Mycological effects as a sign of a phytopathological situation in green landscape

L G Seraya¹, G E Larina¹², I N Kalembet¹, N N Polyakova¹ and A B Petrov¹

¹All-Russian Research Institute of Phytopathology, 5, Institute str., Bolshie Vyazemy, Moscow Region, 143050, Russia
²State University of Land Use Planning, 15, Kazakova str., Moscow, 105064, Russia

E-mail: lab14@vniif.ru

Abstract. Visual signs of the negative influence of various factors in woody plants include the loss of decorativeness and vitality, discolouration of needles, uneven growth, etc. Conifers of the boreal zone, including Siberian fir (Abies sibirica Ledeb.), have the most pronounced decrease in the ability of plants of green plantations to resist extreme environmental conditions. In perennial plantations of Siberian fir, scientists identified a complex of fungi distinguished not only by low biodiversity but also by the abundance of phytopathogens and moulds from the genera Alternaria, Diplodia, Macrophoma, Pestalotia, Sclerophoma, Cucurbitaria. The article shows that under stressed conditions (imbalance in nutrients, etc.), the fir plants in the root zone have critical disturbances or mycological effects which characterize the deterioration of their viability and loss of resistance to disease. This data are useful for phytosanitary monitoring of green plantations and planning environmental protection measures in urban areas.

1. Introduction

Abiotic and biotic environmental factors affect the plant in the process of growth and development. Among the causes of various diseases of both an infectious and non-infectious nature, researchers identify stress – reduced ability to resist extreme environmental conditions, adapt to them and maintain their life potential.

In nature, a woody plant occupies an area of the environment with homogeneous living conditions. The artificial (green) plantations have an anthropogenic, urbanized environment in which all components of the biocenosis are under stress. Visual signs of the negative influence of various factors in woody plants include loss of decorativeness, decreased viability, discolouration of needles, uneven growth, etc. [1, 2]. Phytopathogenic fungi act as initiators of the infectious process, which affect the aerial part and the root system of woody plants.

Our study aimed to study the fungal community of conifers at landscaping sites.

2. Materials and methods

In perennial plantings of Siberian fir (Abies sibirica Ledeb) on the territory of the Moscow agglomeration, we conducted reconnaissance surveys to preserve the decorativeness and functionality of conifers. The period from 2010 to 2019 had a moisture deficit and high temperatures for the European part of Russia, which caused a weakening of growth and drying out of coniferous plantations. The studied green plantations consist of two locations with fir plants of Siberian age 40
years: 1 - park area, where Siberian fir plants form picturesque groups of warty birch and ordinary pine of natural origin; 2 - alley plantings, where Siberian fir plants form dividing strips between lawns and buildings, there is no vegetation of natural origin.

To determine the causes of tree damage, we conducted visual surveys using a scale for assessing categories of condition of woody plants – CCP [3], selected needle, root and soil samples for instrumental analysis. In laboratory conditions, we examined the selected soil samples and determined the physicochemical properties using standard methods adopted in soil science [4, 5].

Micromycetes were isolated using traditional methods of microbiology and phytopathology: plating on solid agar medium, a moist chamber, plating in a drop [6]. We determined the species affiliation of isolates based on cultural and morphological characters according to the determinants for the corresponding taxonomic groups and calculated the frequency of occurrence (FO) in % of the total number of species in the sample [7]. The terminology follows Index Fungorum (http://www.indexfungorum.org).

We analyzed the data using the functionality of the Microsoft Excel software package (2013). The statistical values of the studied indicators obtained during the work have at 95% significance level.

3. The study of the mycological effects

The fir planting from location 1 showed trees of 1-3 state categories: healthy, weakened, greatly weakened. The physicochemical properties of the soil affect the diversity of the microbiome and the condition of higher plants, i.e. determine the most important parameters of the living environment of organisms [8]. In the analyzed soil samples from the root zone of the Siberian fir, the pH is 7.5-7.9, and in areas with background soil, the pH is 7.4-7.8, which corresponds to an alkaline environment and exceeds the optimum soil acidity for Siberian fir equal to 4.5-5.6. Siberian fir is demanding on nutrition, but in the surveyed area, the soil is deficient in nitrogen, high in magnesium and water-soluble salts, including sodium.

We determined the increased content of ammonia nitrogen in the root zone of fir compared with soil taken from birch and pine of natural origin. It characterizes nitrogen loss, destruction of soil structure (clay dispersion, clumpiness), reduction of capillary moisture (desiccation), loss of humus, the abundance of pathogens. We analyzed the value of soil electrical conductivity under plants of different state categories (Fig. 1) as an integral indicator characterizing the influence of soil properties (thermal regime, water holding capacity, structure, mechanical composition, etc.) on the decorativeness and viability of coniferous plants.

The increase in the electrical conductivity correlates with the deterioration of the tree, which is due to the actively ongoing process of salinization of the soil in the root zone of plants, which leads to a limitation of moisture entering the roots. Reasons for unsatisfactory soil conditions in location 1 include structurelessness, overconsolidation of the upper horizons, destruction of organic matter, and, as a result, the growth of phytopathogenic fungi in the soil increases. The fungi of the genus *Phoma* (it is the causative agent of phomosis and leads to drying out of shoots, the formation of necrotic spots in the forehead, the death of the cortex above the root neck) and *Fusarium* (it is the causative agent of fusarium, leading to the development of root rot) complicate the situation in the fir root zone. In soil from the root zone of fir, we determined, among others, phytopathogenic fungi of the genera *Acremonium* and *Verticillium*, and in the rhizosphere (fir roots), we found *Acremonium*, *Clonostachys*, *Fusarium*, *Humicola*, *Phoma*.

The isolated complex from location 1 (*Abies sibirica* Ledeb) included fungi of the following genera:
- roots (rhizosphere) - *Acremonium*, *Clonostachys*, *Fusarium*, *Humicola*, *Phoma*, *Trichoderma*;
- plant elements (shoots) - *Alternaria*, *Aureobasidium*, *Bothrodiscus*, *Colletotrichum*, *Cucurbitaria*, *Diplodia*, *Macrophoma*, *Mucor*, *Phoma*, *Rhizosphera*, *Sclerophoma*;
- plant elements (needles) - *Alternaria*, *Pestalotia*;
- soil from the fir root zone (artificial vegetation) - *Acremonium*, *Alternaria*, *Aspergillus*, *Aureobasidium*, *Clonostachys*, *Fusarium*, *Humicola*, *Trichoderma*, *Verticillium*. 
The natural vegetation (pine, birch) in this location has fungi of the genera *Aureobasidium* (they are saprophytes, widely distributed in the environment), *Clonostachys* (they are distributed in soils and plant residues: roots and litter, parasitic on other fungi), *Humicola* (they are obligate saprotrophs, their growth associated with dead plant debris or soil humus, they cannot develop on plants).

![Figure 1](image)

**Figure 1.** The value of the electrical conductivity of the soil under *Abies sibirica* Ledeb of 1-3 CCP and decorative lawn (or background)

Weakened plants are less resistant to aerogenic diseases. In the warm period, there is an active population of shoots and needles, from the samples of which we also isolated phytopathogenic fungi from the genera *Alternaria, Diplodia* (they lead to the formation of ulcers on the trunk and branches, drying of shoots, needles, wilting of the buds), *Macrophoma* (they lead to drying of shoots), *Pestalotia* (they lead to drying out of shoots, needles), *Sclerophoma* (they lead to sclerophomosis, damage and death of shoots and needles), *Cucurbitaria* (they lead to damage to coniferous kidneys), etc.

The fir plantings from location 2 had the plants of the 1st state category, of the 2nd category (the presence of stumps after pruning, deepening of the root neck, wound cancer) and the 3rd category (overgrown frost-crack, partial drying of the apex, drilling of needles, colonization with stem pests). In the analyzed soil samples taken from the root zone of fir, the pH of the water is 6.8-7.0, which corresponds to a neutral environment, but in this situation, the pH value is critical and can be a factor that weakens the coniferous plant. In the root zone of the fir, we determined an imbalance in nutrients: high phosphate and potassium, low nitrogen, which affects violations in the functionality of the root system.

We instrumentally established deviations in the conductivity indices at the border of the planting pit and lawn: in the root zone of fir, it was 254 mV, on the decorative surface of the lawn it was 90 mV, at the border (edge of the landing pit) it was 602 mV. It characterizes changes in soil formation processes, which affects the distribution of water-soluble salts in the soil solution and the ability of fir roots to absorb the necessary elements. The boundary of the planting pit has a stagnant zone there are the precipitations of sodium-based salts, 287 mg/kg versus 61 mg/kg in the root zone and 77 mg/kg under the lawn. The high carbonate content with sodium allows us to characterize the ongoing processes as active mineralization (or salinization), which is typical for conditions with a moisture
deficit and high water hardness (the calcium content in the water from the water supply system significantly exceeds the norm), which confirms the concentration of carbonate ions in irrigation water and is typical for the conditions of the Moscow agglomeration. This situation affects poor growth and yellowing of needles (chlorosis), it is also due to a deficiency of iron, manganese, an excess of sodium and potassium salts. The weakened plant has low immunity against pathogens and pests. The work of other researchers also confirms it and indicates that the prevalence of coniferous plants resulted from poor soil conditions: heavy clay soils, poor drainage, periodic waterlogging, etc. Under stress (imbalance in nutrients, etc.), Siberian fir plants lost their resistance to disease damage, which worsened their condition and lead to critical disorders or mycological effects in the root zone.

In plants of the 3rd CCP from location 2, we identified fungi of the following genera, considering the place of selection: soil — Clonostachys, Colletotrichum, Cunninghamella, Fusarium, Talaromyces, Trichoderma; shoots and needles - Alternaria, Clonostachys, Chaetomium; roots - Alternaria, Clonostachys, Fusarium, Trishoderma.

During the years of observations, warm autumn and winter contributed to the active development of phytopathogenic fungi of the genus Colletotrichum, a polyphage, the causative agent of anthracnose, which appears visually with brown spots on shoots and worsens the decorativeness of conifers, in the soil (FO is above 20%), in the root zone of fir and the decorative lawn. The change in temperature in the fir root zone confirmed the abundance of mycophilic fungus of the genus Talaromyces (FO is 10-20%). Soil temperature is one of the most important factors of plant life. The high temperature in the root zone of the woody plant increases the oxygen demand of the roots, increased breathing depletes the supply of nutrients in the roots and leads to a general weakening of the plant.

We obtained an interesting result when comparing the representation of the Fusarium, Clonostachys, and Trichoderma genera dominant in the microcenosis of fungi (FO above 40%) in the soil of plants of different status categories (Fig. 2). In the rhizosphere of coniferous plant roots of the second state category, the abundance of micromycetes of the genus Clonostachys and Trichoderma decreased by 10-30% and the frequency of occurrence of Fusarium increased by 20%. It allows us to talk about mycological effects associated with the active development of root rot in plants from this location. We did not observe this pattern in the soil of the root zone.
4. Conclusion
A survey of perennial green plantations showed that with a deterioration in the decorativeness and viability of *Abies sibirica* Ledeb (a transition from the 1st to 3rd CCP), there are changes in the structure of the complex of soil micromycetes, signalling mycological effects. Poor soil conditions—structurelessness, overconsolidation of the upper horizons, nutritional imbalance, impaired hydration and aeration, lead to disturbances in plant growth, depletion of the root system and weakened immunity. The created conditions are favourable for increasing the number of phytopathogenic fungi in the soil, which actively affect the coniferous plant. In artificial plantations from *Abies sibirica* Ledeb in an urbanized environment, we identified a complex of soil fungi characterized by low biodiversity with an abundant presence of phytopathogens and molds. The study found a high abundance of representatives of a number of genera (FO above 40%)—*Acremonium*, *Alternaria*, *Aspergillus*, *Aureobasidium*, *Botrytis*, *Chaetomium*, *Clonostachys*, *Fusarium*, *Humicola*, *Trishoderma*, and in fir rhizosphere—*Clonostachys*, *Fusarium* in the soil of the root.

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