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Editorial: "Forentomics": forest pest and pathogen biology, ecology, and management using omics

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Editorial on the Research Topic
"Forentomics": forest pest and pathogen biology, ecology, and management using omics

Introduction

Forests are indispensable for ecosystem services such as biodiversity conservation and carbon sequestration. However, forest health is increasingly threatened by climate change, which amplifies pest and pathogen outbreaks, leading to large-scale tree mortality and disruption of forest ecosystems, accelerating the transition of forests from carbon sinks to carbon sources and exacerbating global warming. Mitigating these challenges requires a deeper understanding of forest pests and pathogens and their interaction with hosts at the molecular level to develop sustainable and eco-friendly forest management strategies. The present topic showcases the application of cutting-edge omics tools in tackling forest health under climate change. More specifically, "forentomics" represents research on forest trees, pests, pathogens and their interactions within the forest ecosystem using omics methodologies. Advances in omics technologies, including genomics, transcriptomics, proteomics, and metabolomics, have revolutionized the study of trees, pests and pathogen biology and ecology. These tools can provide detailed insights into the molecular interactions governing forest ecosystems, enabling innovative approaches to help mitigate current forestry challenges.

New frontiers in pest and pathogen detection research

Pathogens pose a significant threat to forest health, and precise detection methods are critical for effective management. Araeinejhad et al. focus on *Brenneria goodwinii*, a

bacterial pathogen responsible for oak and oriental beech decline. By developing a highly specific primer set targeting the *hrpN* gene, the study presented a reliable tool for early detection, enabling timely intervention to mitigate disease spread. Furthermore, Marques et al. reported the taxonomic challenges associated with *Physokermes* species, a group of soft-scale insects damaging conifers. The study resolved species boundaries and identified potential species complexes using nuclear and mitochondrial DNA markers. Accurate taxonomic identification is critical for designing targeted management strategies, especially as climate change influences pest and pathogen distributions.

Unveiling the molecular basis of pest adaptations

Many forest pests are able to exploit complex inherent adaptive mechanisms to respond to a changing climate, contributing to their destructive potential. Naseer et al. analyzed the life-stage, tissue, and sex-specific gene expression dynamics of the Eurasian spruce bark beetle (*Ips typographus*). Their study identified detoxification enzymes and gene related to metabolic regulation that may help bark beetles overcome host defenses, creating a foundation for downstream functional studies on key genes. Ramakrishnan et al. further elucidated the hormonal regulation of *I. typographus* physiology, focusing on juvenile hormone III (JH III). Their research unraveled key genes involved in pheromone biosynthesis and detoxification pathways, highlighting the role of JH III in facilitating adaptive responses. This work emphasized the potential for disrupting aggregation behaviors through hormonal manipulation, a promising avenue for managing bark beetle outbreaks. These findings also offer promising targets for RNA interference (RNAi)-based pest management strategies.

Functional genomics and forest ecosystem impacts

The ecological roles of pests and their interactions with forest ecosystems expand beyond direct tree damage. He et al. conducted a genome-wide analysis of carbohydrate-active enzymes (CAZymes) in termites, highlighting their conserved yet adaptable enzymatic repertoire. Termites, as decomposers, contribute to nutrient cycling and pose economic threats due to their wood-digesting capabilities. This study enhances our understanding of termite symbiosis and its implications for forest ecology.

Singh et al. performed foundational work that identified robust reference genes for real-time quantitative PCR in Norway spruce (*Picea abies*). Their study under diverse stress conditions ensured accurate reference genes for various gene expression studies. This methodological advancement supports future functional genomic research in conifers.

Resilient giants: decoding tree defense mechanisms against biotic stresses

Understanding the molecular defense mechanisms of trees is vital for developing pest-resistant selections. Sun et al. employed proteomics and phosphoproteomics to investigate the responses of Chinese pine (*Pinus tabuliformis*) to caterpillar feeding. This study revealed kinase-mediated phosphorylation networks and identified proteins critical to pine defense responses. These findings provide molecular underpinnings for breeding pest-resistant tree varieties and enhancing forest resilience. Furthermore, Pastierovič et al. studied European aspen (*Populus tremula*) responses to spongy moth feeding. Their analyses revealed that defense mechanisms, including increases in phenolic compounds, were activated within minutes of herbivory, confirming the dynamic nature of tree defenses and the importance of timing in tree-pest interactions. Finally, Stanley et al. explored host-pathogen interactions in green ash (*Fraxinus pennsylvanica*), a species severely impacted by the invasive emerald ash borer (*Agrilus planipennis*). Metabolomic analysis identified biochemical markers associated with host resistance, including induced defensive responses in lingering ash populations. These insights are instrumental for breeding programs aimed at preserving ash genetic diversity.

Leveraging omics for sustainable forest management

Integrating omics tools into forest pest and pathogen management is transforming how we manage forest health. From understanding pest adaptation to variable environmental conditions, to elucidating tree defense mechanisms, these studies collectively provide a roadmap for sustainable forest management strategies under climate change. Researchers can develop eco-friendly interventions, from breeding resistant tree varieties to deploying RNAi-based pest controls and implementing early pathogen detection systems. By disentangling the molecular complexities of forest ecosystems, these studies lay the foundation for innovative solutions to a variety of forest health challenges, both present and yet to come.

Conclusion and future perspectives

"Forentomics" represents a new frontier in forest molecular ecology, offering unprecedented opportunities to dissect the intricate interactions between forest trees, pests, and pathogens. The studies presented here illustrate the power of omics tools to address serious forestry challenges, from pest outbreaks to pathogen-induced tree decline. As climate change reshapes forest ecosystems, integrating molecular and ecological insights will be critical for safeguarding forests and their invaluable ecosystem services for generations to come. Future directions in forest protection will increasingly include precision pest control, AI-based early infection/attack and damage

detection systems, resilient tree breeding using AI-powered phenotypic and genotypic selection, prediction models and climate-responsive strategies.

Author contributions

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Conflict of interest

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