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Role of Drones in Insect Pest Management: A Boom in Sustainability

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One of the major components in precision agriculture is crop health monitoring, which includes irrigation, fertilization, pesticide sprays, and timely harvest of the crop. Further, the progressive change in growth and development is critical in crop monitoring and taking suitable decisions to maintain health status. In order to accomplish the task, drones are highly useful for on site detection of problems so as to undertake corrective measures instantly. Although it is expensive to build algorithms and establish relationships between ground truth and spectral signatures, it is a user-friendly technique once the basics studies are done. As labour availability and technical manpower are extremely limited, particularly in India, drones are gaining popularity in the context of smart farming. Insect pests are known to cause catastrophe and drastic reduction in food grain production across the globe. The losses that have been predicted by FAO is over 37% due to pests and diseases. Recently, crops cultivated in India have been threatened by invasive pests like fall army worm (*Spodoptera frugiperda*) in corn and *Rugose spiraling whitefly* in coconut (*Aleurodicus rugiperculatous Martin);* these pests caused extensive damage during the years 2018 and 2019. The plant protection measures are to be taken on a community basis so as to ensure effective management of pests. In India, more than 80% of farmlands are in the category of small and marginal (<1 ha), so it is very difficult to manage the invasive pests. If one field is sprayed, the pests simply shift their feeding to the neighbouring fields. To address this, drones become essential. Drones are unmanned aerial vehicles exploited in a wide array of disciplines such as Defense, monitoring systems, and disaster management but are only beginning to be utilized in agricultural sciences.

Introduction

The biotic stresses caused by pests and diseases are well-known to cause devastation that results in reductions in global food grain production. The FAO has predicted that the losses due to pests and diseases are over 37% (Cao, 2015). They are also severely affecting the crop growth, yield, and quality of produce (Gossen et al., 2008; Berger-Neto et al., 2017). Recently, crops cultivated in India are being threatened by invasive pests such as fall army worm (*Spodoptera frugiperda JE Smith)* in corn and Rugose spiraling whitefly in coconut (*Aleurodicus rugiperculatous Martin)*, causing extensive damage during 2018 and 2019 (Lal and Bikram, 2019). The fall army worm has become a serious matter of concern to the farmers of India, first hitting the Indian subcontinent in May 2018 in the State of Karnataka. The Indian Agricultural Research Institute–Natural Bureau of Agricultural Insect Resources estimated the intensity of infestation to the tune of 9–62% with an economic yield loss of 34%. The incidence of FAW has spread to the neighbouring state of Tamil Nadu where more than 20 districts out of 38 were badly affected in 2019. The effective and rapid interventions and implementation of strategic work plans included drone technology that helped to lessen the incidence of FAW and protect maize crop from infestation while ensuring crop productivity. These pests are to be meticulously monitored and proper technology capsules are to be adopted to save the crops from devastation. Several plant protection strategies are being followed in an integrated way to ensure that crops are protected during the entire crop growing season. The plant protection measures are to be taken on a community basis so as to ensure effective management of pests and diseases. In India, more than 80% of farmlands are in the category of small and marginal (<1 ha), so it is very difficult to manage invasive pests. If one field is sprayed, the pests simply shift their feeding to the neighboring fields. The invasive pests have enormous potential to multiply in an alarming proportion and are almost impossible to manage with conventional methods of plant protection strategies. It is reported that the annual global use of plant protection chemicals against trans-boundary pests was more than 3 billion kg (Heidary et al., 2014). The utilization of pesticides that are sprayed on the crops exceeds 20–30% and the remaining 70–80% goes as run-off, leaching, evaporation, and drift that cause soil and aquatic pollution as well as deteriorating the quality of the crop produce (Markle et al., 2016; Torrent et al., 2017). 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. The design of UAVs should consider various parameters such as droplet size, wind speed, flight speed, and flight height (Zhang et al., 2012, 2015; Qin et al., 2014). Further, meteorological parameters like wind speed, temperature, and relative humidity can affect the efficacy of pesticide sprays under field conditions (Wang et al., 2018). Under natural conditions, it is very difficult to control the meteorological parameters and thus scientists have attempted to study the drones under protected conditions.

Delivery of Droplets

One of the critical factors to be considered for the effectiveness of drone-enabled spray is droplet deposition. The parameters used for measuring the effectiveness of droplet deposition include density, area coverage, and arithmetic mean of droplet size and variation coefficient (Zhu et al., 2011). The droplet deposition density is defined as the number of droplets deposited per unit area which is often measured using blotting paper. Droplet deposition coverage is yet another parameter usually recorded for assessing effectiveness, and is the area of all droplet particles deposited per unit area (Cunha et al., 2012). The arithmetic mean droplet size is the average value of all droplet diameters in one spray sample (Fan, 2011). The co-efficient of variation (CV) measures the uniform spread of droplet deposition in an aerial spraying operation. These four indices can be calculated using the formulae outlined below:

a.	Droplet deposition density (D) :- No. of droplets deposited (n)/area of droplet collection material (A)
b.	Droplet deposition coverage (C) :- Area of droplet deposition (S)/Area of the blotting paper (A)
c.	Arithmetic mean of droplet size (D0) = Σ Di Ni/Σ Ni :- Di is the droplet diameter over time interval , Ni is the number of droplets over time interval
d.	Co-efficient of Variation (CV) = SD/X

Infrared Thermal Imaging

Thermal imaging is a technique to improve the visibility of the reference objects in a dark environment by detecting it using infrared radiation and creating an image based on the information. Thermal imaging, near-infrared illumination, and low-light imaging are the three most commonly used night vision technologies. Infrared thermal imaging can be exploited for assessing the droplet size and distribution in drone-enabled pesticide sprays.

Aerial Spray for Brown Plant Hoppers in Rice

Rice is a staple food crop for more than 2.7 billion people in Asia; the loss of productivity of the crop has been estimated as more than 20% (Brookes and Barfoot, 2003). The brown plant hopper (BPH) *Nilaparvata lugens* causes considerable loss of crop yields globally and is a major pest in India in the late season rice crop planted during September–October (Zhang et al., 2011). 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 inaccessible 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 labor shortage, aerial spray of pesticide using UAVs becomes inevitable (Zhou et al., 2013).

Cotton

Cotton is predominantly cultivated in Australia, Pakistan, India, China, Brazil, and the USA, constituting 80% of the global cotton produced (https://www.wto.org/english/news_e/news16_e/cdac_01jul16_e.pdf). The crop is badly affected by a wide array of defoliating, boll feeding, and sucking pests that devastate the crop to the tune of 10–80% (Sharma et al., 2017). In order to protect the crop from insect pests, huge quantities of pesticides have been used in the past several decades.

Droplet Drift, Deposition, and Distribution Pattern

The unmanned aerial vehicles (UAVs) performance is often affected by environmental factors such as wind speed, direction of wind, temperature, and rain. When spray is undertaken with drones, a small portion of the dosage does not reach the target area, which is popularly referred to as droplet drift or spray drift (Kirk, 2004).

Aerial Spray of Pesticides on Aphids and Spider Mites in Cotton

In cotton, aphids and mites are serious sucking pests of great concern that cause extensive damage to the crop (Lou et al., 2018). In order to address these pests, aerial sprays using drones were attempted. Lou et al. (2018) studied the efficacy of unmanned aerial vehicles (UAVs) on cotton aphids and spider mites. Similar to other literature, they too recorded that droplet uniformity, spread of the pesticide, and deposition were higher at a flight height of 2 m.

Optimal UAV Parameters for Sugarcane

Sugarcane is a long duration crop, and the canopy arrangements are different from other crops. Aerial spray by drones may be advantageous as accessibility to the cropped field is very difficult in sugarcane (Zhang et al., 2011). Use of UAV in sugarcane is very limited. Zhang et al. (2020) conducted experiments to optimize various spray parameters (spray volume, flight height, and flight velocity) and three levels by quad-rotor drone.

Drones to Manage Fall Army Worm in Sugarcane

The Fall Army Worm (*Spodoptera furgiperda*) is one of the invasive pests causing extensive damage in maize (Ganiger et al., 2018). The pest, originally from the USA, migrated to Africa in 2016 and entered southern India in 2018 (Padhee and Prasanna, 2019). It is a polyphagous pest that feeds on a wide range of cereals, millets, sugarcane, banana, and other crops (Khan et al., 2018). It causes extensive damage in a very short span of time.

Conclusion

An extensive review was undertaken to determine the feasibility and utilization of Unmanned Aerial Vehicles (UAVs) or drones for pesticide sprays in various crops. The following are the observations:

1. Drone application in agriculture is primarily focused on pesticide applications. Extensive research has been done on optimization of spray volume, droplet size, spread of droplets, and penetrability as well as efficacy of pesticides in insect pest control (Lou et al., 2018). Many of the optimization parameters indicated were done mainly for pesticides use in agriculture.
2. A majority of the research on UAV for pesticide spray in crops was carried out in rice (Qin et al., 2016), wheat (Wang et al., 2019a), corn (Zheng et al., 2017), cotton (Lou et al., 2018), pepper (Xiao et al., 2020), and sugarcane (Zhang et al., 2019) as these crops consume more pesticides than any others. Further, these crops are cultivated in larger areas in contiguous blocks in developed and developing countries where drone application is feasible.
3. In order to improve insecticidal use efficiencies in crops, drone operational parameters such as flight speed, flight height, nozzle type, payload, and drone type are be optimized for the given situation. Overall, flight height of 2–3 m, flight speed of 3–5 ms^{-1}, two fan nozzle, four rotor UAV, and 15 L payload are found to be optimal to undertake pesticide sprays using drones in agricultural crops (Zhang et al., 2011). Drone efficiencies are to be examined for certain application parameters such as droplet size distribution, droplet coverage, uniformity of droplets, droplet penetrability, droplet drift, and insecticidal efficiency prior to commercial use of drones in agriculture (Lv et al., 2019).
4. There are potential benefits to drone usage in agriculture that include large area coverage, less quantities of pesticides, labor saving, quick response time, and timely operation well before pest occurrence exceeds economic threshold levels (Huang et al., 2018).
5. Despite the fact that there are ample advantages attached to drone technology, every country has its own regulatory guidelines for the use of drones in agriculture (Ayamga et al., 2021). Prior approvals are required from local authorities to use drones in agriculture.

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