FEATURE ARTICLE

Drone application in pest management: A step towards precision agriculture

Kolla Sreedevi, Sushil S.N., Rami Reddy P. V. and Vishnuvardhan Reddy A.

Abstract: Agriculture is the backbone of Indian economy. The profitable crop production depends on several factors of which mechanization and technology advancement are crucial. The advent of artificial intelligence and machine learning technology in the recent past has contributed towards the 'precision farming' or 'smart agriculture'. On these lines, use of unmanned aerial vehicles (UAVs) or more commonly called drones is making rapid strides to ensure efficient resource utilization and enhanced income to farmers. Drone technology in pesticide application is gaining momentum and certainly aids in making better decision towards pest management options for precision agriculture. For effective and efficient use of drones, the knowledge on rules and regulations to fly a drone for the agricultural operations is essential. The Government of India, DGCA to be more precise, has put in place clear guidelines on the use of drones in agriculture and also is taking steps to encourage and popularize drone technology. Several ICAR research institutes and State Agricultural Universities are actively involved in developing crop specific SOPs for drone based pesticide application in various crop ecosystems. An attempt has been made in this article to present the status and scope of using drones for plant protection purpose.

Keywords: Unmanned aerial vehicle, agriculture, bioagents, drone, pesticides, rules and regulations

In this era of artificial intelligence and deep machine learning techniques, use of unmanned aerial vehicles (UAV) or Remotely Piloted Aerial Systems (RPAS), popularly known as drone (dynamic remotely operated navigation equipment), is gaining momentum in various fields. Drone is the popular term often used by the public to denote unmanned aerial vehicle (UAV), which can be an unmanned aircraft or unmanned aerial system (UAS), where the latter refers to a larger system of the airborne portion of the UAV. Drones are controlled/maneuvered by a person located elsewhere through wireless linkages coordinated with the sensor(s) mounted on the UAV, which can be either operated manually, or programmed to operate automatically.

Though development of UAVs was initiated during the early twentieth century for use in military missions, their applications and utilization moved at faster pace in other fields in the recent past. Another important sector where drone application caught attention is agriculture and the first UAV was developed by the Yamaha motor company in 1997 for agricultural purposes (Giles and Billing, 2015).

In tandem with the growing emphasis on smart and precision agriculture, drones emerged as one of the important components of modern agriculture and are being used for different purposes like surveillance, soil mapping, irrigation monitoring, seed dispensing, crop monitoring etc. (Huang et al., 2009). Initially their use was focused towards crop production and monitoring, gradually intensified towards crop protection. Of all the applications, pesticide spraying for crop health management using drones is the fastest growing area to attain accuracy and rapid coverage of larger areas. Certain UAVs are equipped with the cameras and sensors that enable both crop monitoring and pesticide spraying. It ensures saving of time and resources with additional benefits like uniform and thorough coverage in a cost effective manner. Several enterprises in India are working right now on drone technology for delivering food, medicines, and vaccinations. Other industries like agriculture, military and, media entertainment have already adopted drones for various purposes. At present, drones are considered as an essential tool for farmers to accomplish various applications, of which pesticides spraying (Fig. 1) is one of the advantageous and important activities that save their time and labour and ease out the hazardous conventional methods especially in hilly areas (Pathak et al., 2020).

Evolution of drones

Drones are widely used in various sectors of agriculture like mapping and surveying of topographies, surveillance of pest and disease incidence, watershed management and monitoring emergency/ disaster situations.

The first UAVs were developed in Britain and USA in 1917 during the First World War. Subsequently UAVs intended for specific purposes has evolved and the first agricultural drone in the world for aerial spraying was manufactured by Yamaha (Japanese company) during 1990s. These were intended further for use in aerial survey for crop mapping and field analysis. The company introduced Japanese unmanned helicopter Yamaha R-MAX (16 kg payload), which was basically designed for pesticide spraying for agricultural pest management and then crop monitoring. The R-MAX was approved for operation in USA in 2015 by the Federal Aviation Administration. It was extensively used in agriculture for nearly 30 years with proven performance, reliability and efficiency where this unmanned helicopter was fitted with double-acting piston with flat nozzle and impeller (with 300mm diameter) as discharge methods to suit liquid and granular spray application, respectively. The technology became widespread 2010 onwards. Initially it was a fixed wing UAVs, now multi-rotor unmanned aircrafts are into the market. Currently, DJI Agras MG-1S (10 L capacity) (developed for precision variable rate application of liquid pesticides, fertilizers and herbicides), 3WQF120-12 (12 L), 3CD-15 (15L), WSZ-0610 (10 L), HY-B-15L (15 L) are in wide use for agricultural spray operations (Borikar et al., 2022).

In India, in 2022 budget, the Finance Minister of India introduced Drone-as-a-service model naming it as *"Kisan Drones"*. These are intended for use in digitizing the land records, spraying of insecticides, pesticides, nutrients and on whole monitoring and assessing of the crop health.

Regulations and Acts

The Ministry of Civil Aviation (MoCA), Government of India has brought out new Drone Rules, 2021 vide gazette notification CG-DL-E-26082021-229221 dated August 25, 2021 in place of the Unmanned Aircraft Systems Rules 2021 and were subsequently amended by the Drone (Amendment) Rules, 2022 on 15 February 2022 to accommodate and regulate the various drone related activities in India. Recently, the Ministry of Civil Aviation has launched the Digital Sky Platform, a unique unmanned traffic management (UTM) system that facilitates registration and licensing of drones and pilots. The procedures pertaining to issue of Unique Identification Number (UIN), Unmanned Aircraft Operator Permit (UAOP) and related activities are furnished under DGCA RPAS Guidance Manual (DGCA, 2020). It is pertinent to know about the procedures and regulations laid by the Directorate General of Civil Aviation (DGCA) for smooth operation of drones in India.

A license or registration requirement to fly a drone in India

- One should get registered with the DGCA to operate a drone and possesses a license to fly it.

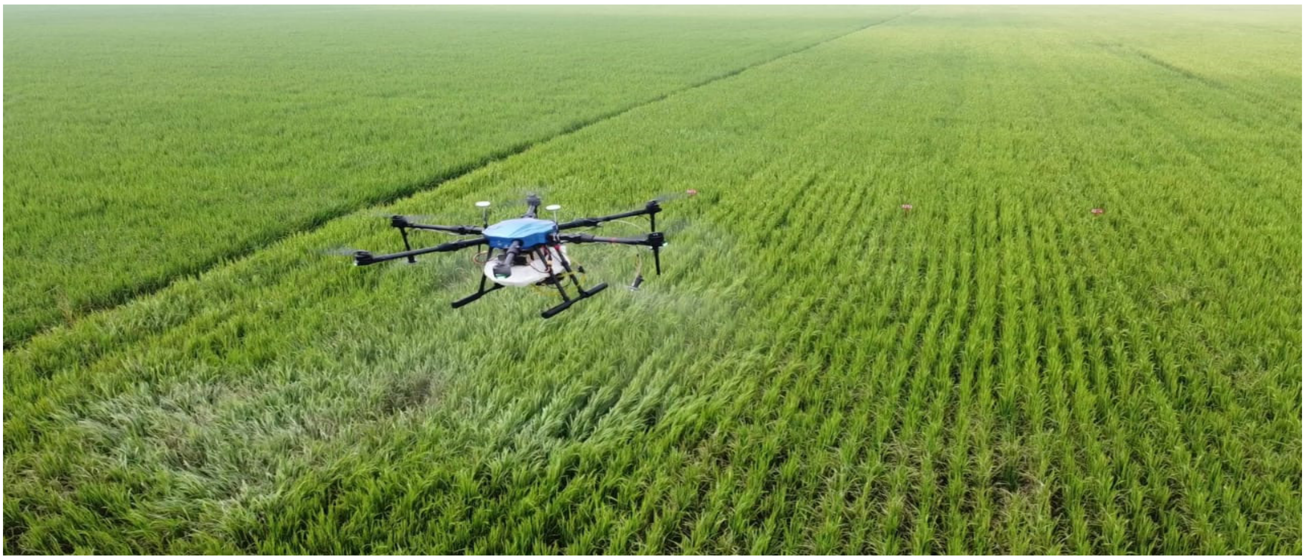

Fig. 1. Pesticide spraying by an agricultural drone in a paddy field

The minimum age limit to fly a drone is above 18 years and should have passed 10th standard along with a completion of training course from a DGCA-approved institution. Upon completion, a written exam need to be passed to receive a remote pilot certificate from the DGCA through the Digital Sky Platform, which comes normally within 15 days or from the Institutions authorized by DGCA. The certificate thus obtained is valid for 10 years.

- Certificate is not required for operating nano drones (weighing less than 250 g) and non-commercial micro drones (weighing less than 2 Kg) under the new rules and the operators should remember not to fly nano and micro drones over 50 ft. above ground level and maintain a speed of 25 m/s.
- The Indian Ministry of Civil Aviation has also deployed an interactive airspace map on the Digital Sky Platform for the convenience of drone operators and all other stakeholders. The map is color-coded into Green, Yellow, and Red zones.
- The drones may be operated freely in the green zones that are earmarked at 400ft above ground level, whereas a special permission is required to fly in yellow zones, which are controlled airspace. Red zones are strictly no-fly zones, which normally include areas such as military bases or nuclear power plants and other sensitive areas that are restricted due to the risk of accidents or national security purposes. The drones are not allowed to be operated near airports or in a densely populated areas.

One can visit https://digitalsky.dgca.gov.in for further more details and get insights into the requirements, criteria, procedures and regulations of UAS operations in India.

Types of drones

Among the different types of drones, especially fixed wing and rotary wing drones, the multi rotor drone especially hexacopter is the widely used one for foliar application of pesticides. The advantage with the multi-rotor drone is propellor turbulence in the crop canopy, that facilitates the better spray droplet penetration into the lower parts of the canopy.

The main categories of UAVs are fixed wing aircraft or vertical take-off and landing rotary wing helicopters or multicopters. A fixed-wing aircraft, require an approach and landing runway and are usually flown in automated mode. It has the advantage of longer endurance and hence can cover larger areas and has a fast flight speed. They can fly at a speed of more than 80 km/h. This makes fixed-wing UAVs ideal for aerial survey, high-resolution aerial photos, mapping and land surveying. In contrast, multirotor UAVs that have lower speed, shorter flight duration and limited payload capacity are easier to pilot manually and need limited space to take off. It's ability to hover around a particular area, and ability to operate in confined areas make them ideal for surveillance and for detecting crop pests, diseases and weeds. The only limitation with the copters is a shorter flight endurance. Hybrids in the form of vertical take-off and landing (VTOL) systems are more versatile operationally as they maintain efficient range without the need for a runway.

UAVs are often dissimilar to conventional aircraft and are obtainable in a range of shapes, sizes, and configurations. The take-off mass of a UAV has been used historically to classify the devices. Frequently used categorizations occur at 2 kg mass, at 25 kg and at 150 kg. The minimum age of the pilot, the expected remote pilot competence, whether the device has to be registered with the CAA or not, the need for electronic identification and installed geo-fencing software are essentially dependent on the category a UAV. The UAVs heavier than 150 kg are generally considered as equivalent to conventional aircraft with obligations to meet analogous airworthiness and certification standards.

UAVs are also classified based on their size – from very small, small, medium to large, the details are furnished hereunder:

Classification based on weight of a drone including payload

(a) Nano drone: Less than or equal to 250 gram;

(b) Micro drone: More than 250 gram and less than or equal to 2 kilogram;

(c) Small drone: More than 2 kilogram and less than or equal to 25 kilogram;

(d) Medium drone: More than 25 kilogram and less than or equal to 150 kilogram; and

(e) Large drone: More than 150 kilogram.

Drone Piloting – a new employment generation platform

The training of drone pilots in flying a drone and also in it's maintenance is an essential component in drone application. The knowledge of the operation as well the management of drone is essential and must undergo training and obtain a certificate to fly a drone to the requisite accurate altitude with precision. In India, the pilot training and the Remote Pilot Certificate has to be obtained from any of the certified training schools authorized by Directorate General of Civil Aviation (DGCA). Initially a few institutes like Indian Institute of Drones, Indian Academy of Drones, Bombay Flying Academy got the DGCA approval for drone pilot training, after which a few more institutes lined up. As the use of drones becoming popular in agriculture especially for pesticidal spraying, the requirement of trained drone pilots and generation of human resource in this direction is very crucial.

Among the State Agricultural Universities, Acharya N G Ranga Agricultural University (ANGRAU), Guntur, Andhra Pradesh is the first one to get DGCA approval for Remote Pilot Training Organization (RPTO) to train the drone pilots to operate the agricultural drones for pesticidal spraying. Developing agricultural drone Pilot human resources with well knitted course curriculum in lines with DGCA and SOP's for drone applications in agriculture is the need of hour and ANGRAU with its established APSARA (A Research Wing of ANGRAU on Drones) proficient in drone pilot coaching has developed 15 days Drone Pilot training curriculum and started imparting training to the agricultural/polytechnic students of ANGRAU as a part of their curriculum to train them as Professional Agricultural Drone pilots (Fig. 2) through its ADITI (Agricultural Drone Incubation and Training Institute) – a RPTO of ANGRAU (Vishnuvardhan Reddy, 2022). Recently the University started Drone pilot training to the farmers facilitated through state agriculture departments. The University has trained 300 pilots in fifteen batches (Fig. 3) till now to fly drones commercially.

Government has taken up a concerted efforts to encourage training institutes and establish courses and programs in the State Agricultural Universities to increase the number of skilled personnel in the industry to promote the drone technology in agriculture.

The drone trainer, drone pilots, software developer will be in great demand in coming future. The Government of India has released a certification scheme for agricultural drones vide gazette notification CG-DL-E26012022-232917 dated January 26, 2022 and now many are the beneficiaries.

Drone requirements for pesticide application/ spraying

The efficiency of agricultural drones in terms of lifting capacity and flight dynamics varies and depends on the following parameters:

1. Number of arms and rotors
2. Rotor positions
3. Location of the nozzles and its configuration
4. Number and type of nozzles
5. Distance between nozzles

Standardizing the above parameters will aid in proper

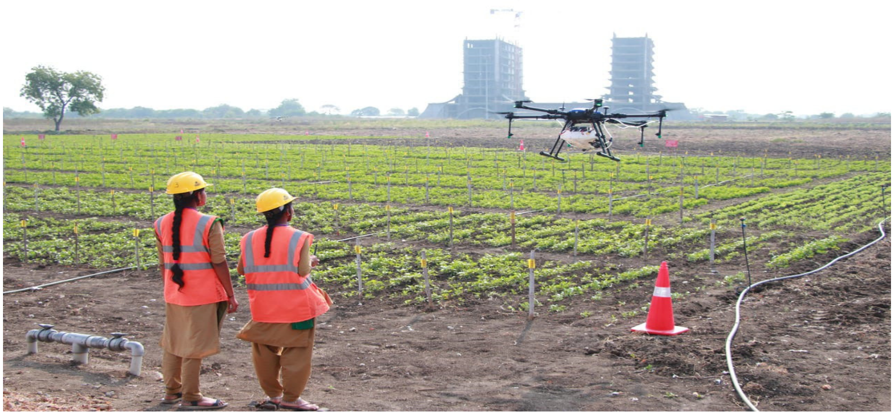

Fig. 2. Trainee pilots flying an agricultural drone

Fig. 3. A batch of drone pilots trained at ANGRAU, Guntur, Andhra Pradesh

pesticide spray coverage, better penetration of spray droplets into the target crop canopy, with less spray drift or spillage. The latest design for discharge of spray solution uses rotary atomizers positioned under large propellors, which are referred as Controlled droplet atomizers (CDAs). The accurate real-time recognition system of spraying areas for UAVs is of utmost importance for UAV-based sprayers. There is a need for developing the deep learning system that enables the classifier recognition to process the computation time based on the collected images from a UAV for a given spraying area. The developed deep learning system can be deployed in real-time to UAV-based sprayers for accurate spraying.

The flight flying altitude and the velocity are very important in determining the spray droplet density and deposition on the crop canopy, which ensures the proper and uniform coverage. These factors need to be evaluated for each type of drone on specific crop and the pesticidal formulation.

Govt. support to popularize drones in agriculture/ Recent initiatives by NARES to popularize drone application and development of SOPs for pesticide application

To promote and popularize the use of drones for agricultural purposes, the Government of India has recently announced a 100% subsidy or Rs10 lakhs, whichever is less to the Farm Machinery Training and Testing Institutes, ICAR Institutes, Krishi Vigyan Kendras and State Agricultural Universities. Additionally, a contingency fund of Rs.6000/ha will also be set up for hiring drones from the Custom Hiring Centres (CHC). The subsidy and the contingency funds will help the farmers to access and adopt this otherwise expensive technology.

The Government organizations like Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs), several other national organizations have started procurement and operations of drones. The major challenges include training of the pilots and developing standard of procedures for spray operations in different crops.

The Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Plant Protection, Quarantine and Storage (DDPQS) and Central Insecticides Board and Registration Committee (CIB&RC) together has come up with the draft Standard of Procedures (SOPs) for use of drones in application of pesticides for crop protection in agriculture, forestry and non-cropped areas. Accordingly a document on “Crop specific standard operating procedure (SOP) for the application of pesticide\s with drones” has been published by Ministry of Agriculture and Farmers Welfare, Department of Agriculture and Farmers Welfare (Mechanization and Technology Division), Government of India, Krishi Bhawan, New Delhi and the document can be accessed at https://farmech.dac.gov.in under 'SOP for DRONE 2023'.

Flight altitude is crucial in determining the spray swath width and the quality of spray deposition into the target canopy. In this direction, ANGRAU was the first SAU to undertake the research and development in drone technology especially in pesticide spraying and development of the crop specific SOPs and evaluated agricultural drone spraying in 10 major crops viz., paddy, blackgram, chickpea, pigeonpea, sugarcane, maize, sugarcane, groundnut, cotton, chilli during 2021-22. They also worked out the drone spraying efficiency with 11 pesticide formulations and the studies revealed that the low volume spraying i.e. 10 L/acre or 25 Litres/ha of the existing formulations @75% of the recommended doses is effective and does not cause phytotoxicity. It works out to a 25% pesticide reduction, which is a definite saving to the pockets of the farmers. The Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana has come up with the SOPs for drone based pesticide application in rice crop. It is pertinent to follow the appropriate rules and regulations while adopting the drone applications in pesticide spraying in agriculture.

Promoting drone industry through 'Make in India'

To popularize the drones in agriculture and especially in spraying operations, the Government has started supporting indigenous drone manufacturing units.

As supported by new regulations and rules in the journey of becoming a global drone hub by 2030, India has banned the import of all drones (with exceptions in defense sector, security purposes and R&D of the technology) to encourage the domestic drone manufacturing industry and push the Indian manufacturing sector to rapidly assimilate technology to cater to the needs of the Indian market.

Fig. 4. A&B: Development of an agricultural drone by the trainees

In line with this Government initiative of Make in India, ANGRAU has developed Drone technology and is the first SAU to start the Kisan Drone RPTO and Kisan Drone production in India through APSARA, which designs and develops its own agricultural drones (24.8 kg all up weight) in the small category called ANGRAU-PUSHPAK with 10L payload (Fig. 4). Several other Institutes and industries have also initiated the manufacture of the agricultural drones to make it cost effective to the farmers, and promote the indigenous drones.

Scope of drone sprays beyond pesticides/ Researchable issues in drone technology

The Ministry of Agriculture, India had released a memorandum on 18 April 2022, which furnishes a list of approved pesticides for spraying by drones on interim basis. The registered pesticide formulations that include fungicides, insecticides, plant growth regulators, botanicals and biopesticides have been provisionally approved for use through drones for a period of two years. The SOPs prescribed by CIB&RC for use of drones in different agricultural, forest and non-cropped areas are to be complied with and the new SOPs may be intimated to CIB&RC for inclusion with the supporting data generation. Another area, which needs to be focused is standardization of macrobial biocontrol agents release through drones.

Release of biocontrol agents using drone technology

In recent years, much emphasis is laid on organic or chemical free farming and hence much focus is given to the biological control that involves release of parasitoids and predators and biopesticide applications in the fields. Here comes another challenge of parasitoid release system by drones. ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru is attempting and working to standardize the technique and develop a delivery system to release the parasitoids at appropriate height on the crop or tree canopy to manage the insect pests. For example, the release of parasitoid, *Encarsia* sp. for the management of rugose spiraling whitefly in coconut and oil palm gardens is a big challenge and SoPs are being developed for the application of the same using drones. Efforts are being made at ICAR-NBAIR in developing the SOPs for release of different insect parasitoids and predators in various crop ecosystems considering all parameters like drone nozzle structure, operation, flying height and velocity, etc.

Benefits of pesticide application using drones

1. Wider crop coverage in lesser time, as the drones speed is higher than the human labour and cover the operational delays.

2. Water saving, as the agricultural drones spray application is of ultra-low volume (ULV) and thus save water in comparison with traditional spraying.

3. Secured, as the drones are operated by trained personnel and all computed.

4. High efficiency as the drones can work double the speed of human labor.

5. Drones aid in monitoring and can detect minute signs of pest attacks, and provide accurate data regarding the degree and range of the attack, which help farmers to calculate the required amount of chemicals to be used that would only protect the crops rather than harming them.

6. Cost effective, works out cheaper in long run and require minimum maintenance.

7. Precision in spraying, as SOPs are developed for specific crops and drift hazards are minimum.

8. Drone application reduces the amount of pesticides, insecticides, and other chemicals and thereby avoid excess use, pollution and detrimental effects associated with the pesticidal application.

Limitations of pesticide application using drones

1. Weather dependent - the spraying cannot be taken up in windy or rainy situation.

2. Knowledge and skill - the drone pilot requires a right skillset and adequate knowledge to understand its operational mechanisms, servicing, etc.

3. Net connectivity - the connectivity should be strong for uninterrupted spraying. Often, net connectivity is poor in villages for the farmers to operate.

4. Development of Standard operating procedures (SOPs) for crops - the dosage, droplet deposition, phytotoxicity studies, etc.

5. Payload capacity - its minimal after keeping in view the drone weight to fly at the requisite height.

6. Less flight time due to relatively higher payload where the drones use ranges from 7-30 minutes with every charge depending upon the field geometry, payload and power capacity.

Certain preliminary points to remember with drone spraying:

1. The coverage capacity - on an average an agricultural drone can cover one acre in 5-8 minutes.

2. Altitude of flying - Drones can be made fly at 50-100 m high depending upon the crop height. Above 50m high, a special authorization is required.

3. Drone with payload capacity

4. Balancing with the pesticide tank and spray operations in harsh weather.

Economics of operational expenses

The agricultural operations have to be eased out in a cost effective manner and mechanized in view of labour shortage and in this direction, there is a scope of 40-50% growth in drone usage and application. The estimated value of the drone technology used across all industries including commercial and public applications amounts to nearly $150 billion, which may increase further in coming years.

The wide use and rapid advancement of drone technology in agriculture lead to reduction in cost and the Government also encouraging the drones in farming practices by providing subsidies to farmers to realize good yields and better management of crops. The market for drones is expected to increase to $200 billion in the upcoming years (Puri et al., 2017). According to recent research, the global drone market within agriculture would grow at 35.9% CAGR and reach $5.7 billion by 2025. The cost of the drones range from 5 to10 lakhs per unit but still on higher side for the farmer to procure and hence the Indian Government has come up with subsidies scheme up to 50% for the small, marginal and women farmers and up to 75% to the farmer groups or FPOs.

Conclusions

With enhanced awareness and government support, drone based farm operations are expected to have wider reach in near future. However standaradization of dosage, dilutions, phytotoxocity, efficacy tests to suit to different cropping systems need to be precisely worked out. There is also a need to minimize the drone weight used in pesticide spraying, maximize the drone flight time and more precise autonomous control of drone (Borikar et al., 2022). Since there is a swift and significant growth of drone application in agriculture, we need to be prepared to overcome all challenges to use UAVs widely. The drone industry is going to spike soon and will become a stronger platform providing numerous job opportunities for the youth. If that is achieved, and vital services are provided, then half the battle is won when it comes to becoming world leader in the drone ecosystem.

Looking further into the future, drone technology is going to change the agriculture sector in several folds. Many Indian startups are coming forward to invest in the industry and produce the low-cost drones, which can help farmers substantially.

References

Borikar G P, Chaitanya G, Deshmukh S R. 2022. Application of drone systems for spraying pesticides in advanced agriculture: A Review. Presented in International Conference on Advances in Mechanical Engineering 2022. IOP publishing Ltd. doi:10.1088/1757-899X/1259/1/012015.

DGCA RPAS Guidance Manual, Revision 2 - 2020, Directorate General of Civil Aviation, Govt. ofIndia, approved 11th March, 2020. https://dgca.gov.in/digigov-portal/jsp/dgca/InventoryList/headerblock/drones/DGCA RPAS Guidance Manual.pdf.

Elan. 2015. FAA grants exemption to unmanned Yamaha RMAX helicopter. Vertical Magazine.

Giles D K, Billing R C. 2015. Deployment and Performance of a UAV for Crop Spraying. Chemical Engineering Transactions 44: 307-322.

Huang Y, Hoffmann W C, Lan Y, Wu W, Fritz B K. 2009. Development of a spray system for an unmanned aerial vehicle platform. Applied Engineering in Agriculture 25(6): 803-809.

Khan S, Tufail M, Khan M T, Khan Z A, Iqbal J, Wasim A. 2021. Real-time recognition of spraying area for UAV sprayers using a deep learning approach. PLoS ONE 16(4): e0249436. https://doi.org/10.1371/journal.pone.0249436

Mogili U M R, Deepak B B V L. 2018. Review on Application of drone systems in precision agriculture. Procedia Computer Science 133: 502-509.

Pathak H, Kumar G A K, Mohapatra S D, Gaikwad B B, Rane J. 2020. Use of Drones in Agriculture: Potentials, Problems and Policy Needs, Publication no. 300, ICAR-NIASM, pp 17.

Puri V, Nayyar A, Raja L. 2017. Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems*, 20(4): 507-518.

Vishnuvardhan Reddy A. 2022. Drone Tech - Flying high in Agriculture. Agriculture Today, April 2022.

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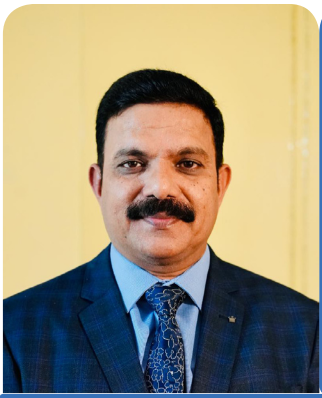

Dr. Satya Nand Sushil graduated from G. B. Pant University of Agriculture and Technology (GBPUA&T), Pantnagar is specialized in Agricultural Entomology especially in Biosystematics, Biological control, IPM, Lac culture, Apiculture, Plant Quarantine, Invasive Pest Management, Plant Protection Regulations & Policies. Dr. Sushil joined ICAR-ILRI (Now NISA), Ranchi in 1994 as Scientist and moved on to ICAR-VPKAS, Almora as Senior Scientist on Direct selection in 2002. Later transferred to ICAR-IISR, Lucknow in 2009 and worked as Principal Scientist till 2022. He served as Plant Protection Adviser, Govt of India, New Delhi during 2013-2016 on deputation (selected through UPSC) and presently working as Director, ICAR-National Bureau of Agricultural Insect Resources, Bengaluru. Dr. Sushil has developed 20 technologies, of which five are commercialized and granted with two patents for inventions entitled "An insect trapping device" and "A process for mass production of Bacillus thuringiensis (Bt) biocide using millet grain based agro-medium". He has been awarded with WIPO Gold Medal - 2008 by World Intellectual Property Organization, Geneva (United Nations Organization) and Societal Innovation Award-2008 by NRDC, New Delhi for his work on white grub management in the North western Himalayan region. He is also recipient of several awards and appreciation certificates. Dr. Sushil served as Chairman or member of several important National committees and International delegations such as Chairman, FAD 01 committee on Pesticides, Bureau of Indian Standards, Govt. of India; Member, Registration Committee for Pesticides, Central Insecticide Board, Genetic Engineering Appraisal Committee (GEAC) (2013-16). He has 102 research publications, 12 books and 11 book chapters to his credit. Email: satya.sushil@icar.gov.in.

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Dr. Adala Vishnuvardhan Reddy, a plant breeder by profession, is a well-known name in the field of Oil seeds research since 1992 and presently discharging duties as Special Officer in ANGRAU. He had an illustrious career spanning over 31 years, with 28 years in Agricultural Research and 13 years in Research Management Position as Vice Chancellor, ANGRAU and Director-ICAR-IIOR. His notable research contributions include, but not limited to, development of 18 varieties/hybrids of crops including sunflower, castor, sesame, safflower, rice, pearl millet, blackgram, redgram, and Jatropha. Created 216 inbreds, 45 CMS lines, 63 'R' lines of sunflower; identified 7 GM resistant genes, 20 rice donors, registered 30 Castor markers, 9 parental lines with NBPGR, introduced high oleic safflower genotypes and licensed biopesticides (Bt-1, Trichoderma, Beauveria) to multiple firms. He handled 18 competitive grants of more than 76 Crore INR. Three years in the office as a Vice-chancellor of ANGRAU (2020 -2023), Dr. Vishnuvardhan Reddy brought in a sea of changes in the spheres of both academics and research besides vastly improving the infrastructure of the varsity. A steep jump in ANGRAU ranking from 31st to 11th position among the 74 agriculture universities in the country, obtaining 6 patents and securing highest number of ICAR JRF and SRF seats (2021) was made possible by his tireless efforts. He is instrumental in placing ANGRAU in forefront as the first SAU with drone pilot training capabilities. Dr. Vishnuvardhan Reddy is bestowed with several awards and laurels for his achievements, both as a researcher as well as an administrator, like Jawaharlal Nehru Award (1993), Andhra Pradesh Scientist Award (2008), N Kaverappa Gold Medal (2014), SCOCH silver award for ANGRAU (2021), and several best AICRP centre awards, seed production awards to name a few. He has about 165 research publications and 11 book chapters to his credit and guided around 50 PG students. Email: adalavishnu63@gmail.com.