BIOLOGICAL CONTROL: A NOVEL APPROACH TO MANAGING EMERGING FOREST DISEASES

HOMED

HOLISTIC MANAGEMENT OF EMERGING FOREST PESTS AND DISEASES

Summary

This policy brief is based on a scientific article prepared in the framework of the HOMED project by Simone Prospero, Leticia Botella, Alberto Santini and Cécile Robin. The article was published in the scholarly journal *Forest Ecology and Management.*

Emerging diseases are recognised as the main current and future threat to forest ecosystems (Fisher et al., 2016; Santini and Battisti, 2019; Thakur et al., 2019). As long as globalisation and international trade intensify, the unintentional movement of pathogens will continue to increase (Westphal et al., 2008; Santini et al., 2013). These non-native introduced pathogens establish themselves easily in new areas where they encounter naïve host trees, with no or few natural enemies and competitors (Mack et al., 2000). Another cause of emerging diseases is climate change, with rising temperature favouring the establishment of exotic pathogens of (sub)tropical origins (Anderson et al., 2004). Gradual changes in climate, as well as climatic extremes, such as drought, heatwaves, hail, flooding, and frost, may alter host tree resistance, thereby promoting diseases caused by native or non-native, often previously harmless, pathogens (Desprez-Loustau et al., 2007).

Despite their increasing occurrence and significance, emerging pathogens in forest ecosystems are still particularly difficult to control because of the specificities of both the hosts and the pathogens. Unlike most agricultural crops, which are annual (e.g. wheat, potatoes), tree generations extend over several decades. A particularly vulnerable tree species or variety cannot, therefore, be changed every year based on emerging threats. Thus, control strategies need to be effective in the long term not only during a specific growing season.

Keywords

biological control agent, native vs. exotic pathogen and host, pathogen resistance, virulence, forest pathogen management, tree diversity

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Relevance to legislation

International conventions

- **Convention on Biological Diversity**
- **International Plant Protection Convention (IPPC)**
- **Agreement on the Application of Sanitary and Phytosanitary Measures (SPS agreement)**

EU legislation

- **EU Biodiversity Strategy for 2030**
- **EU Regulation 1143/2014 on Invasive Alien Species**
- **Directive 2009/128/EC on the sustainable use of pesticides**

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Relevance to actual environmental problems

Forest threats and vitality, Biodiversity loss, Climate change, Alien species invasion, Forest pest management

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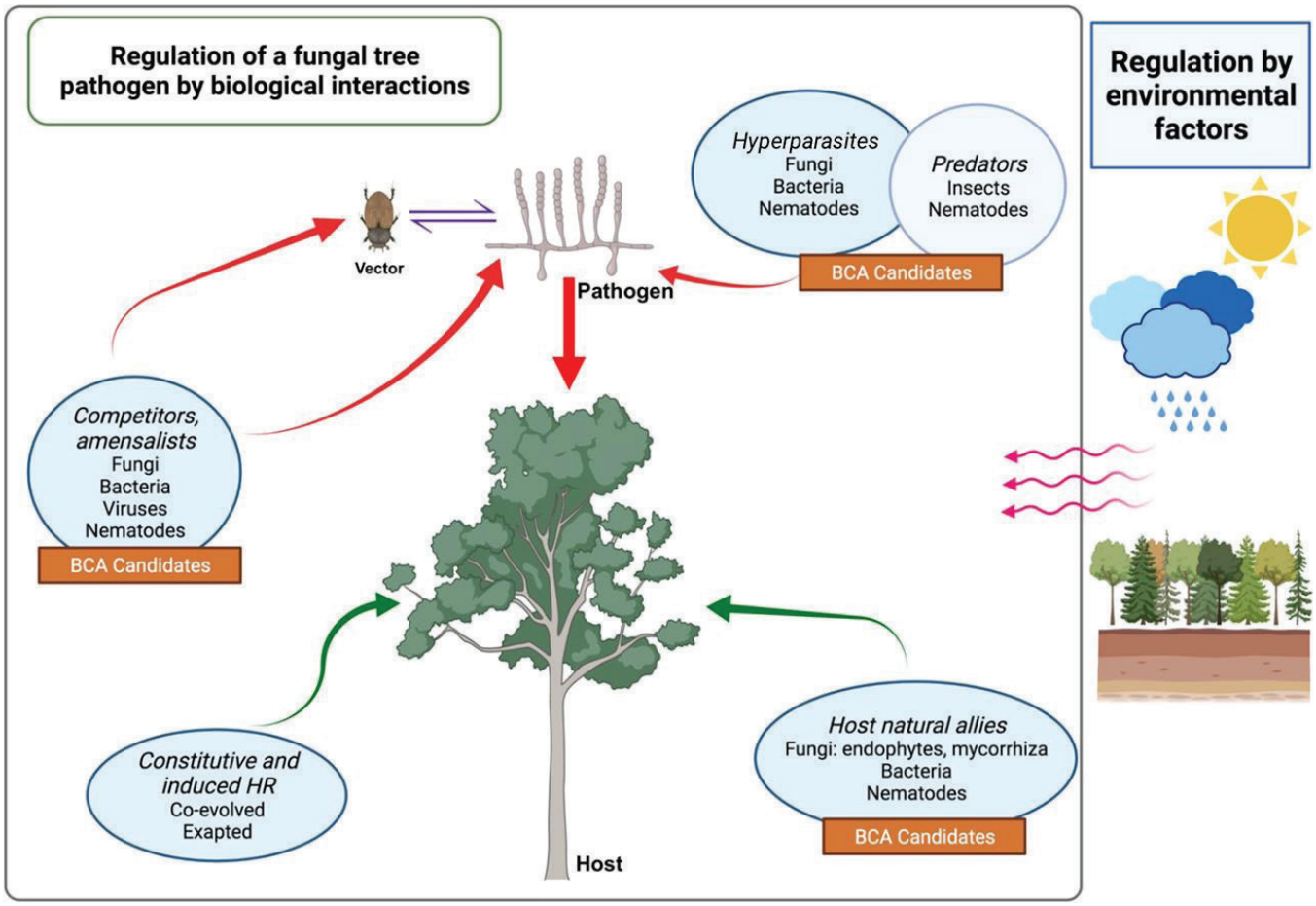
Description of the problem

Biological control (BC) is defined as the use of living beneficial organisms (predators, parasitoids, parasites, antagonists, etc.) to control pests or pathogens. The main goal of biological control is to achieve a self-sustainable and effective control of a pest by maintaining its population below acceptable thresholds. There are three different biological control approaches: (i) Classical biological control, with the introduction of a natural enemy of non-native origin that can self-establish to control an exotic pest in the long term; (ii) Inundative biological control, with repeated releases of exotic biological control agents which, in their new ecosystem, cannot establish sufficiently large populations to mitigate the pest's negative effect; (iii) Conservation biological control, which relies on the pest's native natural enemies, which are favoured through habitat manipulation like plant species diversification.

Although fungi are the main cause of emerging forest diseases, biological control approaches are still poorly applied to mitigate diseases caused by these organisms compared to insect pests. Thus, an effective biological control approach has to be developed for non-native fungal pathogens.



Main factors of regulation of fungal pathogens (including oomycetes) - tree interaction and biological control agent candidates. The outcome of a tree-pathogen interaction is affected by hyperparasites and predators (top-down regulators) that negatively affect the fitness of the pathogen (eventually kill it) in presence of a trophic interaction with it, competitors and antagonists that negatively affect the fitness of the pathogen or its vector without a direct trophic interaction, host natural allies and constitutive and induced host resistance HR (both bottom-up forces) that help the tree against the pathogen. Source: Prospero, S., Botella, L., Santini, A., & Robin, C. (2021).

Recommendations

- To increase the chances of success of biological control of forest pathogens, we suggest a holistic approach, involving the use of predators or hyperparasites, competitors and antagonists, all exerting pressure on the pathogen, as well as bottom-up forces (e.g. mycorrhizae) helping the host to better resist.
- Set up an 8-step protocol for identification of biological control agents for tree pathogens, comprising of: 1) Identification of the causal agent of a disease; 2) Identification of the origin of this pathogen; 3) Collation of data on host tree biology and ecology (e.g., growth, dispersion, survival; the different biological interactions in which it is involved; the abiotic drivers of its distribution, etc.); 4) Decipher the trophic interactions between the host, its pathogens and their natural enemies. This knowledge is the prerequisite for the definition of the best strategy of biological control to deploy; 5) Check the potential of biological control agent candidates and scale-up: the efficacy of the biological control agent candidate has to be initially assessed with in vitro and in planta tests; 6) Screen the best strains/genotypes/provenances of biological control agents: these tests are necessary to choose which strains/genotypes/provenances of the studied biological control agent should be applied to control the target pathogen; 7) Check for adverse effects of biological control agents, including unintended targets; 8) Set up the biological control agent deployment strategy: whatever the pathosystems and the biological control agents are, their deployment should take evolutionary principles into consideration, i.e. preserving capacities to evolve and adapt.
- Develop strategies complementarity to biological control: biological control measures alone are often not effective enough to maintain populations of a pathogen below acceptable thresholds. This is especially true in forest ecosystems, where the outcome of the interaction between pathogen and biological control agents may be strongly affected by biotic and abiotic factors, which can themselves vary significantly on a small scale. Information regarding other potential disease drivers (e.g. changes in the environment or in native pathogen populations) is also necessary to mitigate this disease in an evolutionary and innovative approach. Thus, biological control for the purpose of mitigating emerging forest diseases should be fully integrated with other sustainable management strategies (e.g. sanitation cuttings, reduction of host density, increasing forest biodiversity, and enhancing the use of resistant trees).

Sources

Main source

Prospero, S., Botella, L., Santini, A., & Robin, C. (2021). Biological control of emerging forest diseases: How can we move from dreams to reality? Forest Ecology and Management, 496: 119377. doi:10.1016/j.foreco.2021.119377

Additional sources

Anderson, P.K., Cunningham, A.A., Patel, N.G., Morales, F.J., Epstein, P.R., & Daszak, P. (2004). Emerging infectious diseases of plants: pathogen pollution, climate change and agrotechnology drivers. Trends Ecol. Evol., 19: 535–544. doi:10.1016/j.tree.2004.07.021

Desprez-Loustau, M.L., Robin, C., Reynaud, G., Déqué, M., Badeau, V., Piou, D., Husson, C., & Marçais, B. (2007). Simulating the effects of a climate-change scenario on the geographical range and activity of forestpathogenic fungi. Can. J. Plant Pathol., 29: 101–120. doi:10.1080/07060660709507447

Fisher, M.C., Gow, N.A.R., & Gurr, S.J. (2016). Tackling emerging fungal threats to animal health, food security and ecosystem resilience. Phil. Trans. R. Soc. B, 371: 20160332. doi:10.1098/rstb.2016.0332

Mack, R.N., Simberloff, D., Lonsdale, W.N., Evans, H., Clout, M., & Bazzaz, F.A. (2000). Biotic invasions: causes, epidemiology, global consequences, and control. Ecol. Appl., 10: 689–710. doi:10.1890/1051-0761(2000)010[0689:BICEGC]2.0.CO;2

Santini, A., & Battisti, A. (2019). Complex insect-pathogen interactions in tree pandemics. Front. Physiol., 10: 550. doi:10.3389/fphys.2019.00550

Santini, A., Ghelardini, L., De Pace, C., Desprez-Loustau, M.L., Capretti, P., Chandelier, A., Cech, T., Chira, D., Diamandis, S., Gaitniekis, T., Hantula, J., Holdenrieder, O., Jankovsky, L., Jung, T., Jurc, D., Kirisits, T., Kunca, A., Lygis, V., Malecka, B., Marçais, B., Schmitz, S., Schumacher, J., Solheim, H., Solla, A., Szabò, I., Tsopelas, P., Vannini, A., Vettraino, A.M., Webber, J., Woodward, S., & Stenlid, J. (2013). Biogeographical patterns and determinants of invasion by forest pathogens in Europe. New Phytol., 197: 238–250. doi:10.1111/j.1469-8137.2012.04364.x

Thakur, M.P., van der Putten, W.H., Cobben, M.M.P., van Kleunen, M., & Geisen, S. (2019). Microbial invasions in terrestrial ecosystems. Nat. Rev. Microbiol., 17: 621–631. doi:10.1038/s41579-019-0236-z

Westphal, M.I., Browne, M., MacKinnon, K., & Noble, I. (2008). The link between international trade and the global distribution of invasive alien species. Biol. Invasions, 10: 391–398. doi:10.1007/s10530-007-9138-5