TREE DIVERSITY AND FOREST RESISTANCE TO INSECT PESTS: PROSPECTS FOR FOREST PEST MANAGEMENT

HOMED

HOLISTIC MANAGEMENT OF EMERGING FOREST PESTS AND DISEASES

Summary

This policy brief is based on a scientific article prepared by HOMED project partners Hervé Jactel, Xoaquín Moreira and Bastien Castagneyrol, which was published in the scholarly journal *Annual Review of Entomology*.

One of the main challenges that forest managers face is limiting the damage that native and alien insect pests and pathogens cause on forests. This is important in order to reduce both their ecological and economic impacts. Based on an in-depth analysis of existing research in the area, **increasing tree diversity appears as the most efficient forest management practice for improvement of the forest's resistance to insect pests**. It is therefore recommended that, depending on the ecological and socio-economic context, mixed plantations in alternating strips or mixed hedges surrounding a pure stand of the focal species be prescribed. This will serve as an effective solution to prevent insect pest attacks in future forests, while improving their biodiversity.

Keywords

biodiversity, herbivory, resistance, forest management

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Relevance to legislation

International conventions

- Convention on Biological Diversity
- International Plant Protection Convention (IPPC)

EU legislation

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

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

Forests are essential to meet the growing demand for biomaterials, to contribute to climate change mitigation, and to preserve biodiversity. However, natural threats such as fire, insect pests, and diseases are disrupting the provision of goods and services from forests (Jactel et al. 2021). Climate change is triggering large-scale outbreaks of forest insect pests through increasing temperatures,drought, and storms. Also in the context of global change, the world's forests are exposed to unprecedented threats from biotic hazards (Simler-Williamson et al. 2019). The number of invasions by non-native forest insect pests also continues to increase worldwide, with a significant negative impact on forest functioning and economics. Research has established that aside from the profound impact on forest vitality, non-native forest insect pest invasions could have severe economic consequences (Holmes et al. 2009, Aukema et al. 2011).

Forest pest management has historically relied on the use of agrochemicals, which generally are suited for short-term curative control. Directive 2009/128/EC on the sustainable use of pesticides provides thorough regulation on the acceptable chemical substances that can be applied to control forest pests. However, the adverse consequences of widespread use have triggered severe environmental problems due to their persistence in the air, soil, water, and food, as well as the development of pest resistance (Jactel et al. 2021).

To reduce these risks, the European Union and forest certification schemes prescribe a reduction in the use of pesticides and give priority to the use of preventive, environmentally-friendly methods of forest pest management. One of these methods is based on the improvement of tree diversity (Jactel et. al 2021).

Foresters have commonly observed that the abundance or damage of insect pests are often lower in mixed forests than in tree monocultures. This observation has been termed associational resistance (Root 1973). A new meta-analysis of more than 600 case studies confirmed this pattern: a

given tree species is significantly less damaged by a given insect pest when grown in mixed stands than in pure stands (Jactel et al. 2021).

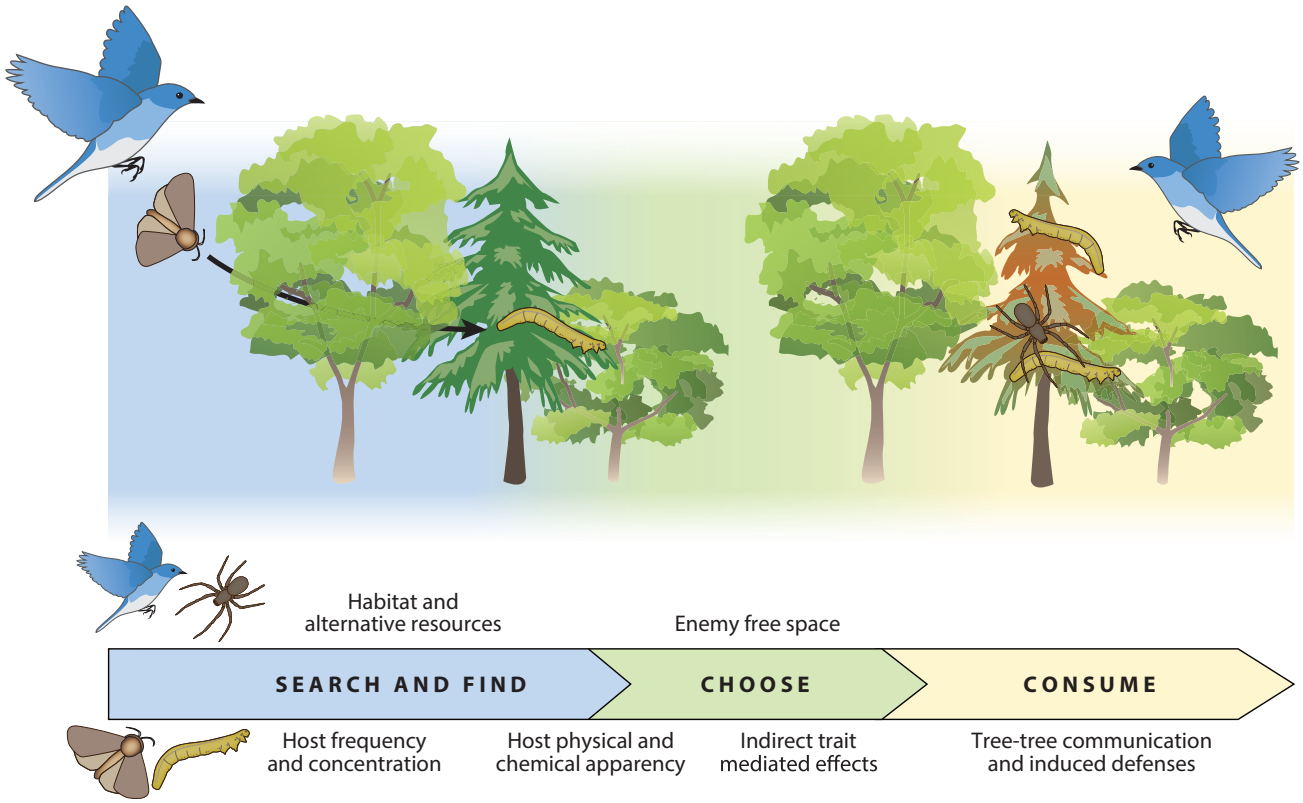
Two main mechanisms have been identified to explain these associational resistance effects. First, the presence of trees from different species around a host tree leads to a lower probability of insect herbivores accessing this host tree, due to disruption of host finding visual or chemical cues (Jactel et al. 2011).

Second, more diverse forests favor greater abundance of pests' natural enemies, such as predators and parasitoids, because of increased availability of micro-habitats or alternatives in resources, leading to reduced insect pest abundance and damage (Staab and Schuldt 2020).

A third mechanism has been more recently proposed, corresponding to the effects of tree diversity on host tree traits involved in the attraction of herbivore natural enemies (Abdala-Roberts et al. 2019) or direct defense against herbivores (Castagneyrol et al. 2018, Moreira et al. 2014).

We recognise that the choice of a companion species for a tree species of key production interest remains to be studied. An associated species with a growth rate that is too low compared to that of the species to be protected nor only would not promote sufficient protection, but also is economically inefficient in terms of low supply of wood products. Species with very contrasting growth rates pose silvicultural management issues, with different thinning regimes and harvesting ages.

Another factor that is also to be taken into account is the spatial arrangement of different species within the mixed forest. It is undeniable that a tree-to-tree species mixing pattern is the most efficient, as it would lead to a more difficult search for a host tree and increase neighborhood effects on trait modification. However, this type of mixing is more difficult to manage in mechanized production forests such as tree plantations.



Conceptual diagram showing how neighborhood diversity around a focal tree can reduce the damage caused by a specialist forest insect through bottom-up and top-down forces at the successive stages of host tree recognition,colonization, and exploitation. Source: Jactel et al. (2021). Tree Diversity and Forest Resistance to Insect Pests: Patterns, Mechanisms and Prospects. Annual Review of Entomology, Vol. 66:- (Volume publication date January 2021). Review in Advance first posted online on September 8, 2020.

Recommendations

Based on the above mentioned observations, we provide forest management recommendations to ensure more efficient and ultimately more sustainable methods of insect pest control.

- **We recommend increasing the diversity of tree species at the stand level to improve their natural resistance to insect pests.**

- We therefore suggest the establishment of mixed forests, or the conversion of pure forests into mixed forests, notably **based on the association between conifers and deciduous trees.**

- We recognise that the choice of a companion species for a productive tree species should be made according to the criteria of growth and productivity, as well as protecting ecological balance and local biodiversity. The choice among forest diversification options should be based on a multidisciplinary analysis of technical, economical, and societal constraints.

- We also think that the spatial arrangement of different species within the mixed forest is of great importance, and that an appropriate balance between forest pest control objectives and managing or harvesting costs must be considered in production forests. For that reason, we suggest an alternative, which is to design and test **mixed plantations in alternating strips** (i.e.rowwise intermingling pattern). This would allow for differentiated silviculture while maintaining close proximity between different species. Another solution that we would also recommend is the establishment of **mixed hedges surrounding a pure stand of the focal species**. This solution has a lower impact on forest managers (particularly in the case of intensively managed plantations). Mixed-species hedgerows can limit host tree accessibility for insect herbivores and serve as a habitat for natural enemies.

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