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Use of Non-Biological Methods for Agarwood Production in *Aquilaria* and *Gyrinops* Species

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Abstract

Agarwood, a highly valued resin from *Aquilaria* and *Gyrinops* species of Family *Thymalaeacea*e, is formed as a defense response to prevent the internal tissue damage caused by stresses. The natural formation of agarwood resin takes a long time and therefore, to meet increasing demand, non-biological methods for agarwood production have been developed, including mechanical, chemical, and physical inducement techniques. Those methods can be categorized into conventional and non-conventional methods. Mechanical methods, such as drilling, girdling, and bark removal create physical injuries that trigger resin production. While cost-effective and simple, these methods often yield inconsistent resin quality and may harm tree health, reducing long-term productivity. Advanced drilling techniques combined with the application of microbe-attractants, such as sugar syrups can enhance resin yield but still face limitations in commercial scale. However, chemical induction methods provide more controlled and efficient resin formation. Techniques like chemical injection and saltwater application mimic natural stressors, inducing oxidative stress and resin synthesis. Chemicals such as sulfuric acid, jasmonic acid, and ethylene have been successfully used, while innovative approaches, named Whole-tree Agarwood-Inducing Technique (Agar-WIT) ensure uniform resin distribution. These methods require technical expertise and pose risks of chemical toxicity to the tree and environment. Physical inducement method; thermal stress utilizes abiotic factors to stimulate stress. These approaches are gaining attraction due to their precision and minimal environmental impact. Thermal stress employs heat to disrupt cellular integrity. Some other physical methods such as aeration and whole-tree agarwood inducing technique are also effective. The aeration method involves inserting an aeration device, made from materials such as plastic, bamboo, or wood, with a diameter of approximately 2 cm, into a wound on the tree. This device prevents the pores from healing, thereby facilitating a long-term infection essential for agarwood formation. The whole-tree agarwood inducing technique employs simple and cost-effective transfusion sets to inject agarwood inducers directly into the xylem section of the tree. This method significantly enhances agarwood production, yielding 4 to 28 times more high-quality agarwood compared to traditional approaches. The comparative analysis of these methods reveals distinct advantages and challenges. Mechanical methods are accessible but less reliable, chemical methods are efficient but require careful handling, and physical methods balance precision with sustainability but need higher costs and expertise. Integrating these approaches with modern innovations offers potential for optimizing agarwood production to meet global demand while preserving ecological balance.

Keywords: *Chemical, Mechanical, Physical, Inducers, Resin formation*