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Feasibility and utilization of Unmanned Aerial Vehicle (UAV) in Integrated Pest Management

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The increasing scarcity of labour and technical expertise, particularly in India, necessitates innovative approaches to agricultural pest management. FAO estimating over 40 percent of global crop production is lost due to pests and diseases. Conventional pesticide application methods are inefficient, with only 20–30% of applied chemicals effectively utilized, while the remainder contributes to environmental pollution. Unmanned Aerial Vehicles (UAVs), or drones, provide an advanced alternative for Integrated Pest Management (IPM). They enable precise, efficient, and timely application of plant protection measures, reducing pesticide use and enhancing environmental safety. Equipped with GPS, sensors, advanced cameras, and artificial intelligence (AI), drones can monitor pest populations, identify species, release biological control agents, apply pesticides directly to infestation hotspots and directly kill the pest. This targeted approach helps reduce resistance development and protect natural enemies. Although initial investment and operational skill requirements pose challenges, the benefits of drones including reduced labour dependency, improved efficiency, and environmental sustainability outweigh these limitations. UAV technology is poised to transform precision agriculture by offering sustainable solutions for improved crop productivity and effective pest management.

Keywords: Unmanned Aerial Vehicles (UAVs), Integrated Pest Management (IPM), Precision Agriculture.

Introduction

As labour availability and technical manpower are extremely limited, particularly in India. Insect pests are known to cause heavy reduction in food grain production across all over world. It is estimated that up to 40 percent of global crop production is lost to plant pests and diseases each year, causing economic damage of more than USD 220 billion annually (FAOSTAT, 2025). Rad, Ray & Barghi (2022) report that up to 95 % of herbicides and 98 % of insecticides may not reach pests and instead enter the environment through wind, runoff, and atmospheric processes. The world population is estimated to be 9–10 billion by the year 2050 (UN DESA, 2024), increasing the need for more food. The agriculture industry is the highest user of clean water, mainly used for irrigation purposes, which can be easily contaminated by pesticides. More than 1200 pesticides and herbicides, some of which are banned in Europe, are currently in use in the world. Although some of these herbicides can be

degraded naturally in the soil, many of them are not easily degraded and remain in the environment for extended periods of time (Youssef *et al.*, 2019). Under these circumstances, effective and timely spraying of plant protection measures are very important. For this, miniaturized unmanned aerial vehicles possess a wide array of benefits that include high efficiency, reduced labor requirement, saving of time and energy, quick response time and vast area coverage, as well as environmental safety (Meng *et al.*, 2018).

What's is Unmanned Aerial Vehicle (UAV)?

A **DRONE** (Dynamic Remotely Operated Navigation Equipment), commonly known as Unmanned Aerial Vehicle (UAV) is essentially flying ROBOT. The aircraft may be remotely controlled or can fly autonomously through software-controlled flight plans in their embedded system working in conjunction with on board SENSOR and Global Positioning System (GPS). The optimal flight height of 1.5-2.0m above crop canopy, flight speed 5m/s, in combination with wind speed of below 5m/s was found to be effective for spraying pesticide with drones. The payload capacity of Drone ranges from 1.0 to 25 kg. Drone can spray cover up to 30 acre/day using multiple batteries (5) with 10 kg pay load(6hrs/day). The Drone operation is being permitted by Ministry of Civil Aviation (MoCA) and Director General of Civil Aviation (DGCA).

Types of UAV (Unmanned Aerial Vehicle) (Bharad *et al.*, 2024)

Unmanned Aerial Vehicle (UAV) is a radio-controlled aircraft which can fly without a human pilot. UAVs with multiple rotors are categorized based on the quantity of rotors on their platform. The various UAV models that have been in operating during the last two decades are shown in fig.:



Component of UAV (Drone)

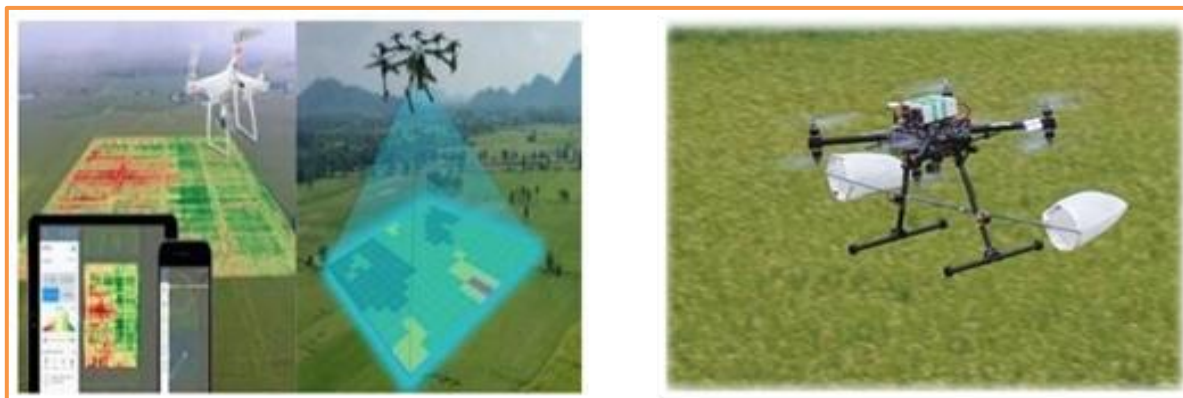
1. **Motor-** Common type used in an hexacopter or octocopter is a brushless DC motor.

2. **Propeller-** For lifting the Drone and destroyed the pest.
3. **Electronic speed controller (ESC)-** To vary the Revolution Per Minute (RPM) of the motor.
4. **FPV camera and Transmitter-** To capture the images and videos.
5. **Flight controller (Brain of UAV)-** Various sensor like Accelerometer and Gyro meter are connected. Accelerator measure acceleration force whether static/dynamic. Gyro meter uses Earth's gravity to determine orientation.
6. **Radio transmitter and receiver-** Radio transmitter transmits comments to the drone (remote). Radio receiver is connected to the Drone.
7. **Pump and Nozzle-** To pressurize the liquid a **12V DC water pump** can be used which has **2.5L/MIN**. **Flat fan type** of nozzle is used for spraying the liquid.
8. **Batteries** – Basically Lithium-ion batteries use in Drone. It can take only 8-9 min to full charge.



Uses of UAV (Drone) in IPM

- a) **Monitoring of Insect Population-** Drone technology is an effective way of monitoring the insect pest in agriculture fields. This involves taking high resolution aerial images of the land area, using remote sensing technology it may be used to monitor crops and detect pest affected areas. This advanced technology helps farmers get accurate information about insect infestation and enables them to take the necessary action in time (Kim *et al.*, 2018).



- b) **Release Biological Control Agents-** Drones can be used to release beneficial insects, that prey on pests. Drone mediated precision releases of natural enemies now a day, drones

are useful tool for augmentative biological control, which depends on the extensive release of natural enemies for immediate control of pests. They could distribute the natural enemies in the exact locations where they are needed, which may level up the efficacy of bio-control agents and reduce costs of distribution.



Eg- In the United States 2019, drones are being used to Release beneficial insects viz., ladybugs, against aphid (*Melanocallis caryaefoliae*) population in pecan nuts trees. (The New York Times, 2020).

- c) **Aerial Spray-** Drones can be used to apply pesticides directly to the pests, rather than spraying the entire field. This reduces the amount of pesticide used and helps to protect the environment.
- d) **Direct killing-** PATS uses advanced camera and drone technology to improve the Integrated Pest Management (IPM) process. The PATS-C cameras monitor the airspace above crops and count insects each night by analyzing their size, speed, and unique flight patterns. Harmful insects are identified and targeted by small PATS-X bat-like drones, which are guided by the camera system and intercept pests' mid-air, eliminating them on impact. After each mission, the drones automatically return to their charging station. This system provides a fast, autonomous, and pesticide-free method of controlling pest populations (PATS Indoor Drone Solutions, 2024).

Case studies

- ❖ **Aerial Spray for Brown Plant Hoppers in Rice-** The BPH causes damage at the late stage of rice growth. During the late stage of the crop, it is very difficult to undertake manual spraying as the leaves of the rice canopy overlap (Sheng *et al.*, 2002). Further, BPH often colonize at the lower part of the plant which is not easily controlled through a manual sprayer. In addition, the muddy fields and overlapping plants makes the conventional system of pesticide spray difficult. In order to overcome the bundle of practical difficulties and acute labour shortage, aerial spray of pesticide using UAV becomes inevitable (Zhou *et al.*, 2013).
- ❖ **Aerial spray in sugarcane-** During the cropping period, spray of pesticide is extremely difficult due to the morphology of the crop and sharp edges of the leaf blades which often injure workers (Zhang *et al.*, 2020). Further, some of the pests (internode borer, top borer) cause heavy loss and farmers find it difficult take up any plant protection measures. Under these circumstances, drones may be of help to deliver sprays in sugarcane fields.
- ❖ **Aerial spray to Manage Fall Army Worm-** The Fall Army Worm (*Spodoptera frugiperda*) is one of the invasive pests causing extensive damage in maize (Ganiger *et al.*, 2018). It is a polyphagous pest that feeds on a wide range of cereals, millets, (Khan *et al.*, 2018). In order to control the pest, quick action has to be taken to ensure that pest population is kept below ETL. Drones are highly useful technology to undertake spray quickly to manage the pest population.
- ❖ **Release of Sterile Insects Technique (SIT)-** Another possible area for use of drones in pest management is the release of sterile insects. Experimental programs to release sterile insects with drones have been successful in controlling codling moth (*Cydia pomonella*) populations in Canada, New Zealand and USA. (Horner *et al.*, 2020).



Drone release of the sterile insects may be cheaper and faster than ground release.

❖ **Drones for desert locust control-** Drones offer a versatile and efficient solution for pest control, particularly in challenging environments. Their ability to navigate tight spaces and access hard-to-reach areas makes them an ideal tool for targeting localized infestations. Unlike traditional vehicle-mounted or hand spraying methods, drones can deliver precise applications of pesticides, minimizing waste and reducing the risk of harming non-target species. By utilizing drones, farmers and pest control professionals can enhance their integrated pest management strategies, leading to more sustainable and effective pest control practices. The ability to quickly deploy drones in response to emerging threats also allows for timely interventions, potentially preventing larger outbreaks and minimizing crop damage. Overall, the integration of drone technology into pest management can significantly improve the efficiency and effectiveness of control measures (Ochieng' et al., 2023)

Advantage

1. Drones provide stressed and healthy images of crops for monitoring.
2. Less time consuming
3. Low labour requirement and reduce labour costs.
4. Increased efficiency.
5. Improved safety.
6. Apply pesticides more precisely and reduce resistant development in pest.
7. Reduced high use of pesticide.

Disadvantage

1. High costs.
2. Requires skilled labours for operation.
3. Can't be used during adverse climatic conditions.
4. Applicable only for large scale spray.
5. Short flying time.
6. Drone Crashes.
7. Flight drones are covered by aviation law.

Conclusion

Drones provide real time and high-quality aerial imagery compared to satellite imagery over agricultural areas. The use of drones in pest management has several advantages over traditional methods. Drones can fly over large areas quickly, which can save time and money. They can also be used to access difficult-to-reach areas, such as crops that are located on steep slopes or in narrow rows. Additionally, drones can be equipped with sensors that can detect pests and diseases at an early stage, when they are easier to control. Overall, the use of drones in pest management is a promising new technology that has the potential to make a significant positive impact on the environment, human health, and crop production.

Future perspectives

The future perspective of drone technology in pest management is very promising. Drones are still a relatively new technology, but they have the potential to revolutionize pest management. As the technology continues to develop, drones are likely to become even more important in the fight against pests. Drones have already vastly altered the agricultural industry and will continue to grow in the coming years. Drones can be used to monitor crops for pests and diseases, apply pesticides more precisely, and even release beneficial insects to control pests. For increasing the yield and reducing the infestation of various insect with less damage to environment drones in future will be like a boon to the farmers.

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