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Stress induced modulation of sesquiterpene biosynthesis in *Santalum album* L.: From abiotic stress to enhanced bioactive compound production

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Abstract

Santalum album L. (Indian sandalwood) produces one of the world's most valuable essential oils, yet significant variability in oil yield (1.3-6.0% w/w) and santalol composition (α-santalol 28-54%, β-santalol 12-28%) among trees and sites remains poorly understood in relation to abiotic stress. Recent molecular, transcriptomic, and field studies reveal that this variability is not random but is regulated by abiotic stress responses through a hierarchical cascade: Reactive oxygen species (ROS) trigger phytohormone signalling, thereby recruiting transcription factors from the SaAREB6, MYB, WRKY, and NAC families. These factors upregulate enzymes in the mevalonate (MVA) pathway, such as HMGR and FPPS, directing farnesyl diphosphate (FPP) flow *via* santalene/bergamotene synthase (SaSSY) and CYP450 oxidases towards santalol production. The literature indicates a hormetic threshold: moderate stress increases santalol yield by 28-45%, whereas severe stress inhibits biosynthesis. Trees in forests experiencing seasonal water deficits consistently produce higher-quality oil than irrigated plantations, highlighting ecological variability as an unintended elicitation trigger. Combining metabolomic, transcriptomic, and systems modelling offers a new route to predictive, precise phytochemistry for woody perennials. This review synthesises mechanistic insights, includes data tables and original conceptual figures, highlights key knowledge gaps, and suggests frameworks for controlled, stress-induced oil enhancement in sandalwood cultivation and management.

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