IECAG 2025 Conference
The 5th International Electronic Conference on Agronomy
15–18 December 2025 | Online
MDPI

UAV Biostimulant Spraying in Tall Sugarcane: Field Efficacy and Rotor-Canopy Airflow Modeling

Shefali Vinod Ramteke[1*], Prof. Dr. Pritish Kumar Varadwaj[1], Dr. Vineet Tiwari[2]

[1] Department of Applied Sciences, Indian Institute of Information Technology Allahabad, India

[2] Department of Management Studies, Indian Institute of Information Technology Allahabad, India

*Corresponding Author: rss2019003@iiita.ac.in

INTRODUCTION & AIM

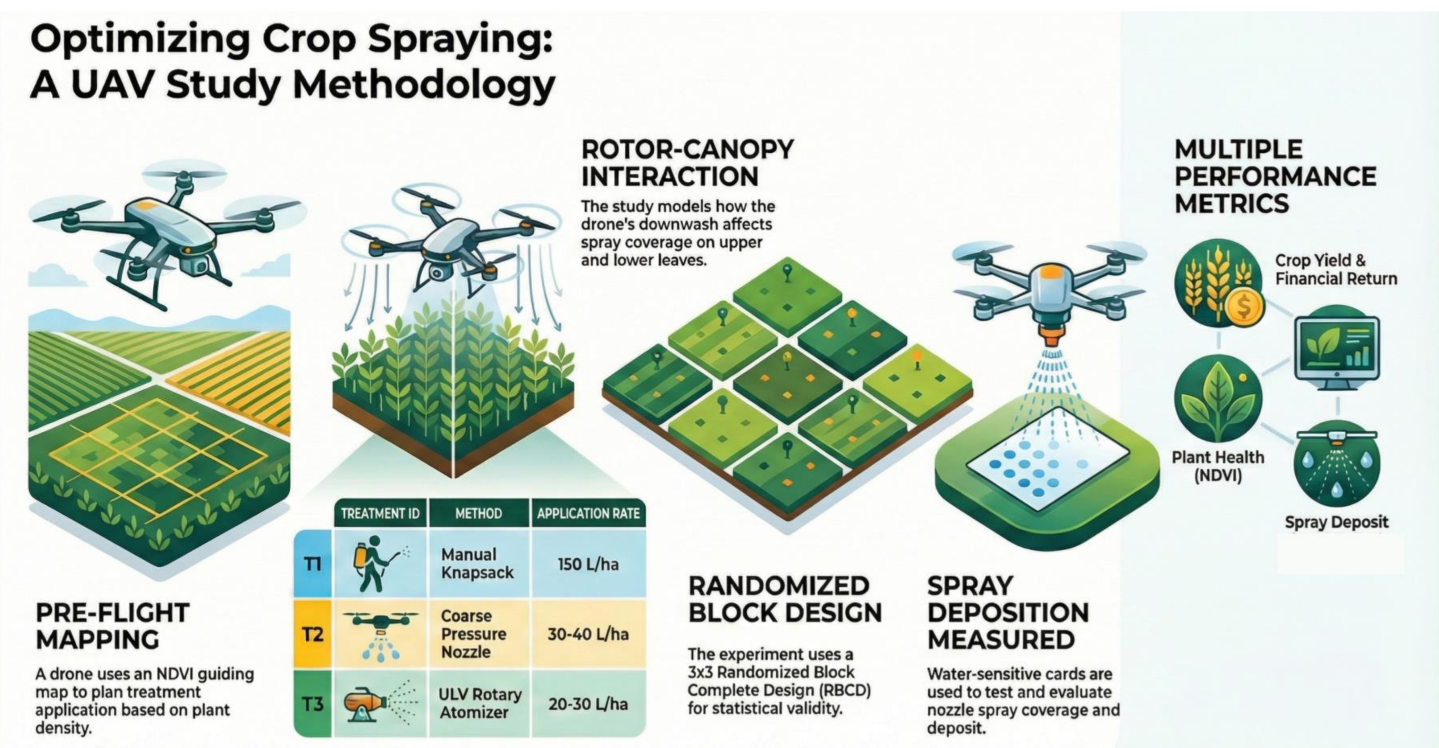
Biostimulants enhance stress tolerance and metabolic activity in crops, but efficient foliar delivery in tall, dense canopies remains challenging. Sugarcane, with canopy heights >2.5 m and high leaf-area density, presents major operational barriers for uniform manual spraying. Unmanned aerial vehicles (UAVs) offer a low-volume, contactless alternative capable of producing fine droplets and penetrating complex canopy structures.

Objective:
Evaluate the feasibility and efficiency of UAV-based biostimulant delivery in sugarcane through:

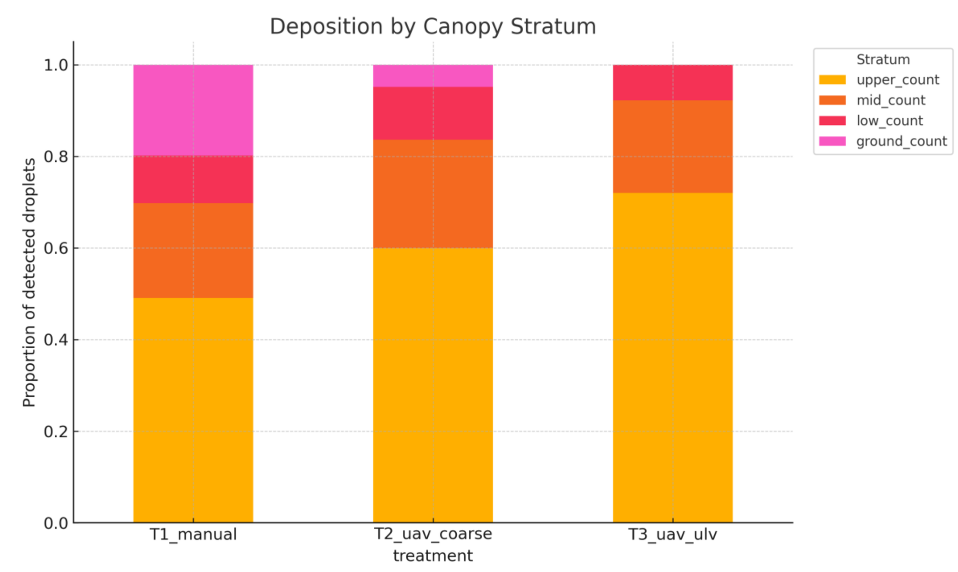
(i) droplet deposition profiling,
(ii) NDVI/SPAD canopy response, and
(iii) yield & economic assessment.

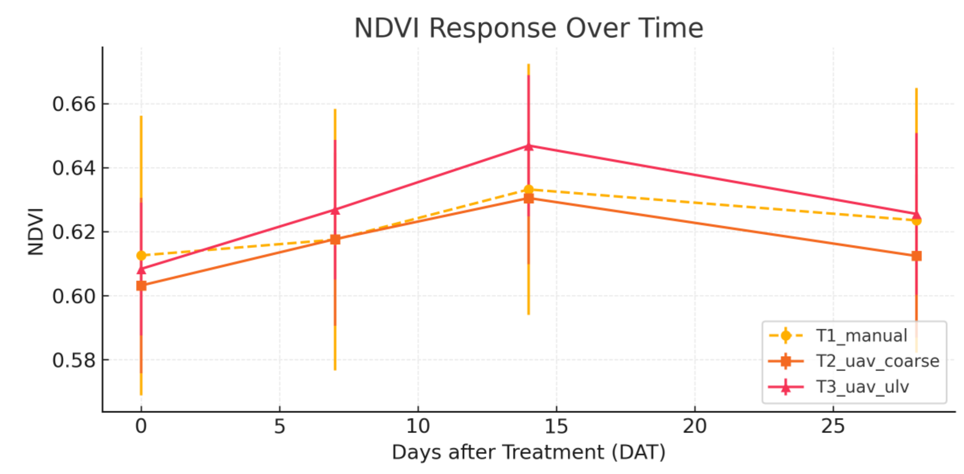
METHOD

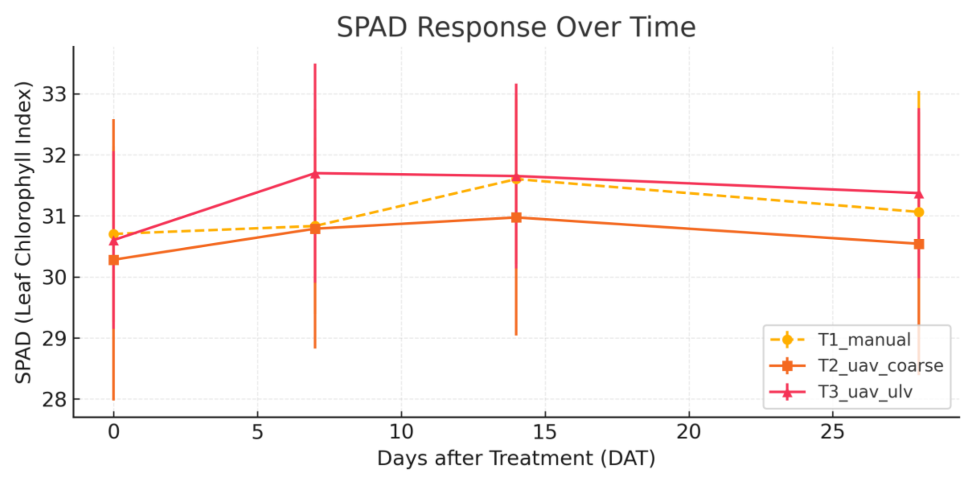
- **Location:** Saharanpur, Uttar Pradesh, India (2023).
- **Design:** RCBD, 3 treatments × 3 replicates.
- **Treatments:**
  - **T1:** Manual spray (150 L·ha⁻¹, flat fan)
  - **T2:** UAV-coarse droplets (30–40 L·ha⁻¹)
  - **T3:** UAV-ULV fine droplets (20–30 L·ha⁻¹, rotary atomizer)
- **Measurements:**
  - Water-sensitive papers at upper/mid/lower canopy
  - Fluorescent tracer quantification
  - NDVI & SPAD at 0, 7, 14, 28 DAT
  - Plot-level yield and cost metrics
- **Modeling:**
  Rotor–canopy airflow model predicts canopy interception; ground loss negligible (<5%) under optimized conditions.

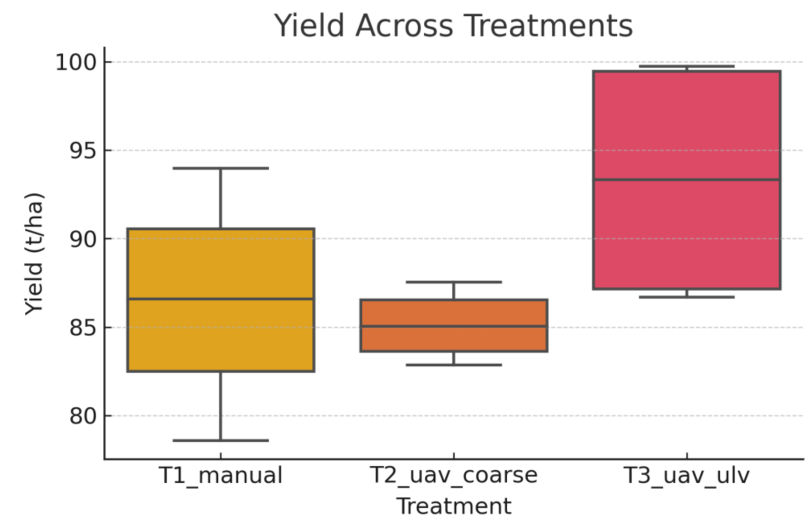


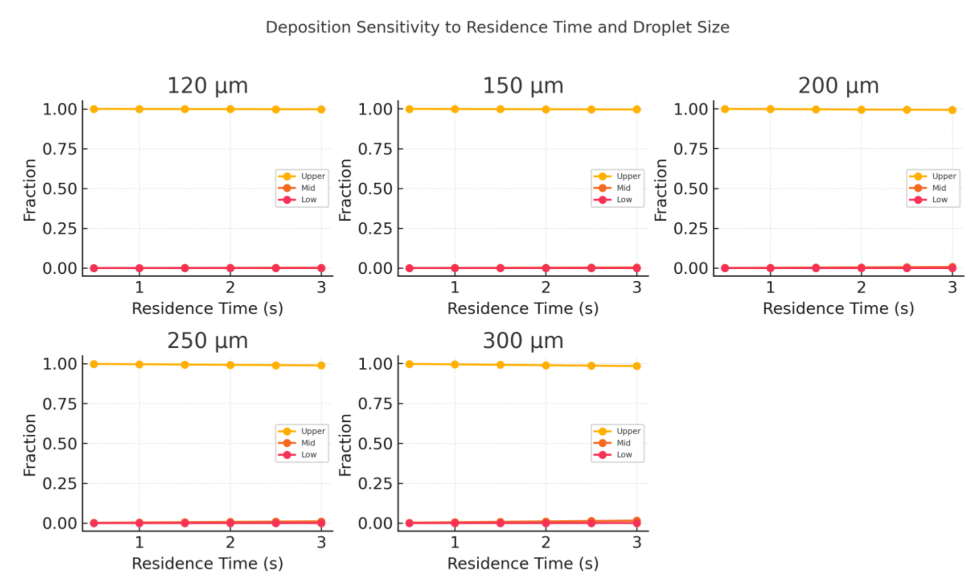
RESULTS & DISCUSSION











Canopy Deposition:
- UAV–ULV achieved 70–72% upper-canopy deposition, with near-zero ground loss.
- Manual spraying showed higher ground deposition and lower uniformity across the vertical profile.
- UAV–coarse provided intermediate penetration but less mid-canopy uniformity than ULV.

Plant Physiological Response (NDVI & SPAD):
- UAV–ULV produced strongest NDVI and SPAD increases at 7–14 DAT, aligning with expected biostimulant activity windows.
- Manual spraying showed modest improvements; UAV–coarse outperformed manual but did not match ULV.
- ULV droplet-size optimization enhanced canopy light-use efficiency and chlorophyll formation.

Operational Efficiency:
- UAV methods reduced carrier volume by **≥70%** compared to manual spraying.
- Improved application precision reduced labor demand and minimized off-target losses under field wind conditions (1–4 m/s).
- NDVI-guided timing ensured optimal biostimulant responsiveness during grand growth and elongation stages.

Yield & Economics:
- UAV–ULV achieved the highest mean yield across blocks.
- Net returns improved due to better canopy interception and lower total input volume.
- UAV spraying offered faster field coverage and lower variability between plots.

CONCLUSION & DISCUSSION

UAV–ULV spraying improved canopy interception and physiological response by optimizing droplet size and airflow interactions within tall sugarcane. Enhanced NDVI/SPAD gains aligned with modeled mid–upper canopy deposition, translating into higher yield and more uniform field performance. UAV-based biostimulant delivery provides a precise, low-volume, and operationally efficient alternative to manual application, especially in dense, vertical canopies.

FUTURE WORK / REFERENCES

Future efforts will integrate full CFD modeling with field-measured turbulence to refine droplet–canopy interaction predictions. Multi-location trials across varieties and crop stages are needed to validate robustness. Additional work will assess long-term economic feasibility, carbon savings, and multi-sensor (RGB–thermal–LiDAR) guidance for real-time UAV spray optimization.

References:

1. Liu, X., Zhang, W., Fu, H., Fu, X., & Qi, L. (2021). Distribution regularity of downwash airflow under rotors of agricultural UAV for plant protection. Int. J. Agric. & Biol. Eng., 14(3). https://doi.org/10.25165/j.ijabe.20211403.4036
2. Matese, A., & Di Gennaro, S. F. (2018). Practical applications of a multisensor UAV platform based on multispectral, thermal and RGB high-resolution images in precision viticulture. Agriculture, 8(7), 116. https://doi.org/10.3390/agriculture8070116
3. Teske, M. E., et al. (2018). Droplet size and spray drift in agricultural applications. Journal of ASTM International, 10(5).
4. Zhang, H., et al. (2016). Evaluation of UAV-based spray systems in agriculture. Biosystems Engineering, 147, 159–166.