DRONES:
A GAME CHANGER IN PLANT DISEASE MANAGEMENT

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INTRODUCTION:

UAVs have emerged as innovative tools in agriculture, revolutionizing crop protection practices. With the ability to be operated remotely or autonomously, they have wider applicability in plant disease management like disease detection and monitoring which can help in disease survey in vast areas, which can prevent disease spread by taking proactive management strategies, along with this UAV spraying has become an alternative plant protection equipment with an increased safety, improved manoeuvrability and enhanced efficiency in comparison to traditional ground spraying methods (Figure 1). These attributes, along with the timely coverage of larger areas and the ability to navigate complex terrains, make UAVs highly advantageous for pesticide application. The global drone market has witnessed significant growth, and according to market intelligence and advisory from Bureau of Indian Standards (BIS) research, it is estimated to reach a staggering $28.47 billion (approximately Rs. 2.09 lakh crores) by the end of 2023. Notably, the dominance of the United States, China, and Israel in the drone market has been prominent. India, however, is projected to contribute around 4.25% to the global market in 2022. The drone market in India is expected to reach $1.81 billion (Rs. 13 330 crores) by the end of the financial year (FY) 2026, with a compound annual growth rate (CAGR) of14.61% (GOI, 2021).

Recognizing the immense potential of drone-based technologies in agriculture, the Government of India has taken proactive steps to facilitate the adoption of this groundbreaking technology in the agricultural sector by introducing pro-drone policies. In addition, the Ministry of Civil Aviation notified the updated Drone Rules of

2021, replacing the highly critiques UAS rules released in March 2021. The liberalized Drone Rules of 2021 are more permissive and are expected to remove all unnecessary operational and entry barriers and create a strong drone ecosystem in the country to make India to be a global hub for drones by 2030.

The government's focus on bringing drone-based technologies into agriculture highlights the importance of embracing this innovation as a necessary tool for the future of precision agriculture (Ragiman et al., 2024).

HOW DRONES SUPPORT PLANT DISEASE MANAGEMENT

1. Disease Monitoring & Early Detection

Drones are transforming the way farmers monitor crop health, offering a faster and more precise approach to detecting diseases before they spread. Equipped with advanced imaging sensors like RGB, multispectral, hyperspectral and thermal cameras, they provide detailed insights that traditional scouting methods simply can't match. RGB cameras capture visible light to detect early signs of disease, such as leaf discoloration caused by infections like rust or blight. Multispectral sensors take this further by analysing plant stress through chlorophyll content, leaf moisture and overall vigour, helping identify diseases before visible symptoms develop.

Hyperspectral imaging, with its ability to scan hundreds of narrow spectral bands, detects subtle biochemical changes linked to fungal, bacterial and viral infections. Thermal cameras complement these technologies by identifying temperature fluctuations in crops, a key indicator of disease stress even before plants show physical symptoms. By integrating these imaging methods, drones offer a powerful tool for large-scale, real-time monitoring, enabling farmers to detect diseases early, make informed decisions and implement targeted interventions. This not only reduces crop losses but also minimizes the need for excessive pesticide use, leading to more sustainable and cost-effective farming practices.

2. Precision Spraying of Pesticides

The spraying of pesticides has long been the backbone of plant disease management. However, conventional methods tend to lead to excessive application of pesticides, high costs and damage to the environment (Tudi et al., 2021). Precision spraying, with the help of drones, has emerged as a game-changer to these issues by ensuring precise, efficient and sustainable application of pesticides along with reducing cost of labour. The advantages of drone-based pesticide spraying are optimized application efficiency, lowering environmental impact, minimization of human exposure, improved crop protection, real time plant monitoring dynamic adjustment, economical and scalable. Next-generation drones have AI-powered sensors that monitor plant health in real-time. The systems dynamically adjust spraying intensity and coverage in accordance with changing disease severity across different parts of the field. With the agricultural industry increasingly embracing technological innovations, the application of drones in disease control is likely to increase rapidly.

3. AI & Data-Driven Disease Prediction

AI-powered drones, integrated with IoT, are revolutionizing agriculture by predicting plant diseases before they take hold. Instead of merely detecting infections, these smart drones analyze real-time environmental data such as temperature, humidity, and soil moisture along with high-resolution multispectral and thermal images to identify subtle stress signals in crops. Advanced machine learning models then process this information to map high-risk zones, giving farmers a crucial head start in disease prevention. By combining predictive analytics with GIS-based mapping, farmers can visualize potential outbreak areas and implement targeted measures like precision spraying or biological controls before infections spread. This proactive approach not only reduces excessive pesticide use and lowers costs but also safeguards yields and promotes long-term agricultural sustainability. With AI-driven disease forecasting, farmers can shift from reactive to preventive strategies, ensuring healthier crops and a more resilient food system.

ADVANTAGES OF DRONE-BASED PLANT DISEASE MANAGEMENT

➤ Early Detection: Prevents huge crop losses by detecting diseases in their initial stages.
➤ Less Pesticide Usage: Saves money and minimizes environmental degradation.
➤ Improved Efficiency: Scans large fields in a short duration compared to manual scouting.
➤ Reduced Human Exposure: Reduces the risk of chemical exposure for farmworkers.
➤ Data-Driven Insights: Provides actionable intelligence for precision agriculture.

CHALLENGES & LIMITATIONS

➤ Although drone technology has great potential, it has some limitations:
➤ High Initial Cost: High-end drones with imaging and AI capabilities are expensive.
➤ Regulatory Constraints: Most nations have strict regulations on the use of drones in agriculture.
➤ Need for Skilled Operators: Farmers need training to use drones effectively.
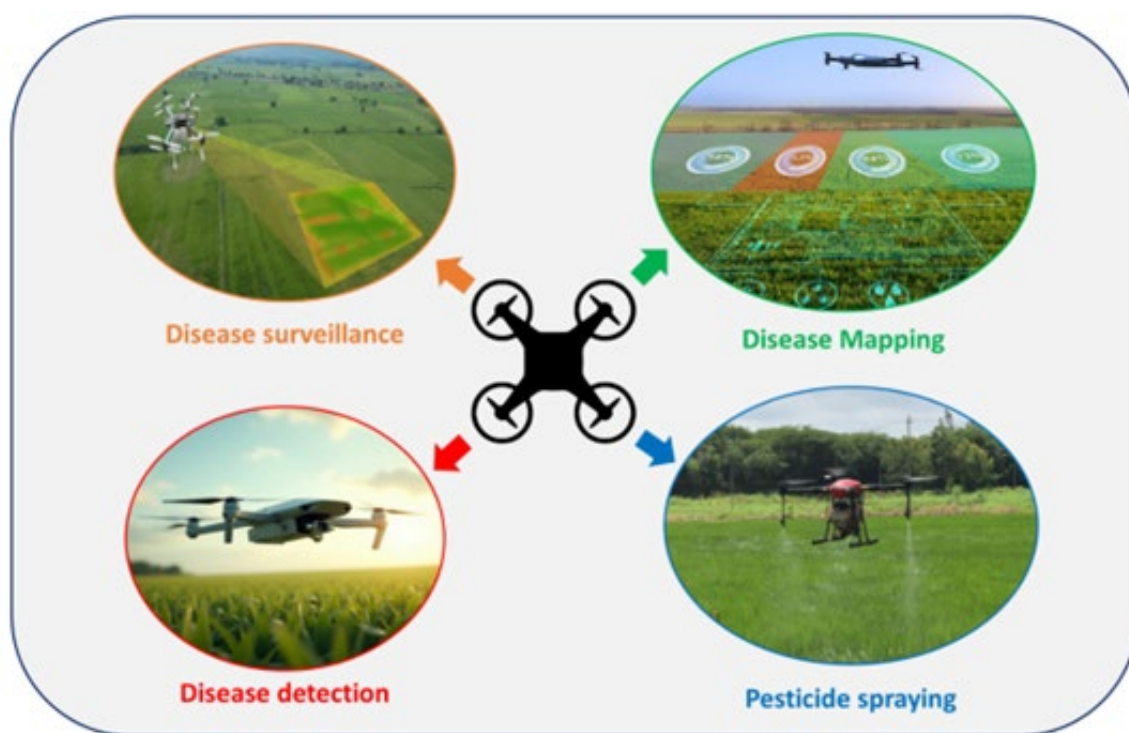➤ Restricted battery life limits working hours.

Figure 1. Applications of drone in plant disease management

CONCLUSION

Drones are revolutionizing plant disease management with precision, efficiency and sustainability. With technological advancements, their application will find greater use, empowering farmers to control plant diseases effectively, reduce losses and ensure food security. Governments, scientists and Agri-tech companies must come together and overcome challenges to realize the full potential of drones in agriculture.