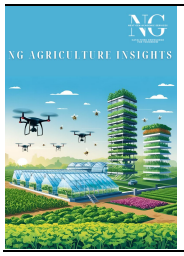

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From Knapsack to Drone: Revolutionizing Pest Management in Indian Agriculture

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A B S T R A C T

India's agricultural pest control is moving towards labour-less conventional spraying to precision and smart technologies. This shift from knapsack sprayers to agricultural drones is a pivotal moment in this shift. Knapsack sprayers are still inexpensive and convenient for small farms, but they take a lot of work and full participation from the operator. Agricultural drones that are fitted with GPS, various sensors, and cameras, as well as spraying equipment, can enhance the speed, accessibility, and accuracy of crop protection activities. They are not just used for spraying but also for crop monitoring, pest surveillance, field assessment and site specific management. ICAR demonstrations have been successful in demonstrating their ability to save spray-water and increase their operational efficiency, and government initiatives (Sub-Mission on Agricultural Mechanization) have facilitated more field demonstrations. But the high cost, operator training, weather conditions, spray drift, regulatory requirements and crop specific application procedures are still significant. The future of pest management using drones will be characterised by using Integrated Pest Management, remote sensing, AI and data-driven decision making to achieve timely, accurate and efficient crop protection, while minimising resources.

Keywords: *Agricultural drones, Precision agriculture, Pest management, UAV spraying, Smart farming*

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1. INTRODUCTION

The agriculture sector in India is making a quick transition from traditional to mechanized and precision agriculture. An obvious example is the use of agricultural drones instead of the traditional knapsack sprayer, which is a change from manual spraying to smarter and more efficient crop management (Athare *et al*., 2024; Sinha, 2020). Knapsack sprayers continue to be popular because they are simple, affordable, portable and suitable for small farms. But it is very labour intensive, the operator must carry the spray tank and keep the pressure by hand. This can lead to

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higher labour demand and/or uneven spray application. Use of mechanized and tractor-mounted sprayers increased the spraying capacity, however, under Indian farming conditions fragmented fields, wet soils, uneven terrain and standing crops are common problems that affect the use of mechanized and tractor-mounted sprayers (Sinha, 2020). Agricultural drones, also known as unmanned aerial vehicles (UAVs), are one of the new solutions that are developed by integrating aerial mobility with GPS, sensors, cameras and spraying systems. They can be deployed in areas of crop crops where human or machinery access is limited and offer the potential for more targeted and effective crop protection (Athare *et al*., 2024; Sinha, 2020).

2. FROM MANUAL SPRAYING TO AGRICULTURAL DRONES

For years, the knapsack sprayer has been a low-cost and easy-to-use protection device for Indian farmers. It has proved to be very useful thanks to its ability to be carried, its low cost, its ease of use and its adaptability to small and fragmented farms. Spraying, however, is a labour-intensive activity performed by the operator who has to carry the spray tank and physically get into the crop, thus increasing the chances of uneven spraying and direct contact with spray droplets (Sinha, 2020). Manual spraying was hindered by the need to spray faster and bigger fields, leading to the invention of power-powered sprayers and tractor-mounted sprayers. But they can experience challenges in some of the following areas: standing crops, uneven crop, wet soils, and narrow fields or in fragmented holdings. This has helped to facilitate the growth of more flexible technologies that function without moving within the crop. Agricultural drones are the next step in this evolution. A typical spraying drone integrates a battery, flight controller, GPS, tank, pump, nozzles, sensors and communication systems. These components allow the drone to follow a planned flight path and apply agricultural inputs from above with greater control over flight and application parameters (Sinha, 2020).

3. DRONES: MORE THAN FLYING SPRAYERS

The importance of agricultural drones goes beyond simply spraying pesticides. With cameras, sensors, GPS and imaging technologies, drones can support crop monitoring, pest surveillance, field assessment and precision crop management. Aerial images can help identify areas showing crop stress or abnormal growth, which can then be inspected and treated when necessary (Sinha, 2020; Athare *et al*., 2024).

Drone monitoring → Detection of pest/stress → Field assessment → Site-specific decision → Precision application → Follow-up monitoring

Table 1. Comparison of knapsack sprayer and agricultural drone

Parameter	Knapsack sprayer	Agricultural drone
Operation	Manual	Remote/Automated
Operator movement	Walks inside field	Operates from field boundary/nearby
Carrying burden	Tank carried by operator	Payload carried by drone
Field coverage	Relatively slow	Rapid
Application	Dependent on operator	Controlled through flight parameters
Water requirement	Generally higher	Can use ultra-low volume application
Crop accessibility	Difficult in tall/dense crops	Better access to difficult areas
Operator exposure	Relatively high	Reduced direct exposure
Monitoring capability	Very limited	Cameras/sensors can be integrated
Precision potential	Low to moderate	High
Data generation	Minimal	GPS, imagery and application data possible
Suitability	Small-scale conventional spraying	Precision and large-area applications

4. DRONES IN CROP PROTECTION

Drones have potential applications in the spraying of insecticides, fungicides, herbicides, biopesticides, liquid fertilizers and micronutrients, wherever their use is approved and appropriately recommended. ICAR-NBAIR has demonstrated drone-based application of oil-based biopesticide formulations in crops including coconut, brinjal, mango, sugarcane, arecanut and rice. Drones are

particularly useful in tall crops and fields where conventional machinery or manual spraying is difficult. ICAR-NBAIR demonstrations have also reported rapid field coverage of about 7–8 minutes per acre under suitable operating conditions. However, faster spraying does not automatically mean better pest control. Droplet size, nozzle type, flight height, speed, wind, canopy structure, formulation, spray drift and application rate must be properly considered to achieve effective spray deposition.

5. SAVING LABOUR, TIME AND WATER

One of the major advantages of drone-based spraying is the potential to reduce the time and labour required for crop protection. Unlike conventional spraying, workers do not need to carry the spray solution and move throughout the crop. Many drone systems can also operate at relatively low spray volumes, reducing the amount of water that needs to be transported into the field. ICAR-Central Potato Research Institute reported that approximately 20 L water/ha was sufficient for drone spraying under potato production conditions, compared with approximately 500–750 L/ha under conventional spraying. However, this should not be considered a universal spray-volume recommendation because water requirement varies with crop, formulation, equipment, nozzle system and operating conditions (ICAR-CPRI, 2022). Drones have the potential to provide faster field coverage, reduced labour dependence, lower spray-water requirements, improved accessibility, reduced direct operator exposure and better opportunities for precision application.

6. GOVERNMENT SUPPORT AND INSTITUTIONAL DEMONSTRATIONS

The adoption of agricultural drones in India is being supported through government initiatives and demonstrations by ICAR institutions, Krishi Vigyan Kendras and State Agricultural Universities. Under the Sub-Mission on Agricultural Mechanization (SMAM), financial assistance has been provided for agricultural drones and demonstrations. They reported more than 40,928 drone demonstrations covering 40,918 ha had been conducted with ₹52.5 crore in financial support.

7. Challenges and the Way Forward

Drones are not a complete replacement for conventional sprayers. High initial investment, the need for trained operators, weather dependency, spray drift, regulatory requirements and crop-specific application standards remain important challenges. Spray effectiveness depends on proper calibration of nozzle type, droplet size, flight height, speed, formulation and other operating parameters. For small and marginal farmers, individual ownership may not always be economical. Custom Hiring Centres (CHCs), Farmer Producer Organizations (FPOs), cooperatives and drone service providers can make drone technology more accessible by providing it as a shared service. The future of agricultural drones lies in their integration with artificial intelligence, machine learning, IoT, satellite imagery and ground sensors. Such integration could help identify pest hotspots, recognize crop stress and diseases, and support more targeted application of crop-protection inputs. Drones may also create new opportunities for rural youth as trained pilots, service providers, data analysts and precision-agriculture consultants.

8. CONCLUSION

The adoption of the agricultural drone by farmers instead of the knapsack sprayer exemplifies the remarkable technological advancements in Indian agriculture. Knapsack sprayers are still economical and convenient, but are very labour intensive. Mechanised sprayers helped to increase the efficiency of spraying; however, in fragmented fields where fields are wet or inaccessible, spraying could be challenging. In addition to GPS and remote operation, agricultural drones are equipped with sensors and precision spraying, which serves as an extra level of crop protection. They can assist in applying pesticides/biopesticide, monitoring crops, pest/disease surveillance and precision crop management (Athare et al., 2024; Sinha, 2020). The technology has been demonstrated in the field by ICAR and has proven to be practical, especially for minimizing the amount of spray water required and the efficiency of crop-protection operations. Its adoption and field demonstrations have been further encouraged with government support via SMAM. But drones are not a replacement for the conventional sprayers, however. Still, there are issues like high cost, requirement of trained operators, weather, spray drift, and regulatory requirements and spraying practices that need attention. The true power of drones is that

they can be used in conjunction with Integrated Pest Management, remote sensing, artificial intelligence, and data-driven decision making. The intent is not just to apply more spray more quickly, but to identify pest infestations early, to apply inputs as needed, to conserve resources, to enhance farmer safety, and to create sustainable crop production.

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