna (Rossnev & Petkov, 1993) and on *Sequoidendron giganteum* planted as ornamental trees in Sofia (Georgieva, 2016).

Disease symptoms

The pathogen *Sphaeropsis sapinea* affects needles, shoots, twigs, branches, bark, cones and stems of infected trees (Swart et al., 1985). The damages consist of discoloration, deformation or reduction of growth, necrosis of tissues and blue stain of wood. It is most possible resin flow on shoots to be observed as well. Often, signs consisting of fungal fruiting bodies also occur around the infected tissue. Withering of young needles that alter the external portion of the crown, and also death of shoots and buds occur in severely affected trees (Capretti et al., 2013).

The most common symptom associated with *S. sapinea* infection is shoot blight (Gibson, 1979). The needles lag behind in their growth and change color to tan or brown. The fungus spreads quickly and briefly covers all needles and tissues of young shoots, and by the end of the growing season, they are completely dry and dead. In approximately three weeks, black pycnidia appear on the surface of dead needles (Chou, 1976; Gibson, 1979). Cankers form as a result of bud and shoot infection can girdle individual branches or kill the entire tree (Waterman, 1943).

Collar rot and root disease is often seen on young seedlings in the nurseries. The root collar tissue becomes discolored, resinous droplets and pycnidia development were established in the surrounding tissue (Palmer & Nicholls, 1985; Petkov, 1990).

Sphaeropsis sapinea can persist asymoptomatic in seedlings, branches, cones and needles (Flowers et al., 2001) and proliferates when the host is under stress (Stanosz et al., 2005). The presence of *S. sapinea* in asymptomatic seedlings poses a problem to the forest industry for the management of *Sphaeropsis* related diseases.

The fungus may also cause latent infections for long periods within apparently healthy trees, and that difference in symptomatology may cause problems in identification, especially during field survey work (Flowers et al., 2001; Stanosz et al., 2001). The study found that real-time quantitative PCR was a reliable technique to diagnose this disease and suggests that it can also be used to study fungal behaviour in host tissue when only low amounts of inoculum are available, and can also be used to study the effect of fungal growth in host tissue during the early stages of an infection, as for example when it is desired to determine the effect of water stress on the fungal biomass and particularly to quantify fungal growth in the latent or endophytic phase (Luchi et al., 2005).

Biology of the pathogen

Sphaeropsis sapinea is a weak parasite that preferably invades tissues with high nutrient content, such as the mesophyllum, vascular cambium and phloem of trees weakened by abiotic factors (Capretti et al., 2013). In Bulgaria, the biology and ecological requirements of *S. sapinea* were studied by Petkov (1990; 1992; 2000). Occasionally, conidia release and dispersal become in the second half of April and lasts until late May-June, coinciding with the period of the formation of new shoots (Petkov, 1992). Most often, the pycnidia are formed at the base of dead needles and scales of two-year-old cones. Under moist conditions, pycnidia release a large amount of elliptical, non-septate and hyaline at first, and later dark brown conidia, non-septate, rarely two-septate. On infected seedlings in the nurseries, pycnidia are formed around the root collar. They can be positioned individually or in groups. Spreading of conidia is realized by wind, raindrops or transportation of infected plant parts. From the infected trees where the pathogen accomplishes its reproduction, the infection could reaches new trees and gradually spreads to neighboring stands.

Ecological factors

Sphaeropsis sapinea is considered as an extremely dangerous pathogen with a wide distribution in temperate forests, particularly in monoculture plantations located on sites characterized by high humidity during the flushing period and mild temperatures in the summer (Gibbs, 1984). According to Fabre et al. (2011) the main factors associated with the occurrence of *S. sapinea* were host species, winter temperature, and summer precipitation. The spread of diseases contributes to drought, lack of water causes the host plant stress, and may terminate *S. sapinea* latency period (Stanosz et al., 2001). Infected shoots and needles dry out, so the tree growth is slowing and eventually dies.

In Bulgaria, large territories of pine stand being affected by drought were subsequently attacked by the pathogen *S. sapinea* recent emerging of infections caused by this pathogen has developed rapidly as a consequence of the prolonged drought periods with lack of precipitation in growing seasons (Dobreva et al., 2016). Favourable environmental conditions for the mass occurrence of the disease was found along Black

see coast at sites with high air humidity – near ponds and streams, closed valleys with common fogs. This moisture conditions allow the growth of shoots and young needles, but also favours the emerging of fungal fruit bodies, releasing and germination of conidia, all of which increase the possibility of trees becoming infected (Capretti et al., 2013). The temperature is other important environmental factors affecting spore germination. The conidia of *S. sapinea* germinate at wide temperature range – from 6°C to 36°C, with an optimum at 26°C (Petkov, 1992).

Pathogenicity

Sphaeropsis sapinea has been recognized as endophytes, and weak or latent pathogens of conifers, active only locally and periodically (in specific weather conditions), able to colonize stressed, weakened, injured or dying woody tissues (Capretti et al., 2013). In Bulgaria, the recent outbreak of disease is a result from the present combination of susceptible hosts and suitable environmental factors that affected the distribution and infectivity of the pathogen. After first emerging of the infection, it has existed in the environment and rapidly increased its pathogenicity. The rate of defoliation and discoloration of infected pine trees has altered over the years, with varying intensity according to the specific environmental conditions of sites. *S. sapinea* causes serious disturbances in the development and growth of trees (Rossnev et al., 2008). Development in the crowns of pine trees is easily recognizable by browning and death of annual needles, shoots and buds, necrosis of the skin, blue stains of wood. In stands, where the infections lasted several seasons, trees are often subsequently attacked by secondary agents such as aggressive xylophage and pathogens.

Drought, combined with a high temperature in growing season induce stress in trees and thereby predisposes them to be attacked by *S. sapinea* and other pathogens and pests (Georgiev et al., 2017). The high existence of *S. sapinea* outbreaks contributed considerably to the physiological weakness of pine trees and they become more susceptible to attack by aggressive xylophages and other fungal pathogens.

Control

Appropriate silvicultural treatments such as pruning and thinning can affect health status and survival of pine plantation in the country. In infected stands, sanitary felling has to be conducted. Trees that are a source of infection have to be removed from plantations and urban ecosystems. Pruning of trees has to be carried out in periods unfavorable for the occurrence of infection – in a cool and dry weather. In forest nurseries, it is recommended to apply copper-containing formulations during the period of spore dissemination; remove and burn the infected seedlings.

The current high levels of *Sphaeropsis sapinea* occurrence, together with the ongoing more virulent evolution of the pathogen, suggests that infections will continue to emerge and probably increase and emphasizes the urgent need for effective surveillance and control.

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