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REVIEW PAPER

Disease prevention instead of fungicides – An emerging reality in forest protection

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ABSTRACT

The susceptibility of trees to disease is affected by various management and environmental factors, with the incidence of infectious diseases as an important indicator of forest health. Although plant protection products (PPP) are an important element of disease prevention and tree therapy, their use is primarily in forest nurseries. The increasingly limited use of PPP to protect managed forests against pests and pathogens results from European Union regulations that place greater emphasis on Integrated Pest Management (IPM). This article discusses past use of protective measures in Polish forests, describes errors and oversimplifications in historical pest control practices, and examines the effects of limitations on the use of fungicides on current forest health in Poland. Non-chemical forest management approaches that can provide effective preventive and protective measures against infectious diseases are recommended based on a review of past practices.

KEY WORDS

managed forests, infectious diseases, pathogens, fungicides, prevention

Introduction

It is estimated that 64% of the world's agricultural land (approximately 24.5 million km^2) is at risk from pesticide contamination (Tang *et al.*, 2021). Of the land at high risk of contamination, about 34% is located in regions of high biodiversity, 5% in areas of water scarcity, and 19% in low- and middle-income countries. Tang *et al.* (2012) also found that 61.7% (2.3 million km^2) of European land is at high risk of pesticide exposure. The average rate of application of active substances of pesticides in Europe in 2017 was 3.5 kg/ha (Siuda, 2021), while in Poland it increased from 1.5 kg/ha in 2009 (Jankowiak *et al.*, 2012) to 2.5 kg/ha in 2017 (Siuda, 2021). The application of active substances in tomato and cucumber greenhouse production is much higher than field crops, in 1998 reaching as much as 80 kg/ha (Golinowska, 2012). In contrast to agriculture, rates of application of pesticides in forest areas is largely unknown.

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In the past, approaches to forestry in many European countries changed depending on the demand for wood and socialtrends (Sturtevant *et al.*, 2007; Płotkowski, 2010; Brang *et al.*, 2014; Kant and Alavalapati, 2014). Management practices affected forests in ways that altered their susceptibility to pests and created forest health issues. For example, the afforestation of agricultural land in the post-war years in Poland and other Central European countries resulted in the establishment of intensively managed stands of pine, spruce, birch, or alder. These forests were subject to large-scale felling, including summer felling to provide a continuous supply of wood throughout the year. Various types of strip cuts were used that made trees susceptible to windthrow and root plate upheaval. Large scale tapping of Scots pine was carried out to obtain resin, soils were drained leading to periods of drought, and there was aerial spraying of insecticides, including DDT, among many other activities (Suwała, 2003; Magnuszewski and Tomusiak, 2013; Głowacka *et al.*, 2014; Zachara, 2017). At the time, these practices were often considered innovative.. They made it possible to protect commercial forest stands (e.g., spraying pesticides during pest gradation period in the 1980s) and created an impression of modern forestry as they were accompanied by a significant increase in the country's forest cover (Sierota, 2011).

The ex-post analysis of forestry in Poland in the almost one hundred years since national independence allows us to identify forestry practices that we can now see did not always work, were not well implemented or were simply poor forest management. These often resulted from policies imposed on forest management in previous times (Klocek, 2006), but were also due to inadequate understanding of forest ecology, simplifications of practices or to reduce costs. Nature itself frequently corrected mistakes – often in a dramatic way (Sierota *et al.*, 2020). An example of a questionable practice – which is apparent today – is monoculture plantings used in *post-war* afforestation, mainly with Scots pine *Pinus sylvestris* L. on former agricultural land in the lowlands, or Norway spruce *Picea abies* (L.) H. Karst. in the mountains. Monocultures were later seen to be conducive to insect outbreaks (2 million m^3 in 1980-1983), large fires (9 thousand ha in 1996), fungal epiphytosis (1 million ha in 1996-1997) and blowdown (7.5 million m^3 in 2017) (Sierota *et al.*, 2019).

Infectious diseases affecting forests can impact the implementation of sustainable forestry. Forests should fulfill productive, social and educational functions (Rykowski, 2006; Brzeziecki, 2008; Płotkowski, 2010). In addition to these benefits, forests provide ecological services that are carried out through natural processes.

This paper examines the role of fungi in creating threats to forests and the role that forest management can play in affecting phytopathological losses in forest stands. Some forest management activities were of greater significance in countries that underwent significant political and economic transformations, such as the former East Germany, Poland, Lithuania and Ukraine. Against this background, the influence of fungal pathogens on the current health conditions of forests and the possibilities for disease prevention and control are presented. Recommendations are provided which, in the face of decreasing availability of plant protection products, have promise as non-chemical methods of protection against forest pathogens.

Fungi as natural components of ecosystems

Fungi, together with bacteria, micro- and macrofauna and fungus-like organisms are decomposers that participate in many biogeochemical processes. Their activity mineralizes organic matter and provides nutrients that are essential for the development of other organisms, especially autotrophic plants (Sippola and Renvall, 1999; Harmon *et al.*, 2004). Fungi perform various trophic functions in forest ecosystems and are grouped as pathogens (necrotrophs) or saprotrophs, and symbionts or endophytes (Rodriguez and Redman, 1997; Araújo *et. al.*, 2017). At the same time, environmental conditions and their effects on plant growth can alter the ecological role of fungi (Wrzosek *et al.*, 2017). Under conditions of water and thermal stress in trees, saprotrophs may become weak pathogens, and fungi with pathogenic antagonists may become food opportunists and take over the role of a pathotroph, reducing plant health. A basic feature of pathogens is the presence of an enzymatic apparatus with specific biochemical abilities and evolutionally oriented strategies for influencing its host (Esquerré-Tugayé *et al.*, 2000; Gibson *et al.*, 2011). In the case of forest stands, substrates (i.e., the lignocellulose complex) are colonized by hyphae of different pathogens that are adapted to decay tree tissues at different stages of development, from seed in a cone to the wood of dead trees (Blanchette, 1995; Boddy and Watkinson, 1995).

Fungi play important and varied roles in shaping forest development. Some fungi enter the trophic system through tree roots and create mycorrhiza (ectotrophic or endotrophic), thanks to their ability to supply trees with water and minerals and defend against pathogens, ensuring the healthy development of trees and stands and allowing communication among trees in a stand (Kormanik *et al.*, 1980; Lehto and Zwiazek, 2011). Pathogens can overcome tree defences and lead to tree disease and death, which is why they are considered 'harmful' to commercial forests. Other fungi inhabit extremely weakened or dead trees or their parts, decomposing wood cell walls and leading to wood decomposition and, as a result, the formation of so-called 'deadwood' (Harmon *et al.*, 1986; Bobiec *et al.*, 2004).

In nurseries, plantations and managed stands, fungi are perceived through the prism of the damage they can cause. Fungi can cause the death of individual roots or branches, decrease the annual height and radial growth of trees, as a result, decrease wood production. In 2020, fungal diseases caused production losses in forest nurseries in Poland alone on 23% of their area. Among the most serious fungal diseases affecting seedlings, Polish foresters identified damping-off pathogens (140.7 ha in 2020), needle cast diseases (73.4 ha in 2020) and powdery mildew on oak (134.4 ha in 2020) (Sikora *et al.*, 2020). Pathogenic activity results both from the natural occurrence of fungi in the forest environment and from some disease-promoting management activities, which cause significant economic losses (Županić *et al.*, 2009; Sierota, 2011; Garbelotto and Gonthier, 2013). Pathogenic fungi found in stands managed for wood production are therefore undesirable and are preferably controlled at whatever stage of stand development they arise, although this runs counter to the maxim of Manion (2003), which states that: 'forests need a healthy amount of diseases' (Maresi and Salvadori, 2004).

Forest protection against pathogens – past and present

Fungal pathogens have long been known to be one of the main factors causing timber losses in commercial forestry. With this in mind, forestry practitioners have at different times and in different jurisdictions recommended a variety of preventive and protective measures (Nicolotti *et al.*, 1999; Pratt *et al.*, 2000; Berglund *et al.*, 2005). Disease prevention can be important at different times during stand management, such as when harvesting seeds (from standing and down trees, into sheets, not from the soil), during seed storage, during preparation for sowing and stratification, when sowing in soil in fields or in containers in nurseries (Kondoh *et al.*, 2001; Knudsen *et al.*, 2004; Dumroese and James, 2005). Protection is also carried out during stand establishment, during young and mature stand phases, and sometimes right up to the time of harvesting (Matyjaszczyk and Skrzecz, 2020).

In forestry, fungal and fungus-like pathogens have generally been perceived as causing disease, especially in nurseries where they have been the focus of chemical control. Due to the small nursery area under cultivation of individual species (in all of Poland, for example, the total area of forest nurseries is only 1860 ha (GUS, 2020), with Scots pine occupying a total of 140.1 ha in nurseries, spruce 6.6 ha and oak 118.6 ha). The significant threat of losses to disease during seedling production means that many intensive prophylactic and therapeutic methods are used in nurseries. The short life cycles of pathogens have at times required the application of high doses of active substances over short periods of time (Grzywacz, 1993; Sierota, 1997; Oszako *et al.*, 2009). Chemicals to protect against pathogens in nurseries have sometimes been repeatedly applied during one growing season. In addition to fungicide applications, soil and foliar chemical fertilizers are routinely applied in tree nurseries (Gower and Son, 1992). Studies on the influence of pesticide residues, including fungicides, on soil microorganisms, on mycorrhiza and on beneficial mesofauna have been conducted only recently (Sławska, 2006; Baćmaga *et al.*, 2007; Kuc and Aleksandrowicz-Trzcińska, 2012; Aleksandrowicz-Trzcińska *et al.*, 2013; Hamera-Dzierżanowska *et al.*, 2014).

The history of forest disease protection is filled with examples of chemical and physical methods used to prevent and control emerging pathogens. For instance, the Bordeaux mixture and Californian liquid, which were used to protect against oak powdery mildew and needle cast diseases until the 1970s (Yarwood, 1957; Pammel, 2017), thermal sterilization or fumigation of nursery substrates (Vaartaja, 1967; Dawson, 1972), and herbicides, including the popular Roundup® (Giesy *et al.*, 2000). The question may be asked whether natural genetic defence mechanisms in the surrounding microbiological environment have been lost – or at least weakened – by using chemical control measures to protect forests for wood production? There are well-known examples of soil degradation because of changes in soil microorganisms in former nurseries in Poland, even after several decades (Gierczak *et al.*, 1987; Stępniewska and Krupińska, 2002). This results from heavy use of chemical plant protection products that have depleted or even eliminated natural communities of soil fungi, including antagonistic and mycorrhizal fungi, as well as beneficial bacteria (Nowak, 1993; Niewiadomska *et al.*, 2005; Hamera-Dzierżanowska *et al.*, 2014). In such cases, heavy use of fertilizers may be needed for adequate seedling growth (Irwin *et al.*, 1998). In addition, reduced efficacy of fungicides has often resulted from the repeated use of chemical controls containing the same active ingredient or with the same mechanism of action, which increased fungal resistance or reduced sensitivity to particular chemical ingredients (Damicone, 2014; Pieczul, 2015). Heavy use of chemical controls was also carried out because of a lack of resources to diagnose pathogens and for early intervention, both of which go against the concepts behind Integrated Pest Management (Castello and Teale, 2011).

At the same time, significant changes in the forest environment have increased the potential for pathogen infection and weakened tree resilience in Poland. These environmentally predisposing factors include high levels of industrial emissions, numerous and repeated forest ground fires, floods, and hurricanes (Sierota, 2011). In some countries, the strategy for responding to damaging events in the forest environment was to plant container seedlings – an approach that combines modern engineering technology with biotechnology (Kowalski *et al.*, 2007; Szabla and Pabian, 2009). The aim was to provide seedlings with improved biological and physical characteristics for planting in areas that were historically difficult to regenerate, such as habitats depleted of nutrients, contaminated soils, and reclaimed areas. In contrast to a planting-based approach to forest regeneration, the use of natural regeneration has more recently taken on greater importance in forest management in many countries (Haila, 1994; Rozwałka, 1998; Brzeziecki, 2008).

Forest health problems caused by climatic extremes can alter the behaviour of pathogen-host systems. They are expressed by changes in photosynthesis, altered plant growth and development, and ultimately incremental traits of trees. In addition, there can be increased frequency of occurrences of greater pathogenicity, such as: sclerotics or chlamydospores tolerant to high temperature (Mykhayliv and Sierota, 2010; Sierota and Małecka, 2015; Kubiak *et al.*, 2017). The increase in average annual temperature and precipitation deficits (including snow) that have occurred in recent decades have affected stand productivity, the diversity of tree species, and the behaviour of pests and pathogens, which taken all together will alter the importance of and approaches to forest protection (Kundzewicz, 2014).

Since 2014, integrated pest management (IPM) has been a requirement in agriculture and forestry in Poland, in which the aim is to reduce populations of agro- and hylophages below thresholds causing economic harm, using both non-chemical methods of prevention and treatment, as well as to promote natural disease resistance in the environment (FAO, 1973). In 2009, the European Union adopted the so-called 'pesticide package', consisting of several amendments and new directives and regulations of the Parliament and of the Council (Directive 2009/127/EC; Directive 2009/128/EC; Regulation (EC) No 1107/2009 and Regulation (EC) No 1185/2009), which is the basis for pesticide use regulations in individual countries (Regulation EC). This means a ban on the use of, or a gradual withdrawal from, the market of plant protection products, including fungicides intended for use in forestry. Additionally, pesticide use has been limited by the rules in force in Forest Stewardship Council (FSC) certified forests (FSC, 2018 and 2019a; Głowacka and Perlińska, 2015). Pesticides that remain available to forestry are generally used only in nurseries. Some pesticide treatments (e.g., chemical protection against outbreaks of *Erisiphales*, *Pucciniales*) may be repeated several times, but even then satisfactory protection is not always achieved (Kuc and Aleksandrowicz-Trzcińska, 2012; Okorski *et al.*, 2015). This may be due to pesticide applications missing the so-called 'treatment window' for timely, effective protection of plants, which is understood to be during the early stage of pathogen development in plant tissues. The effectiveness of plant protection treatments can also be limited by variable weather conditions, as has been seen in recent years when mild winter temperatures enabled pathogenic fungi to survive in an active form so that they showed up earlier in the spring, combined with highly damaging late spring frosts (Matyjaszczyk *et al.*, 2019).

An additional factor affecting the control of forest pathogens is the reduced availability of plant protection products, a restriction in part to prevent the development of pathogen resistance to active substances in pesticides. This is caused by the withdrawal of approval of some active substances under regulations implemented by the European Commission. Poland has more fungicides approved for use in forestry than other European countries (Skrzecz and Perlińska, 2018), however, products containing chlorothalonil, thiuram, fenamidone, and thiophanate-methyl, have already been withdrawn from the market by regulation. In 2021, the approvals for mancozeb and sulphur will expire. In coming years, the list will be reduced further by withdrawal of approvals for preparations based on boscalid, cyprodinil, dimethomorph, tebuconazole, cyproconazole, metalaxyl, sedaxane, bupirimate, azoxystrobin, methylkrezoxime, pyraclostrobin, propamocarb and copper oxychloride. Among fungicides, the most commonly used active ingredient with a broad spectrum of activity is thiophanate methyl, found in up to seven products. An example illustrating the extent of changes in plant protection is the pending withdrawal by 2024 of all 12 products currently used to protect oak against powdery mildew (Szmidla and Karmiłowicz, 2019, Meszka *et al.*, 2016). Of the 33 fungicides approved for forestry use in Poland (Szmidla and Sikora, 2020), as many as 16 are restricted by the FSC, which significantly limits their use, especially in forest stands (Leśkiewicz, 2018; FSC, 2019b). The number of fungicides available for use by Slovak foresters is similar to that of Polish foresters. In the register of approved plant protection products kept by the Central Control and Testing Institute in Agriculture in Bratislava, 21 fungicides are listed, but they are based on only two active substances – mancozeb and sulphur. By way of comparison, in Lithuania (according to their State Plant Service under the Ministry of Agriculture), only 7 fungicides are approved for use in forests, two of which are biological preparations based on *Phlebiopsis gigantea* (Fr.) Jülich.

It is worth noting that in Europe, preparations containing three biological control agents (BCA): *P. gigantea*, *Pythium oligandrum* Dreschler and *Trichoderma* spp., are available for use for protection against harmful fungi. The species *P. gigantea* is used in the biopesticide Rotstop. *Phlebiopsis gigantea* creates a selective three-dimensional barrier in the soil root zone to prevent the pathogen *Heterobasidion* spp. forming fruiting bodies and primary infections on pine and spruce (Pratt *et al.*, 2000; Kubiak *et al.*, 2016; Kvakkestad *et al.*, 2020). According to national pesticide databases, Rotstop has been registered in Poland, Norway, Sweden, Estonia, Lithuania, and Czech Republic, among others. In addition, several versions of *P. gigantea*-based biopesticides have been formulated based on local strains of the fungus, such as the PG suspension in the UK and PG IBL in Poland (Zaluma *et al.*, 2021). In addition, the oomycete *P. oligandrum* is used in biopesticides such as Polyversum WP, Polygandron STP and Polygandron TTP. These preparations are recommended for use in forestry in Latvia, Czech Republic, Poland and Ireland. *P. oligandrum* in these products reduces *Phytophthora* infections of host plants by its mycoparasitic and competitive activity and by the induction of a plant defence reaction that results from stimulating phytohormones that trigger host plant resistance mechanisms against diseases. This useful BCA is characterized by active growth along the hyphae of the host plant and the production of enzymes that partially or completely degrade the host cell wall (Foley and Deacon, 1986). The enzymes chitinase and cellulase are involved in these complex mycoparasitic interactions, resulting in antibiosis, and antagonism. Fungi of the genus *Trichoderma* are used as BCAs in Europe, for example *T. asperellum* Samuels, Lieckf. & Nirenberg and *T. harzianum* Rifai. Biological plant protection products based on these species are registered, e.g., in Poland (Xilon WP), Belarus (Fungilex L), United Kingdom (T34 Biocontrol) and Czech Republic (Trianum P). The mode of action of *Trichoderma* spp. as biocontrol agents may be direct, by parasitizing the target organisms, or indirect, by competition, environmental modification, or promotion of plant defence mechanisms (Benitez *et al.*, 2004). Species from this genus produce, harzianic acid, viridin glovirin, alamethicin, and other metabolites that limit the growth and development of seedling gangrene complex microorganisms (Sant *et al.*, 2010; Wrzosek *et al.*, 2017). For example, in interactions with plants, *T. asperellum* induced immunity and activated the SAR (Systemic Acquired Resistance) and ISR (Induced Systemic Resistance) mechanisms, acting as plant bioprotectors and biostimulators (Chou *et al.*, 2019).

There are ongoing attempts to develop other methods of biological control and new biopesticides, such as those described by Hauptman *et al.* (2013); Lamichhane *et al.* (2017) and Kvakkestad *et al.* (2020), based on the principles of biological control defined by Eilenberg (2007) and also in the approaches used for IPM.

Forest management offences and opportunities for disease prevention

'Forest silviculture failures are successes for forest protection' is an adage that is not entirely groundless. In other words, silvicultural practices can at times create unintended disease management problems. The phytopathologist can find evidence of this in a number of activities used in forest management (Munson *et al.*, 1993; Sierota and Małecka, 2003; Żółciak *et al.*, 2020). Here are just a few of the 'sins' that can be found in traditional, routine forest management activities, that can lead to pathological problems in stands:

- overreliance on routine and rote plans in forest management (e.g., not taking into account soil fertility, planning harvests without accounting for disease risk);
- lack of effective and repeated monitoring of the state of the forest at the stand level (e.g., data provided by forest inventories can be subject to numerous errors);
- the use of chemical plant protection products in nurseries and crops without an accurate diagnosis of the disease/diseases organisms to allow selection of effective active substances that can be applied at the most effective time;
- underutilization of natural regeneration for afforestation and for reforestation of harvested stands;
- ploughing in furrows and stump areas rather than creating 'root rot gaps' (*i.e.*, planting in the presence of infected roots or rhizomorphs increases infection risk);
- planting without ensuring optimal conditions for mycorrhizae (e.g., removal of small roots when lifting seedlings in the nursery, allowing roots to desiccate, planting in a manner not suitable for local soil conditions);
- no requirement to treat stumps with the fungus *P. gigantea* after cleaning and thinning stands established on post-agricultural land;
- limited knowledge of forest phytopathology and, more broadly, forest protection practices among some fieldwork contractors, e.g., in Poland, Zakłady Usług Leśnych (ZUL).

Attention should also be paid to diversifying the training of forestry contractors to understand practices that increase phytopathological protection, and often supervision by forest administration. Insufficient funding for research on the effectiveness of non-chemical forest protection methods is needed (Karmiłowicz *et al.*, 2018; Matyjaszczyk *et al.*, 2019; Wodzicki, 2019).

'It is better to prevent than to cure' – this simple saying fits well with the aims of sustainable forest management, integrated plant protection, and with the principles of forest protection (Tainter and Baker, 1996). In managed stands, preventive measures should take into account monitoring, management planning, silviculture, and harvesting. In each of these areas of human activity, events may occur that result in the emergence of a potential or real disease threat. The consequences of insufficient knowledge, delays in implementing management actions to address disease issues, or even negligence, combined with the unpredictable impacts of environmental disturbances, will often be followed by the development of an infectious disease that leads to economic loss (Fisher *et al.*, 2013; Dyderski *et al.*, 2017; Hurley *et al.*, 2017).

What preventive maintenance measures are available in light of the limited range of available pesticides? Here are some examples for use in forestry and plantation management:

- seed collection and storage: collect seeds on sheets or directly from trees, not from the soil; during seed storage, ensure appropriate temperature, humidity and air exchange (avoid high CO_2 concentrations); provide adequate ventilation and consider disinfecting rooms and containers with ozone or UV light;
- sow seeds: ensure a suitable, pathogen-free substrate, suitable for the germination and growth of the particular tree species, use green and black fallow, alternate seedlings grown in open nurserieswith sowing of yellow lupine (for soil enrichment with organic

and mineral compounds, in particular, the ability to activate phosphorus), ensure proper sowing density, careful weeding without pulling so-called weeds (to avoid disrupting the structure of mycorrhizal mycelium in the soil, avoid or prudently undercut roots of older seedlings;
- container seedlings: use proven substrates, free from pathogens, with careful use of slow-release fertilizer, and irrigation to avoid drought (using water from a water source known to be free of Oomycete spores causing phytophthorosis); avoid placing container seedlings on sites with sandy soils (to avoid rapid drying of the roots during drought);
- afforestation: fragment the plough layer; plough several times with a plow deepener (with the expectation that birds will feed on grubs that appear); sowing mustard seeds in order to reduce the number of grubs of *Melolontha* and soilborne pathogens;
- forest renewal: remove stumps – leave wood remaining on the surface with the use of mycelium that decompose stumps (decomposition of root wood and protection against *Melolontha* spp. weevils); plant in known '*Armillaria* rot gaps' and '*Heterobasidion* rot gaps' areas, protect trees by treating stumps with *P. gigantea*; drying out of cuttings (waiting), avoid ploughing to prevent tearing/wounding of the mycelia and rhizomorphs of beneficial fungi; point planting of container seedlings into soil when exposed to weeds using a tubular columns;
- larch protection against larch needle blight *Meria laricis* Vuill.: if possible, rake and remove dropped infected needles or cover them with soil in order to prevent spore release into the air;
- protection against pine twist rust *Melampsora pinitorqua* Rostr. and other rusts *Melampsora* spp.: Eliminate aspen poplars (secondary host) from around the nursery and from the cultivation and neighbourhood (for a distance of approx. 500 m); leave grasses under any remaining aspen to reduce shedding of basidiospores from fallen leaves;
- protection of nursery seedlings and plantations from diseases affecting fir (*i.e.*, *Melampsorella caryophyllacearum* (DC.) J. Schröt.) and larch (*i.e.*, *Dasyscypha willkommii* (Hartig) Dennis): avoid unnecessary pruning and protect wounds after pruning where it is necessary, remove infected trees before they produce fruiting bodies;
- Scots pine protection against mistletoe *Viscum album* subsp. *austriacum* (Wiesb.) Vollm.: early removal of branches; prudent use of thinning in threatened stands; mechanical removalof mistletoe plants;
- protection of harvested wood left in the forest: sinking harvested trees or spraying them with water to increase moisture content of the wood above 100%, the threshold favourable to infection by blue-stain fungi or colonization by insects.

In conclusion, one could say with regards to tree disease control that 'the methods are well known but are too time-consuming and too expensive to carry out'. But are they really so unreasonable, given the immeasurable and measurable losses that arise in stands every year as a result of so-called forest pests, that cause immeasurable and measurable reductions in forest values?

Overall, we conclude that 'Prevention is the best form of protection!'.

Authors' contributions

All authors substantially conceived the ideas, contributed to conceptualization, resources, writing the original draft, and reviewing and editing the text.

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Conflicts of interest

Authors declare no personal circumstances or interests that may be perceived as inappropriately influencing the representation or interpretation of reported research results.

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STRESZCZENIE

Profilaktyka zamiast fungicydów – niezbędna rzeczywistość

Aktualny stan zdrowotny lasu jest wynikiem zwiększonej, pod wpływem różnych czynników, predyspozycji chorobowej drzew oraz wzrastającego udziału sprawców. Stosowane w praktyce gospodarczej środki ochrony roślin są jednym z istotnych elementów profilaktyki i terapii, przede wszystkim w szkółkach leśnych. Obowiązujące również w leśnictwie zasady IPM oraz obligatoryjne ograniczenia wynikające z przepisów Unii Europejskiej coraz bardziej utrudniają stosowanie fungicydów do ochrony lasów gospodarczych przed patogenami. W pracy omówiono retrospektywnie dotychczasowe działania ochronne na przykładzie polskich lasów oraz wskazano podstawowe błędy i uproszczenia gospodarki leśnej w przeszłości. Zwrócono uwagę na obecne uwarunkowania wynikające z ograniczonego stosowania fungicydów, proponując szersze działania z zakresu szeroko rozumianej profilaktyki. W gospodarce leśnej możliwe jest bowiem stosowanie skutecznych zabiegów profilaktyczno-ochronnych, zmniejszających ryzyko inicjowania chorób infekcyjnych drzew leśnych i rozpraszających skalę zagrożenia bez konieczności stosowania fungicydów. Przedstawiono przykłady zaleceń wskazujących na możliwość skutecznego stosowania niechemicznych metod w ochronie lasu przed patogenami.