Mistletoe Infestation as a Transboundary Problem

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Abstract

The rapid spread of the hemiparasitic shrub of the European white-berry mistletoe, *Viscum album* (L.), in the Kaliningrad region is alarming. One of the probable reasons for this phenomenon is global warming. Another factor favourably affecting the development and reproduction of mistletoe is the increase in the number of bird species feeding on it and dispersing its seeds. The lack of a scientifically based and properly organized control against this phenomenon could be regarded as yet another factor contributing to the spread of mistletoe. Moreover, there is no single opinion on the mistletoe effect on woody plants. Therefore, the question arises of the scrupulous study of biology, physiology, aetiology and biochemistry of mistletoe in the Kaliningrad region, along with the issue of mechanical mistletoe removal. In this connection, the experience of neighbouring countries inhabited by the plant and using it for various purposes is of particular interest.

Keywords

The European white-berry mistletoe (*Viscum album* (L.)) · Spread · The Kaliningrad region · Removal

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Introduction

Due to the influence of the climatic and anthropogenic factors, species not characteristic of certain ecotopes are forced to shift their ranges to find a new ecological niche. During the last 10 years, the number of trees infected by the semiparasitic shrub of the European white-berry mistletoe, *Viscum album* (L.), has been increasing in the Kaliningrad region. The European mistletoe is a recognized stressor for host trees and shrubs (Sangüesa-Barreda et al. 2018). Due to the fact that mistletoe is spread by birds, and birds do not recognize administrative borders, the problem of the Kaliningrad region becomes a problem for its neighbouring countries. Thus this issue is of a transboundary nature.

Material

The genera Viscum belonging to the mistletoe family Loranthaceae includes about 100 species of evergreen semiparasitic plants growing in subtropical, tropical and temperate regions of Eurasia. According to host specificity, the mistletoe is classified into three subspecies: *Viscum album* L. Scp. Platyspermum growing on deciduous plants; *Viscum album* L. Scp. Abietis growing only on Abies alba, European silver fir; *Viscum album* L. Scp. Laxum—a pine mistletoe growing on pine trees and rarely on spruce (Vardanyan et al. 2011).

The most common species in western and southern Europe is the European white-berry mistletoe (*V. album* (L.)). In the north and east of Europe, there is *V. coloratum* (Kom.). Its appearance is quite similar to that of the European mistletoe; however, its berries are yellow and orange. Latvia represents the northern range limit of the European mistletoe in the Baltic States. Both species occur in Russia with *Viscum coloratum* (Kom.) found in the Far East. In the countries bordering Russia, coloured mistletoe is a strictly protected species; therefore, its study in recent years has focused primarily on its genetic and ecological conservation (Kim et al. 2017).

Mistletoe is an evergreen semiparasitic shrub epiphyte of spherical shape with a diameter of 20–150 cm growing on the branches of deciduous trees (oak, poplar, willow, maple, birch, linden, pear, elm, apple, hawthorn, walnut, hornbeam, false acacia, plum, pine, spruce, etc.). The most susceptible to mistletoe infestation are trees with increased water balance, hygrophytes and softwood trees. Nevertheless, mistletoe can occur on hardwoods and weakened trees.

Results

Mistletoe is dioecious having separate male and female plants. Through root-like structures called haustoria that penetrate into the wood, mistletoe attaches to a host tree and absorbs its nutrients. Mistletoe is dichotomously branched. It is possible to estimate the age of a mistletoe bush simply by counting the number of forks, as its green and brown branches fork once per year.

The branches are brittle, breaking apart easily at the nodes. The yellowish green leaves are opposite, sessile, coriaceous with 3–4 clearly marked longitudinal veins. The leaves contain chlorophyll that makes mistletoe capable of photosynthesis, thus the shrub is only semiparasitic. Moreover, when a host tree sheds its leaves mistletoe might provide it with carbohydrates. Mistletoe itself sheds in autumn with only second-year leaves falling. It shows a high rate of transpiration ensured by a supplementary mechanism of stomatal opening. Transpiration rate in some mistletoe species is ten times higher than in their host plants. The small, yellowish-green unisexual flowers of mistletoe grow in groups in the top forks of the branches. Staminate flowers are larger than pistillate which do not exceed 2 mm in diameter. Mistletoe fruit is a round pseudo-berry, approximately 10 mm in diameter. Unripe fruit is green, ripe one is translucent white. The seed is large, approximately 8 mm in diameter, embedded in a viscid pulp in a pod coat. Seeds contain up to three embryos.

At the moment, there is no data on the ecological relationships between mistletoe and its host trees in the Kaliningrad region, and the information on the anatomical and morphological characteristics associated with the specific nature of this species is not sufficient.

In our zone, the flowering season is in late winter. White berries remain on the plant for over a year. With its seeds being dispersed by berry-eating birds, mistletoe is an ornithochorous plant. Birds pecking its fruit in autumn and winter spread seeds long distances when flying to other woodlands and migrating to nesting areas. The seed either passes through the bird's digestive system and germinates on tree barks where it falls or adheres to the bird's beak, and is removed while the bird tries to wipe it off by scraping it on to another tree's branch. The seed glues to a new host forming haustoria that penetrate the tree's bark. Viscin contained in mistletoe berries and covering its seeds is a crucial factor in the survival of the species.

The list of birds cited with the European mistletoe fruit consumption includes 28 species (Nechaev 2008). According to the effect their beaks and digestive tracts have on fruit and seeds, mistletoe-eating birds form the following groups (Nechaev 2008):

1. Birds breaking fruit and seeds into smaller pieces with their beaks; mostly consuming "kernel" seeds only (finches: Pine Grosbeak, Hawfinch, Redpoll and others; tits; Tree Sparrow).
2. Birds swallowing whole fruits and grinding them completely or partially with gastroliths in gizzard (Galliformes: Hazel Grouse, Pheasant and others).

3. Birds swallowing whole fruits not damaging seeds with their beaks. They digest only the fruit pulp while the seeds remain undamaged and are later defecated (Grey-headed and Black Woodpeckers, Grey Starling, Corvidae: Jay, Azure-winged Magpie, Nutcracker, Large-billed Crow, Carrion Crow; Dusky Thrush and other thrushes; Bohemian Waxwing, Japanese Waxwing).

The enormous increase in the number of representatives of the family Corvidae in cities, including the urban area of the Kaliningrad region, resulted in these birds' contribution to the spread of mistletoe. This growth is caused by unorganised landfill sites around towns and villages providing a plentiful food supply.

Discussion

Mistletoe is a wild-growing medicinal plant. Today, the content of antioxidants in medicinal plants, particularly in mistletoe, is drawing a lot of attention (Onay-Ucar et al. 2012). The intensification of free radical oxidation damages the structure and properties of lipid membranes establishing the direct correlation between the excess of free radicals and the risk of dangerous diseases (Chupakhina et al. 2014). Plant antioxidants are biologically active substances that bind excessive free radicals and inhibit increased lipid oxidation and the formation of unwanted oxidation products (Chupakhina et al. 2014). In this regard, the evaluation of the antioxidant properties of plants is of some practical interest, with mistletoe as a medicinal plant being of particular interest.

The European mistletoe has been used since ancient times (V century BC) and is still used in traditional medicine for treating a wide variety of diseases: atherosclerosis, inflammatory kidney disease, chronic metritis, gastric and pancreatic diseases, pulmonary tuberculosis, bronchial asthma, hemorrhoids, hemorrhages, diabetes mellitus, etc. (Vardanyan et al. 2011). A large number of medicinal substances in mistletoe makes it possible to use the plant to treat hypertension, neuralgia, asthma, degenerative disk disease, rheumatism and gout, swollen lymph nodes and abscesses. Some researchers discuss the issue of using mistletoe for treating human and animal cancer (Christen-Clott et al. 2010; Zhao et al. 2011). The reason for such a "universal" therapeutic effect of the European mistletoe is its complex and rich chemical composition. The leaves and young shoots are used for medicine production as they contain oleanolic and ursolic acids. They are also rich in resinous substances and fatty oils (Zarkovic et al. 1998). Other agents present in mistletoe include alkaloids, saponins, lupeol, viscerin, viscotoxin, choline and acetylcholine, propionylcholine and tyramine (Zarkovic et al. 1998; Vardanyan et al. 2011).

Mistletoe leaves also contain carbohydrates, polyhydric alcohols, organic acids, triterpenoids, gum, sterols, nitrogen compounds, polypeptides, lectins, A, C, E vitamins, phenols and their derivatives, tannins, phenolcarboxylic acids and their derivatives, flavonoids, chalcones, higher fatty acids, wax, carotenoids

(Vardanyan et al. 2011). Mistletoe berries contain fatty oil, gum, resinous substances, carotene, and ascorbic acid. The above chemical constituents of the European mistletoe, including flavonoids, carotenoids, vitamins A, C, E, nitrogen-containing compounds, and phenols, indicate its antioxidant properties (Zhao et al. 2011; Nazaruk and Orlikowski 2015). However, the chemical composition of the species Viscum, in particular, *V. album* L., is argued to be not thoroughly studied, and the antioxidant properties of the extract of white-berried mistletoe leaves are of certain interest. The extract of another mistletoe type, *V. coloratum*, contains 41 identified compounds, including 11 flavonoids, 2 hormones, 14 benzenoids, inositol, 2 pyrimidines, 4 triterpenoids, viscolin, 5 steroids, and a new flavanone-(2S)-7,4′-dihydroxy-5,3′-dimethoxyflavanone (Yao et al. 2006, 2007). Recently Chinese researchers have extracted a homoeriodictyol-7-O-Beta-D-glucopyranoside from *Viscum coloratum*. This flavonoid has an inhibitory effect upon platelet-activating factor causing bronchospasm and eosinophilic infiltration of airway mucosa (Chu et al. 2008; Zhao et al. 2007). This natural inhibitor provides a basis for drug development. Moreover, all flavonoids of *V. album* and *V. coloratum* have antioxidant activity (Yao et al. 2006, 2007) and cardioprotective properties (Chu et al. 2008; Zhao et al. 2007).

Mistletonone, diarylheptanoid from *Viscum coloratum*, and 1,3-diphenylpropane (viscolin) (Su et al. 2006), also have a pronounced antioxidant effect and can be used for treating diseases caused by oxidative stress (Yao et al. 2006, 2007).

Viscotoxins and lectins stand out of known mistletoe components. (Ochocka and Piotrowski 2002). Viscotoxins are the most active protein substances, rich in cysteine, particularly a- and b- thionines having an effect on the plant's membrane. There are four identified mistletoe's viscotoxins: A1, A2, A3 and B (Klein et al. 2002). Their amino acid sequence shows their high homology. Viscotoxins can assemble into complexes with other protein toxins, thereby changing their cytotoxic effect on target cells. Presumably, viscotoxins provide plants with the protection from viruses, bacteria and fungi. There are data (Klein et al. 2002) indicating the stimulating effect of viscotoxins on antibody production. Despite ongoing studies, the function and mechanism of their biological effects remain unclear (Yao et al. 2006).

Being a semiparasite, the mistletoe harms its host plant. Some authors believe that mistletoe infestation results in the death of the tree (Yelpitiforov et al. 2017). Other researchers believe that mistletoe can be used not only as an indicator of the health of woody plants but also as an environment pollution indicator (Yelpitiforov et al. 2017). Heavy-metal sensitive species most correctly reflecting the pollution level in urban areas are of considerable importance as bioindicators of heavy metal contamination (Chupakhina et al. 2017). Mistletoe leaves and haustoria have exceptional heavy metal-accumulating capacity resulting in host plant weakening. Moreover, as mistletoe feeds on its host's mineral elements it absorbs nutrients from the tree as well as stimulates the accumulation of certain elements rather than others, e.g., barium (Yelpitiforov et al. 2017).

Furthermore, mistletoe can be a stress test for wood species' resistance to colonization by this and other semiparasitic plants. This will allow for determining a plant species composition that is resistant to mistletoe infestation in order to prevent it from spreading.

Conclusions

There is no standard technique for *Viscum album* and its subspecies management. However, the only effective control method is the mechanical removal of mistletoe branches from a host tree. Extensive use of mistletoe's active components would promote its removal.

Mistletoe is mechanically harvested to be used as Christmas and wedding decorations. The Kaliningrad region does not have this decorative tradition. However, the plant is widely used to create a festive mood in winter, for example, in Germany. This might be the reason why mistletoe is visually not observed on the trees in Berlin, Dresden, Hanover, Munich or Hesse.

Despite the unusual ornamental appearance of the trees with green mistletoe balls on them, especially when leaves fall, it should be borne in mind that this semiparasite causes tree dehydration and reduces its wind resistance. In the Kaliningrad region mistletoe cut during sanitation pruning is transported to a solid waste site and disposed together with other pruning wastes, although it appears on some regional Red lists as a rare and protected species (Velichkin 2012). Not exploiting the region's potential as the source of this medicinal raw material seems unpractical.

The level of mistletoe infestation in the Kaliningrad region is so high that it demands action. Planting trees that are not susceptible to mistletoe infestation will prevent it from spreading. However, this is a long-term solution. The required immediate intervention is mistletoe mechanical harvesting for medicinal and decorative purposes (floral compositions). Sanitation mistletoe pruning will result in improved host vigour and increased wind resistance, as well as it will have a positive effect on the transboundary spread of this semiparasitic shrub.

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