Unmanned aerial vehicle (UAV) assisted insecticide application in crop management

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Ensuring the efficient and prompt application of plant protection measures is crucial in agriculture. Unmanned aerial vehicles offer advantages in this regard, such as increased efficiency, decreased labour demands, time and energy savings, swift response times, extensive area coverage, and enhanced environmental safety (Subramanian et al., 2021). The Central and state agriculture departments, research institutions, and manufacturing companies have focused on developing and manufacturing drones to meet the needs of Indian agriculture. The most recent standard operating procedure (SOP) regarding the UAV assisted application of insecticides in India was published in the year 2023 (https://farmech.dac.gov.in/New_Folder/TTC_SOP_2023-4.pdf). It is a significant development in agricultural technology that makes accurate chemical administration at the field level. This SOP guarantees effective, safe, and ecologically responsible insecticide application under a variety of agro-climatic situations by simplifying processes and attending to crop-specific requirements. This comprehensive manual provides farmers with adequate information and resources to maximize their crop management techniques. It was developed cooperatively by specialists from various sectors, including the Ministry of Agriculture, ICAR institutes, state agricultural universities (SAUs), and drone industries. This SOP signifies a new era of precision farming by embracing the transformational potential of UAV technology, which will help in increasing agricultural output, profitability, and sustainability.

Evolution of Drones

Amid the enigmatic skies of innovation, the story about drones is unfolded. In 1907, the Brequet brothers debuted the Gyroplane No.1, a quadcopter that flew a few feet above the ground. The Kettering Bug appeared in 1915 during World War I, capable of attacking targets up to 120 km away. In 1920, Etienne Oehmichen's No.2 quadcopter defied critics by hovering smoothly. The 1980s saw the development of covert military prototypes for reconnaissance. In the 2000s, consumer drones such as quadcopters and hexacopters were used to capture landscapes and memories. The 2010s saw a revolution, with drones changing agriculture, filmmaking, and delivery. Abe Karem is considered as the founder of drone technology, where he built the first fully functional drone for Israel in 1974, but not meant for agriculture. Drones have witnessed fast development and increased use since 1991, beginning with continuous deployment during the Gulf War. The Predator drone, introduced in 1996, revolutionised weaponized drones. Following Hurricane Katrina, UAVs were allowed in US civilian airspace for disaster relief in 2006, boosting the consumer drone business. In 2010, Parrot introduced the AR Drone, which can be controlled via smartphone. DJI's Phantom series, which debuted in 2013, helped popularise consumer drones. The same year, firms like FedEx and Amazon began investigating drone delivery. Since 2014, drone use has increased dramatically across industries, with the market expected to reach $92 billion by 2030. In 2020, drones played an important part in pandemic response, prompting regulatory adjustments and new applications in India as well as in other parts of the world. Drones are now-a-days ubiquitous, monitoring electricity lines and, recording epic sagas, weaving tales over the skies (Consortiq- https://consortiq.com/uas-resources/short-history-unmanned-aerial-vehicles-uavs).

Application of UAVs in Agriculture

UAV, which stands for unmanned aerial vehicle, often referred to as Drone is an aircraft without a human pilot on board. UAVs may fly either under remote control by a human operator or, if so designed and equipped, autonomously via onboard sensors, navigation systems, and computers (Advanced Navigation-https://www.advancednavigation.com/glossary/uav). Unmanned aerial vehicles were first utilised in agriculture in 1921, when the USDA and US Army used them to dust crops. Thurling was the first to utilise a camera on a drone, capturing vertical shots of weeds back in 1985. Yamaha launched the R-50, the first UAV for crop dusting, in 1987 and commercialised it in 1989.

In modern precision agriculture, UAVs (drones) are critical for proactive monitoring and quick response to difficulties. They undertake duties such as agro-spraying, which can cover up to 10 acres per hour (Ukhurebor et al., 2022), decreasing labour and lowering health hazards associated with chemical exposure. UAVs capture real-time photos and videos, allowing for faster agricultural interventions and improved farm security. They are less expensive than other sensing technologies, particularly for medium- and large-scale farms (Norasma et al., 2021). UAVs provide noninvasiveness, adaptability, and efficiency. They enable remote surveying and analysis of soil properties, facilitating informed decision-making. Tailored SOPs optimise drone use according to climate and terrain, increasing efficiency and sustainability. Overall, UAVs revolutionise agriculture by improving precision, efficiency, and sustainability.

Techniques for creating SOPs for drone-assisted insecticide application in crops

It involves thorough data collection *via* online survey schedules and rigorous scientific debates. Committee members held multiple discussions with industry representatives in order to ascertain what experimental data was needed in order to formulate the SOP. A survey schedule was carefully designed, covering a range of topics including pesticide formulas, drone specifications, and environmental conditions. This schedule, which allows for both traditional and online submission, was distributed to ICAR Institutes, SAUs, and the private sector. Seventy-seven replies in all, encompassing a variety of experimental data on drone-assisted pesticide application across ten key crops, were received. Using this information, particular SOPs were created, concentrating on important factors including crop canopy volume, development stages, pesticide dosage and concentration, and operating circumstances to guarantee accuracy and effectiveness in pesticides application *via* drones.

SOPs (Standard Operating Procedure) of some chosen crops

Ten crops (rice, maize, cotton, groundnut, pigeon pea, safflower, sesame, soybean, sugarcane, and wheat) were the subjects of the data collection. SOPs were customized to ensure maximum bio-efficacy and absence of phytotoxicity based on drone, sprayer, crop, and weather data. We assumed a conventional drone, under 25 kg in weight, with a 10-liter tank. To minimise drift and crop damage, the drone's height above the crop canopy and speed of flight were optimised. Across the range of pesticide doses evaluated, no phytotoxicity was seen. The Southern Plateau and Hills, Trans-Gangetic Plains Agro-climatic areas, were the sites of the experiments. During spraying, drone flying speed varies between 4-5 m/s on average. In the case of sugarcane and soybeans, it may be lowered to 2-4 m/s. Drone height above the canopy can be maintained at 1.5–2.0 m, but for sugarcane and wheat, it is more than 3 m. On average, water volume is maintained at 20 l/ha in the early stage and 25 l/ha in the later stages of the crop. Anti-drift flat fan nozzles are used where the droplet size for insecticides is maintained at 250–350 µm with a 0.3–0.6 litre/minute discharge rate and a 60–120° angle for spraying. Pressure is maintained at 2–3 bars. Most preferably, <35°C temperature is maintained along with >50% humidity. Spraying is strictly prohibited during rainy, foggy, or misty conditions (Crop Specific Standard Operating Procedure (SOP) for the Application of Pesticides with Drones, Ministry of Agriculture and Farmers Welfare Department of Agriculture and Farmers Welfare, 2023).

General instructions for pest management in crops

1. Avoid spraying if heavy rain is forecast in the next 1-2 days.
2. Choose targeted insecticides over broad-spectrum insecticides, ideally those with green labels.
3. Rotate insecticides to prevent using the same one again or those with similar modes of action.
4. Use insecticides only as a last resort, particularly when the pest to damage ratio is high.
5. Use bio-pesticides or chemicals sparingly, according to package recommendations, and target susceptible pest life phases.
6. When working with insecticides, always wear protective gear such as masks and gloves.
7. Wait 48 hours after spraying before visiting the field, and allow at least 30 days before harvesting maize corn following chemical application.

Recent government initiatives for facilitating the use of drones in agriculture

The Indian government has offered a series of drone purchasing incentives in order to make drones cheaper to farmers and other stakeholders, as well as to promote drone use. To encourage the usage of Kisan Drones, the Indian Agriculture Ministry is

Table 1. Crop wise list of insecticides tested for crop safety using UAVs

Sl. NO	Insecticide	Formulation	Crop
1.	Chlorantraniliprole	18.5SC	Rice
2.	Triflumezopyrim	10SC	
3.	Pymetrozine	50WG	
4.	Dinotefuran	50SG	
5.	Cartap hydrochloride	50SP	
6.	Flonicamid	50WG	Cotton
7.	Spinetoram	11.7SC	
8.	Fipronil	5SC	
9.	Diafenthiuron	50WP	
10.	Imidacloprid	17.8SL	
11.	Chlorantraniliprole	18.5SC	Redgram
12.	Flubendiamide	39.35SC	
13.	Indoxacarb	14.50SC	
14.	Spinosad	45SC	Redgram
15.	Emamectin Benzoate	5SG	
16.	Chlorantraniliprole	18.5SC	Groundnut
17.	Chlorantraniliprole	18.5SC	Soybean

(Source: SOP for the application of insecticides with Drones, Ministry of Agriculture and Farmers Welfare Department of Agriculture and Farmers Welfare, 2023) granting a 50% or maximum INR 0.5 million subsidy to SC-ST, small and marginal farmers, women, and farmers in the northeastern states to purchase drones. Other farmers will receive financial help up to 40%, or a maximum of INR 0.4 million. Farm Machinery Training & Testing Institutes, ICAR institutions, KVKs, and SAUs are eligible to get full financing for drones from the central government for demonstration purposes.

The followings are key government initiatives to promote the usage of drones:

1. The Liberal Drone Rules, 2021, are one of the main government initiatives to encourage the use of drones.
2. Drone Airspace Map, which opens 400 feet to 90% of the airspace.
3. The drone production-linked incentive programme, or PLI.
4. Policy Framework for UAS Traffic Management (UTM).
5. A simpler procedure for drone certification under "Drone Certification Scheme 2022".
6. Mission 'Drone Shakti' (launched on 1st February, 2022) which aims to assist drone related startups.
7. Import restrictions on foreign drones but the ease in importing parts of drones from abroad was notified under the Drone import policy in February 2022.
8. The Ministry of Agriculture launched a financial subsidy programme in January 2022 with the goal of making it easier for people to buy agricultural drones etc.

Bharat Drone Mahotsav 2022, held on 27th and 28th May in New Delhi, was India's biggest drone festival till date. Prime Minister Narendra Modi opened the event, spoke with kisan drone pilots, and saw drone displays. Over 70 exhibitors demonstrated a variety of drone applications, including a Made in India drone taxi prototype. The festival highlighted the government's efforts to advance the drone sector, particularly in the field of agriculture (Beriya, 2022).

Conclusion

A notable achievement in agricultural technology is the creation of an Advanced Standard Operating Procedure (SOP) for Accurate Drone Assisted Insecticide Application in Crop Management. This all-inclusive manual, which was created by professionals from several fields working together, leverages the revolutionary potential of drone technology to guarantee accurate, secure, and environmentally responsible pesticide application. This method, which ushers in a new era of precision farming, maximizes productivity and sustainability by customizing SOPs to particular crops and environmental conditions. The focus on pesticide compounds relevant to certain crops and general pest management guidelines emphasizes the dedication to efficient and ethical farming techniques. As technology progresses and costs decline, drones are becoming increasingly affordable and accessible for agricultural purposes. This affordability and accessibility have spurred greater adoption among farmers, especially small-scale ones who previously lacked access to such technology.

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