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Impact of pesticide residues on the phytopharmaceutical properties of major medicinal plants of India

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Abstract

Medicinal plants constitute the backbone of traditional healthcare systems in India and contribute significantly to global phytopharmaceutical markets. However, the extensive use of synthetic pesticides during cultivation has raised concerns regarding the accumulation of pesticide residues in medicinal plant materials. This review critically examines current evidence on the occurrence, analytical detection, and biological implications of pesticide residues in major medicinal plants of India, emphasizing the effects of pesticide residues on phytochemical composition, secondary metabolite biosynthesis, and pharmacological efficacy by interfering with metabolic pathways, inducing oxidative stress, and degrading bioactive constituents. These concerns extend beyond efficacy to significant toxicological risks for human health, while also posing challenges for regulatory frameworks aimed at ensuring the quality, safety, and standardization of herbal products. Sustainable production strategies such as integrated pest management, organic cultivation, and bioremediation approaches offer practical solutions for minimizing residues and preserving phytochemical integrity. This review highlightds the need for integrated research linking pesticide exposure with phytochemical and pharmacological outcomes, strengthened residue monitoring and harmonized regulatory frameworks to ensure safe, residue-free medicinal plant production and sustain the therapeutic and commercial value of India's herbal resources.

