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Optimizing Drone Spraying in Mango Orchards with Ultra-Low-Volume Nozzle Configurations for Sustainable Agriculture in Northern India

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INTRODUCTION & AIM

Mango (*Mangifera indica*) cultivation is a key component of India's horticultural economy, particularly in Northern states, where climatic conditions favor large-scale orchard development. However, the vertical and lateral density of mango canopies poses significant challenges for conventional spraying methods, leading to uneven coverage and increased pesticide usage (Khot et al., 2012). Precision horticulture, leveraging drone technologies and variable-rate spray systems, offers a promising solution to address these inefficiencies (Zhang & Kovacs, 2012).

This study investigates the performance of Ultra-Low Volume (ULV) nozzle configurations mounted on agricultural drones to optimize spray deposition across stratified mango canopies. The goal is to identify nozzle strategies that maximize spray coverage and canopy penetration while reducing agrochemical waste and ecological impact, thereby contributing to sustainable orchard management practices.

METHOD

Field trials were conducted in Northern India during the mango flowering and early fruit-setting phase (June–August 2024). A commercial quadcopter drone was equipped with two ULV nozzle types: TeeJet® 110° XR, producing medium-fan droplet profiles, and HYPRO® ULV, optimized for fine mist generation. Fluorescent dye was used as a tracer to simulate agrochemical deposition, enabling non-toxic, visual quantification of spray performance. Spray cards (Meylin cards) were strategically positioned in three vertical canopy zones—upper, middle, and lower—to evaluate spatial deposition. Environmental parameters were recorded during each spraying session, with wind speed ranging from 2–4 km/h, temperature between 30–35°C, and relative humidity of 70–80%. Spray coverage (%) and canopy penetration (%) were analyzed using digital imaging and statistical processing. Analysis of variance (ANOVA) and Tukey's HSD tests were employed to determine statistical significance between nozzle-canopy combinations (Ritz et al., 2015).

RESULTS & DISCUSSION

TeeJet® 110° XR achieved superior coverage in the upper (80.4%) and middle (78.0%) canopy layers with penetration values of 70.0% and 68.0%, respectively. HYPRO® ULV performed best in the lower canopy (79.4% coverage, 69.3% penetration). ANOVA confirmed significant effects of nozzle type and canopy layer on spray distribution ($p < 0.05$). Tukey's test further revealed TeeJet® as more effective in the upper canopy, while HYPRO® was optimal for lower-layer penetration in Table 1.

Table 1. Spray Performance Summary

Nozzle Type	Canopy Layer	Mean Coverage (%)	Mean Penetration (%)
TeeJet® 110° XR	Upper	80.4	70.0
TeeJet® 110° XR	Middle	78.0	68.0
TeeJet® 110° XR	Lower	75.2	65.7
HYPRO® ULV	Upper	83.4	73.0
HYPRO® ULV	Middle	81.2	71.0
HYPRO® ULV	Lower	79.4	69.3

CONCLUSION

This study confirms the importance of customized drone spraying strategies based on canopy architecture and environmental context. While TeeJet® XR nozzles are more effective for upper canopy applications, HYPRO® ULV nozzles offer better performance in denser, lower foliage zones. Integrating canopy-aware nozzle selection can substantially reduce chemical inputs, improve crop protection efficiency, and support climate-smart orchard practices. Drone-based ULV systems, when optimized, hold significant potential for enhancing sustainable horticulture in India and beyond.

FUTURE WORK / REFERENCES

Future work will expand this framework to multi-crop systems, integrate image-based dye quantification for higher precision, and explore adaptive drone spraying with real-time canopy sensing. Further, performance evaluations under variable wind and terrain conditions will be conducted to build robust operational guidelines for farmers and agribusinesses.

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